Proceedings

7th International Conference

On

Sustainable Development

ICSD 2019, Rome, Italy

Book of Proceeding

Selected Full Papers

European Center of
Sustainable Development
Rome, 2019

Proceedings of the 7th International Conference on Sustainable Development

7th ICSD 04-05 September 2019, Rome, Italy

Book of Proceedings

Editing: Pierangelo Magnini
Scientific Coordinator: Gihan Diab
Editorial Coordinator: Cesare Anselmi

ISBN 979-12-200-9523-5

9 791220 095235

Publisher: European Center of Sustainable Development

Printed by Gruppo Atena.net Srl Via del Lavoro, 22, 36040, Grisignano VI, Italy Tel: 0039/0444613696 Web: http://www.atena.net

Contents

Introduction

The 7th *ICSD 2019 is* organized by the European Center of Sustainable Development, at the Roma Eventi- Fontana di Trevi, Piazza della Pilotta, 4 Rome, Italy from:

Wednesday 04 to Thursday 05 September, 2019

7th ICSD2019 will be an excellent opportunity to present your projects and discuss the latest results in the field of Sustainability Science. The general aim of the conference is to promote international collaboration in Sustainability Science and related disciplines.
The Conference theme is *Creating a unified foundation for the Sustainable Development: research, practice and education*. This theme emphasizes the strong foundation that is provided by using research to inform our everyday practices, policies, and research approaches. The 2017 Conference will once again provide a forum for the sharing of ideas, presentation of research findings, and discussion of professional issues relevant to Sustainability Science.
On behalf of the Scientific Program Committee, I have great pleasure in presenting this important event of the Scientific Community.

The Conference topics are distributed in the range of the following streams within the ICSD2019 program:

1. Economic Sustainability:
2. Environmental Sustainability:
3. Socio-Cultural Sustainability:

This Book is a collection of Selected papers presented in the 7th ICSD 2019, Rome, Italy.
All manuscripts went through a double blinded peer reviewing process by members of the ICSD2019 Steering Committee for rating of quality and presentation content.

Further details in accordance with the instructions of the ICSD2019 are provided on the Call for Papers page at: www.ecsdev.org

I would like to thank you for your scientific contribution to the Second International Conference on Sustainable Development and look forward to having the opportunity to showcase and disseminate your research.
Special thanks also to the organizing committee, and all the people that worked hard, to bring in light this considerable event

Yours sincerely

Professor Gian Paolo Caselli

Chair, 7th ICSD2019 Steering Committee

International Steering Committee:

Conference Program

1. Will Curtains Come Down for the Sustainable Theatre – Evaluating Growth Challenges from an Island Nation

Seck Tan

ABSTRACT:
Sustainable development (as defined by The Brundtland Report) points to development that meets the needs of the present without compromising the ability of future generations to meet their own. However, sustainable development denotes different perspectives to different audience; and for development to be truly sustainable, growth must be inclusive and demands equal attention to the tri-nexus of economy, society and the environment. Unfortunately, this is far from reality. In an effort to continue growing, economies pedestalize economic progress where attention is skewed towards economic performance with an intentional disregard to the environment. For the purpose of this paper, sustainable development focuses on debates between the twin-nexus of economy and the environment. This paper highlights sustainable development challenges for Singapore (an island nation). While most studies centered on Singapore's miraculous growth, few have examined the island's use of its environmental capital for economic growth. Island economies face similar development challenges like most global economies; the difference lies in their natural endowments (or the lack of). This highlights the need for policies to advance ecosystem preservation in land-scarce Singapore. With the use of a simple environmental valuation framework, it is demonstrated that the island nation has not fared too badly in protecting its environmental capital.

Keywords: Ecosystem, Environmental Capital, Island Nation, Singapore, Sustainable Development

Dr. Seck Tan is Assistant Professor at the Singapore Institute of Technology (SIT), Singapore. Seck's main research focus is on sustainable development and environmental economics. These are made with reference to environmental accounting, valuation of environmental goods and services, and resource management applied to commodity-rich economies. Seck is an applied economist with broad research interests in policy analysis and policy recommendation towards sustainable development, and evidence-based public policy formulation in relation to energy and environmental issues. He has been quoted and interviewed on mainstream media pertaining to climate change and weather issues. At SIT, he holds the role of Deputy Programme Director for Bachelor of Science (Honours) in Air Transport Management.

1. Introduction

Growth is expanding the community with natural endowments such as, land and other resources towards a better standard of living via improved economic performance. Conversely, development is enhancing livability for instance, culture and heritage, education, employment, safety, and community development. Natural endowments are finite resources. Once a resource contributes to growth, it cannot be utilized for another purpose. Therefore, growth cannot be sustainable. It is development that is sustainable. The Brundtland Report defines sustainable development as, development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland *et al.*, 1987).

For development to be truly sustainable, there must be inclusive growth with equal emphasis to the tri-nexus of economy, the environment and society. To continue growing, economies pedestalize economic progress where attention is skewed towards economic performance with an intentional denial of the environment. Economic growth has resulted in an environmental crisis and in response to the crisis, unconventional models of development (Dzeraviaha, 2018) have gained acceptance in explaining sustainable development. Notwithstanding, various modes of development must remain faithful to nature as it has been well documented that nature is capital [see Daly (1991, 1996, 2005, 2007)]; an essential component of economic growth.

An economy utilizes available resources to grow; traditional theories of economic growth present these resources as factors of production in the form of physical and human capital. But growth is not purely attributed to the two identified capitals. The environment must also be accounted because an economy remains a subset of the ecosystem. Thus, the service rendered by the ecosystem cannot be neglected as it contributes to economic growth. For development to be sustainable, economies must consider maintaining and protecting the ecosystem – herein lies the close-knit relationship between economy and the environment. And it is this relationship which forms the focal argument of this paper that is, sustainable development must balance the debates between the twin-nexus of economy and the environment.

1.1 Island Nations

A healthy ecosystem is a pre-requisite for sustainable development of an economy and hence, the protection and preservation of the ecosystem is critical towards a sound and functional economy. Island nations are resource deficient and vulnerable to external shocks, the sustainability predicament requires an appreciation for the ecosystem and an acknowledgment of the role it plays in economic development. Further, sustainable development is distinct in an island setting due to an island's limited growth options. Sustainable development challenges have plagued small island nations (Kerr, 2005 and Douglas, 2006). This paper makes advancement on the work that Kerr (2005) and Douglas (2006) had developed for small island nations on sustainable development.

Sustainability challenges can be pressing to island nations (Deschenes and Chertow, 2004) as they are geographically isolated and with limited natural resources. Studies of sustainability on islands have suggested that regional support (Bass and Dalal-Clayton, 1995; and Wallner *et al.*, 1996) in particular, kin relationships and cooperative development efforts (van der Velde *et al.*, 2007) are essential ingredients towards sustainable development. Island nations are confronted with environmental consequences from the utilization of fragile natural resources for economic development (van der Velde *et al.*, 2007). Nevertheless, island nations continue to embrace the development challenge in a bid to grow economically and stay relevant – or simply, survive.

Growth does not discriminate between economies (that includes both land-lock and island nations, and cusp between land-lock and island nations) aspiring towards greater economic progress. However, in the process of attaining economic growth, natural capital is utilized. Relative to other economies, this is more damaging to island nations in their precarious state and context of resource scarcity. For island nations with a lack of resource endowment, urbanization is deem as an effortless way to attain economic growth – put another way, urbanization has a positive impact on economic growth (Un-habitat, 2010); but urbanization can also be detrimental to the environment (Grimmond, 2007; McCarthy, 2010).

1.2 Uniting Sustainability and Island Nations

Sustainability points to the ability to maintain an activity at a consistent rate over a period of time. For an economy to enjoy sustainability, it requires a consistent rate of development fueled by economic growth. To attain environmental sustainability, the ecosystem must not be utilized beyond its rate of depletion. This concept of sustainability depicts a causal framing of how environmental problems can potentially endanger the well-being of economic, ecological, and social systems (Jenkins and Bauman, 2009). The service offered by the ecosystem towards economic growth is not indefinite – which implies that sustainability of economic growth for island nations may just be faux.

In an urban context, sustainability is possible with development strategies that protects the ecosystem. But against an island context, sustainability poses a significant challenge, as small island states may not have the capacity to embrace much needed development requirements due to limitation of economies of scale and isolated locations. That is, small island developing states (SIDS) can be susceptible as they are limited in physique, restricted in bio-physical and socio-economic senses (van der Velde *et al.*, 2007), and ecologically fragile and economically vulnerable (Ghina, 2003). Moreover, environmental issues are a priority for SIDS as a healthy environment forms the basis of all life-support systems, including that of human well-being and socio-economic development (Ghina, 2003). SIDS are "special cases" where they had been characterized by size, remoteness, insularity, and vulnerability to external shocks (UN, 2014).

However, there are deviations to the SIDS definition such as, Singapore.[1] The island nation would not be aptly recognize as a SIDS "special case" towards sustainable development. Although it is physically small, it is not remote nor insular (it is geographically surrounded by ASEAN[2] neighbors); and is more than vulnerable to external shocks (environment, financial and health crises[3]). Singapore is a small island[4] but certainly more advance than a developing state. It is more advance due to its extensively city-like arrangement with continuous urbanization evolvement (gentrification). As a resource deficit island, it needs incessant urban rejuvenation because gentrification delivers economic boost, provides capacity building for future development, and serves inevitable population expansion. Hence, Singapore is more fittingly an island as well as a city-state.

This makes the paper unique in its approach to highlight urbanization strategies in an island context towards sustainable development – which is critical with climate change threat. Studies on Singapore's urbanization highlighted balancing acts between economic growth and social and political elements (Hassan, 1969), economic growth and historical and culture elements (Lee, 1996), and associated conservation and cultural (Kong, 2000) policy recommendations. Early studies on sustainable development (Ooi, 1994; Khan

---

[1] Singapore is a SIDS https://sustainabledevelopment.un.org/topics/sids/list but displays deviations as discussed by the paragraph.

[2] The 10 ASEAN nations include: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

[3] Respective crises are the regional South-East Asia haze (environment), 2007-08 Global Financial Crisis (financial), 2003 Severe Acute Respiratory Syndrome (SARS).

[4] At independence (1965), the island had a land area of 580 square kilometres; and grew to 719 square kilometres 50 years later (2015) from land reclamation. See Department of Statistics, Singapore http://www.singstat.gov.sg/statistics/latest-data The Economist (2015) forecasted that land area will grow to 775 square kilometres by 2030.

1995) presented an excellent record of fast economic growth and balanced environmental management. Regrettably, the momentum of analyzing sustainable development in Singapore did not advance much – a balancing act between economic growth and environmental protection was rarely voiced. At best, it was concerns on coastal development (Wong, 1998) and discussions on assessing the environmental impacts (Hesp, 1995; Tan, 2017).

This is comprehensible as growth and development takes priority for developing a growing city-state. Nevertheless, growth has already taken its toll on Singapore that is, urbanization increased flood frequency and channel degradation (Gupta, 1982), gave rise to slum formation (Ooi and Phua, 2007), and caused changes to local climate (Li *et al*., 2016). Relevant studies on the city-state circled around urban planning (Yeoh, 1996; Ng, 1999); urbanization and globalization (Yeoh and Chang, 2001; Chang *et al*., 2004), with minimal scrutiny of the environment. This paper contributes by weighing in on development policies of the island nation – with environmental protection at its core. Further, the focus on Singapore in this piece provides sustainability debate in Asia urban policies and adds a different perspective to mega cities of those presented in Chiu (2012).

Following this introduction, an overview of Singapore and the island nation's policy on development are examined. This is ensued by a simple environmental valuation framework to demonstrate the island nation's effort at protecting its environmental capital. An examination of the findings will be discussed, with a brief analysis on sustainable development for the island nation concluding this paper.

2. Area Under Study: Singapore and Development Policies

Singapore is an island nation born out of crisis when it was forced towards independence in 1965. The Singapore government (post-independence) engages in market forces and government interventions to stabilize the small open economy. Although land and natural resources are scarce, its strategic location means that entrepôt trade (where exports and imports are channeled in and out of) became the primary source of Singapore's economic development during the formative years. The main driver of Singapore's economy progressed from a production based industry to one of service centric (although it remains the world's largest bunkering port). Entrepôt trade evolved to foreign direct investments (FDI) and export-led industries in the provision of local employment. As the industry focus shifted from labor-intensive to capital-intensive to value-added production, jobs moved upstream and created a set of valuable skillsets for the locals.

This raised the standard of living as well as quality of living (accessible and comprehensive healthcare) for the Singapore population. The success of Singapore in the first 50 years provides an opportunity to review development options for the next 50 years. In the past five decades, economic development was fueled by strong FDI and export-oriented industries. The investment climate in Singapore has been attractive for foreign investors with low corporate taxes, stable political landscape, well-regulated banking system, good fiscal health, and vast foreign exchange reserves. A trade-dependent economy is not sustainable (Tang *et al*., 2015) and export-led growth has its limitations. Coupled with a small domestic market, there are competencies which Singapore lacks in comparison to her regional neighbors for example, Taiwan in productivity and value-creation, and Hong Kong in the financial sector.

Sustainable development demands that the well-beings of economy, environment and society are factored towards the formulation of public policies. For Singapore to attain sustainable development, hard economic growth must be balanced with soft innovative growth so that the island nation continues to remain an attractive option for investors and migrants (source of labor force) alike. A key ingredient for this achievement is quick and nimble bureaucracy; with a true test of the success dependent on how the island nation reacts to extreme events and how they are managed (Tan and Lai, 2016). After all, such events will certainly ensure that the island nation be better prepared should similar occurrences happen in the future. Hard economic growth is a result of bureaucratic efficiency where market mechanisms are used in close coordination and integration with public policies and programs (Thomas and Lim, 2001).

To balance hard economic growth with soft innovative growth, Tan and Phang (2005) added that bureaucratic efficiency ought to be complemented by advanced market infrastructure. Sustainable development requires collective actions on hard economic and soft innovative growth; but to date, Singapore's sustainability goals appear to be of secondary importance and subsumed within the needs of urban development and economic growth (Ooi, 2005). The argument remains that Singapore is an "alternative-energy disadvantaged country" and development policies are skewed towards the convenience of economic progress. Justification to this argument is attributed to economics and regulation. To the first justification, economics. Evaluating Singapore's environmental policy has been broadly based on reassessing renewables' cost-effectiveness (Hamilton-Hart, 2006) which alludes that economics precedes environmental impacts.

The second justification refers to regulation involving the use of Environmental Impact Assessments (EIA). Although its use in Singapore may inconvenience the promotion of physical development (Chua, 2005) and economic growth, EIA has gained traction of late (Tan, 2017). To further this traction, an option is to complement EIA with strategic environmental assessment (SEA) where cumulative impacts of multiple developments are considered. Even though Hong Kong and Taiwan have dissimilar approaches to environmental policies, both countries have utilized SEA (Victor and Agamuthu, 2014) in conjunction with public policy to good effects. As an island nation in the fight for environmental protection, Singapore may emulate the success of its neighbors by considering EIA and SEA when formulating environmental policies and be a policy setter for environmental stewardship[5].

Uncertainties remain on how existing living standards can be maintained whilst development takes place with an improvement in environmental degradation and negative externalities. To date, Singapore's environmental policies[6] aim to boost efficiency of resource utilization; enhance a green eco-urban environment; and engage community on capacity building. Different sectors demand different initiatives in enabling a holistic approach for development, examples include: 1. Incineration of sludge as opposed to

[5] For instance, Australia has the Environment Protection and Biodiversity Conservation (EPBC) Act with a primary objective of protecting the environment from development risks by requiring a comprehensive evaluation of project impacts on the environment to be conducted.

[6] The 2015 Sustainable Singapore Blueprint, http://www.mewr.gov.sg/ssb/

plastic incineration for waste management; 2. Utilization of renewables as sources of power generation; 3. Energy performance standards for household electrical appliances; 4. Carbon emissions-based vehicle scheme for automobiles; 5. Legislation for all buildings to be subjected to audits and reporting which encourages innovative building design; 6. Grants available for the development of energy efficient technologies.

Given its fair share of debates, sustainable development is not easy to define, let alone being the strategic focus for protecting the environment. And believers and supporters of sustainable development interpret it in very different manners. Henceforth, it is hoped that a quantitative approach will reduce the tension across different subjects – for numbers are comprehensive and universal. The next section presents a simple environmental valuation framework to demonstrate the island nation's effort at protecting its environmental capital.

3. Methodology: Simple Environmental Valuation Framework

A significant aspect of sustainable development studies is to incorporate the value of ecosystem in determining how an economy has performed. This framework hinges from a consumption perspective with carbon dioxide (CO_2) as a proxy for environmental degradation with associated costing from the literature. Depreciation of the environment proxy by carbon emissions is at a cost of USD100 per ton. [See Stern (2007), Ackerman *et al.* (2009), Hope (2011), and Karstad (2012)]. A consumption (equivalent to expenditure) framework of an economy comprises of consumption (households), investment (firms), government spending, and exports and imports. These aggregates to the income of the economy. It is assumed that environmental depreciation is a linear proportion of income with two levels of income (standard and revised). [See Tan (2015) and please refer to the Appendix for detailed derivation of the algebra].

The Singapore economy is operationalize with a simple time-series illustration to show its environmental degradation and differing paths of economic progression.

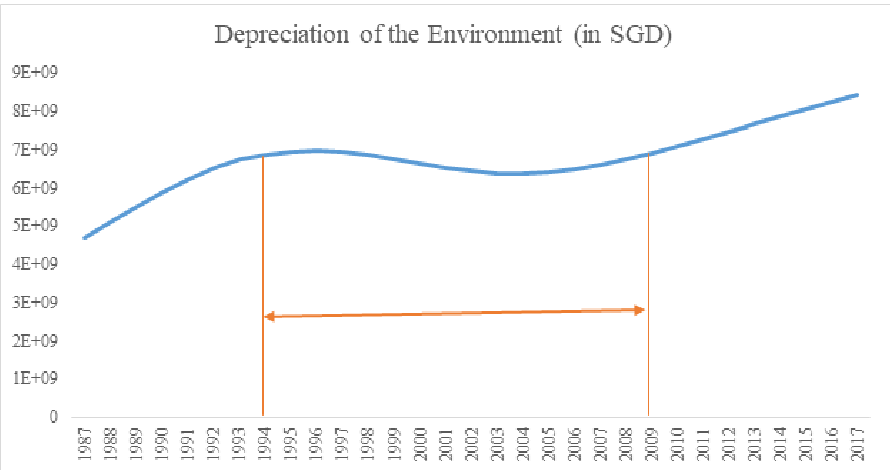


Figure 1: Singapore Depreciation of the Environment in 2010 Constant Singapore Dollar
Data Source: World Development Indicators, 2018

Figure 1 demonstrates that over a period of 15 years (1994-2009), the environment is degrading at a moderate rate; however, the general observed trend for environmental depreciation is rising and remains scarce towards end of observed period.

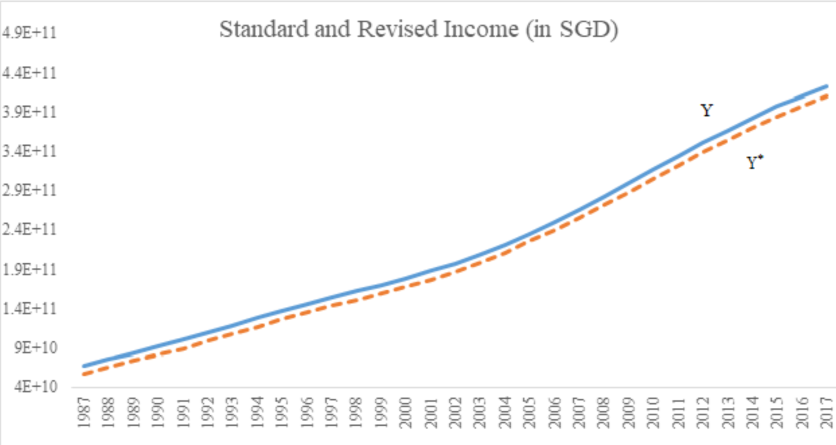


Figure 2: Standard Framework (Y) and Revised (Sustainable) Framework (Y^*)
Data Source: World Development Indicators, 2018

The divergence between standard income (solid) and revised income (dotted) is minimal which suggests an effective development model; though, income is clearly overstated when environment is not taken into account.

4. Conclusion

This paper explores the concept of sustainable development with particular emphasis on economic growth within an ecosystem domain, and associated development policy options applied to an island nation. The misconstrued concept of sustainable growth is refined and restored to the rightful concept of sustainable development. This concept is applied to precarious island nations who must develop with an appreciation that growth is rendered by a service from the ecosystem. Sustainable studies have been conducted on economies, on mega cities and city states. But few studies have been undertaken for city states who are also island nations. Singapore is subscribed as a small island developing state; though it is more appropriately defined as both an island and a city-state that is, an island city state.

There are two interesting explanations for using Singapore as an illustration. One, it offers a deviation to the definition of small island developing states where it is not isolated (in proximity to ASEAN neighbors) and had undergone continuous urbanization (as a growth option). Two, dated studies of the island nation had revolved around urban planning; urbanization and globalization; and urban regeneration, with minimal scrutiny of the environment. Such a study will be of interest to matured cities at a juncture of reviewing their urbanization strategies with sustainability in cognizance. Any updated urban development analyses of island nations must offer due recognition to the environment for instance, slower economic growth or increase growth at a sensible pace.

The environmental valuation framework indicates that Singapore's environmental capital has undergone moderate depreciation. This further translates to minimal divergence between standard and revised income levels, though income is clearly inflated with no consideration for the environment. Being a resource scarce economy, the island nation requires incessant urban rejuvenation to deliver and enable economic progress. Nonetheless, a strategy of this nature must understand that the ecosystem is central. Hence, there should be no debates on preserving and protecting the ecosystem. The implication on development policies is clearly on emphasizing the discourse on sustainable development. For now, it appears that the curtains are staying up for the sustainable theatre.

5. Acknowledgements

The author would like to thank the Editor-in-Chief, Editors, and anonymous referees for their constructive feedback. With the usual disclaimers, the author remains grateful to A. Tan and L. Ewe.

References

Ackerman, F., Stanton, E.A., DeCanio, S.J., Goodstein, E., Howarth, R.B., Norgaard, R.B., Norman, C.S., Sheeran, K.A. (2009). The Economics of 350: The Benefits and Costs of Climate Stabilization, Economics for Equity and the Environment Network.

Bass, S.C. and Dalal-Clayton, D.B. (1995). *Small Island States and Sustainable Development: Strategic Issues and Experience-7755iied*. IIED.

Brundtland, G., Khalid, M., Agnelli, S., Al-Athel, S., Chidzero, B., Fadika, L., Hauff, V., Lang, I., Shijun, M., de Botero, M.M. and Singh, M. (1987). *Our common future (\'brundtland report\').*

Chang, T.C., Huang, S. and Savage, V.R. (2004). On the waterfront: Globalization and urbanization in Singapore. *Urban Geography*, 25(5), pp. 413-436.

Chiu, R.L.H. (2012). Urban Sustainability and the Urban Forms of China's Leading Mega Cities: Beijing, Shanghai and Guangzhou. *Urban Policy and Research*, 30(4), pp. 359-383.

Chua, B.H. (2005). Liberalization without democratization: Singapore in the next decade. In: Loh, F.K.W, Ojendal, J., eds., *Southeast Asian responses to globalization: restructuring governance and deepening democracy*, NIAS, pp. 57-82.

Daly, H.E. (1991). Towards an Environmental Macroeconomics. *Land Economics*, 67(2), pp. 255-259.

Daly, H.E. (1996). *Beyond Growth*, Beacon Press, Boston, United States of America.

Daly, H.E. (2005). Economics in a Full World. *Scientific American*, 293(3), pp. 100-107.

Daly, H.E. (2007). *Ecological Economics and Sustainable Development, Selected Essays of Herman Daly*. Edward Elgar, Cheltenham, UK, Northampton, MA, USA.

Deschenes, P.J. and Chertow, M. (2004). An island approach to industrial ecology: towards sustainability in the island context. *Journal of Environmental Planning and Management*, 47(2), pp. 201-217.

Douglas, C.H. (2006). Small island states and territories: sustainable development issues and strategies–challenges for changing islands in a changing world. *Sustainable Development*, 14(2), pp.75-80.

Dzeraviaha, I. (2018). Mainstream economics toolkit within the ecological economics framework. *Ecological Economics*, 148, pp.15-21.

Ghina, F. (2003). Sustainable development in small island developing states. *Environment, Development and Sustainability*, 5(1-2), pp.139-165.

Grimmond, S.U.E. (2007). Urbanization and global environmental change: local effects of urban warming. *The Geographical Journal*, 173(1), pp. 83-88.

Gupta, A. (1982). Observations on the effects of urbanization on runoff and sediment production in Singapore. *Singapore Journal of Tropical Geography*, 3(2), pp. 137-146.

Hamilton-Hart, N. (2006). Singapore's Climate Change Policy: The Limits of Learning. *Contemporary Southeast Asia: A Journal of International and Strategic Affairs*, Vol. 28, No. 3, December 2006, pp. 363-384.

Hassan, R. (1969). Population change and urbanization in Singapore. *Civilizations*, pp. 169-188.

Hesp, P.A. (1995). The Environmental Impact Assessment process in Singapore with particular respect to coastal environments and the role of NGOs. *Journal of Coastal Conservation*, 1(2), pp. 135-144.

Hope, C.W. (2011). The Social Cost of CO2 from the PAGE09 Model, *Economics*, Discussion Paper 2011-39, September.

Jenkins, W. and Bauman, W. eds. (2009), Berkshire Encyclopedia of Sustainability: Vol 1. The Spirit of Sustainability, Berkshire Publishing Group.

Karstad, PI 2012, 'The Price on Carbon should Increase', Statoil Innovate Blog, 24 April.

Tan, S. (2015). Sustainable Development: An Empirical Illustration for Saudi Arabia, *The Journal of Developing Areas*, 49(6), pp. 517-529.

Kerr, S.A. (2005). What is small island sustainable development about?. *Ocean & Coastal Management*, 48(7-8), pp. 503-524.

Khan, M.A. (1995). Sustainable development: The key concepts, issues and implications. Keynote paper given at the international sustainable development research conference, 27–29 March 1995, Manchester, UK, *Sustainable Development*, 3(2), pp. 63-69.

Kong, L. (2000). Cultural policy in Singapore: negotiating economic and socio-cultural agendas. *Geoforum*, 31(4), pp. 409-424.

Lee, S.L. (1996). Urban conservation policy and the preservation of historical and cultural heritage: The case of Singapore. *Cities*, 13(6), pp. 399-409.

Li, X.X., Koh, T.Y., Panda, J. and Norford, L.K. (2016). Impact of urbanization patterns on the local climate of a tropical city, Singapore: An ensemble study. *Journal of Geophysical Research: Atmospheres*, 121(9), pp. 4386-4403.

McCarthy, M.P., Best, M.J., & Betts, R.A. (2010). Climate change in cities due to global warming and urban effects. *Geophysical Research Letters*, 37(9), pp. 1-5.

Ooi, G.L. (1994). A centralized approach to environmental management. The case of Singapore. *Sustainable Development*, 2(1), pp. 17-22.

Ooi, G.L. (2005). Sustainability and Cities: Concept and Assessment, Institute of Policy Studies and World Scientific Publishing.

Ooi, G.L. and Phua, K.H. (2007). Urbanization and slum formation. *Journal of Urban Health*, 84(1), pp. 27-34.

Stern, N. (2007). The Economics of Climate Change: The Stern Review, Cambridge University Press, UK.

Tan, K.S. and Phang, S.Y. (2005). From Efficiency-Driven to Innovation-Driven Economic Growth: Perspectives from Singapore. *World Bank Policy Research Working Paper 3569*, April 2005.

Tan, S. (2017). Strategy for Environmental Sustainability for Island-State Singapore – Engaging the Public. *Asian Journal of Public Affairs*, 9(2), pp. 1-18.

Tan, S. and Lai, A. (2016). Economic Repercussions of Extreme Events for an Island Nation: Case of Singapore. *The Singapore Economic Review*, 61(1), pp. 1-19.

Tang, C.F., Lai, Y.W., Ozturk, I. (2015). How stable is the export-led growth hypothesis? Evidence from Asia's Four Little Dragons. *Economic Modelling*, 44, pp. 229-235.

United Nations (UN), (2014). Trends in Sustainable Development Small Island Developing States (SIDS). New York.

Un-habitat. (2010). State of the world's cities 2010/2011: bridging the urban divide. EarthScan.

van der Velde, M., Green, S.R., Vanclooster, M. and Clothier, B.E. (2007). Sustainable development in small island developing states: Agricultural intensification, economic development, and freshwater resources management on the coral atoll of Tongatapu. *Ecological Economics*, 61(2-3), pp. 456-468.

Wallner, H.P., Narodoslawsky, M. and Moser, F. (1996). Islands of sustainability: a bottom-up approach towards sustainable development. *Environment and Planning A*, 28(10), pp.1763-1778.

Wong, P.P. (1998). Coastal tourism development in Southeast Asia: relevance and lessons for coastal zone management. *Ocean & Coastal Management*, 38(2), pp. 89-109.

Yeoh, S.A.B. (1996). *Contesting space: Power relations and the urban built environment in colonial Singapore.* Oxford University Press.

Yeoh, B.S. and Chang, T.C. (2001). Globalizing Singapore: debating transnational flows in the city. *Urban Studies*, *38*(7), pp. 1025-1044.

Appendix: A Simple Keynesian Aggregate Expenditure Framework

The following analysis is based on a simple Keynesian framework where aggregate income (Y) is determined by aggregate expenditure. Aggregate expenditure is limited to GDP where the sum of government expenditure (G) and net exports (NX) are constant (denoted by □□□ barring consumption (C) and investment (I) during a given time period. The methodology employed relies on the analytics of point estimates.

The assumed functional definitions of C and I are:

C = □□□□□□ Y (1)

$$I = \bar{I} + \delta Y \quad (2)$$

In (1), □□ and □ represent autonomous consumption and marginal propensity to consume. By assuming □ = 0, the point estimate value of □ is $\left(\frac{C}{Y}\right)$. In (2), $\bar{I}$ represents fixed investment which is assumed to be contained in □ such that □□ = $\bar{I}$ + G + NX) and point estimate values of □ (propensity to invest) are defined as $\left(\frac{I - \bar{I}}{Y}\right)$.

A simple definition for the equilibrating value of Y within standard framework based on Y ≡ GDP is given by:

$$Y^{*} = \frac{\Phi}{[1 - \beta - \delta]} \quad (3)$$

For the sustainable framework, equilibrium for income determination is redefined as (Y ≡ GDP – D_{KN}), where D_{KN} is the depreciation of environmental capital (KN). In a simple Keynesian framework, KN can be afforded a similar measurement to manufactured capital (KM), analogous to that of an income-bearing asset. That is, KN will undergo the same depreciation treatment as KM to account for the loss in its ability to generate future income. If the depreciation of environmental capital (D_{KN}) is a simple linear proportion □ of GDP, it follows that □□□ is defined as:

$$\gamma = \frac{D_{KN}}{GDP} \quad (4)$$

With the consideration of □□□□ the revised equilibrating value of income Y^{**} will be:

$$Y^{**} = \frac{\Phi(1-\gamma)}{[1-(1-\gamma)(\beta+\delta)]} \quad (5)$$

In the first instance, point estimates for □□□□□□□□ and □ from 1987 to 2017 are obtained. The data required to measure Y^{*} and Y^{**} [Consumption (C), investment (I), and depreciation of environmental capital (D_{KN})] have been smoothed by the Hodrick-Prescott (HP) filter. This allows the separation of business cycles from actual data and ensures that the time series is smoothed and less sensitive to short-term fluctuations but more sensitive to long-term fluctuations.

For illustrative convenience, the analysis of KN is confined to the depreciation of the air shed in terms of air pollution from CO_2 emissions; consequently, the value of D_{KN} is restricted to the cost of CO_2 abatement. The use of CO_2 is preferred as it is uncomplicated with reliable time series data. The greenhouse gases include CO_2, methane (CH_4), nitrous oxide (N_2O), and other greenhouse gases (GHG) [which includes hydrofluorocarbons (HFC), perfluorinated compounds (PFC), sulphur hexaflourinated compounds (PFC) and sulphur hexafluoride (SF_6)].

2. Competitive Electricity Generation and the Albanian Investment Opportunities

Dr. Aranit Shkurti

Abstract

In recent years, the generation of electricity by the power plants has undergone considerable variations, both for socio-economic reasons, but also for simple meteorological reasons, given the 100% dependence of the system relies on hydro power plants. In this context, it is important to remember that this cumbersome relationship between water and hydropower energy must be changed in the future, to avoid putting the entire energy system in imbalance in the case of a simple dry season.

Based on the historical data and considering the potential investments, the effects on the generation system are expected at a maximum rate of 1-1.5% annual increase in the available electricity for final consumption. Meanwhile using the annual load profile for the average consumption, the prediction of the total electricity demand is estimated to increase at the rate of 3-5% in the coming years.

If the current investments do not follow the increase in the demand rate, the imports will increase further putting the government expenditure on an additional financial pressure. The electricity prices in Albania do not follow the market volatility but are fixed from the Energy Authority. Since family consumption constitutes about 49% of total consumption, a variation in electricity could create further socio-economic instability in the country, compromising the efforts to join the EU.

Key word: electricity demand, project finance, household consumption, independent power plants

Dr. Aranit Shkurti is an Assistant Professor of Statistics, College of Engineering and Technology, American University of the Middle East, Kuwait. More than 10 years of Experience in the field. PhD University of Rome, “La Sapienza”, Italy.

1. Introduction

Albania dependents on the imports of electricity by an average of 30% of the total electricity consumption, except for those years with heavy rainfall (Fig.1). Furthermore, the surge in the price of oil, or the slowdown in investments in nuclear energy, creates uncertainty about the future of the availability of energy imports at reasonable prices.

In 2009, the Czech operator CEZ acquired 76% of the National Distribution Operator, becoming the first fully operational foreign investor in the electro-energy sector. In two years of CEZ work, it has encountered a series of problems, due in part to the legacy of the previous public monopoly, such as the debts accumulated in the past, and the credits from energy users, especially from institutional ones. The conflicts stored with various entities and users gradually pushed the CEZ's operation in a difficult condition that was impossible to resolve (Holzner & Schwarzhappel, 2018). The legal landscape in the region is not entirely encouraging, given the similarity of the problem in Bulgaria, again with CEZ, or in Macedonia with the Austrian EVN (Grieveson & Holzner, 2018).

The national energy company (KESH) currently imports electricity on annual or semi-annual contracts, encountering difficulties in entering into long-term contracts. Furthermore there is a persistent difficulty of suppliers to meet their commitments (Uvalic, 2014).

Several studies on the demand and supply of electricity in the countries of South Eastern Europe (Sredojević, 2017) (DJUKIĆ, REDŽEPAGIĆ, & VUKOVIĆ, 2014), showed that the energy deficit can increase in the region in the years to come, if substantial investments are not made for an additional generation. This indicates that energy imports will be even more difficult to procure. Already at the moment, neighboring countries such as Greece, Macedonia or Italy are net importers of electricity (Holzner & Schwarzhappel, 2018).

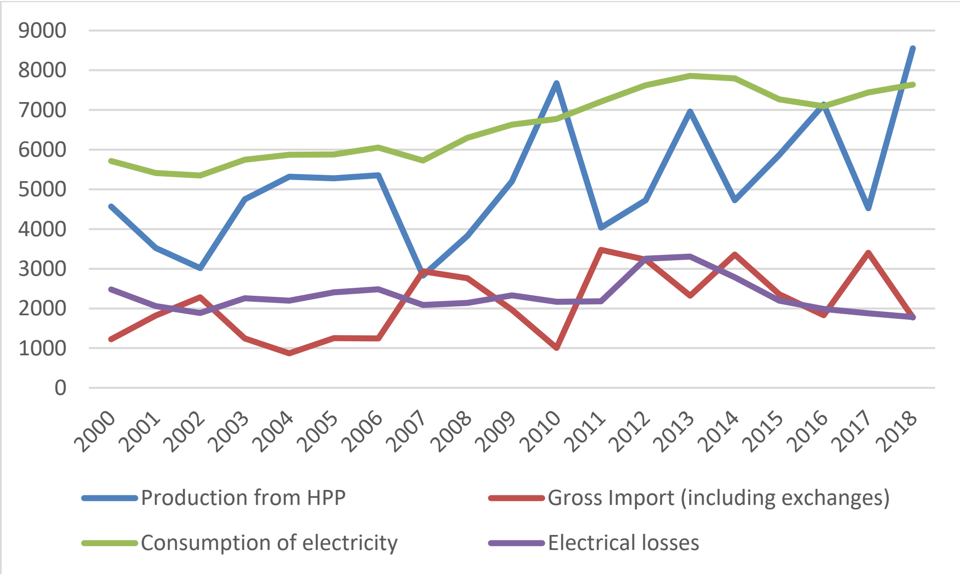


Figure 1 Production and Consumption of electric energy in GWh in the period 2000-2018
Source: http://databaza.instat.gov.al

In addition to the construction of new plants, KESH must also take care of the maintenance of existing ones, which are often in precarious situations. Big HPPs require particular protection due to the danger they can present to civilian populations (Celo & Bualoti, 2010).

In formulating development strategies in the division of generation, the characteristics of the Albanian system must be taken into account, such as the disproportionate ratio between the HPP production capacity, the concentration of generation sources in the North and consumers in the Central part of the country, the lack of significant investments in the sector in the past 30 years, the lack of investment attraction, as a result of the low price of electricity (Gjoka, 2016).

2. The existing generation system

As mentioned earlier, the electricity generation system is dominated by hydroelectric, with smaller spas, the majority of which have been suspended or dismantled permanently, given the obsolete technology, and the unsustainable operating costs.

The three main power plants of the Drin waterfall are:

Fierza HPP (500 MW);
Koman HPP (600 MW);
Vau Dejës (250 MW);
The waterfall of the river Mati, always located in the north of the country:
Ulza HPP and Shkopeti HPP with a total of 52 MW.
The Bistrica 1 and 2 power plants on the Bistrica River, with a total capacity of 28.5 MW
Independent power plants contribute with 31% of the total electricity or 2701 Gwh during 2018
The only thermal power plant is that of Vlora 1 with an installed capacity of 93 MW, but not yet operative.

Table 1 Quarterly balance of electric power in GWh year 2018

	2018-1	2018-2	2018-3	2018-4	Total
A Available electricity (A=1+2-3)	**2123**	**1739**	**1812**	**1964**	**7639**
1 Net domestic production (1=1.1+1.2+1.3)	3213	2707	1630	1003	**8552**
1.1 Thermo	0	0	0	0	**0**
1.2 Hydro (1.2=a+b)	3213	2707	1630	1003	**8552**
a Net public producers (a=a.1-a.2)	2087	1795	1304	665	**5851**
a.1 Gross public producers	2105	1810	1315	672	**5902**
a.2 Losses and own consumption	18	15	11	7	**51**
b Independent power producers	1126	912	326	337	**2701**
2 Gross import (including exchanges)	115	139	470	1049	**1772**
3 Gross export (including exchanges)	1205	1106	287	87	**2685**
	2123	1739	1812	1964	**7639**
B Consumption of electricity (B=1+2)					
1 Electrical losses (1=1.1+1.2)	599	390	356	438	**1783**
1.1 Losses in transmission	87	75	45	36	**243**
1.2 Losses in distribution (1.2=a+b)	513	315	312	402	**1540**
a Technical losses in distribution	343	234	234	259	**1071**
b Non technical losses in distribution	169	81	77	143	**470**
2 Consumption of electricity by domestic users (2=2.1+2.2)	1524	1349	1456	1527	**5856**
2.1 Households	790	591	607	693	**2682**
2.2 Non households	734	758	848	834	**3174**

Source: http://databaza.instat.gov.al

So far a number of operators have expressed interest in investments in the electro-energy field. Mainly these are direct investments to small and medium-sized power plants. Approximately today approx. 213 concessions for the construction of plants up to 50 MW. Some concessions are pending due to strong public concern about the environmental impact like Kalivaci. These arguments highlight the difficulty of foreign operators and capital to penetrate the energy market.

3. Methodology

This study is taking in consideration a series of thermal and hydro power plant generation projects, identified in the period 2020-2025. In order to have a clear view of the volume of energy needed to meet the demand of the country, the study took into consideration a scenario of increased demand by pursuing the current trend.

Table 1 Balance of electric power 2008 – 2018 in GWh

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
01 A. Available electricity	6296	6629	6773	7211	7619	7857	7794	7265	7094	7440	7639
02 A.1.Net domestic production	3831	5201	7674	4036	4725	6959	4726	5866	7136	4525	8552
03 A.1.1.Thermo	0	0	0	0	0	0	0	0	0	0	0
04 A.1.2.Hydro	3831	5201	7674	4036	4725	6959	4726	5866	7136	4525	8552
05 A.2.Gross Import (including exchanges)	2759	1964	1005	3475	3230	2323	3356	2355	1827	3403	1772
06 A.3.Gross Export (including exchanges)	293	536	1906	301	336	1425	288	956	1869	488	2685
07 B. Consumption of electricity	6296	6629	6773	7211	7619	7857	7794	7265	7094	7440	7639
08 B.1.Electrical losses	2140	2328	2167	2179	3251	3306	2783	2196	1986	1876	1783
09 B.2.Consumption of electricity by domestic users	4156	4301	4606	5032	4368	4551	5011	5069	5108	5563	5856

Source: http://databaza.instat.gov.al

In determining the strategy for the development of the generation sector, the recommendations of the study take approximate values on the potential to be installed in the various projects.
Regarding the priorities of these projects, at the present stage it is difficult to define each project separately, since none of them have independent assessments of feasibility and environmental impact. Starting from these data, an effort to understand the trend of the Electricity Consumption and Electricity Losses was performed through a simple trend regression.

Table 3. Trend equation for Consumption of electricity period (2000-2018)

Regression Statistics			Coefficients	Standard Error	t Stat	P-value
Multiple R	0.9144	Intercept	5184.09	173.05	29.95	0.00
R Square	0.836	time	141.38	15.17	9.31	0.00
Adjusted R Square	0.826					
Standard Error	362.363					
Observations	19					

Table 4. Trend equation for Electric losses period (2000-2018)

Regression Statistics				Coefficients	Standard Error	t Stat	P-value
Multiple R	0.0402		Intercept	2277.50	204.717	11.1	0.00
R Square	0.0016		time	2.980	17.954	0.16	0.8701
Adjusted R Square	-0.057						
Standard Error	428.66						
Observations	19						

Collecting the conclusions of the simulation, in correspondence to the characteristics of the system mentioned above, we can reach these results:
The electricity demand has a steady but continuous positive trend (Table 2). By 2025 an estimated volume of 8860 GWh will be needed. Meanwhile the Electric losses do not follow a regular trend (Table 3), this is due to the production of energy that is quite variable, but also to non-technical losses, that are illegal connections mainly in the distribution transmission system.
For the short term, until the commissioning of new thermal plants, which, given the trend of investments, will not happen before 2025, the coverage of the country's energy needs will continue to be fulfilled by imports, up to the maximum limits of 2500-3500 TWh per year, taking into account a GDP growth of approximately 3% per year, especially for the industrial and service sectors, which present the most dynamic trends.

An upper bound of the imports is connected to

a) government expenditure constraints,
b) electricity prices in the domestic and international market and finally
c) the transmission and distribution system infrastructure that is not fully equipped to receive overload in the grid[7].

In addition to national production, elements of a broader context can also be introduced in the analysis of development scenarios. By analyzing the difference between the respective power generation structures, there is an option to reduce the cost of generation through close cooperation between the electricity systems of Albania and Kosovo. In Kosovo, production is mainly based on energy from the TECs, due to the convenience of the latter in a country that has large quantities of lignite . The generation coming from the TECs, unlike the water generation, is static over time, without fluctuations of an exogenous nature. In this sense, the systems can be complementary to each other, given the lack of HPPs in Kosovo, and thermal ones in Albania. This collaboration cannot present itself as a justification for not building new TECs in Albania, rather it must flow into the exchange of electricity between the two countries in particular moments of energy needs. This proposal was examined by the energy authorities of the two countries;

[7] The total transmission capacity (TTC) represents the maximum value of the exchange program between two areas, meeting the mandatory work safety standards for each System, if for the period for which the TTC estimate is made, network conditions and model generation - consumption, are well known in advance.

for the moment there are already exchanges, which we hope to be implement further in the future through long term agreements.

4. PPP options in Albania

The need for Project Financing through BOO / BOOT type schemes in the energy sector consists in the financing of a particular economic unit (Lock, 2003), or of an investment project economically separate from its promoters (Steffen, 2018), whose lenders evaluate its creditworthiness on the basis of cash flows generated. It consists in the constitution of an independent legal entity for the realization of an economic initiative financed with debt without recourse (and with risk capital), whose only source of remuneration is represented by the cash flows produced during management (Grimsey & Lewis, 2007).

The main feature of the tool consists in the separation between the project and its sponsors through the establishment of an ad hoc company, called SPV - *special purpose vehicle* - capable of isolating the initiative, its cash flows and its risks, from a legal, economic, patrimonial and technical point of view (through the so-called *ring fence*) from the business activities of the individual promoters. The success of the project is also based on a system of contractual guarantees, a security package, which makes it possible to allocate responsibility for the risks associated with the project to the numerous parties involved in the operation, through a complex system of contracts (Weber, Staub-Bisang, & Alfen, 2016).

In general, when financial conditions are inadequate to support new generation projects, IPPs can be invited to develop, build and operate new power plants with the necessary clauses to supply the available capacity to connected quantities of energy. Even if the investment has the financial resources necessary for the construction of new plants, it is important to continue an investigation of the price auction processes, among the various IPP choices. The government must thus encourage the construction of privately run power plants, to encourage competitiveness in the sector.

This scheme is used for the construction of public administration charging infrastructures and requires the administration to pay a fee for the availability of the infrastructure and related services. At this moment, the idea is spreading among many public administrations, also as a result of positions with poor technical validity, that leasing represents a more efficient solution for carrying out tariff-based operations on the PA, as an alternative to the PF, considered burdensome, complex and subject to frequent bankruptcies. The criticalities of the PF will certainly weaken leasing as well, considering that the two instruments can be assimilated and that the ineffectiveness of the first is not attributable to the nature of the instrument, but rather to the way in which it was used. In the United Kingdom, France and Spain, in fact, the PF for the construction of infrastructures with charges on the PA (such as healthcare investments or public lighting systems) is based on a leasing scheme (the so-called BLT - *build lease and transfer*), precisely because the infrastructure created is leased to the public company for the duration of the concession. The operation is then associated, in relation to the specific needs of the public administration, with the management of some or all of the *non-core services* . Therefore, in these three countries there is no formal distinction between two substantially identical instruments, which indeed merge to originate the so-called PF with

pricing on the public administration.
The projects suitable for the development of PPPs are the central ones, which can be built in a relatively short period (less than 2 years), with a flexible operation in both maintenance and fuel. The best technologies available in the sector, aimed at meeting the above requirements are fuel oil or natural gas plants with combined combustion cycle (CCGT).
cycle gas turbines (*Combined Cycle Gas Turbine*) can use both fuel oil and natural gas (when available) mixed fuel. They can have variable capacities, from 60 to 600 MW. The main advantage of CCGT plants is their net efficiency, which nowadays reaches up to 58% for large units, and up to 50% for smaller ones. In this direction they are considered among the best energy systems, which use fossil fuels. On the other hand, it is important to specify that CCGT plants have relatively low investment costs, even for small units.

As far as thermal energy is concerned, the most convenient technologies are:
TEC with combined turbine cycle (CCGT); distillate petroleum fuel or liquefied gas
TEC with gas turbines (SCGT); distillate petroleum fuel or liquefied gas;
Conventional TEC of steam turbines: coal or mazut fuel.

In the hydro-energy sector, in addition to the reconstruction of small power plants already underway, the most realistic projects to be implemented are the HECs of:
Bushati (84 MW) on the Drin River;
Skavica (250 MW) on the Drini i Zi river.
The two projects that proved to be more convenient are that of Bratila and that of Skavica , also with respect to the construction of the TECs. Their marginal cost is lower only if petroleum distillate is used in the TECs, while if liquefied gas is used, the TECs are more advantageous.
In addition to this, all investments in the southern part of the country bring benefits on the side of energy transmission. As for the other HECs, these are more expensive than the petroleum distillate TECs.

5. Discussion and Conclusions

The project financing in Albania has mainly two possible directions, it can be non - recourse (the lenders finance the SPV and in the event of default there is no possibility of relying on the sponsors) and limited recourse (the sponsor can take on a further risk than that of simply subscribing a share of the capital of the SPV) and in addition we can distinguish the works into: warm (works that are able to generate revenue streams suitable for repaying the loan), cold (works that do not generate income but are socially useful: the state pays a quid to the sponsors) and lukewarm (works that partly generate revenues and are also subsidized by the PA).
The organization of the energy market, in order to operate in a medium-long term path, needs access by third parties as soon as possible, free to enter into bilateral contracts with local operators. This environment must guarantee energy producers the right to choose the counterpart, without binding the offer to the distribution monopoly. Furthermore, the public transmission operator (OST) must guarantee flows in the network without placing preference constraints on the local market. All these operations must be

supervised by the public Authority for the Regularization of Electricity (ERE). Given the peculiarity of the energy asset and the very fragile balance of its marketing, only these guarantees can push foreign investors to venture into the Albanian market.

In previous years, many international consortia have expressed interest in the construction of hydroelectric plants, but also thermoelectric ones, setting up contractual formats of the IPP type. Potential investors later asked for long-term PPA contracts with KESH and OST. These agreements are essential in securing the financing of the investment scheme.

Given the importance of the energy sector in Albania, as the fulcrum of the country's much-suffered economic take-off, the promotion of private investments in the sector is a strategically important commitment. Analyzing the premises of the energy market, the liberalization of production operators, the conditions seem more than attractive. Domestic capital is generally insufficient to make the necessary investments in the medium-large generation. Foreign direct investments may unlock the situation, given the persisting contractual and regulatory obstacles. In order to foster a safe climate for investments in the energy sector, the country needs a transparent and coherent institutional *framework*, in order to favor independent investments in power plants *(*IPP). The liberalization process of the energy market has adopted the Bilateral Market model in the medium to long term. The institutional context must adapt to support projects of this type, drawing inspiration from the best international experience gained in the field.

In addition to this, during the transitional period of the opening of the electricity market, provision will be needed to be implemented in Public Private Partnership projects. In this direction, it is possible to take advantage of the experience gained in the USA, UK, Spain, etc. , that the most efficient ways for an immediate start-up of the electricity markets are the medium-long term Agreements for the Purchase of Energy PPA (Power Purchase Agreements) (Churchill, 1996). These agreements smoothen the way to the new market, providing a necessary grace period for the profitable commercialization of electricity.

The institutional context must encourage these PPAs, especially during the initial and transitional phase of the liberalization of the energy market. In addition to this, the regulatory environment must comply with the EU guidelines and directives, not only in anticipation of a forthcoming integration into the Union, but also to give signals of transparency to potential investors. In this way it is possible to guarantee financial sustainability for energy projects, and to guarantee the security of energy supplies in the years to come.

References

Carafa, L., Frisari, G., & Vidican, G. (2016). *Electricity transition in the Middle East and North Africa: a de-risking governance approach* (Vol. 128). Elsevier.

Celo, M., & Bualoti, R. (2010). Impacts of the rehabilitation of Drin river cascade on Albanian power system reliability. *6*(3), pp. 146-151.

Churchill, A. (1996). *Avoiding pitfalls in project finance and investment: The lessons of experience* (Vol. 9). Elsevier.

DJUKIĆ, M., REDŽEPAGIĆ, S., & VUKOVIĆ, D. (2014). *FINANCING ENERGY EFFICIENCY AND RENEWABLE ENERGY PROJECTS IN WESTERN BALKANS BY RAISING CAPITAL ON FINANCIAL MARKETS*. CEMAFI International, Nice, France.

Gjoka, F. (2016). Challenges and Prospects of Foreign Direct Investments in Hydropower Sector in Albania.

Grieveson, R., & Holzner, M. (2018). *Investment in the Western Balkans.*

Grimsey, D., & Lewis, M. (2007). *Public private partnerships: The worldwide revolution in infrastructure provision and project finance.* Edward Elgar Publishing.

Gross, R., Blyth, W., & Heptonstall, P. (2010). *Risks, revenues and investment in electricity generation: Why policy needs to look beyond costs* (Vol. 32). Elsevier.

Hoffman, S. (2007). *The law and business of international project finance: a resource for governments, sponsors, lawyers, and project participants.* Cambridge University Press.

Holzner, M., & Schwarzhappel, M. (2018). *Infrastructure investment in the Western Balkans: a first analysis.*

Kordić, Z., Herenčić, L., Trade, H., Pašičko, R., & Carrington, D. (n.d.). *Renewable Energy Cooperation Potential between Member States and West Balkan Countries.*

Koroneos, C., & Nanaki, E. (2007). *Electric energy sustainability in the Eastern Balkans* (Vol. 35). Elsevier.

Lock, R. (2003). The future of project finance: a respite or its demise? *16*(8), pp. 35-38.

Madácsi, R. (2015). *Project finance in Hungarian electricity sector. Effect of feed-in tariff system's change onto power plant investments.* Corvinus University of Budapest Faculty of Economics.

Mavrakis, D. (1998). *Prospects for the development of a peripheral electricity market in the Balkan region.*

McGovern, T., & Hicks, C. (2004). *Deregulation and restructuring of the global electricity supply industry and its impact upon power plant suppliers* (Vol. 89). Elsevier.

Naidoo, A. (2008). *Financing power in Africa: electricity* (Vol. 8). Institute of Municipal Finance Officers (IMFO).

Phomsoupha, X. (2012). *Project financing in Laos' hydropower for export of electricity to Thailand* (Vol. 10).

Rivera, A. (2017). Disclosable Version of the ISR-Energy Community of South East Europe APL Program-APL 5 for Albania DAM SAFETY-P110481-Sequence No: 12.

Sredojević, S. (2017). *ANALYSIS OF THE PUBLIC-PRIVATE PARTNERSHIP MARKET IN THE WESTERN BALKAN REGION: LESSONS LEARNED AND PERSPECTIVES.*

Steffen, B. (2018). The importance of project finance for renewable energy projects. *69*, pp. 280-294.

Uvalic, M. (2014). *Regional cooperation in the Western Balkans.* Routledge.

Weber, B., Staub-Bisang, M., & Alfen, H. (2016). *Infrastructure as an asset class: investment strategy, sustainability, project finance and PPP.* John wiley & sons.

Xhafa, B. (2009). Financial Appraisal on a Hydropower Plant. A Case Study in Albania.

Zhand, N. (2000). *Moving Towards a Competitive Electricity Market-The Dilemma of Project Finance in the Wake of the Asian Financial Crisis* (Vol. 9). HeinOnline.

3. Novel Affordable, Reliable and Efficient Technologies to Help Addressing the Water-Energy-Food Nexus

Francesco Meneguzzo, Federica Zabini, Lorenzo Albanese, Alfonso Crisci

ABSTRACT:
Improving the food system sustainability and security has become an urgent global challenge. In this regard, one of the most effective routes is the shift of the human diet toward healthier and more sustainable consumption, involving in particular the prevalence of plant-based food. Controlled hydrodynamic cavitation (HC) technologies could help considerably in this transition. HC techniques are gaining increased scientific interest, and are quickly spreading across a wide range of technical fields, recently showing surprising performances with biological raw materials related to the food, agricultural and forestry sectors and resources. HC processes enjoy recognized advantages in the acceleration of the processing steps of plant-based food, the extraction of valuable bioactive compounds, the reduction and the valorization of waste streams, as well as the superior efficiency in resource use, energy consumption, process yield, and exergy balance than competing processes. Thus, HC is very promising candidate to help addressing the water-energy-food nexus, and, ultimately, sustainability. Findings obtained from direct experimental trials and recent literature concerning applications to food processing, provide a strong basis for novel investigation aimed at standardization, starting from the identification of the most suitable devices and the optimal processing parameters, eventually oriented to further spreading of HC applications.

Keywords: affordability; food; health; hydrodynamic cavitation; process yields; sustainability; water

Dr. Francesco Meneguzzo is permanent researcher at the Institute of Biometeorology, National Research Council, Florence, Italy. Physicist, he started his career as a meteorologist and climatologist, then focused on energy systems and policies, finally on technological innovation in the agro-food sector. Currently, he is Scientific head of the HCT-agrifood Lab, where he investigates about the applications of controlled hydrodynamic cavitation techniques to the processing of food and biomasses. He participated to several international and national research projects, was Grant Professor of Meteorology at the University of Pisa, Italy, lecturer at post-university Master courses, and expert member of governmental commissions. He is co-author of about 150 scientific articles, book chapters, technical reports, conference presentations, and is frequent reviewer for primary scientific journals. He was appointed as inventor in a patent concerning a novel device and related method for the production of beer.

Dr. Federica Zabini is permanent technician at the Institute of Biometeorology, National Research Council, Florence, Italy. As an expert in scientific communication, her research areas include science communication about climate change, energy consumption and sustainable lifestyles. She participated to the "Kyoto Observatory" project of Tuscany Region to support monitoring, reporting and management of carbon balance in Tuscany (GHG emissions and CO2-absorbing capability of the vegetation). She is part of the communication team at LaMMA – Regional Weather Service of Tuscany, Italy. Currently, she is also responsible for project development at the HCT-agrifood Lab, where she investigates about the applications of controlled hydrodynamic cavitation techniques to the processing of food and biomasses. She is co-author of few scientific articles, book chapters, technical reports, and conference presentations, and is reviewer for primary scientific journals.

Dr. Lorenzo Albanese is permanent researcher at the Institute of Biometeorology, National Research Council, Florence, Italy. Agronomist and enologist, he started his career as a technologist in the field of transformation of agricultural products. His scientific interests shifted towards energy systems and devices, then to technological innovation in the agro-food sector. Currently, he is head of experimental activities of the HCT-agrifood Lab, where he investigates about the applications of controlled hydrodynamic cavitation techniques to the processing of food and biomasses. He participated to several international and national research projects, and is co-author of tenths of scientific articles, book chapters, technical reports, and conference presentations. He was appointed as inventor in a patent concerning a novel device and related method for the production of beer.

Dr. Alfonso Crisci is permanent researcher at the Institute of Biometeorology, National Research Council, Florence, Italy. Updating own agronomic/biometeorological background, his scientific interests are now focused on data mining techniques covering different scientific fields and investigation challenges. He is currently data scientist at the HCT-agrifood Lab, where he investigates physical and chemical data workflows provided by different applications of controlled hydrodynamic cavitation concerning food and biomass processing. He participated to several international and national research projects, and is co-author of tenths of scientific articles, book chapters, technical reports, and conference presentations. As an R package developer, he follows open and reproducible scientific frameworks in code and data production.

1. Introduction

Food production accounts for a large share of the anthropogenic environmental impacts. Almost half of the ice-free land area of the Earth is used as cropland or pastureland, with the global agriculture and food production systems releasing more than 25% of all greenhouse gases (GHGs) (Tilman & Clark, 2014), as well as being responsible for about one third of the soil degradation, and the main driver of losses of biodiversity (Bajželj et al., 2014).

The food production system is the largest user of freshwater and a key driver in pollution of aquatic and terrestrial ecosystems, due to agrochemicals and excessive use of nitrogen and phosphorus (Springmann et al., 2018). At the European level, the food sector is still one of the most water and energy demanding sectors (Rohmer, Gerdessen, & Claassen, 2019).

In a recent study, it was estimated that, worldwide, 5.2 billion ton of carbon dioxide were emitted in 2010 by the food system (Springmann et al., 2018). As well, it occupied 12.6 million km^2 of cropland, used 1,810 km^3 of freshwater resources from surface and groundwater (bluewater), and spread 104 Tg of nitrogen, and 18 Tg of phosphorus in the form of fertilizers.

In the same study, the food production and consumption were projected to change between 2010 and 2050 because of the expected socioeconomic dynamics, such as the global population growth by about a third, and a tripling of the global income. As a result, the environmental pressure of the food system was predicted increasing by 50–92% for each indicator, in the absence of technological change and other mitigation measures, with GHG emissions growing by an average of 87%, cropland use by 67%, and bluewater use by 65% (Springmann et al., 2018).

The urgency for securing food supply chains was also pointed out by several authors. It was based on rising population and income in emerging countries, leading to predict a doubling of food demand from 2000 to 2050, as well as on the impending shortage of both the needed energy inputs and the availability of further agriculturally usable land (Motesharrei et al., 2017; Taylor & Tainter, 2016).

The sustainability of food production and supply chains is driven by energy efficiency, functionality, and waste reduction, as well as healthy diets are generally more sustainable. Indeed, it was estimated that the economic benefits of a shift to plant-based diets, due to reduced health care costs, would surpass the value of the environmental benefits, overall benefits totaling up to 13% of global gross domestic product in 2050 (Springmann, Godfray, Rayner, & Scarborough, 2016).

On the environmental side, as pointed out by a recent study, the reason underlying the benefits brought by a shift to plant-based diets lies in the very limited conversion rate, around 15%, of proteins derived from vegetable raw materials, used to feed livestock, which become eventually available to human consumption (Di Paola, Rulli, & Santini, 2017). Therefore, the food production model based on animal-based proteins is much more expensive in terms of land area (2.4 to 33 times), and GHG emissions (2.4 to 240 times).

New or emerging technologies, aiming to improve or even replace existing ones in specific segments of the food production chain, should comply with the need for higher water and energy efficiency standards, as well as help to facilitate the transition to plant-based food. Among such technologies, those based on controlled hydrodynamic cavitation (HC) stand out for their relative cheapness and straightforward scalability, as well as the capability to enhance the extraction of bioactive compounds from plant materials, as extensively documented in a recent review for the fields of vegetable beverages and the wider food production and supply chain (Albanese & Meneguzzo, 2019a).

HC is defined as the phenomenon of generation, growth and collapse of microbubbles due to pressure variations in a liquid flow, triggered and sustained by several different methods. The most practical and scalable methods foresee pumping the flow through one of more constrictions of suitable geometry, such as Venturi tubes and orifice plates, in comparison to which, devices based on rotating parts are much more expensive, and impose higher operating and maintenance costs (Sarvothaman, Simpson, & Ranade, 2018).

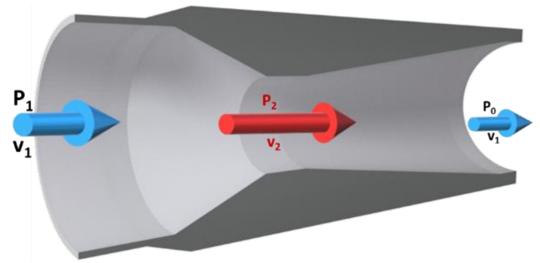
The increase in kinetic energy at the constriction occurs at the expense of pressure, leading to microbubbles and nanobubbles generation, which subsequently collapse under pressure recovery downstream of the constriction (Gogate & Pandit, 2001). The violent collapses of the cavitation bubbles result in the generation of localized hot spots endowed with extremely high-energy density (Pawar, Mahulkar, Pandit, Roy, & Moholkar, 2017; Yasui, Tuziuti, Sivakumar, & Iida, 2004), highly reactive free radicals and turbulence, which can result in the intensification of various physical/chemical phenomena.

Recently, cavitation-based technologies got remarkable attention as efficient and affordable routes to the intensification of different physical and chemical processing applications, from wastewater remediation (Ciriminna, Albanese, Meneguzzo, & Pagliaro, 2017; Dindar, 2016; Doltade et al., 2019), to preparation of nanoemulsions, biodiesel synthesis, water disinfection, and nanoparticle synthesis (Carpenter, Badve, et al., 2017), and many others. As well, in the recent past, cavitation gained a great reputation as a greener extraction method, and for its usefulness in the intensification of food and pharmaceuticals processes (Carpenter, Badve, et al., 2017; Panda & Manickam, 2019a), mainly due to its capability to remove or degrade toxic solvents, reduce process time and energy consumption, and achieve higher extraction yield.

This review discusses the current state of HC applications to the food production chain, whose potential for large-scale, advantageous implementation has been largely recognized as not only feasible, but also relatively fast and straightforward. However, their full exploitation at the market level has been so far hindered by a persisting lack of standardization (Sarvothaman et al., 2018).

2. Fundamentals of Controlled Hydrodynamic Cavitation

This short presentation of fundamentals of HC processes is limited to non-moving setups, such as Venturi tubes and orifice plates, *i.e.*, the most practical and convenient ones, as mentioned in Section 1. Fig. 1(A) represents a circular-shaped Venturi tube with a convergence section, a nozzle, and a divergence section, whose respective geometries, in particular convergence and divergence angles, are dictated by a fairly long history of experiments, theory, and numerical modeling (Albanese, Ciriminna, Meneguzzo, & Pagliaro, 2015). Fig. 1(B) represents a slit Venturi, generally endowed with higher performances in comparison with the circular setup (Carpenter, Badve, et al., 2017).



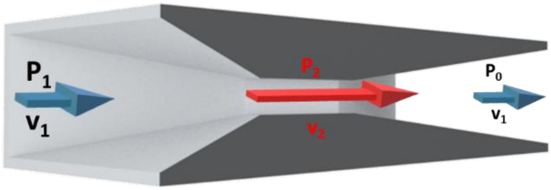


Figure 1. Schematic representations of HC reactor in the form of a circular (A) and slit (B) Venturi tube. P_1, P_2, and P_0, are the upstream bulk pressure, the pressure at the nozzle, and the downstream bulk pressure, respectively, whereas v_1 represents the fluid speed, upstream and downstream of the HC reactor, and v_2 represents the fluid speed at the nozzle of the HC reactor.

The liquid acceleration, and the respective pressure drop, are regulated by the Bernoulli's equation (Pawar et al., 2017), i.e., the conservation of the mechanical energy for a moving fluid, represented in Eq. (1):

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \qquad (1)$$

where P_1 and P_2 (Nm^{-2}) are the upstream bulk pressure, and the pressure at the nozzle, respectively, ρ (kgm^{-3}) is the fluid density, v_1 and v_2 (ms^{-1}) are the fluid speed upstream and through the nozzle, respectively, h_1 and h_2 (m) are the heights of the fluid, and g (ms^{-2}) is gravity. The third term at each side of Eq. (1) represents the specific potential energy, while the second term represents the specific kinetic energy. Assuming equal heights, the pressure drop ($P_2<P_1$) at the reactor's nozzle arises because of the fluid acceleration due to mass conservation ($v_2>v_1$). Whenever P_2 drops below the vapor pressure, at a certain temperature level, local evaporation occurs, and vapor bubbles are generated.

The dynamics of cavitation bubbles is quite complex. In a recent comprehensive article on HC dynamics, the Rayleigh-Plesset equation of bubble dynamics, representing the radial motion of the cavitation bubble, is only one in a set of four basic equations, the others representing the diffusive flux of water vapor molecules, the heat conduction across bubble wall, and the overall energy balance (Pawar et al., 2017). However, a widely used dimensionless quantity, named cavitation number (σ) and derived from the Bernoulli's equation, can be used to characterize the cavitation intensity in a flow system, in terms of easily measurable physical quantities. Its representativeness holds in most of relatively simple HC reactors, such as Venturi tubes and orifice plates (Pawar et al., 2017), and relate it with the cavitational intensity, with cavitation generally arising for σ<1. The cavitation number is represented in Eq. (2):

$$\sigma = (P_0 - P_v) / (0.5 \cdot \rho \cdot v_2^{\ 2}) \qquad (2)$$

where P_v (Nm^{-2}) is the liquid vapor pressure (a function of the average temperature for any given liquid), and the other symbols have the same meaning as in Eq. (1). Apparently, σ represents the ratio between the pressure drop needed to achieve vaporization, and the specific kinetic energy at the cavitation inception section. Despite some recent, motivated criticism (Šarc, Stepišnik-Perdih, Petkovšek, & Dular, 2017), σ allows representing the features of HC processes with confidence for most of practical purposes (Soyama & Hoshino, 2016), provided that the relevant quantities are measured properly.

Briefly, three intervals in the range of values assumed by the cavitation number were identified, corresponding to distinct HC regimes (Bagal & Gogate, 2014; Gogate, 2002):

- $0<\sigma<0.1$ – cavitation can be chocked, with an almost stationary bubble cloud arising from the merging of individual bubbles, and no, or very weak and rare, collapsing events, in a regime called supercavitation.
- $0.1<\sigma<1$ – cavitation is developed, with fairly strong and frequent collapses.
- $\sigma>1$ – cavitation becomes residual, depending on the nature and concentration of impurities and dissolved gases, and virtually absent for $\sigma>4$, with rare but very strong collapses.

However, cavitation regimes are subtly modulated by several details, such as the reactor's geometry (Carpenter, Badve, et al., 2017; Šarc et al., 2017), the flow rate and the inlet pressure, the geometry and the mechanical power of the impellers (Carpenter, Badve, et al., 2017; Pawar et al., 2017), as well as the content in dissolved gases and solid particles (Patil & Pandit, 2007). The medium temperature also plays an important role, with a peak in cavitation aggressiveness around 60°C (Dular, 2016; Li, Yang, Shi, Zhao, & Li, 2018).

Cavitation processes concentrate the energy of the bulk liquid medium, up to extremely high local density, into a myriad of microscopic hot spots, located at the collapse of the bubbles (Pawar et al., 2017; Yasui et al., 2004). As a result, extreme physical phenomena arise, such as temperature and pressure transients up to 5,000-10,000 K and >300 atm, respectively, very strong shear forces, micro-jets and pressure shockwaves. Powerful oxidants form, such as hydroxyl radicals (·OH, oxidation potential 2.80 eV), as a result of water splitting (Yasui et al., 2004), whose generation was explained by a set of reactions based on theoretical and experimental arguments (Carpenter, Badve, et al., 2017; Ciriminna et al., 2017; Sarvothaman et al., 2018).

While oxidation processes are needed for the degradation of organic contaminants, they are harmful for the quality of processed food liquids (Ngadi, Latheef, & Kassama, 2012). However, within the range of HC regimes used in food applications, and absent any specific oxidizing additives, such processes are too mild to represent a real threat (Yusaf & Al-Juboori, 2014). Actually, no oxidation whatsoever was observed either in wort or in final beer produced by means of HC-assisted brewing processes (Albanese, Ciriminna, Meneguzzo, & Pagliaro, 2017).

As extensively discussed in a recent review study (Albanese & Meneguzzo, 2019a), among fixed HC reactors, Venturi tubes were preferred over orifice plates in the treatment of viscous food liquids. This superiority holds especially with liquids containing solid

particles, as well as for the inactivation of spoilage microorganisms (Albanese et al., 2015), and for the creation of oil-in-water stable nanoemulsions (Carpenter, George, & Saharan, 2017).
However, a virtually endless variety of Venturi reactors exists, leading to different results in terms of process yields. At the respective optimized geometries, as a rule, slit Venturi reactors outperform circular Venturi in terms of process yields. This holds, for example, for the removal of total organic content from recalcitrant pollutants in wastewater, and for the creation of stable oil-in-water nanoemulsions; as well, wide margins exist for further improving the performances, including the effect of the slit length as a function of its height (Barik & Gogate, 2017; Carpenter, Badve, et al., 2017; Ramisetty, Pandit, & Gogate, 2014).

3. Hydrodynamic Cavitation and the Water-Energy-Food Nexus

3.1 Water and energy in the food production chain

The food production chain revolves around water, with the main clean water fluxes involved in food growth (farming), cleaning and processing, and wastewater streams deriving from the water discharge after any of the above-mentioned uses, with wastewater, desirably, not simply discharged as sewage, but recovered for further use.
Energy supply, in turn, powers cleaning and remediating systems for input water and wastewater streams, as well as food-processing devices, the latter comprising essential steps, such as those aimed at grinding and homogeneization, ensuring microbiological and physical stability, and food storage. Substantial amounts of energy, as well as other resources such as soil improvers and fertilizers, and pesticides, are also required to grow food.
The food itself supplies energy to humans, along with macronutrients and micronutrients. Vitamins and other micronutrients, such as certain phytochemicals available in plant-based food, modulate the effectiveness of the physiological use of food energy, and are essential for health and well-being (Bayram et al., 2018; Willett et al., 2019). Thus, food-manufacturing processes are desirable, which combine the capabilities of producing safe, health-effective, and durable products, while achieving high process yields (*i.e.*, actual net production of desired products per unit energy supplied to the process) with regard to target properties of the products. Based on the desirable spreading of plant-based food in the human diet, as highlighted in Section 1, processes able to enhance the nutritional and nutraceutical value of products derived from vegetable materials, including unconventional sources, such as waste and byproducts of the food and biomass processing chains, would be extremely desirable too.

3.2 Energy-saving HC applications in the food production chain

Basically, HC's outperformance over conventional techniques lies in the fact that physico-chemical and biological reactions and processes can be carried out faster and more efficiently at ambient conditions, and at a lower cost, due to the intense energy delivery at the molecular level in the course of bubbles collapse (Carpenter, Badve, et al., 2017). Consequently, HC processing times were found generally shorter than in conventional extraction techniques, due to the maximization of the mass transfer coefficient generated by cavitation, translating into lower energy consumption (Cravotto

et al., 2018).
In applications requiring working temperatures above the room level, such as in water disinfection and food pasteurization and sterilization, the heating efficiency can affect remarkably the process yields. HC processes showed excellent heating efficiency with a rotor-stator setup of the reactor (Sun et al., 2018). As well, all else being equal, the thermal efficiency was surprisingly higher when a closed loop pumping system comprised a Venturi-shaped HC reactor (Bermejo, Escaler, & Dular, 2018). It should also be noted that electricity is the only power source for HC processes, and it is increasingly generated worldwide by means of renewable energy sources; thus, spreading the adoption of HC techniques would contribute to a substantial improvement of the exergetic sustainability of the food production chain (Zisopoulos, Rossier-Miranda, van der Goot, & Boom, 2017).
A recent, comprehensive and authoritative review explored the main fields where HC can be applied, as a process intensification technique, with distinct advantages over competing techniques (Holkar, Jadhav, Pinjari, & Pandit, 2019). Such processes include water disinfection, wastewater treatment, emulsification, crystallization, synthesis of nanomaterials, delignification, depolymerization, and extraction from biological materials, resulting in higher energy efficiency and process yield, higher efficacy, reduced resource use (solvents, surfactants, oxidizing reagents, etc.), lesser or no toxic byproducts, and, sometimes, higher quality products. Moreover, in the same study, HC's superiority over other cavitation techniques, such as the acoustic and optic ones, was firmly asserted, in terms of efficacy beyond the laboratory scale, energy efficiency, and scalability, although this topic was substantially decided long ago (Gogate & Pandit, 2005; Gogate et al., 2001; Save, Pandit, & Joshi, 1997).
In another recent review, the process yield metric was standardized, aimed at the objective comparison of the energy efficiency of different processes and competing technologies resulting in the same products (Albanese & Meneguzzo, 2019a). Yields resulting from HC-assisted processes always exceeded the corresponding figures associated to any other technology, either conventional or newer, with acoustic cavitation (AC) lagging behind by a factor greater than three. In particular, conventional heat treatment, typical of food pasteurization processes, while outperforming some of the newer techniques, such as high pressure or pulsed electric field, lagged behind HC by a factor of at least 1.2. However, in the case of complex processes, implemented in a single unit operation HC-based system, such as for beer-brewing (Albanese et al., 2017), with pasteurization being only one among many different process steps, the outperformance rose to a factor of around 2.5, or even higher under particular brewing conditions (Albanese, Ciriminna, Meneguzzo, & Pagliaro, 2018).
Lately, higher process yields achieved by means of HC processes were shown for different applications. In the enhancement of biochar properties, HC processes achieved process yields 7 to 30 times higher in comparison with conventional slow thermal pyrolysis (Albanese, Baronti, et al., 2019). In the food production field, the HC-driven lethality effect for yeasts, and heat-resistant molds, was shown to be higher by at least an order of magnitude in comparison with high-pressure homogenization, and two orders of magnitude in comparison with AC (Fan, Martynenko, Doucette, Hughes, & Fillmore, 2018).

3.3 Water-saving HC applications in the food production chain

HC processes can contribute to save and preserve freshwater resources in different stages of the food production chain. A recent study investigated the effects of irrigation with tap water enriched with air micro- and nano-bubbles, generated by means of a Venturi tube HC reactor provided with an air inlet valve, on some morphological and physiological properties of cucumbers grown in greenhouse (Dahrazma, Naghedinia, Ghasemian Gorji, & Saghravani, 2019). Stem length, leaves number, blossom number, chlorophyll a, chlorophyll b, and carotenoids, increased by 1.14, 2.86, 3.80, 1.34, 1.44 and 1.35 times, respectively, in the plants after 12 weeks. The higher crop yield, and the enhanced functional properties, could help saving farming cost, land consumption, and irrigation water.

Irrigation water can be saved for crops growing in soils showing higher water-retaining properties. Biochar manufactured with the assistance of HC processes showed enhanced physical properties, likely leading to increased water retention when deployed in the soil (Albanese, Baronti, et al., 2019).

HC processes were shown able to extract more phytochemicals, such as polyphenols and flavonoids, and achieve remarkably higher antioxidant activity, in comparison with conventional extraction techniques, without the use of any synthetic solvent, *i.e.*, with water as the only solvent. Case studies included cereals and fruits (Lohani, Muthukumarappan, & Meletharayil, 2016), as well as other vegetable and plant materials, such as fir needles (Albanese, Bonetti, D'Acqui, Meneguzzo, & Zabini, 2019). Solvent-free extraction allowed not only the extraction of healthier and safer products, but also a reduction of waste byproducts and wastewater, thus, in principle, the reuse of processing water, or even the direct use of the resulting aqueous solutions for human consumption.

Many studies demonstrated the higher comparative efficacy and efficiency of HC processes in the mineralization, degradation, and reduction, of the total organic content and the chemical oxygen demand of wastewaters containing organic pollutants. The respective performance increased with the use of suitable oxidizing additives, such as hydrogen peroxide, in remarkably lower doses in comparison with conventional techniques, as well avoiding the generation of hazardous byproducts (Ciriminna et al., 2017). The removal of persistent and recalcitrant pesticides was especially interesting for applications to farming-generated wastewater (Panda & Manickam, 2019b).

Finally, HC processes have shown unrivaled ability in the real-scale disinfection of water from spoilage and harmful microorganisms, with a curious double peak of efficacy, one in the developed cavitation regime at relatively high levels of the cavitation number (Albanese et al., 2015; Carpenter, Badve, et al., 2017), the other in the supercavitation regime (Šarc, Kosel, Stopar, Oder, & Dular, 2018). As well, laboratory-scale HC processes were shown able to inactivate even some viruses (Kosel et al., 2017). Combined capabilities to effectively and efficiently remediate and disinfect wastewater, in principle could allow their reuse for further irrigation, leading to the saving of freshwater resources.

3.4 HC-driven exploitation of plant-based food

As shortly discussed in Section 1, the shift to a plant-based diet is likely to be the single most important step to alleviate the burden of the food production chain on the terrestrial ecosystems and the climate. As well, it is likely to lead to comparable or even greater benefits to the general health, alleviating the related economic burden.

Evidence has accumulated about significant inverse correlations between plant antioxidants intake and the risk for cardiovascular diseases, type 2 diabetes, hypercholesterolemia, some cancers, and other globally spreading chronic diseases (Albanese et al., 2018; Tang et al., 2017), as well as no recommended upper limits apply to the intake of antioxidants, for the purpose of health benefits. Indeed, a monotonic increase of the ratio of the antioxidant activity (AA) to the oxidant status in the human blood serum (serum antioxidant/oxidant balance), with the long-term intake of antioxidant bioactive compounds, was recently found, and related to a sort of homeostatic equilibrium (Laus et al., 2017; Soccio, Laus, Alfarano, et al., 2018).

Lately, by means of a novel AA assay, more representative of the real human physiology, a very effective synergism was demonstrated among mixtures of food-grade extracts, as well as among hydrophilic, lipophilic and insoluble-bound phenolic extracts (Soccio, Laus, Flagella, et al., 2018). Such synergism was up to two orders of magnitude greater than revealed by means of classical *in vitro* assays. This result supported the long-known evidence about the higher effectivity of mixtures of plant phytochemicals (including phenolics, carotenoids, vitamin E, lignans, β-glucan, inulin, resistant starch, sterols, and phytates), for the prevention of cancer, cardiovascular disease, type 2 diabetes, and all-cause mortality, in comparison to single phytochemicals (Rui Hai Liu, 2004, 2007). So much, that it was recommended long since to acquire antioxidants or bioactive compounds through whole-food consumption, rather than from expensive dietary supplements (R. H. Liu, 2013).

Therefore, processing of plant foods, including vegetable beverages, should at least avoid damaging the bioactive phytochemicals, for example due to thermal degradation (Domínguez Avila, Wall Medrano, Ruiz Pardo, Montalvo González, & González Aguilar, 2017), while preserving their variety and abundance, including bound phenolics. Whole beverages, possibly including multiple functional ingredients, have the potential to convey superior health benefits than extracts, supplements, and single-ingredient beverages, provided that bioactive compounds are effectively extracted in the liquid phase, as well as go mostly undamaged in the processing. Moreover, processing costs should be kept as low as possible, translating into affordability for end users, as well as the sensorial properties of the products should be as attractive to the general public as possible.

HC processes can lead to enhanced extraction of bioactive compounds in the aqueous phase (*i.e.*, in the end product), by means of the increased release of the respective fraction bound in carbohydrates, lignin, pectin, and proteins, due to the increase of the mass transfer rate and the interphase area (Cravotto et al., 2018; Panda & Manickam, 2019a). Combined with the reduced degradation of the bioactive compounds, due to lower working temperatures (Martynenko & Chen, 2016), higher AA levels could be achieved (Albanese & Meneguzzo, 2019a).

In the case of blueberry (Fan et al., 2018; Martynenko, Astatkie, & Satanina, 2015; Martynenko & Chen, 2016), and cranberry (Chen & Martynenko, 2017), the HC-based enhanced extraction of bioactive compounds (especially anthocyanins) from the whole fruits, combined with superior shelf life achieved at moderate temperatures, allowed straightforward industrialization ("Healthy Berries Ltd – Superfruit Purée," 2019). With sorghum flour and apple pomace, the HC treatment led to AA increasing by 38.6% and 97%, respectively (Lohani et al., 2016).

In the HC-assisted brewing process, increased extraction of polyphenols, and higher AA, was shown with raw unmalted grains (Albanese et al., 2018), as well as boosted extraction of prenylflavonoids from pelletized hops (Ciriminna et al., 2018), both leading to improved healthy properties and shelf life of the end product. Along with higher process yields (Albanese & Meneguzzo, 2019b), these distinctive advantages allowed the development of the HC-based brewing system up to the industrial level (CAVIBEER | CNR & Bysea S.r.l., 2018).

High content of polyphenols and flavonoids, and surprisingly high AA, were revealed in aqueous solutions obtained by means of real-scale, HC-driven solvent-free extraction of silver fir (*Abies Alba* Mill) needles in a concentration as low as 0.44% w/v (Albanese, Bonetti, et al., 2019). In particular, the *in vitro* AA at the level of 10 μg/ml (IC_{50}, DPPH assay) was higher than shown by most reference substances, as well as by vitamins C and E.

The transition to plant-based diets could be facilitated by the full exploitation of nutrients, mainly proteins, which are generally available in lower concentration than in animal-based food. Reduction of particle size and effective cell disruption were the basic steps allowing a HC-based high pressure homogenization treatment to increase the protein availability from soybean processing materials, especially slurry, with the protein extraction yield increased by 82% (Preece, Hooshyar, Krijgsman, Fryer, & Zuidam, 2017). The HC treatment was found to outperform the AC one, as well as showed straightforward scalability. HC-based manufacturing of soymilk is already an industrial reality ("Food industry - TECNIDOS Sistemas y Procesos," 2019).

HC processes found convenient application also with unconventional, land-neutral plant materials, such as microalgae. High HC-driven extraction yield of lipids (25.9–99%) from microalgae (*Nannochloropsis salina*) was obtained, due to the effective cell disruption, showing decreased energy consumption and straightforward scalability (Lee & Han, 2015), as well as it emerged as the fastest process of lipid extraction in comparison to conventional methods (Setyawan, Mulyono, & Budiman, 2018). HC-based edible oil (including algae's oil) extraction and refining technologies have already reached the industrial level ("Degumming | Arisdyne," 2019; "Edible oil refining | Cavitation Technologies, Inc.," 2019).

3.5 Advantageous HC applications in the food production chain

HC technologies, and the related methods, can help addressing any of the steps related to the food production chain, from farming to storage. A scheme highlighting the possible contributions of HC processes is shown in Fig. 2, with details provided in Table 1.

It should be noted that biochar, which can be conveniently manufactured with the assistance of HC processes (Albanese, Baronti, et al., 2019), can in turn be applied to both soil amendment and water retention, and wastewater remediation. Moreover, the food processing step can be assisted by HC processes if the food material can be pumped along a hydraulic circuit, *i.e.*, if it consists of a liquid or mixed solid-liquid matrix, such as, for example, beer wort containing water, grains, and hops (Albanese et al., 2017).

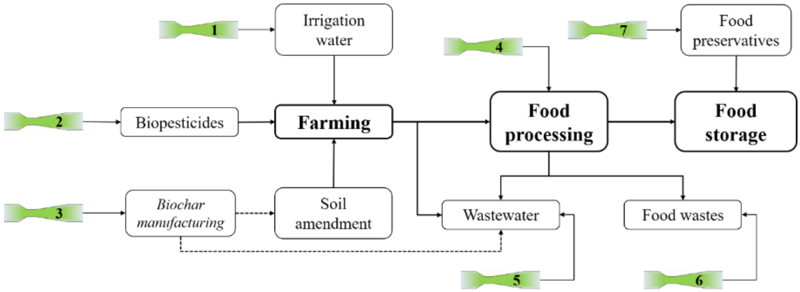


Figure 2. Partial scheme of the possible contributions of hydrodynamic cavitation processes to conventional food production chains. Numbers refer to HC processes applicable to different steps of the food production chains.

Table 1. Possible contributions of hydrodynamic cavitation processes to conventional food production chains: details.

Step[a]	Main applications	HC setup / regime[b]	Main relative advantages[c]	TRL[d]	References[e]
1	Desalination of sea and brackish water	Rotor-stator / supercavitation	Absence of scaling / fouling; higher energy and economical efficiency	3	(Zheng et al., 2019)
	Oxygen-enriched irrigation water	Venturi / developed cavitation	Increase in plant growth and enhancement of physiological indices	6	(Dahrazma et al., 2019)
2	Stable nanoemulsions of essential oils as biopesticides	Venturi / developed cavitation	Less use of emulsifiers/surfactants; more effective action; controlled and prolonged release	3	(Albanese, Bonetti, et al., 2019)[f]
3	Enhancement of biochar properties for soil amendment and water retention	Venturi / developed cavitation	Enhanced physico-chemical properties; higher energy efficiency and process yield	6	(Albanese, Baronti, et al., 2019)
4	Food liquids homogenization, pasteurization and sterilization, emulsification, extraction and reaction intensification, single-unit operation	Any setup / developed cavitation	Enhanced preservation of thermolabile compounds; enhanced physical and microbiological stability; higher energy efficiency and process yield	5-9	(Albanese & Meneguzzo, 2019b)
5	Removal/degradation of organic and recalcitrant water pollutants	Any setup / developed cavitation	Less use of oxidizing additives; higher energy efficiency and process yield	5-9	(Ciriminna et al., 2017)
	Water disinfection from bacteria and harmful microorganisms	Rotor-stator and Venturi / supercavitation	Enhanced microbiological stability; higher energy and economic efficiency	4	(Šarc et al., 2018)
6	Extraction of valuable bioactive compounds, solubilization	Any setup / developed cavitation	Economic valorization of food wastes; more efficient use of residues to feed livestock or biogas generation plants	9	(Grillo et al., 2019)
7	Extraction of antioxidant and antimicrobial compounds affecting shelf-life	Venturi / developed cavitation	Enhanced extraction rate; higher energy efficiency and process yield	8	(Ciriminna et al., 2018)

[a] Numbers in this column refer to Fig. 2.
[b] Relative to the cited reference.

[c] In comparison with competing technologies.
[d] Technology readiness level (Mankins, 2009).
[e] Only the most representative or recent reference is supplied for each of the considered applications.
[f] This reference recommends the relevant application for further research.

4. Discussion and Conclusions

At the current stage of development, hydrodynamic cavitation technologies are ready to favor a substantial efficiency leap in virtually any step of the food production chain, due to their applicability to many different processes, either stand-alone or in synergy with conventional techniques, the ability to intensify physico-chemical reactions and processes, the superior process yields, and the straightforward scalability. However, the lack of adequate standardization for any given application, affecting both the proper choice among different classes of HC reactors, and, within a specific class of reactors, the choice of the suitable process parameters, are still partially hindering the widespread adoption.

Nevertheless, industrial-level applications are emerging and fulfilling promises, while scholars are increasingly active in the search for new applications, and the definition of case-specific structural and process parameters. This review provided a short but hopefully representative view of the current trends.

About future perspectives, it should be noted that HC techniques can be applied to the processing of virtually any food material that has been the subject of experiments by means of AC techniques, provided that such material can be pumped along a piping system. Since AC has been experimented much more frequently, and with far more substances, than HC, including in food processing and extraction applications, although mostly at the laboratory scale, a virtually endless field of new applications for HC processes exists, with proven advantages, such as straightforward scalability and much higher process yields, likely to extend to any new case study.

As a representative example, AC-assisted extraction of polyphenols from maritime pine sawdust, a by-product from the industry of wood transformation, thus non-competitive with either food crops and land use, outperformed conventional maceration by 40% at the laboratory scale, such figure decreasing with scaling-up (Meullemiestre, Petitcolas, Maache-Rezzoug, Chemat, & Rezzoug, 2016). The opposite trend is expected for a possible HC application to the same process, which is thus recommended for further research.

Sometimes, industry seems to have taken advantage of research, to turn laboratory-scale AC applications into real-scale marketable HC systems. This is the case of the extraction of bioactive compounds from *Cannabis Sativa* L., such as polyphenols, flavonoids, and cannabinoids, which was shown to increase at least by 100% under AC conditions, in comparison with the control extraction (Agarwal, Máthé, Hofmann, & Csóka, 2018). In 2018, a company introduced in the market an HC-based extraction system, claimed to treat the whole plant, converting cannabinoids into nanoemulsions, and, combined with moderate working temperatures, ensuring higher bioavailability, in additions to using much less solvents, and cutting production costs ("PhytoX | Hydrodynamic Extraction | Full Spectrum Extraction Cannabis," 2018).

Both phytochemicals whose dietary intake is potentially beneficial to human health, and plants candidate for the respective extraction, are countless, with the *in vivo* effects still to be determined in most of the cases, let alone the possible synergisms and the methods of use, such as for the fortification of functional and medicinal beverages (Eksi, Kurbanoglu, & Ozkan, 2019). Either AC or HC have not yet been applied to the vast majority of plant materials and the extraction of the respective phytochemicals. This evidence, combined with quickly rising market trends for plant-based, healthy beverages, as well as for greener pesticides, offer research and applications concerning HC techniques and methods, with their proven competitive advantages, a bright future ahead.

References

Agarwal, C., Máthé, K., Hofmann, T., & Csóka, L. (2018). Ultrasound-Assisted Extraction of Cannabinoids from Cannabis Sativa L. Optimized by Response Surface Methodology. *Journal of Food Science*, *83*(3), 700–710. https://doi.org/10.1111/1750-3841.14075

Albanese, L., Baronti, S., Liguori, F., Meneguzzo, F., Barbaro, P., & Vaccari, F. P. (2019). Hydrodynamic cavitation as an energy efficient process to increase biochar surface area and porosity: A case study. *Journal of Cleaner Production*, *210*, 159–169. https://doi.org/10.1016/J.JCLEPRO.2018.10.341

Albanese, L., Bonetti, A., D'Acqui, L. P., Meneguzzo, F., & Zabini, F. (2019). Affordable Production of Antioxidant Aqueous Solutions by Hydrodynamic Cavitation Processing of Silver Fir (Abies Alba Mill.) Needles. *Foods*, *8*(2), 65. https://doi.org/10.3390/foods8020065

Albanese, L., Ciriminna, R., Meneguzzo, F., & Pagliaro, M. (2015). Energy efficient inactivation of Saccharomyces cerevisiae via controlled hydrodynamic cavitation. *Energy Science & Engineering*, *3*(3), 221–238. https://doi.org/10.1002/ese3.62

Albanese, L., Ciriminna, R., Meneguzzo, F., & Pagliaro, M. (2017). Beer-brewing powered by controlled hydrodynamic cavitation: Theory and real-scale experiments. *Journal of Cleaner Production*, *142*, 1457–1470. https://doi.org/10.1016/j.jclepro.2016.11.162

Albanese, L., Ciriminna, R., Meneguzzo, F., & Pagliaro, M. (2018). Innovative beer-brewing of typical, old and healthy wheat varieties to boost their spreading. *Journal of Cleaner Production*, *171*, 297–311. https://doi.org/10.1016/j.jclepro.2017.10.027

Albanese, L., & Meneguzzo, F. (2019a). 10 - Hydrodynamic Cavitation Technologies: A Pathway to More Sustainable, Healthier Beverages, and Food Supply Chains. In A. M. Grumezescu & A. M. Holban (Eds.), *Processing and Sustainability of Beverages* (pp. 319–372). https://doi.org/10.1016/B978-0-12-815259-1.00010-0

Albanese, L., & Meneguzzo, F. (2019b). 7 - Hydrodynamic Cavitation-Assisted Processing of Vegetable Beverages: Review and the Case of Beer-Brewing. In A. M. Grumezescu & A. M. Holban (Eds.), *Production and Management of Beverages* (pp. 211–257). https://doi.org/10.1016/B978-0-12-815260-7.00007-9

Bagal, M. V, & Gogate, P. R. (2014). Wastewater treatment using hybrid treatment schemes based on cavitation and Fenton chemistry: a review. *Ultrasonics Sonochemistry*, *21*(1), 1–14. https://doi.org/10.1016/j.ultsonch.2013.07.009

Bajželj, B., Richards, K. S., Allwood, J. M., Smith, P., Dennis, J. S., Curmi, E., & Gilligan, C. A. (2014). Importance of food-demand management for climate mitigation. *Nature Climate Change*, *4*(10), 924–929. https://doi.org/10.1038/nclimate2353

Barik, A. J., & Gogate, P. R. (2017). Hybrid treatment strategies for 2,4,6-trichlorophenol degradation based on combination of hydrodynamic cavitation and AOPs. *Ultrasonics Sonochemistry*, *40*, 383–394. https://doi.org/10.1016/j.ultsonch.2017.07.029

Bayram, B., González-Sarrías, A., Istas, G., Garcia-Aloy, M., Morand, C., Tuohy, K., … Mena, P. (2018). Breakthroughs in the Health Effects of Plant Food Bioactives: A Perspective on Microbiomics, Nutri(epi)genomics, and Metabolomics. *Journal of Agricultural and Food Chemistry*, *66*(41), 10686–10692. https://doi.org/10.1021/acs.jafc.8b03385

Bermejo, D., Escaler, X., & Dular, M. (2018). Experimental Investigation of the Cavitation Effects on the Heat Generation in a Closed Loop Pumping System. In J. Katz & B. Adamson (Eds.), *The 10th International Symposium on Cavitation (CAV2018)*. Retrieved from https://cav2018.jhu.edu/wp-content/uploads/Escaler-Xavier.pdf

Carpenter, J., Badve, M., Rajoriya, S., George, S., Saharan, V. K., & Pandit, A. B. (2017). Hydrodynamic cavitation: an emerging technology for the intensification of various chemical and physical processes in a chemical process industry. *Reviews in Chemical Engineering*, *33*(5), 433–468. https://doi.org/10.1515/revce-2016-0032

Carpenter, J., George, S., & Saharan, V. K. (2017). Low pressure hydrodynamic cavitating device for producing highly stable oil in water emulsion: Effect of geometry and cavitation number. *Chemical Engineering and Processing: Process Intensification*, *116*, 97–104. https://doi.org/10.1016/j.cep.2017.02.013

CAVIBEER | CNR & Bysea S.r.l. (2018). Cavibeer. Retrieved January 9, 2019, from http://www.cavibeer.com/

Chen, Y., & Martynenko, A. (2017). Storage stability of cranberry puree products processed with hydrothermodynamic (HTD) technology. *LWT - Food Science and Technology*, *79*, 543–553. https://doi.org/10.1016/j.lwt.2016.10.060

Ciriminna, R., Albanese, L., Di Stefano, V., Delisi, R., Avellone, G., Meneguzzo, F., & Pagliaro, M. (2018). Beer produced via hydrodynamic cavitation retains higher amounts of xanthohumol and other hops prenylflavonoids. *LWT - Food Science and Technology*, *91*, 160–167. https://doi.org/10.1016/j.lwt.2018.01.037

Ciriminna, R., Albanese, L., Meneguzzo, F., & Pagliaro, M. (2017). Wastewater remediation via controlled hydrocavitation. *Environmental Reviews*, *25*(2), 175–183. https://doi.org/10.1139/er-2016-0064

Cravotto, G., Mariatti, F., Gunjevic, V., Secondo, M., Villa, M., Parolin, J., & Cavaglià, G. (2018). Pilot Scale Cavitational Reactors and Other Enabling Technologies to Design the Industrial Recovery of Polyphenols from Agro-Food By-Products, a Technical and Economical Overview. *Foods*, *7*(9), 130. https://doi.org/10.3390/foods7090130

Dahrazma, B., Naghedinia, A., Ghasemian Gorji, H., & Saghravani, S. F. (2019). Morphological and Physiological Responses of Cucumis sativus L. to Water with Micro-Nanobubbles. *Journal of Agricultural Science and Technology*, *21*(1), 181–192. Retrieved from http://jast.modares.ac.ir/article-23-15964-en.html

Degumming | Arisdyne. (2019). Retrieved April 7, 2019, from http://www.arisdyne.com/content/degumming

Di Paola, A., Rulli, M. C., & Santini, M. (2017). Human food vs. animal feed debate. A thorough analysis of environmental footprints. *Land Use Policy*, *67*, 652–659. https://doi.org/10.1016/j.landusepol.2017.06.017

Dindar, E. (2016). An Overview of the Application of Hydrodinamic Cavitation for the Intensification of Wastewater Treatment Applications: A Review. *Innovative Energy & Research*, *5*(137), 1–7. https://doi.org/10.4172/ier.1000137

Doltade, S. B., Dastane, G. G., Jadhav, N. L., Pandit, A. B., Pinjari, D. V., Somkuwar, N., & Paswan, R. (2019). Hydrodynamic cavitation as an imperative technology for the treatment of petroleum refinery effluent. *Journal of Water Process Engineering*, *29*, 100768. https://doi.org/10.1016/j.jwpe.2019.02.008

Domínguez Avila, J. A., Wall Medrano, A., Ruiz Pardo, C. A., Montalvo González, E., & González Aguilar, G. A. (2017). Use of nonthermal technologies in the production of functional beverages from vegetable ingredients to preserve heat-labile phytochemicals. *Journal of Food Processing and Preservation*, e13506. https://doi.org/10.1111/jfpp.13506

Dular, M. (2016). Hydrodynamic cavitation damage in water at elevated temperatures. *Wear*, *346*, 78–86. https://doi.org/10.1016/j.wear.2015.11.007

Edible oil refining | Cavitation Technologies, Inc. (2019). Retrieved April 7, 2019, from http://www.ctinanotech.com/technology/edible-oil-refining

Eksi, G., Kurbanoglu, S., & Ozkan, S. A. (2019). Fortification of Functional and Medicinal Beverages With Botanical Products and Their Analysis. In A. M. Grumezescu & A. M. Holban (Eds.), *Engineering Tools in the Beverage Industry* (pp. 351–404). https://doi.org/10.1016/B978-0-12-815258-4.00012-3

Fan, L., Martynenko, A., Doucette, C., Hughes, T., & Fillmore, S. (2018). Microbial Quality and Shelf Life of Blueberry Purée Developed Using Cavitation Technology. *Journal of Food Science*, *83*(3), 732–739. https://doi.org/10.1111/1750-3841.14073

Food industry - TECNIDOS Sistemas y Procesos. (2019). Retrieved October 23, 2017, from http://www.tecnidos.com/en/index.php/nanocavitacion-hidrodinamica/industria-alimentaria/

Gogate, P. R. (2002). Cavitation: an auxiliary technique in wastewater treatment schemes. *Advances in Environmental Research*, *6*(3), 335–358. https://doi.org/10.1016/S1093-0191(01)00067-3

Gogate, P. R., & Pandit, A. B. (2001). Hydrodynamic cavitation reactors: a state of the art review. *Reviews in Chemical Engineering*, *17*(1), 1–85. https://doi.org/10.1515/REVCE.2001.17.1.1

Gogate, P. R., & Pandit, A. B. (2005). A review and assessment of hydrodynamic cavitation as a technology for the future. *Ultrasonics Sonochemistry*, *12*(1–2 SPEC. ISS.), 21–27. https://doi.org/10.1016/j.ultsonch.2004.03.007

Gogate, P. R., Shirgaonkar, I. Z., Sivakumar, M., Senthilkumar, P., Vichare, N. P., & Pandit, A. B. (2001). Cavitation reactors: Efficiency assessment using a model reaction. *AIChE Journal*, *47*(11), 2526–2538. https://doi.org/10.1002/aic.690471115

Grillo, G., Boffa, L., Binello, A., Mantegna, S., Cravotto, G., Chemat, F., … Telysheva, G. (2019). Cocoa bean shell waste valorisation; extraction from lab to pilot-scale cavitational reactors. *Food Research International*, *115*, 200–208. https://doi.org/10.1016/j.foodres.2018.08.057

Healthy Berries Ltd – Superfruit Purée. (2019). Retrieved April 7, 2019, from https://lovehealthyberries.ca/

Holkar, C. R., Jadhav, A. J., Pinjari, D. V., & Pandit, A. B. (2019). Cavitationally Driven Transformations: A Technique of Process Intensification. *Industrial & Engineering Chemistry Research*, acs.iecr.8b04524. https://doi.org/10.1021/acs.iecr.8b04524

Kosel, J., Gutiérrez-Aguirre, I., Rački, N., Dreo, T., Ravnikar, M., & Dular, M. (2017). Efficient inactivation of MS-2 virus in water by hydrodynamic cavitation. *Water Research*, *124*, 465–471. https://doi.org/10.1016/j.watres.2017.07.077

Laus, M. N., Soccio, M., Alfarano, M., Pasqualone, A., Lenucci, M. S., Di Miceli, G., & Pastore, D. (2017). Different effectiveness of two pastas supplemented with either lipophilic or hydrophilic/phenolic antioxidants in affecting serum as evaluated by the novel Antioxidant/Oxidant Balance approach. *Food Chemistry*, *221*, 278–288. https://doi.org/10.1016/j.foodchem.2016.10.050

Lee, I., & Han, J. I. (2015). Simultaneous treatment (cell disruption and lipid extraction) of wet microalgae using hydrodynamic cavitation for enhancing the lipid yield. *Bioresource Technology*, *186*, 246–251. https://doi.org/10.1016/j.biortech.2015.03.045

Li, W., Yang, Y., Shi, W. D., Zhao, X., & Li, W. (2018). The correction and evaluation of cavitation model considering the thermodynamic effect. *Mathematical Problems in Engineering*, *2018*(Article ID 7217513), 1–11. https://doi.org/10.1155/2018/7217513

Liu, R. H. (2004). Potential synergy of phytochemicals in cancer prevention: mechanism of action. *The Journal of Nutrition*, *134*(12 Suppl), 3479S–3485S. https://doi.org/10.1093/jn/134.12.3479S

Liu, R. H. (2007). Whole grain phytochemicals and health. *Journal of Cereal Science*, *46*(3), 207–219. https://doi.org/10.1016/j.jcs.2007.06.010

Liu, R. H. (2013). Health-Promoting Components of Fruits and Vegetables in the Diet. *Advances in Nutrition: An International Review Journal*, *4*(3), 384S–392S. https://doi.org/10.3945/an.112.003517

Lohani, U. C., Muthukumarappan, K., & Meletharayil, G. H. (2016). Application of hydrodynamic cavitation to improve antioxidant activity in sorghum flour and apple pomace. *Food and Bioproducts Processing*, *100*, 335–343. https://doi.org/10.1016/j.fbp.2016.08.005

Mankins, J. C. (2009). Technology readiness assessments: A retrospective. *Acta Astronautica*, *65*(9–10), 1216–1223. https://doi.org/10.1016/j.actaastro.2009.03.058

Martynenko, A., Astatkie, T., & Satanina, V. (2015). Novel hydrothermodynamic food processing technology. *Journal of Food Engineering*, *152*, 8–16. https://doi.org/10.1016/j.jfoodeng.2014.11.016

Martynenko, A., & Chen, Y. (2016). Degradation kinetics of total anthocyanins and formation of polymeric color in blueberry hydrothermodynamic (HTD) processing. *Journal of Food Engineering*, *171*, 44–51. https://doi.org/10.1016/j.jfoodeng.2015.10.008

Meullemiestre, A., Petitcolas, E., Maache-Rezzoug, Z., Chemat, F., & Rezzoug, S. A. (2016). Impact of ultrasound on solid–liquid extraction of phenolic compounds from maritime pine sawdust waste. Kinetics, optimization and large scale experiments. *Ultrasonics Sonochemistry*, *28*, 230–239. https://doi.org/10.1016/J.ULTSONCH.2015.07.022

Motesharrei, S., Rivas, J., Kalnay, E., Asrar, G. R., Busalacchi, A. J., Cahalan, R. F., … Zeng, N. (2017). Modeling sustainability: Population, inequality, consumption, and bidirectional coupling of the Earth and human Systems. *National Science Review*, *3*(4), 470–494. https://doi.org/10.1093/nsr/nww081

Ngadi, M. O., Latheef, M. Bin, & Kassama, L. (2012). Emerging technologies for microbial control in food processing. In J. I. Boye & Y. Arcand (Eds.), *Green technologies in food production and processing* (pp. 363–411). https://doi.org/10.1007/978-1-4614-1587-9_14

Panda, D., & Manickam, S. (2019a). Cavitation Technology—The Future of Greener Extraction Method: A Review on the Extraction of Natural Products and Process Intensification Mechanism and Perspectives. *Applied Sciences*, *9*(4), 766. https://doi.org/10.3390/app9040766

Panda, D., & Manickam, S. (2019b). Hydrodynamic cavitation assisted degradation of persistent endocrine-disrupting organochlorine pesticide Dicofol: Optimization of operating parameters and investigations on the mechanism of intensification. *Ultrasonics Sonochemistry*, *51*, 526–532. https://doi.org/10.1016/j.ultsonch.2018.04.003

Patil, M. N., & Pandit, A. B. (2007). Cavitation - A novel technique for making stable nano-suspensions. *Ultrasonics Sonochemistry*, *14*(5), 519–530. https://doi.org/10.1016/j.ultsonch.2006.10.007

Pawar, S. K., Mahulkar, A. V., Pandit, A. B., Roy, K., & Moholkar, V. S. (2017). Sonochemical effect induced by hydrodynamic cavitation: Comparison of venturi/orifice flow geometries. *AIChE Journal*, *63*(10), 4705–4716. https://doi.org/10.1002/aic.15812

PhytoX | Hydrodynamic Extraction | Full Spectrum Extraction Cannabis. (2018). Retrieved April 7, 2019, from http://iasocorp.com/phytox/

Preece, K. E., Hooshyar, N., Krijgsman, A. J., Fryer, P. J., & Zuidam, N. J. (2017). Intensification of protein extraction from soybean processing materials using hydrodynamic cavitation. *Innovative Food Science and Emerging Technologies*, *41*, 47–55. https://doi.org/10.1016/j.ifset.2017.01.002

Ramisetty, K. A., Pandit, A. B., & Gogate, P. R. (2014). Novel Approach of Producing Oil in Water Emulsion Using Hydrodynamic Cavitation Reactor. *Industrial & Engineering Chemistry Research*, *53*(42), 16508–16515. https://doi.org/10.1021/ie502753d

Rohmer, S. U. K., Gerdessen, J. C., & Claassen, G. D. H. (2019). Sustainable supply chain design in the food system with dietary considerations: A multi-objective analysis. *European Journal of Operational Research*, *273*(3), 1149–1164. https://doi.org/10.1016/j.ejor.2018.09.006

Šarc, A., Kosel, J., Stopar, D., Oder, M., & Dular, M. (2018). Removal of bacteria Legionella pneumophila , Escherichia coli, and Bacillus subtilis by (super)cavitation. *Ultrasonics Sonochemistry*, *42*, 228–236. https://doi.org/10.1016/j.ultsonch.2017.11.004

Šarc, A., Stepišnik-Perdih, T., Petkovšek, M., & Dular, M. (2017). The issue of cavitation number value in studies of water treatment by hydrodynamic cavitation. *Ultrasonics Sonochemistry*, *34*, 51–59. https://doi.org/10.1016/j.ultsonch.2016.05.020

Sarvothaman, V. P., Simpson, A. T., & Ranade, V. V. (2018). Modelling of vortex based hydrodynamic cavitation reactors. *Chemical Engineering Journal*. https://doi.org/10.1016/j.cej.2018.08.025

Save, S. S., Pandit, A. B., & Joshi, J. B. (1997). Use of Hydrodynamic cavitation for large scale microbial cell disruption. *Trans IChemE*, *75*(C), 41–49. https://doi.org/DOI: 10.1205/096030897531351

Setyawan, M., Mulyono, P., & Budiman, A. (2018). Comparison of Nannochloropsis sp . cells disruption between hydrodynamic cavitation and conventional extraction. *MATEC Web of Conferences - ICET4SD 2017*, *154*, 01023. https://doi.org/10.1051/matecconf/201815401023

Soccio, M., Laus, M., Flagella, Z., Pastore, D., Soccio, M., Laus, M. N., … Pastore, D. (2018). Assessment of Antioxidant Capacity and Putative Healthy Effects of Natural Plant Products Using Soybean Lipoxygenase-Based Methods. An Overview. *Molecules*, *23*(12), 3244. https://doi.org/10.3390/molecules23123244

Soccio, M., Laus, M. N., Alfarano, M., Dalfino, G., Panunzio, M. F., & Pastore, D. (2018). Antioxidant/Oxidant Balance as a novel approach to evaluate the effect on serum of long-term intake of plant antioxidant-rich foods. *Journal of Functional Foods*, *40*, 778–784. https://doi.org/10.1016/j.jff.2017.12.012

Soyama, H., & Hoshino, J. (2016). Enhancing the aggressive intensity of hydrodynamic cavitation through a Venturi tube by increasing the pressure in the region where the bubbles collapse. *AIP Advances*, *6*, 045113. https://doi.org/10.1063/1.4947572

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., … Willett, W. (2018). Options for keeping the food system within environmental limits. *Nature*, *562*(7728), 519–525. https://doi.org/10.1038/s41586-018-0594-0

Springmann, M., Godfray, H. C. J., Rayner, M., & Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences*, *113*(15), 4146–4151. https://doi.org/10.1073/pnas.1523119113

Sun, X., Park, J. J., Kim, H. S., Lee, S. H., Seong, S. J., Om, A. S., & Yoon, J. Y. (2018). Experimental investigation of the thermal and disinfection performances of a novel hydrodynamic cavitation reactor. *Ultrasonics Sonochemistry*, *49*, 13–23. https://doi.org/10.1016/j.ultsonch.2018.02.039

Tang, G. Y., Meng, X., Li, Y., Zhao, C. N., Liu, Q., & Li, H. Bin. (2017). Effects of vegetables on cardiovascular diseases and related mechanisms. *Nutrients*, *9*(8), 857. https://doi.org/10.3390/nu9080857

Taylor, T. G., & Tainter, J. A. (2016). The Nexus of Population, Energy, Innovation, and Complexity. *American Journal of Economics and Sociology*, *75*(4), 1005–1043. https://doi.org/10.1111/ajes.12162

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/10.1038/nature13959

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. J. L. (2019). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet (London, England)*, *393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Yasui, K., Tuziuti, T., Sivakumar, M., & Iida, Y. (2004). Sonoluminescence. *Applied Spectroscopy Reviews*, *39*(3), 399–436. https://doi.org/10.1081/ASR-200030202

Yusaf, T., & Al-Juboori, R. a. (2014). Alternative methods of microorganism disruption for agricultural applications. *Applied Energy*, *114*, 909–923. https://doi.org/10.1016/j.apenergy.2013.08.085

Zheng, Z., Li, Q., Wang, L., Yao, L., Cai, W., Li, H., & Li, F. (2019). Numerical study on morphological characteristics of rotational natural supercavitation by rotational supercavitating evaporator with optimized blade shape. *Journal of Hydrodynamics*, 1–17. https://doi.org/10.1007/s42241-019-0007-3

Zisopoulos, F. K., Rossier-Miranda, F. J., van der Goot, A. J., & Boom, R. M. (2017). The use of exergetic indicators in the food industry – A review. *Critical Reviews in Food Science and Nutrition*, *57*(1), 197–211. https://doi.org/10.1080/10408398.2014.975335

4. Sustainable Land use Planning Solutions for Water Resource Management in Serbia

Jelena Živanović Miljković, Marijana Pantić, Ljubiša Bezbradica

ABSTRACT:
The paper starts from the fact that spatial and urban planning promote sound land use planning and express interests in the sustainable development of land, water and related resources and infrastructure. The authors investigate existing of sustainable land use planning solutions for water resources management within spatial planning documents.
With regard to the fact that integration of water management (i.e. drinking water management, wastewater management etc.) and land use planning is essential in achieving sustainable development, this paper (1) introduces a national framework for sustainable land use and water management in Serbia; (2) analyzes the role of land use and water related issues within the land use decision making process; and (3) discusses and outlines the sustainable land use solutions within planning documents developed for special purpose areas, with focus on effects of land use planning solution on water resource management.

Keywords: urban and spatial planning, sustainable land use, water management, Serbia

Dr Jelena Živanović Miljković holds BSc, MSc and PhD degrees in Spatial Planning from the University of Belgrade, Faculty of Geography. She works as a Research Fellow at the Institute of Architecture and Urban & Spatial Planning of Serbia. Her research interests are focused on spatial, urban and peri-urban planning, land use planning, land policy, land development, and land property rights. She is a member of the Serbian Spatial Planners Association, Engineering Chamber of Serbia and International Academic Association on Planning, Law and Property Rights (PLPR).

Dr Marijana Pantić holds BSc and MSc degrees reworded by the Faculty of Geography University of Belgrade and PhD degree reworded by the Technische Universität Dresden - Faculty of Environmental Sciences. Currently she works as a Research Fellow at the Institute of Architecture and Urban & Spatial Planning of Serbia. Her research interests are focused on spatial and urban planning, demography, settlement network and typology, and mountain areas. She is a part of the "Cities in the future" initiative by the Academy of Engineering Sciences of Serbia.

Ljubiša Bezbradica holds M.Eng. degree from University of Belgrade, Faculty of Forestry. He works as a Research Trainee at the Institute of Architecture and Urban & Spatial Planning of Serbia. His research interests are focused on protection of soil from erosion, sustainable use of water resources in spatial planning. He is a member of the Engineering Chamber of Serbia.

1. Introduction

Sustainable water resources management and securing availability of water resources are among 17 global sustainable development goals that should be achieved until 2030 at all levels (UN, 2015). The Water Framework Directive (2001), regulates an integrated water protection in the EU and it requires the spatial identification of all activities liable to have impact on water bodies.

Water management issues have a spatial planning dimension (Dühr et al., 2010), where the spatial planning plays a significant role in water protection. Largely successful, the integrated water resources planning approach has become a guiding principle for countries worldwide. Rodríguez et al. (2015) emphasize that it is necessary to establish coordination strategies between land use planning and water resource management, which is expected to improve future sustainability of a region. Nevertheless, it was noticed that there is certain disconnection between land use planning and water resources planning due to different levels of government and decision makers responsible for land use planning and for water planning (Tarlock, 2002; Dobricic, Marjanovic, 2017).

There are water reservoirs of different primary purpose – for water-supply, energy production (hydro power-plants) or for mitigation of consequences expected due to torrent flows. In the case of reservoirs planned for water-supply, use of the surrounding land is more restrictive. This is in other to secure their primary purpose – high water quality. On the other hand, legal and planning framework allow much higher level of creativity when it comes to multifunctional land use and development of activities around reservoirs with primary function in energy production or mitigation of excessive precipitation impact (Pihler et al., 2013; Danilović Hristić et al., 2018).

In cooperation with other complementary disciplines, spatial planning in Serbia represents the key instrument for balancing between land use change and consequences that the change can bring (Spasić et al., 2009). The practice of changing environment exists in the country since centuries, which includes construction of complex elements of infrastructure such as – river regulations, embankments, dams, irrigation and drainage systems, etc. (Dobricic, Marjanovic, 2017). Without spatial planning and spatial plans, water management in Serbia would remain mainly in jurisdiction of public institutions that take care only on sectoral and technical issues, thus omitting integrated approach and complexity of environment (Pihler et al., 2013). Therefore, the role of spatial planning is to balance between protection and development, which is reflected in relativization of conflicts (Pantic et al., 2018).

This paper starts from the fact that planning, regulation and use of space in Serbia bases, inter alia, on the principle of rational and sustainable use of resources. The authors systemize and evaluate land use solutions given within the planning documents developed for special purpose areas for the water supply reservoirs, following their main purposes – water supply and protection against flooding.

2. Methodology

The research is conducted using qualitative research methods, literature review, document analysis, analysis of the institutional and regulatory framework and case study analysis. The international documents set out the context of the analysis, but the main focus was on analyzing the national spatial documents. The documents have been analyzed in order to identify sustainable land use planning solutions for water resources management in Serbia. In order to present the water resource issues within the planning, the authors conducted an analysis of the case studies represented in newly developed special purpose area spatial plans (SPASPs) for existing water supply reservoirs – Prvonek and Vrutci, and for planned water supply reservoir – Jelašnica (Figure 1), adopted in the period 2017-2018. Comprehensive qualitative assessment of the land use planning solutions regarding measures for water protection and protection from water is defined regarding restrictions implemented in land use (Prvonek and Vrutci) and land use change in case of the planned water reservoir (Jelašnica) (Table 1).

Figure 1: The location of case studies in the Republic of Serbia.
*Source: elaborated by the authors. *The map is symbolic.*

Table 1: Basic spatial and land information of analysed SPASPs.

Reservoir	Watershed within the plan (%)	Area outside of watershed (%)	Average terrain slope in watershed (%)
Jelašnica	35.4	64.6	30.0
Prvonek	75.0	25.0	35.0
Vrutci	54.4	45.6	18.3

Source: SPASP Jelašnica, 2017; SPASP Prvonek, 2018; SPASP Vrutci, 2018.

3. National Legal Framework for Sustainable Land Use and Water Management in Serbia

The Republic of Serbia, in accordance with its European integration process, continuously performs activities on innovation of the strategic, legislative and planning framework. Serbia has the main strategic documents governing the environmental policy, including water resources, together with implementation programs. The national development policy framed by various strategies, aims to define the basic conditions for the implementation of the globally accepted trend of sustainable development.

Sustainable use and protection of natural values in Serbia is provided by solutions of Spatial Plan of the Republic of Serbia (2010) and National Strategy for Sustainable Use of Natural Resources and Properties (2012), while long-term water management directions are determined by the Water Management Strategy (2017).

Water is a natural resource and it is owned by the Republic of Serbia. Both water and water land are considered as public good. Unlike water, water land can be in all forms of ownership (private, public and cooperative). The state is concerned about integrated water management i.e. to implementation of measures and activities aimed at maintaining and improving the water regime, ensuring the required quantities of water required for different purposes, protection of water against pollution and protection of other assets in the case of extreme water events.

Water Management Master Plan of the Republic of Serbia (2002) is a long-term plan for the maintenance and development of the water regime in an entire or part of a water area in Serbia. It establishes a basic strategy for water use, water protection and protection from water, and provides solutions that ensure the maintenance and development of the water regime, with the most favorable and best-performing technical and financial solutions for integrated water management. This document is in the accordance with the Spatial Plan of the Republic of Serbia, the strategy in the field of environment and other relevant domestic planning documents. Nevertheless, the role of this document within the current planning and regulatory framework remains unclear despite the fact that this document contains valuable strategic directions not all of which have been integrated into the Water Management Strategy (Dobricic, Marjanovic, 2017).

Water protection issues have a legal basis in the Law on Environment Protection (2004) and the Law on Water (2010). The Law on Environment Protection (2004) regulates integrated environmental protection system and establishes natural values management through the planning of sustainable use and the preservation of their quality and diversity. The Law on Water (2010) regulates the legal status of waters, integrated water management (use and protection of water, protection against water and development of water resources), management of water facilities and water land[8]. Water land is in function of maintenance and improvement of the water regime and it is used for the construction and reconstruction of water facilities, maintenance of the river beds, as well as for protection against harmful effects of water. Also, water land can be used for construction of other public facilities (i.e. public line infrastructure facilities) or for the performing of economic activities (i.e. formation of temporary gravel and sand deposits; sport, recreation and tourism; agricultural activities).

In addition, both laws on water resource protection proclaim the establishment of three levels of protection – i.e. zones of protection, which are further regulated through by-laws. This primarily involves delineation of a construction zone at multiply locations, which depends on the capacity of the water resources and on the level of vulnerability, as well as the purpose of the construction on the locations. In certain zones, where the protection area is delimited, some activities are being allowed by regulations that are in accordance with the primary purpose for which the reservoir was created.

4. Relationship between Land Use Planning Solutions and Water Resources

Spatial planning is an activity primarily aimed at protecting goods of public interest. As such, it is also recognized as an area that is a segment in water protection (Water Management Strategy, 2017), since water supply represent an activity of public interest. In Serbia, the Law on Planning and Construction (2009) (LPC) regulates the field of spatial and urban planning and the adoption of planning documents, the documents for the implementation of spatial plans, as well as the urban technical documents. Spatial planning documents include the Spatial Plan of the Republic of Serbia, regional spatial plans, spatial plans for the local governmental units and special purpose area spatial plans. After adoption, implementation of a spatial and an urban plan is legally binding for all institutions at national, regional and local level.

The spatial planning documents contain protection measures, regulation and use of all elements of the environment, as well as water resources. National spatial plan, i.e. the Spatial Plan of the Republic of Serbia (2010) could also be concerned as a legal act, since it is adopted and published in the same manner as any other law. It defines proposals and

[8] Water land is the land constantly or occasionally under the water, for which special hydrological, geomorphological and biological relations occur and impact the water and coastal ecosystems.

directives for all spatial development issues and measures and instruments for their implementing.
One of the basic actions by which spatial planning protects water resources, as well as public interest, is land use zoning. The zoning, as established standards of acceptable land use, helps to control undesirable impacts and represents the best way to reduce spatial conflicts in land use (Pantić et al., 2019). The Order on Protection Regimes (2012) defines three levels of protection within zone of protection whereby I level of protection regime strictly prohibits any use of natural resources, the construction, works and activities within the protected area. Since water sources are being assigned three zones distinguished by level of protection (by the Law on Nature Protection), spatial planning integrates them into land use planning process.
According to the Law on Environment Protection (2004) the development of a strategic environmental impact assessment is mandatory for all strategies, plans, programs and represents the bases for spatial and urban plans, i.e. for land use planning. The procedure for developing spatial and urban plans, as well as the Strategic Environmental Impact Assessment, implies public participation in decision making.
Therefore, the task for spatial planning is to, within defined protection zones that allow few or more diverse types of construction, subtract locations where these activities are still prohibited – this refers to locations of public interest such as water-source zones (Pantic et al., 2019). Consequently, planning solutions and propositions define the "regime of use", i.e. obligations and restrictions regarding the manner of use (Živanović Miljković, 2018), while such zoning within spatial plans often put limitations or prohibition of building in order to preserve public interest and sustainable use of natural resources. Owners of immovable property i.e. land and buildings / facilities are restricted in the use of their property by certain obligations and responsibilities.
The legal framework in Serbia is very decisive regarding the prohibition, limitation of rights and obligations of owners and users of water land and water facilities. Namely, an owner, i.e. an user of the property (land, i.e. parcel and facilities) located in the zone of sanitary protection, is obliged to adapt the way of using its own property to the newly established conditions for the use and maintenance of the sanitary protection zone. The water source sanitary protection zone is also implemented in the land use planning process, since the Law on Planning and Construction sets the principles and protection, regulation and development propositions. Also, the boundaries of water land are usually included into spatial and urban plans.

5. Results and Discussion

Spatial planning regulates sustainable land use within water management by defining principles, goals, general and specific aims, as well as by defining measures according to certain topic (e.g. agriculture, forestry, environment). The primary role of the SPASPs, analysed for the purpose of this paper, is water supply, with tendency to define use of the areas in multifunctional purposes. Additional activities, which are also subject of SPSPs, are the most commonly water protection, protection against water, silt control, tourism, and in some cases energy production. Spatial plan, as a document, has a fundamental role for sanitary protection of an entire watershed and facilities build for water protection and protection against water purposes. Whenever it is possible (depending on the state government decision), SPASPs cover the broader area than the watershed itself in order to use more flexible land use possibilities for economic revival outside of the sanitary protection zones. This aspect is particularly relevant for local communities and for enhancing general territorial balance at the national level, because areas planned for construction of water supply reservoirs are usually mountainous, sparsely populated and economically hindered. In addition, spatial plans are also foundation for solving property rights issues, setting building parcels for hydro-technical facilities and separation of water land from other types of land use. As such, spatial plans contain information about current state on soil types, terrain geology and erosion risks.

Even though some protection measures are defined already by the acts at the national level and through activities of responsible institutions (e.g. in forest management), spatial plans integrate different sorts of protection measures, taking care to balance the primary purpose to protect a water reservoir and, on the other hand, to bring in certain elements with potential to animate the area. One of the examples where protection measures are being defined before development of a plan is forest categorisation according to international ecological certificate – SGS-FM/COC-009244, which defines High Conservation Value Forests (HCVF), i.e. forest land of high importance. The forests are usually designed as anti-erosion and water purification measure. Another example is sanitary protection zoning that is, prior to a spatial plan, defined by the Order on Methods for Delimitation and Maintenance of Sanitary Protection Zones at Water-supply Source (Official Gazette, 2008). Since the Order regulates restrictions, a SPASP task is to upgrade it by defining activities which are allowed and complementary to the primary purpose of reservoir area.

Table 2: Land use planning solutions for water resource management in Serbia.

MEASURES	**WATER PROTECTION**	• Defining (protection) zones
		• Introduction of solid waste and waste water collection and treatment system
		Regulation (sanitation) of existing dumps
		Introduction of water collection and water treatment system
		• Establishment (improvement) of monitoring system
		Establishment and maintenance of watershed pollution sources cadastre
		Intensified control of illegal building
		• Reconstruction and construction of water system infrastructure and objects
		• Introduction of dangerous and harmful materials risk management
		• Conservation and displacement of cemeteries to outside of watershed area
		• Prohibited use of agricultural fertilizers
		• Local population awareness rising
		Introduction of payments for water-related ecosystem services
	PROTECTION FROM WATER	• Erosion prevention in reservoir watershed
		Biological measures
		Technical measures
		• Water evacuation system in case of flood
		Bell-mouth spillway
		Overflow windows

Source: based on SPASP Jelašnica, 2017; SPASP Prvonek, 2018; SPASP Vrutci, 2018.

5.1 Zoning

Zoning of a spatial plan area is the base for defining other measures. Usual procedure in spatial planning of a special purpose area for water-supply sources is territorial division in four zones: zone of I, II, and III level of protection and fourth zone which is not explicitly in function of protection.

Zone of I level of protection is actually the zone of implicit sanitary protection, delimited in such a way to include reservoir itself with reservoir's surface and a 10 m wide belt in horizontal projection from the reservoir's surface at the maximal level outwards. In addition, the zone includes all streams in the watershed, but with the difference that the 10-year water peak level is taken as a reference. Almost all activities are restricted in the zone, except those with purpose of the system control, monitoring and maintenance. Therefore, it is not allowed to use motor boats, to swim (people or animals), practice agriculture, build or dispose waste. What is allowed, but is not directly related to water-supply source functioning, is fishing for non-commercial purposes. Short sections of road infrastructure are also allowed, because it is necessary for system maintenance.

The zone of II level of protection is defined as inner zone of sanitary protection. It starts at dam and spans upstream in 500 m width horizontal projection from the edged of the I zone outwards. Activities that are restricted in this zone are building residential buildings, accommodation and sport facilities, gathering in large number (e.g. for a manifestation, camping). Agricultural activities are allowed, but with no use of pesticides or herbicides. Existing rural households are obliged to secure safe and sanitary waste water collection and treatment within twelve months from the day of the SPASP adoption. The buildings or facilities are allowed to be refurbished and adapted to other suitable purposes. Any kind of mining activities is forbidden as well as waste dumps, extension of cemeteries or formation of new ones. Exploitation of woods is allowed, but not the clear-cutting.

The zone of III level of protection, defined as zone of broader sanitary protection, occupies remaining territory of water-supply source watershed (watershed without the zones of I and II level of protection). The activities that are also restricted in this zone are mining, waste disposal and free waste-water disposal. Therefore, residential and tourism buildings and facilities, which are allowed here, are matter of controlled development. In common cases, when settlements consist of hamlets or houses scattered over hilly/mountainous terrain, defined solution for waste-water and sewage is a system built at a household level, alternatively at the level of a household group. However, the local systems are defined to be impermeable, so that surface and ground water quality within watershed is not to be impaired. From the aspect of tourism development, this zone is open for picnic activities, hiking and biking trails, construction of view-points, shelters and restaurants.

The zone IV is not defined by legislative acts, but it is included in the SPASPs. It extends from the outer line of the zone III to inner line of area defined as subject of spatial plan. This zone is reserved to more flexible activity and economic development, including communal and accommodation infrastructure, and commercial activities in function of economic revival of rural areas. The rules of protection, valid for the zone, are not defined by SPASPs or legislative acts, but by local planning documents (urban and spatial plans).

5.2 Waste problems

For low population density, rural areas have become just recently treated more seriously regarding solid waste and waste-water collection and waste-water disposal in Serbia. Since water treatment has not been set as a standard in all urban areas, current focus of spatial plans is rather on solid waste treatment. The waste issue is highly relevant in the case of water-supply sources because purpose of an entire system can be endangered by water or solid waste pollution. Due to the organized waste collection and disposal, there are vast of illegal dumps and landfills spread out through rural areas. The most common locations are river beds, ravines, areas along the roads.

In analysed plans, starting point is areas without organized collection and disposal system. In order to solve the problem, SPASPs, at the first place, suggest removal of existing illegal waste dumps and sanitation of the locations, followed by waste evacuation outside of the watershed area, particularly outside of the zone of I and II level of protection. The plans also define locations for regional landfills that are target points for solid waste disposal, both for the waste collected by sanitation of illegal dumps and for the future waste collection activities. The measure also includes disposal of waste produced by domestic animals. The plans also suggest a decentralized waste management system in rural settlements in a form of mobile centres. Expectedly, those documents proclaim prohibition of the disposal in places that are not defined as waste dumps, including the disposal of municipal and construction waste into the watershed.

Ironically, households within water-supply source and its watershed do not have organized water-supply, but rather solved issue at individual or household level. In a system where water-supply is not collectively resolved, it is not to expect that waste-water treatment issue is solved. Therefore, SPASPs try to tackle the issue by defining introduction of controlled and sanitarily safe collection and treatment of waste-water (communal and atmospheric water, and water used in agriculture).

5.3 Monitoring

Some forms of monitoring usually exist within the territories of analysed plans, but it is conducted irregularly or incompletely regarding parameters range. Therefore, it cannot be said that spatial plans proclaim establishment of monitoring system, but it could be certainly stressed that plans are relevant in raising awareness on this topic by demanding improvements. It proclaims systemic monitoring of both quantitative and qualitative features of water in a reservoir, of the streams pertaining to the watershed and of the water-sources of the individual households.

But not only water is to be monitored. The plans also proclaim monitoring over soil qualities. Another measure regarding monitoring in water-supply source areas is creation of a polluter cadastre (a data-base including spatial allocation of data). Even though it is not explicitly stated in the plans, the cadastre could be combined with an intensified inspection and prevention of illegal building, which is significant problem, not only in analysed areas but in the entire country. Lastly, the proclamation for an introduction of information and monitoring system on forests it should be mentioned.

5.4 Anti-erosion measures

In the remote areas around the existing Prvonek water reservoir and the planned Jelašnica reservoir, erosion is a result of natural processes. However, in the case of the

Vrutci reservoir and its watershed, anthropogenic action consequences are more significant because the area is located closer to the more densely populated settlements. However, the anti-erosion measures defined by the spatial plans are distinguished as biological measures and technical measures.

In the group of biological measures pertain the afforestation and melioration of pastures, grassing the grooves, an erection of wattle and other barriers to prevent soil wash-out. For the already forested areas, the monitoring it planned and for some of the areas endangered by erosion an introduction of new forests is planned. On the other hand, planned technical measures are conduction of action for reservoir protection from eutrophication. All in all, forests are seen as the protectors of water in the entire watershed. Building various elements of supra- and –infrastructure, the plans aim at protection from blizzards in winter, natural disasters in summer (storms, torrents, and landslides), etc.

5.5 Flood water evacuation

Besides its primary function to secure quality water supply to the entire region, the reservoirs have a protective function. As artificial structures, the reservoirs have capacity to control level of water, which can be adjusted according to current needs. In the case of torrent flows appearing in small streams within watershed, a raising level of the reservoir surface can be allowed. This action is combined with a bell-mouth spillway, which ends with a slowing slope in order to mitigate water energy of the incoming wave. This is the case of embankment dams (Prvonek and Jelašnica).

The other case is a system at gravity dam (Vrutci), which is made of concrete. A water flow system in regular situations here consists of outlets in the lower half of the construction, but in the case of water peak or flood is designed a system of overflow windows. The system consists of the openings (windows), placed one next to each other, in the central part of the dam. With its height of 3 m and length that takes approximately 20% of overall length of the dam, they are positioned high on the construction, close to the crown of the dam (Figure 1). The system is designed for flood waves and it could successfully manage a 10.000 years water peak, thus preventing flooding downstream from the dam.

(a) Prvonek dam *(b) Vrutci dam*

Figure 2: Types of dams and peak water protection systems. Source: IAUS, 2017.

5.6 Cemeteries under the control

In spite of the fact that water-supply reservoirs are placed rather in remote areas, they are inhabited by a century long inheritance of settlements, which keep part of the history at local cemeteries. Land use solutions within SPASPs allow the extension of existing cemeteries only in the zone of III level of the protection and only in compliance to protection measures defined for this zone and in accordance to the sanitary standards.

5.7 Raising awareness of population

One part of the listed measures greatly depend on the public institutions, their financing, prompt organisation and maintenance willingness. However, the role of the local population is also of atmost relevance because they are the direct users of the space and could harm the system if they do not understand well its purpose and significance. Therefore, rising a level of informativeness (informal ways) and education (formal way) are additional measures prescribed by spatial plans in order to maximise positive outcomes. Informativeness and education is not relevant to spread only among the local population, but also among the visitors (tourists, mountain-hikers, bikers, etc.).

In effort to ensure the best results, the SPASPs introduce certain measures for balancing between restrictions and incentives. For example, key measure for the ecosystem capacity preservation is an introduction of the payments for water-related ecosystem services and complementary institutional and organisational adaptations. On the other hand, imposed restrictions are mitigated by some forms of compensation to the local population.

6. Conclusions

The water management issues are present in land use planning process, since the water protection is an obligatory issue that has to be considered within all planning documents. The spatial planning documents have a significant integrative role and represent a guiding development instrument of development of the analyzed areas. The land use planning, as one of the mechanisms with an impact on the reduction of pressure on land and other resources (Živanović Miljković, Popović 2014), as well as zoning regulations and implementation of plans are typically enacted to address measures for resource protection.

The SPASPs are being currently in implementation. The analysis of land use planning solutions has shown that the SPASPs introduced both measures for water protection and protection against water. At the same time, these measures also have a legal basis for the implementation, with clear delegated tasks in operationalization.

The measures set by the special purpose area spatial plans in order to regulate land use within watershed of the water-supply reservoirs are partially imposed by legislative acts, but, on the other hand, they are shaped out through the spatial planning solutions. The protection zones, and zoning in general, are the starting point in land use planning, where creativity in shaping land use is limited, but, therefore, spatial plans, whenever it is possible, delineate spatial plan territories broader than watersheds themself. This allows to the spatial planners to be more creative in featuring not only protection measures but also development measures.

The primary goal of spatial plans prepared for the type of analysed areas - water-supply sources – is securing high quality of water in reservoirs (I or I/II class by national standards), as well as in all streams within the watershed. This indicates that the primary task of spatial plans is in compliance with primary purpose of the reservoirs. Considering the complexity of the water-system in nature, measures proposed to regulated water-supply are not related only to water protection, but also to soil and biodiversity protection, as well as innovativeness and education of local population and other beneficiaries of the areas.

An adequate land use and regulation also implies the implementation of planning solutions, and cooperative planning between water management and land use. It is necessary to respect the zoning and land use solutions at all levels.

7. Acknowledgements

This chapter has been prepared within the scientific projects No. III 47014 and TR 36036, financed by the Republic of Serbia Ministry of Education, Science and Technological Development in the period 2011–2019.

References

Danilović Hristić, N., Stefanović, N., Petrić, J. (2018). Opportunities for Development of Tourist Potentials in Protected Areas of the Water Storage Reservoirs, on the Example of Spatial Plans of the Special Purpose Areas in Serbia. In Facta Universitatis Series: Architecture and Civil Engineering Vol. 16, No 3 (pp. 489-500).

Dobricic, M., Marjanovic, P. (2017). Interaction between Water Protection and Spatial Planning. Water Research and Management, Vol. 7, No. 3, pp. 3-15.

Dühr, S., Colomb, C., Nadin V. (2010). European Spatial Planning and Territorial Cooperation, Routledge: London.

IAUS (Institute of Architecture and Urban & Spatial Planning of Serbia) (2017). Internal database. Belgrade.

Law on Environment Protection, Official Gazette of the RS, No. 135/2004, 36/2009, 36/2009, 72/2009, 43/2011, 14/2016, 76/2018, 95/2018, 95/2018).

Law on Nature Protection (2009/2016), Official Gazette of the Republic of Serbia No. 36/2009, last amended in 14/2016.

Law on Planning and Construction, Official Gazette of the Republic of Serbia No. 72/2009, 81/2009 - corr., 64/2010 – Constitutional Court decision, 24/2011, 121/2012, 42/2013 - Constitutional Court decision, 50/2013 - Constitutional Court decision, 98/2013 - Constitutional Court decision, 132/2014, 145/2014.

Law on Water, Official Gazette of the Republic of Serbia, No. 30/2010, 93/2012, 101/2016, 95/2018 and 95/2018 – other Law.

National Strategy for sustainable use of natural resources and properties, Official Gazette of RS, No 33/2012.

Order on Methods for Delimitation and Maintenance of Sanitary Protection Zones at Water-supply Source (2008). "Official Gazette of the Republic of Serbia" No. 92/2008.

Pantic, M., Milijic, S., Zivanovic Miljkovic, J. (2018). Spatial Planning as a Land-Use and Building Regulation Tool for Protected Natural Areas in Serbia. In P. Mitković (Ed.), ICUP2018 2nd International Conference on Urban Planning – Proceedings (pp. 331-338). Niš (Serbia): Faculty of Civil Engineering and Architecture, University of Nis.

Pantić, M., Živanović Miljković, J., Milijić, S. (2019) Land Use and Building Regulations: The Case of Spatial Plans for Protected Natural Areas (Serbia), *Facta Universitatis Series: Architecture and Civil Engineering*, (in press).

Pihler, V., Zelenović Vasiljević, T., Dunčić, D. (2013). Water Management, Environmental Protection and Spatial Planning Reconciliation – "Accommodating" the Danube and the Tisa River in Serbia. *Spatium* 29. 49-52.

Rodríguez, M. I., Grindlay, A. L., Cuevas, M. M., Zamorano, M. (2015) Integrating land use planning and water resource management: threshold scenarios – a tool to reach sustainability, WIT Transactions on Ecology and The Environment, Vol 192, Ecosystems and Sustainable Development X, WIT Press, pp. 231-242.

Spasić, N., Jokić, V., Maričić, T. (2009). Managing Spatial Development in Zones Undergoing Major Structural Changes. *Spatium* 21. 53-65.

Spatial Plan of the Republic of Serbia, Official Gazette of the RS, No. 88/10.

Special Purpose Area Spatial Plan for Jelašnica Water Supply Reservoir (2017). "Official Gazette of the Republic of Serbia" No. 39/2017.

Special Purpose Area Spatial Plan for Prvonek Reservoir (2018). "Official Gazette of the Republic of Serbia" No. 89/2018.

Special Purpose Area Spatial Plan for Vrutci Reservoir (2018). "Official Gazette of the Republic of Serbia" No. 89/2018.

Tarlock, A. D. (2002). *Connecting Land, Water, and Growth (with L. Lucero)*, 34 Urb. Law. 971.

UN (2015). Transforming our world: the 2030 Agenda for Sustainable Development, New York.

Water Framework Directive (2001). European Commission, Brussels.

Water Management Master Plan of the Republic of Serbia, Official Gazette of the RS, No. 11/2002.

Water Management Strategy until 2034 at the territory of the Republic of Serbia. Official Gazette of the RS, No. 3/2017.

Živanović Miljković J, Popović V. 2014. Land use regulation and property rights regime over land in Serbia. *Spatium* 32: 22-27.

Živanović Miljković, J. 2018. Urban Land Use Regulation in Serbia: An Analysis of Its Effects on Property Rights, in: Jean-Claude Bolay, Tamara Maričić and Slavka Zeković (Eds.) *A Support to Urban Development Process*, EPFL and IAUS. pp. 129-147.

5. The Role of Geothermal Waters in Sustainable Development Application of Main North Center Algerian Hot Springs (Righa, Biban, Ksena)

Abdelkader Ait Ouali, Abderrahmane Issaadi, Abdelhakim Ayadi, Khaled Imessad

ABSTRACT:
The study zone is one of the significant thermal waters in the north Algeria. It is characterized by a cold climate with intense rain rates 700 mm/year. The Jurassic geothermal reservoir system is exploited by artesian thermal springs and traditional wells for agricultural purposes. The main reservoir lithology characterised by calcareous formations which yield the chemical features of highly mineralized Na-Cl type representing the thermal waters. Three main Hot springs was samples collected June 2018 with a temperature average between 55 and 80° C and conductivities range from 2520 to 3766 µS/cm. For a better application of geothermal water sites a multidisciplinary methods was adopted, geological site study, water chemistry and touristic impact for local economic development. In this study a final map was realized of geothermal potential for possible exploitation of this.

Keywords: Biban, thermal springs, sustainable development, geothermal use, water chemistry

(PhD) Abdelkader Ait Ouali Permanent researcher at CDER (Centre de Développement des Energies Renouvelables) Algiers Algeria. Third Cycle Diploma in Geology (Hydrogeology & Geothermy). Currently working under geothermal team, geothermal reservoir exploration and thermal springs chemistry investigations.
Pr Abderrahmane Issaadi, Hydrogeology laboratory USTHB University, USTHB, BP 32 El Alia 16111, Bab Ezzouar 16111, Algérie.
Abdelhakim Ayadi, CRAAG, Centre de Recherche en Astronomie Astrophysique et Géophysique, Algiers, Algeria
Khaled Imessad, Laboratory Head, CDER / Centre de Développement des Energies Renouvelables

1. Introduction

Since the most remote times, prehistoric man has been interested in hot springs and left witnesses of his wisdom. The Romans when they settle in Algeria will build thermal on the main hot springs. Agglomerations develop nearby such are: Aquac Calidae (Hammam Righa), Aquae Masa Castra (Hammam Berrouaghia).
In addition to these major centers, it can be seen that at the level of the main hot springs, there are also Roman pools. It was not until 1970 that the local scientist focused on the study of thermal waters [1].
In addition, fossil fuels are more easily mobilized, which is interference to the development of other energies. However, in recent years, special attention has been paid to renewable alternative energies. The geothermal waters of the study zone are among the most famous Algerian hot Spas. They have been used for balneology and bathing [2]. The discharge temperature ranges between 22°C to 94°C. The hottest springs are located in Guelma and Biban geothermal areas (94°C, 80°C respectively). These hot springs are associated with seismic active zones close to fault systems [3].
These conditions give rise to high geothermal potential [4]. Several thermal springs in the north of Algeria have been investigated by many authors [5-9]. However, geothermal potential, thermal springs temperature mapping, and reservoir temperature should be

reinvestigated in all the identified geothermal sites in Algeria.
In March 2018, field work campaign was conducted in Righa and Biban geothermal provinces. Temperature, pH and flow rate have been measured in-situ. The temperature was found ranging between 29°C and 80°C. Geological conditions and thermal gradients show that central north part of Algeria is more likely favorable for the presence of geothermal reservoirs of medium to high temperatures [10]. In the present study, the objective is to better assess the main geothermal temperature class for the geothermal sites and to estimate the geothermal potential using geological field works and available hydrochemistry data. All results are represented in final global mapping for helping local authorities to continue using this renewable energy in sustainable development.

2. General Aspect of the Study Area

The Tellian Atlas extends from the littoral to the southern links of the Tell. The latter goes from Tiaret in the West to Sidi-Aissa in the East via Ksar el Boukhari. This ensemble is relayed to the south by the high inter-atlasic low lands located between the preceding domain and the Saharan Atlas which covers the eastern part. [11,11,13].
The study area is part of the Tellian Atlas, it is located in the north center of Algeria contains most important hot springs of the country (Righa, Biban, Ksena, Sidi-Yhaia and Ibainan). This zone is limited to the North by the coastline, it extends from Ain defla in the west to Bejaia to the East and South by Bibanique barrier (Figure 1)

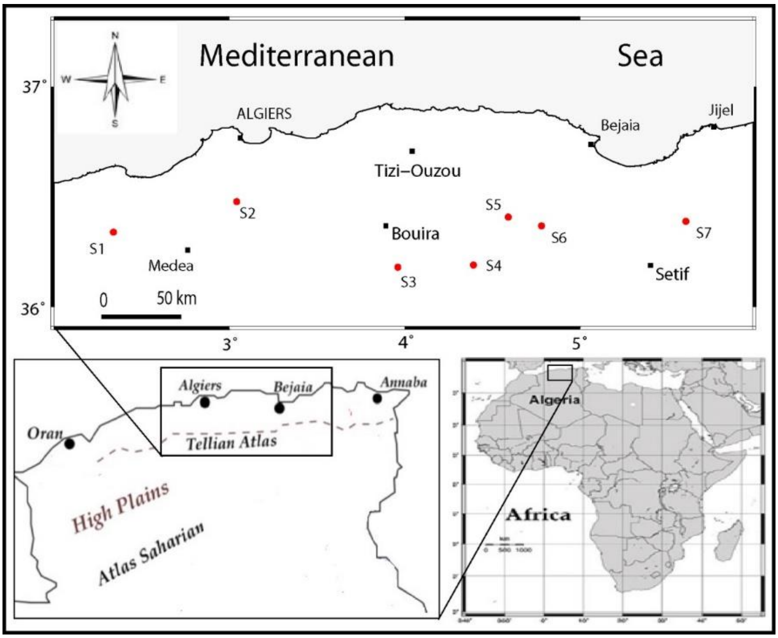


Figure 1. Location map of the study area

We distinguish the crystalline rocks and limestone chains in the study area, the crystalline formations are very developed in the East and only represented by some fragments very dispersed in the North of the Mitidja (Cape Matifou, Bouzareah, Chonoua). [14,14,16].

A huge limestone chain characterizes the eastern Tellian area (east of Algiers and Medea). This limestone litholgy located in high kabylie, culminates at 2308 m as high altitude mountain. The north of Algeria, and in particular the whole of Tell, is characterized by a significant rainfall.
The average rainfall recorded is relatively constant (700 mm). The remoteness of the sea and the decrease of altitude result in a lowering of the rainfall. Indeed, beyond the Bibanic barrier and Ouarsenis, a fairly clear decrease has been observed, with an average rainfall of about 500 mm [17].

3. Methodology

Seven main geothermal springs of north central Algeria were reinvestigated recently. During field work campaign (March 2018), physicochemical parameters such as water temperature, pH, conductivity, TDS are measured using WTW multi-parameters (2C10-0011FB). Thermal water samples were collected into 500-ml polyethylene bottles, cleaned with distilled water before collecting the thermal fluid. Chemical analyses of thermal waters were performed at "hydrogeology laboratory of Algiers university".
For chemical plotting, the free software "Diagramme"-copyright, provided by Avignon hydrogeology laboratory (http://www.lha.univ-avignon.fr/LHA-Logiciels.htm), was used. Some maps were prepared using the public domain Generic mapping Tool (GMT) software [18].
Une campagne d'investigation sur le terrain pour la population local sur le rôle des stations thermales sur développement durable de la région, comme on aussi installé et aménagé des sites proche des sources chaude pour une production agricole chauffé à base de la géothermie afin de donner des récoltes hors saisons.
Throughout the fields investigation campaign some questions given for the local populations on the role of Spas on the region's sustainable development.
We managed some potential sites to geothermal energy exploitation in small economical projects near hot springs.

4. Results and Discussion

4.1 Thermal waters chemistry of the study area

The measurement of the physicochemical parameters (temperature, pH and conductivity) of the geothermal sites was lead in field campaign (2018). The temperature and chemical data of the geothermal sampling sites from the study area are listed in Table 1.

Table 1. Temperature and chemical data for main thermal springs in the study are

ID	Hot Springs	T(°C)	pH	TDS (mg/l)	Flow rate (l/s)
S1	Righa	68	6,5	3520	2
S2	Melouan	39	7,55	2052	4
S3	Kséna	60	6,45	3302	10
S4	Biban	80	6,52	14108	8
S5	Sidi-Yahia	44	6,45	14770	28
S6	Ibainan	60	6,69	13482	5

S7	Dahamcha	29	7,2	2230	2

The chemistry water type of thermal springs was done using Piper triangular ternary diagram (Figure 2). Most sampled waters are categorized by the supremacy of Cl-SO_4 over HCO_3, and Na-K over Ca-Mg. Chemical analyses of the major elements for the ten hot spring samples are characterized by high concentration of Na^+ and Cl^- with pH ranging from 6.45 to 7.55 and TDS oscillating between 2052 and 14770 mg/l. The tendency near the chloride corner (saline hot spring type) is mainly the result of the dissolution of the evaporate rocks in the water.

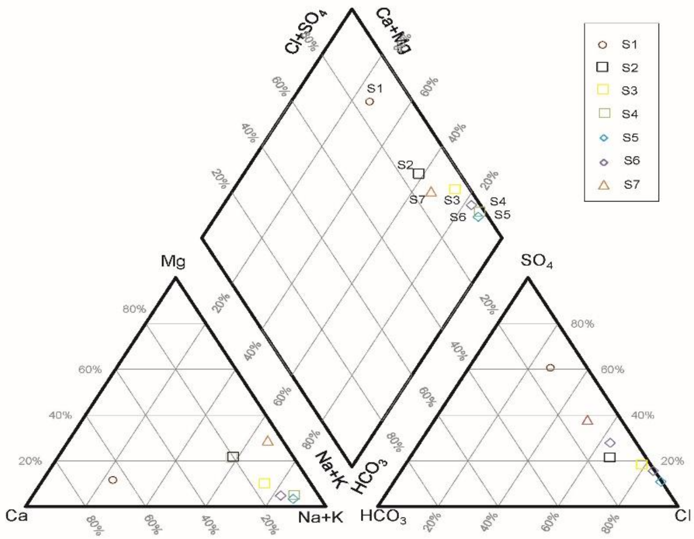


Figure 2. Piper diagram for hot springs from the study area (2018 campaign)

The calcium increase in the water is the result of reaction produced at high temperature between chlorinate-alkaline water and basalts.

4.2 Geothermal potential map

The geothermal potential was determinated for the samples. The distribution of thermal potential over the study area is in agreement with the variation of the water temperature measured at the surface (Figure 3).

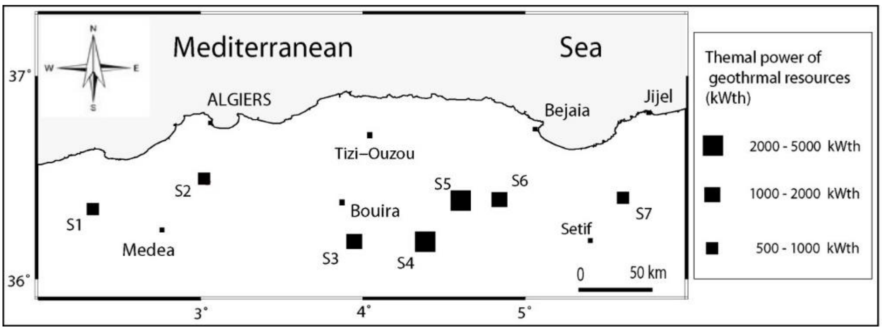


Figure 3. Geothermal potential location mapping

High potential is observed in the central part of Biban region. Geothermal potential is calculated using the following equation (Eq 1) (Signorelli 2004):

$$P = 1000\frac{Q(T-t)}{239} \quad (1)$$

where P is the potential geothermal power (kW_{th}), Q is the discharge (l/s), T is the initial temperature (°C) and t is the final temperature after cooling (°C), arbitrarily fixed at 10°C [19].

Currently, geothermal resources are used in baths and Spas such those of the (S1), (S2), (S3) considered as the main Hammam (traditional bath) in the study area with temperature greater than 60°C. The sites with high geothermal potential could be used in greenhouse heating and in touristic Spa. In North center area, an important geothermal resource (over 4000 kw_{th}) was calculated for the spring (S4 and S5).

4.3 Geothermal exploitation and sustainable impact mapping

Geothermal energy possible uses in Biban and Righa provinces are presented in Figure 4. Hot springs discharge temperatures range from 29 to 80 ºC and the hottest spring temperature was measured near Biban area.

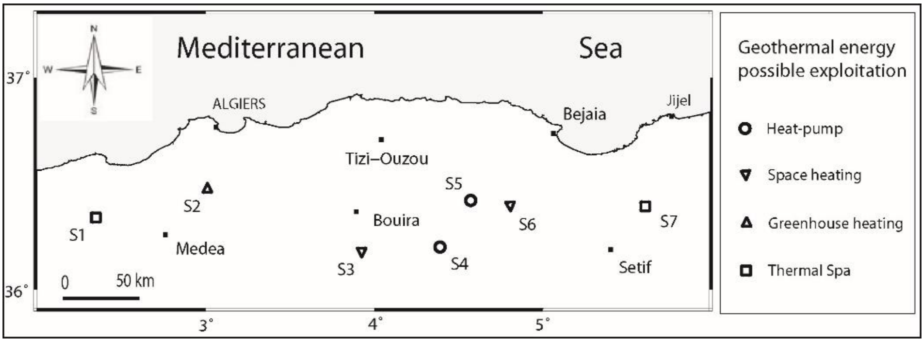


Figure 4. Geothermal exploitation and sustainable impact mapping

In this study, an inventory of seven (7) main hot springs was done. The hyper-thermal springs (temperatures over 45 °C) represented more than half sampling springs (S1, S3, S4 and S6). Ortho-thermal water temperatures range from 37 to 45 °C. Ortho-thermal waters are found in one geothermal springs (S5). The last class had temperature average between 22 to 37 °C, represented by one geothermal discharge (S7). One global map was realized for geothermal energy possible use in to the Biban and Righa province. In the west part area (S1, S2 and S3), the direct use of geothermal energy was recommended for Spas, space and greenhouse heating. In the west part of the study zone (S4, S5, S6 and S7), a possible application of geothermal energy in heat pump and space heating.

5. Conclusion

The study of thermal water from Righa and Biban geothermal provinces was carried out in order to investigate the thermal water temperature and chemistry parameters. The physicochemical composition of seven thermal springs, with various methods such as fields works and Piper diagram was examined. The arrangement of major geochemistry elements has provided a comprehensive understanding of the mineralization processes that reinforce the geochemical evolution of the thermal water inside the study area. Combination of geological and hydrogeological methods highlighted a good relation between chemical processes and hydrothermal flow system. Data analysis showed that thermal waters in the study area come from geothermal Jurassic reservoir. Hydrochemistry results indicate that 70 % of water samples are chloride sodic chemical types. A global mapping was performed to illustrate the geothermal potential and its possible uses in different economic sectors.

6. Acknowledgments

The authors are grateful to Prof. N. Yassaa, the Director of CDER to have supported our study. We are in debt to Dr. Farida Ousadou for her help to use GMT software.

References

[1] Verdeil, P., 1982, "Algerian thermalism in its geostructural setting. How hydrogeology

[2] Issaadi, A., 1992, "Le thermalisme dans son cadre géostructural, apports à la connaissance de la structure profonde de l'Algérie et de ses ressources géothermales," Thèse Doctorat en Sciences, University of Science and Technology Houari Boumedienne Algiers, Algeria.

[3] Meghraoui, M., 1988, "Géologie des zones sismiques du nord de l'Algérie, paléo-sismologie, Tectonique active et synthèse sismotectonique ," Thèse de Doctorat d'état, Université de Paris Sud, Orsay, Paris, France.

[4] Saibi, H., 2009, "Geothermal resources in Algeria," Renewable and Sustainable Energy Reviews 13 (9) 2544-2552.

[5] Takherist, D., and Lesquer, A., 1989, "Détermination du flux de chaleur en Algérie," Canadian Journal of Earth Sciences. 26, 615-626.

[6] Bouchareb-Haouchine, F.Z., and Boudoukha, A., 2009, "Hydrogeochemical and lithostructural approach of deep circulations in the mounts of Hodna Algeria," European journal of Scientific Research. ISSN 1450-216X. 37 (1) 12-20.

[7] Kedaid, F., 2002, "Algerian geothermal country report," Geothermal and Volcanological, Research Report of Kyushu University (11) 4-6.

[8] Fekraoui, A., and Kedaid, F., 2005, "Geothermal resources and uses in Algeria: a country updates report," Proceedings of the WGC, pages 1-8.

[9] Bouchareb-Haouchine, F.Z., 2012, "Etude Hydrochimique des Sources Thermales de l'Algérie du Nord-Potentialités Géothermiques," Thèse Doctorat en Sciences, University of Science and Technology Houari Boumedienne, Algiers, Algeria.

[10] Saibi, H., 2015, "Geothermal Resources in Algeria," Proceedings of the WGC, Australia-New Zealand pages 31–34.

[11] Kiken, M., 1975, "Étude géologique du Hodna, du Titteri et de la partie occidentale des Biban," Publ, Serv, Carte géol. Algérie, Série, (46) 217- 281.

[12] Bracène, R., 2002, "Géodynamique du Nord de l'Algérie : impact sur l'exploration pétrolière," Ph.D. dissertation, University of Cergy-Pontoise, France.

[13] Bracène, R., and Frizon, D., 2002, "The origin of intraplate deformation in the Atlas system of western and central Algeria: from Jurassic rifting to Cenozoic-Quaternary inversion," Tectonophysics (357) 207-226.

[14] Durand-Delga, M., and Fonboté, J.M., 1980, "Le cadre structural de la Méditerranée occidentale, géologie des chaînes alpines issues de la Téthys," Colloque no 5, 26° Congrès Géologique International, Mem, BRGM, Paris pp. 67-85.

[15] Wildi, J. W., 1983, "La chaîne tello-rifaine (Algérie, Maroc, Tunisie): Structure, stratigraphie et évolution du Trias au Miocène," Rev, Géol, Dyn, Géogr Phys. 24, 201-297.

[16] Aïte, M.O., and Gélard, J. P., 1997, "Distension néogène post-collisionnelle sur le transect de Grande-Kabylie (Algérie)," Bull, Soc, géol. France 168 (4) 423–436.
[17] Vila, J. M., 1980, "La chaine alpine d'Algérie orientale et des confins algéro-tunisiens," Thèse de Doctorat, Université de Pierre et Marie Curie, Paris, France.
[18] Wessel, P., Smith, H.F., 1998. New, improved version of the generic mapping tools released. EOS Trans. AGU 79, 579.
[19] Signorelli, S., 2004. Geoscientific investigations for the use of shallow low-enthalpy systems. Dissertation Nr. 15-519. ETH Zürich, Zurich, Switzerland.

6. Rainfall in Bangladesh: Is Rainwater Harvesting a Sustainable Approach for Governing Rainwater?

M. Rafiqul Islam

ABSTRACT:
Global environmental change affects the intensity and frequency of rainfall that increases the necessity for sustainable management of rainwater. It is more important for rain intensive country like Bangladesh otherwise it creates further problems like water logging, flood, soil erosion, and water borne diseases. Based on the survey of 80 rainwater harvesters in the Coastal Bangladesh in 2017, this paper evaluates whether rainwater harvesting is sustainable approach to govern rainwater or not by using social and ecological performance measures of Social Ecological System (SES) of Elinor Ostrom. This study found that rainwater harvesting does not affect environment, it is an acceptable approach in family and society, help to develop biodiversity condition, create resilience to climate change impact, improve equitable access to water, efficient use of rainwater, improve women performance regarding water supply to the family, contribute in achieving sustainable development goal, and do not overharvest of rainwater that could create environmental problem. Beyond these measures, it needs rainwater harvesting controlling mechanism like formal operation rule or policy to avoid overharvesting and ensure more sustainability in governing rainwater.

Keywords: Accountability; Biodiversity; Efficiency; Resilience; Equity; Rainwater Harvesting; Sustainable Approach; Sustainable Management of Rainwater

M. Rafiqul Islam is a Ph.D. Student, Department of Economics, University of Verona, Italy where he is investigating possibility of "Rainwater Harvesting in Fighting Climatic Concerns and Women Empowerment in Bangladesh". Before of his current position, he completed MSc (Master of Science), MBA (Master of Business Administration) at Twente University, Netherlands, and Dhaka University, Bangladesh respectively. Previously, he worked as Program Organizer Officer at BRAC in Bangladesh. He has some experiences in performing job in research project in Dhaka University, Bangladesh, and University of British Columbia, Canada. Based on his experiences and study, he published two articles in 2017 and two in 2018 in internationally renowned journal. His major areas of research interests are water governance/management, sustainable development, rainwater harvesting, climate change, women empowerment, environmental conservation, community livelihoods, and Bangladesh.

1. Introduction

Water resource is one of the main pillars of sustainable development that acknowledged in the United Nations Conference on Sustainable Development at Rio de Janeiro in 1992. The Sustainable Development Goals of the United Nations has given importance on sustainable management of water resources (Goal 6) and ensure available safe water for all. Therefore, the present study focuses on a sustainable approach to govern rainwater by integrating social and ecological performance measures in Southwest Bangladesh. It is expected that this study will contribute to the development of sustainable water resources management concepts and understand the phenomena of sustainable approach for governing rainwater in terms of social and ecological performance measures in rain intensive country like Bangladesh.

Bangladesh is well known for climate-induced extreme events such as drought, flood, cyclone, storm surges, river bank erosion, and salinity intrusion. Rainfall is one of the meteorological variables that play a very important role in the hydrological cycle and on these climate-induced extreme events (Islam and Hasan, 2012). Climate change has a profound impact on intensity and frequency of rainfall all over the world and global warming will intensify it (Allan and Soden, 2008; Wasimi, 2009). Alexander et al. (2006) argued that the intensity of rainfall is increasing worldwide that lead to the enhancement of heavy rainfall indices. Goswami et al. (2006) found that intensity and frequency of rainfall have been increasing over Central India. They analyzed the data from 1951 to 2002. This extension of rainfall in terms of frequency and intensity has a large impact on Bangladesh as the country is one of the most rain intense countries in the world. However, in the northwestern part of the country, drought is a common phenomenon (Shahid, 2008; Shahid and Behrawan, 2008). The country has experienced a number of dry and wet periods in the last fifty years (Shahid, 2010). Global warming has already started to affect the rainfall patterns and facilitate frequent extreme events such as droughts, floods, and heavy rainfall all over the world (Briffa et al. 2009; Schmidli and Frei, 2005; Zhang et al. 2009) and will widen the gap between wet season and dry season. It indicated that more and less rainfall will take place in wet season and dry season respectively. This increasing trend of erratic rainfall affects the region's drinking water supply, agricultural production, and environment. Moreover, water demand will increase due to population growth, intensification of agricultural production, urbanization, and economic development (Ismail, 2016). Both of these issues create challenges for the Government of Bangladesh, donor agencies, and non-government organization to manage the rainwater, mitigate the effect, and make the socioeconomic development sustainable in the region. In this context, it needs to find out the way to sustainable governance of rainwater in Bangladesh. Otherwise, it will hamper the socioeconomic and environment developmental effort.

Rainwater harvesting is the collection, storing, and utilizing runoff from roofs or ground surfaces for productive use in domestic water supply, agricultural use, and environmental management (Anderson and Burton, 2009; Falkenmark et al. 2001; Liniger et al. 2011; Niggi, 2003; Worm and Hatum, 2006). It has been using for centuries over the globe. Rainwater can be used for different purposes like irrigation, drinking, washing, and cooking (Worm and Hatum, 2006). Generally, there are three different kinds of rainwater harvesting systems (RHS) such as rooftop catchment system, runoff catchment system, and in-situ catchment system (Pachpute et al. 2009). Studer and Linger (2013) argued that there are three main components of rainwater harvesting: (i) catchment or collection area where rainfall is the runoff and harvested. It can be rooftop, pavement, cultivated or uncultivated land, compacted surfaces, open rangelands, and rocky areas; (ii) Conveyance system where runoff is carried out via gutters, and pipes; (iii) Storage facility where collected rainwater is stored until it is used. Oweis et al. (2012) found that collected rainwater can be stored above the ground (e.g. jars, soil or plastic tank, ponds or reservoirs) or below the ground (e.g. cisterns) as groundwater. When considering the rainwater harvesting as an alternative or supplement source of water it needs to consider the sustainable issue for applying this system.

There are not many studies regarding the factors of determining the sustainability of RHS. Pachpute et al. (2009) found that RHS has been facing some constraints such as lack of policy support and budget, lack of knowledge and skills that can facilitate institutions, and inadequate scientific and socioeconomic knowledge. These constraints

are affecting the sustainable aspect of rainwater harvesting. Ostrom (2009) indicated that outcome of a natural resources (e.g. rainwater) from the interaction of resource systems, resource units, users, governance systems in large social, economic, and political settings can be measured in terms of social performance indicators such as accountability, efficiency, equity, conflict etc. and ecological performance measures such as overharvested, biodiversity, sustainability etc. Efficiency and effectiveness use of collected rainwater rely on skills, investment capacities, and technical knowledge of the user. The climatic variability at regional scale increases the frequency of extreme events (e.g. prolonged drought and dry spell, intensity of rainfall etc.) which lead to affect the temporal and spatial availability of rainfall/runoff (Mizyed, 2008; Trisan and Polcher, 2008) Rockstrȍm et al. (2007) found that it is needed to adopt the small catchment management approach for upgrading rainfed agriculture as well as contribute to the environmental conservation by reducing water withdrawal from groundwater source.
The sustainable approach for governing rainwater under various biophysical and socioeconomic positions is a key for large scale socioeconomic and environmental development in coastal Bangladesh. Sustainable approach signifies that the "present harvesting, use and consumption of natural resources through rainwater harvesting system can be continued into the future for optimal livelihoods generation" (Pachpute et al. 2009: 2817). Pachpute et al. (2009) argued that there are three main attributes to determine whether RHS is sustainable or not. Such attributes are (i) dependable water supply and production potential; (ii) minimum negative impact on natural resources and environment; and (iii) effective water use. This study used the social performance measures and ecological performance measures of Social and Ecological System (SES) framework of Elinor Ostrom to determine whether rainwater harvesting is a sustainable approach to govern rainwater or not.

2. Materials and Methods

In order to assess the sustainable approach of rainwater management, it needs quality information. For collecting quality information, it needs to use specific tools and technique. This chapter explores what information is collected, how, and what methods applied to collect and analyze collected information. It includes social performance measures information in terms of efficient use of rainwater, equity, acceptance of rainwater harvesting in family and society and ecological performance measures regarding overharvesting, biodiversity, resilience, and sustainability. Figure 1 shows the analytical framework of this study.

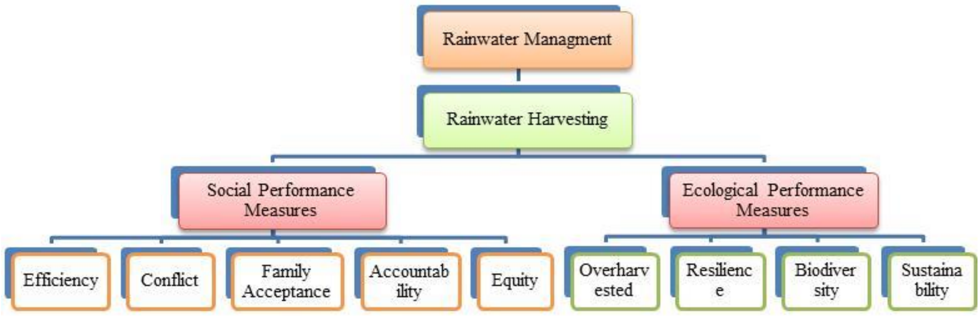


Figure 1: Analytical framework for measuring social and ecological performance of rainwater harvesting (Adapted from Ostrom, 2005, 2007, 2009)

Information for checking the sustainable approach of rainwater harvesting was collected from a coastal community of Bangladesh through the participatory approach. Participatory Rural Appraisal (PRA) is "a family of approaches and methods to enable rural people to share, enhances, and analyzes their knowledge of life and conditions, to plan and act" (Chambers, 1994:953). PRA methods applied in this study because its main objective is to empower local people and produce sustainable actions and institutions as long term outcomes (Chambers, 1994). Chambers (1994) argued that PRA not only helps to discover the profound knowledge of villagers but also their creative abilities to sustainable management of natural resources. Its different tools such as participatory social mapping, semi-structured interview, key informants, transect walk, short standard schedules, and group discussion with local people used to collect information from the study site.

Focus group discussions (FGD) (10-15 participants) were held in three different places in the study site. FGDs were held on the basis of open-ended semi-structured interview questions. FGD commenced with a brief explanation of the research objective and expectations from the participants in the FGD. They were asked to identify the outcome of rainwater harvesting in terms of efficiency, social and family acceptance, equity, biodiversity, overharvesting, accountability, and environmental impact. Participants drew connections between the role of government and NGOs and the application of rainwater harvesting system. Moreover, they suggested that if they would get benefit from either of these in terms of finance, technical knowledge, and training, this system of rainwater management would be more effective, efficient, and sustainable as well as could address their water crises problem.

Besides FGD, the author also used key informant (participatory social mapping used to select key informant), transect walk with local people in the study site for discussing, listening, observing, and asking about rainwater harvesting, and short standard schedule tools to collect information on rainwater harvesting as rainwater management tools and its performance measure in terms of social and ecological performance measures.

3. Study Location

As I have mentioned that the paper focuses on one coastal community of Bangladesh. One coastal community of Bagerhat District was selected as the study site because they are a good representative of coastal communities in terms of climate change vulnerability, socioeconomic position, and dependability on natural resources. More importantly, they have been practicing rainwater harvesting for a long time for addressing their water crises problem. The area is attributed by poverty striven people who are more than 90 percent depend on natural resources and agriculture for their livelihood. The community belongs to Mongla Upazila (Upazila: subunit of a district) located at the Low Elevation Coastal Zone (LECZ) of Bangladesh. LECZ can be defined as an area with a coastline up to ten-meter sea level elevation (McGranahan et al. 2007). The name of the community is *Chilla* under Mongla Upazila of Bagerhat District in Bangladesh. Coastal areas of Bangladesh suffer with different kind of climatic and non-climatic extreme events such as salinity intrusion, storm surge, cyclone, sea level rise, floods, erratic rainfall, drought, and endemic poverty (Huq et al. 2015). Figure 2 shows the study site in Bangladesh.

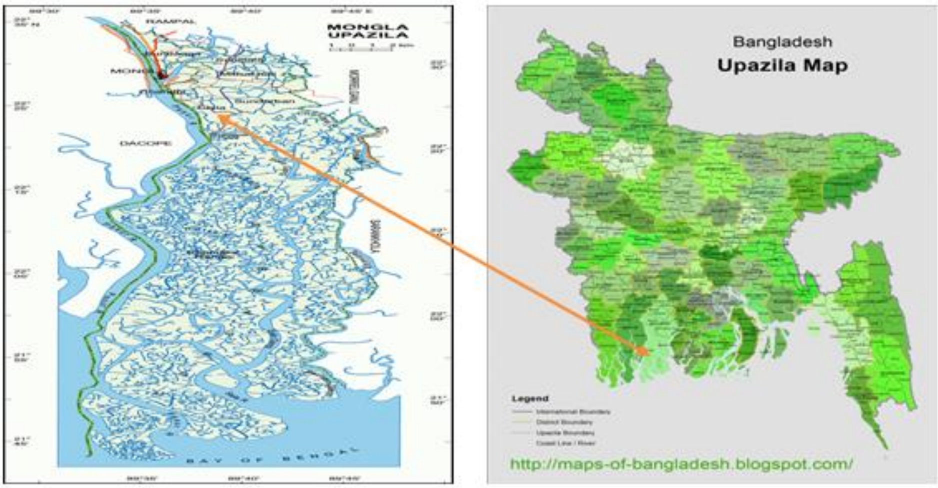


Figure 2: Location of the study site

Source: https://www.google.com/search?q=Mongla+Upazila+Map+with+Villages&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjr6KrQ-Y3hAhUMsqQKHfsoCGAQ_AUIDigB&biw=1366&bih=626#imgrc=HjL8RDZzc4umjM: and http://3.bp.blogspot.com/_Xh4MstvdVIw/TAll8Z6iRYI/AAAAAAAAAIM/KzO6yuch_ko/s1600/Upazila%2BMap%2Bof%2BBangladesh.gif

4. Social and Ecological Performance Measures

The research primarily centered on two performance measures of Elinor Ostrom's SES framework. The first major performance measure is social and the second is ecological. It is the outcome of an ecological resource through an interaction process of resource system, resource unit, users, and governance system in large socioeconomic and political settings.

4.1 Social Performance Measures

4.1.1 Equity

Equitable access to water is very important and remains one of the major challenges for sustainable development. Generally, water management programs by government offered benefits to rich people in terms of access to water by providing finance or water harvesting materials or digging large and deep freshwater pond under the control of these rich people. As development funds are going to rich people poor people are more suffered and deprive their right in terms of access to water. Moreover, it increases the inequity in society. But rainwater harvesting system makes women and poor people better by increasing access to water that makes the positive contribution to their livelihood. Some of the participatory projects found that rainwater harvesting helps to maintain equity in terms of access to water and ensures that almost everyone benefitted from rainwater. According to the household survey, 89 percent of respondents replied positively in terms of access to water with rainwater harvesting. They also mentioned that during monsoon their access to water improves significantly due to their rainwater harvesting facility. Although their harvesting facility is not well equipped like rich people but it helps in access to water. If they don't have it they will face the same problem like summer when they don't have access to water because of lack of financial capacity to buy water from either water trader or water company or lack of political power.

During summer, the difference between rich and poor people in terms of access to water is very high but it is low in monsoon. The reason behind this is rainwater harvesting and financial capacity. There are some factors working behind this aspect: (i) rich people have the capacity to buy water from either water trader or water company; (ii) they have a deep and large freshwater pond; (iii) getting benefit from government and non-government organization for accessing water. However, the coastal community gets neither of those benefits as they are poor and does not have political and monetary power so that it is not possible to get access to water like rich people. In this context, rainwater harvesting can contribute to equitable access to water in the study site.

4.1.2 Efficiency

Rainwater is natural resources and most of the household at Chila capture, store, and use rainwater for various purposes such as cooking, bathing, washing, drinking, and other domestic purposes. In the study group, 93.75% of households collect and use rainwater but everyone can't use collected rainwater over the whole year because of a storage problem. They also can't use rainwater for all purposes due to the same problem. They use collected rainwater for a different purpose in different seasons. For instance, during the dry season[9], they use rainwater for drinking purpose only because rainfall does not take place frequently. However, during monsoon[10], it uses for all purposes from drinking to bathing as the rainfall takes place almost every day. If they don't capture rainwater like other regions (e.g. Dhaka) it would runoff to canal, rivers, and pond where water is saline which might cause to increase the volume of saline water. In this circumstance, rainwater harvesting ensures efficient use of the natural resource (e.g. rainwater) and addresses their water crises problem.

4.1.3 Accountability

[9] Dry season= summer. It indicates the period from March to June

[10] Monsoon=wet season=rainy season. It indicates the period from June to October

Accountability is strongly connected to two aspects in this study: (i) to the women's performance in supplying and managing water for her family as they are primarily responsible in managing water for the family; (ii) rainwater harvesting increases in access to water for women that make the positive contribution to their performance. Figure 3 shows the relation among rainwater harvesting, access to water and women performance. However, in coastal Bangladesh, women are socioeconomically vulnerable and climate change impact has been deteriorating their position with creating more challenges in terms of supplying water to the family but rainwater harvesting helps them to perform their duty effectively. They can supply sufficient water to the family during the rainy season as there is sufficient rainfall. They can also store rainwater for using beyond the monsoon.

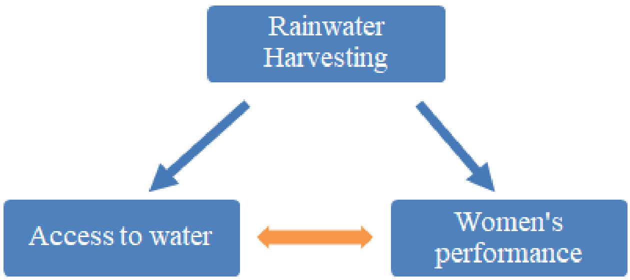


Figure 3: Relation between rainwater harvesting and accountability in terms of access to water for women and their performance

In the coastal zone of Bangladesh, women and girls are responsible for supplying water to the family. They are always exposing to the risk of water crises for their family in terms of handling pressure from collecting, using, and storing water for future use. They need to manage water for their family. If they can't manage, it could bring a devastating impact on their family. Rainwater harvesting can improve the access to water for women and girls that ensure their accountability to the family regarding the supplying water to the family. According to the survey, all of them informed that their water supply improves with rainwater harvesting. They also informed that if they have enough storage capacity to store rainwater they could collect enough rainwater for the whole year and they could perform their duty more effectively.

4.1.4 Conflict

Rainwater harvesting system uses to collect rainwater, store for future, and for present use. The collected water uses for different purposes like dishwashing, cooking, drinking, bathing, and other domestic purposes so that everyone tries to get benefit from rainwater. In this context, social coherence is very important for maintaining the system. This study found that social class and other norms do not affect rainwater harvesting as the system has been using from generation to generation in the area. Regarding this aspect, there are some factors are important to consider such as different people use the collected water for different purposes, collect a different volume of water, and use the different technique to collect water so that it can arise conflict among them. If it causes conflict among them the system might not be useful and effective for them.

During the study, the researcher asked the participants are they face any social conflict regarding rainwater harvesting or are they get complain against the system. As per response of the questions, they informed that nobody complaints against the system even they cooperate with each other to effective and efficient use of collected rainwater. They also informed that they share their skills and knowledge to improve their rainwater collection technique because the endurance of quality of collected water depends on the collection technique and storing methods.

4.1.5 Family Acceptance

Family acceptance is another major attribute to check the sustainability of the system as the system is using in the household and for the family member. If the family member does not support the system, the system is vulnerable in that specific family so that it is very important to get family support to operate the system and maintain the system. This support can be in terms of rainwater collection, cleaning the storage tank and other materials, installing the infrastructure etc. According to the field study of this research, the entire participants informed that they are getting support from the family member. For instance, the person is not in the home who generally operate the system during rainfall but another person is in the home. The person who is in the home will collect the rainwater. Moreover, the adult person can't go inside of the storage tank so that a young member of the family helps to clean the storage tank.

4.2 Ecological Performance Measures

4.2.1 Overharvested

In light of increasing water crises problem, particularly in the climate change affected coastal region, it is possible to overexploit the rainwater to address the problem. If all rainwater is collected then it will create problems. Rainwater runoff washed the pollutants and wastages from inland to pond to river to oceans. In the ocean, it is dissolved naturally. If all rainwater is collected then all pollutants and wastages will remain in the same position (e.g. inland, agriculture field, pond, local freshwater bodies etc.) that will create further problems. Moreover, rainwater is a major source of recharging the groundwater. Collection of all rainwater will hamper the recharge of groundwater and lower the groundwater level that will create problem in access to water level by wells. Moreover, ultimately it will create problem for the local ecosystem.

In Bangladesh, there is no policy regarding rainwater harvesting. In the study area, people can't overexploit the rainwater due to lack of financial capacity, and technical know-how. Even they can't collect enough rainwater for their own purpose due to the same constraint. But as climate change impact increases the intensity of water crises problem will be increased so that people will try to manage their water crises with overexploitation of resource (e.g. rainwater) which is available to them. Generally, people try to solve their problem with the resources which are available and easily reachable to them. For example, people have been using groundwater as the main source of water as it is available, cheap, and easily reachable. This practice increased significantly in the last 50 years that lead to overexploitation. This overexploitation endangers the sustainability of aquifer. In the same way, there is a possibility to overexploit the rainwater in near future to address the water crises problem so that it is better to prepare and apply the proper policy to monitor the rainwater harvesting to stop overexploitation of rainwater.

4.2.2 Biodiversity

Water is very important ingredient for living beings and nothing can exist without water. Water is a prerequisite for sustaining both inland and marine biodiversity. Accessibility and ingredients of water govern and control the efficiency of biodiversity conservation. It is a matter of fact but true that policymaker, academics, and other concern bodies face serious challenges to protect biodiversity. Biodiversity suffers when water becomes scarce. For example, during dry season a number of wild animals migrate from water scarce areas to another area where water is available. In this situation, hunters use water as a trap to hunt the animals. Proper water resource management can play a very important role in protecting biodiversity. For this purpose, rainwater harvesting can play an important role for existing plants, animals, and other microbes. As the country receives ample rainfall it can be collected which could address water crises problem and ultimately contribute to biodiversity conservation.

Local community rears local livestock such as cows, chicken, duck, goat, and other species during monsoon as the water is available but they can't do this during the dry season as the water becomes scarce. People do not get local livestock in the market during the dry season as local people do not rear it in that season. They have to visit another market or place to get the local livestock. The meat of local livestock is tastier than other livestock so that people are always looking for those livestock particularly for the special program such as the wedding, birthday, the celebration of New Year, and other festivals. Even people look for local livestock when their relative visits them. As rainwater harvesting increase in access to water for the family so that we can say that it also contributes to local biodiversity.

4.2.3 Sustainability

Sustainability is the process to maintain balance in an environment where utilize the resource in such a way that does not harm the environment. Moreover, sustainability is the avoidance of the depletion of natural resources in pursuit of maintains ecological balance. Rainwater harvesting can contribute to sustainability in two aspects such as improve water supply and reduce rainwater runoff. These two lead to other aspect which shows in figure 4:

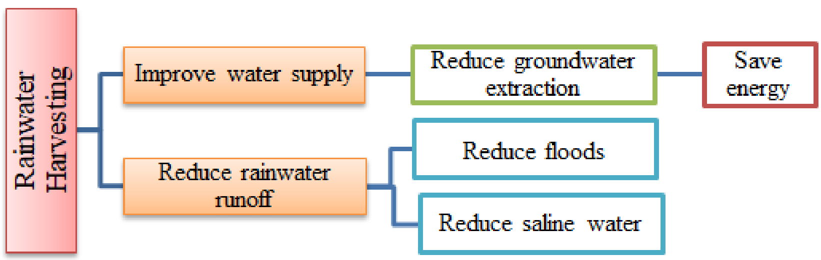


Figure 4: Contribution of rainwater harvesting on sustainability

The study already found that rainwater harvesting increases water supply in the study site that contributes to sustainability directly and indirectly. In the study site, the main source of water is groundwater, river water, and rainwater (Islam, 2017). River water is only useable only in some period of rainy season because rainwater can reduce the intensity of salinity so that people can use river water. As groundwater is one of the main sources of water people are heavily reliant on this source. This dependence leads overexploitation of the source. For instance, groundwater level in Dhaka city is lowering by 1 meter every year (Sengupta et al. 2012) due to over-extraction and it can threaten the sustainability of aquifer. People use rainwater and fulfill their demand through rainwater harvesting rather than groundwater that can reduce the volume of water extraction from the ground source. Moreover, rainwater harvesting does not need energy but groundwater extraction with water pumps needs energy (Abdullah and Rahman, 2015). In this context, rainwater harvesting can save energy. In the current world, energy production is one of the most responsible factors for global warming that ultimately lead to climate change. The climate change impact is the most prominent constrains for achieving sustainable development goals (SDG). Here it is assumable that rainwater harvesting contributes to sustainable development through improving water supply that leads to the reduction in groundwater extraction and energy saving. It is notable to mention that SDG 6 is about to access to water so that rainwater harvesting contributes to this goal directly.

Reduce rainwater runoff is another aspect in which rainwater harvesting can contribute in terms of sustainability. It can reduce the volume of rainwater runoff that leads to reducing the volume of saline water as the entire water source (e.g. river, groundwater, pond, canal etc.) near to the study site is polluted with saline water. If rainwater is runoff then it would increase the volume of saline water in those sources and will increase the volume of water in those sources that can lead to local floods. For instance, in 2016, heavy rainfall caused floods where 3.7 million people were affected in nineteen districts. The study site was one of the worst affected areas for this flood.

4.2.4 Resilience

Climate change effect increases the extreme events such as sea level rise, floods, droughts, storm surges, cyclone, and salinity intrusion and these climate-induced events greatly facilitate the water crises problem in the coastal region. Moreover, climate change impact increases the intensity and frequency of rainfall that also creates the opportunity for using it for resilience purpose. Resilience is the capacity to absorb the disturbance and retain the same structure (Walker et al. 2004). The research has already found and mentioned in the previous section that rainwater harvesting increases water supply. For this reason, it is mentionable that rainwater harvesting helps to use rainwater for resilience purposes by increasing access to water in the water crises period. It is not only increasing access to water but also creating the opportunity for business development that can also contribute to an increase in resilience to climate change impact. For instance, people buy pond water from the local water trader during the dry season. Water trader collects water from the large pond[11] and supplies to the local people. They have been doing this business for a long time. Most of the time they can't fulfill water supply demand. Moreover, rainwater has higher quality and demand than pond water but they don't have enough storage capacity and technical capacity to keep it for a long time for the business purpose. If the water trader, as well as rainwater harvester, has the financial and technical capacity they could exploit the opportunity[12] created by climate change and build resiliency against water crises problem arise from climate change impact, water

[11] Where the water is fresh and not polluted with saline

[12] The intensity and frequency of rainfall will increase due to climate change impact

governance and management problem, and other anthropological interventions.

5. Concluding Remark

The SDGs 6 are highly unlikely to be met without proper management of rainwater. Failure to sustainable management of rainwater it can bring devastating effect to society and environment with facilitating floods, water logging, and soil erosion particularly in rain intensive country like Bangladesh.

Sustainable rainwater management is a daunting challenge. It is not only for Bangladesh but also for other countries that have been receiving ample rainfall. There is a big difference between Bangladesh and other countries, is the degree and extent of climate change impact face by Bangladesh as the country is one of the most vulnerable countries to climate change effect. It is enviable that local people are creative in addressing their problem. Moreover, this paper focuses on the community approach in managing rainwater and addressing their water crises problem without harming the environment. The study found that the practice is a sustainable approach to manage rainwater regarding biodiversity conservation, resiliency, sustainability, equitable access to water, and social acceptance. Unfortunately, the people still need government assistance in terms of policy, either finance or rainwater harvesting materials, and training for a more effective and sustainable application of rainwater harvesting for effective management of rainwater.

As coastal people are facing water crises problems particularly in the dry season so that there is a possibility of overharvesting of rainwater in addressing the crises. Harvesting policy can reduce overharvesting possibility of rainwater. This can contribute to sustainable development as overharvesting might hamper natural ecological flow. However, financial or rainwater harvesting materials help can enable the poor people to build rainwater harvesting infrastructure that can make them able to store enough rainwater for the whole year. It might address their water crises problem and will bring socioeconomic benefit to them.

Sustainable development approach is needed to manage rainwater over the long term to overcome the challenges faced by this community practice. It is an interconnected nature of challenges, addressing them is complex and difficult which needs planned management strategies. The initiative should be taken to address these problems so that the community's rainwater management practice can ensure sustainability in managing the rainwater.

The findings have formed the basis for further study in finding the sustainable approach for managing the rainwater in Bangladesh. It is not a conclusive study. In order to move towards a conclusive decision for managing rainwater, more ethnographic and empirical studies are required.

References

Abdullah, H.M., and Rahman, M.M (2015). Initiating rain water harvest technology for climate change induced drought resilient agriculture: scope and challenges in Bangladesh, *JAEID*, 109(2):189-208, DOI:10.12895/jaeid.20153.334

Allan, R.P., and Soden, B.J. (2008). Atmospheric Warming and the Amplification of Precipitation Extremes. *Science,* 321(5895): 1481-1484.

Alexander, L.V., Zhang, X., Peterson, T.C., Caesar, J., Gleason, B., Klein Tank, A.M.G., Haylock, M., Collins, D., Trewin, B., Rahimzadeh, F., Tagipour, A., Rupa Kumar, K., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D.B., Burn, J., Aguilar, E., Brunet, M., Taylor, M., New, M., Zhai, Rusticucci, M., and Vazquez-Aguirre, J.L. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research*, 111 (5): 1-22.

Anderson, I.M. and Burton, M. (2009). Best Practices and Guidelines for Water Harvesting and Community Based (Small Scale) Irrigation in the Nile Basin. Water Harvesting

Report. Part I – Best Practices in Water Harvesting. Part II – Guidelines for the implementation of best practices in Water Harvesting. Appendix A: List of Reference Material. Kent, Nile Basin Initiative. *Efficient Water Use for Agricultural Production Project (EWUAP).*

Briffa, K.R., van der Schrier, G., and Jones, P.D. (2009). Wet and dry summers in Europe since 1750: evidence of increasing drought. *International Journal of Climatology* **29**(13): 1894–1905.

Chambers, R. (1994). The Origins and Practice of Participatory Rural Appraisal. *World Development,* 22(7): 953-969

Falkenmark, M., Fox, P., Persson, G. and J. Rockström. 2001. Water Harvesting for Upgrading of Rainfed Agriculture: Problem Analysis and Research Needs. Stockholm

International Water Institute (SIWI) Report 11, Stockholm.

Goswami, B.N., Venugopal, V., Sangupta, D., Madhusoodanan, M.S., and Prince, K.X. (2006). Increasing trend of extreme rain events over India in a warming environment. *Science*, 314(5804): 1442–1445

Huq, N., Huge, J., Boon, E., and Gain, A.K. (2015). Climate Change Impacts in Agricultural Communities in Rural Areas of Coastal Bangladesh: A Tale of Many Stories. *Sustainability: Open Access,* 7:8437-8460, doi: 10.3390/su7078437

Islam, M.M., Chou, F.N.F., Kabir, M.R., and Liaw, C.H. (2010). Rainwater: A Potential Alternative Source for Scarce Safe Drinking and Arsenic Contaminated Water in Bangladesh. *Water Resources Management,* 24:3987-4008, DOI:10.1007/s11269-010-9643-7

Ismail, H. (2016). Climate Change, Food and Water Security in Bangladesh. *Future Directions international,* Strategic Analysis Paper

Liniger, H., Mekdaschi Studer, R., Hauert, C. and Gurtner, M.(2011). Sustainable Land Management in Practice: Guidelines and Best Practices for Sub-Saharan Africa. *Terr Africa*, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO)

McGranahan, G., BALK, D., and Anderson, B. (2007). The rising tide: Assessing the risk of climate change and human settlements in low elevation coastal zones. *Environ. Urban,* 19: 17-37

Ngigi, S. N. (2003). Rainwater Harvesting for Improved Food Security: Promising Technologies in the Greater Horn of Africa. Greater Horn of Africa Rainwater Partnership

(GHARP) and Kenya Rainwater Association (KRA), Nairobi, Kenya

Oweis, T.Y., Prinz, D. and Hachum, A.Y. (2012). Water Harvesting for Agriculture in the Dry Area. *ICARDA*, CRC Press/ Balkema, Leiden, the Netherlands

Schmidli, .J, and Frei, C. (2005). Trends of heavy precipitation and wet and dry spells in Switzerland during the 20th century. *International Journal of Climatology* **25**(6): 753–771.

Sengupta, S., Kang, A., and Jcob, N (2012). *Water Wealth A Briefing Paper on the state of Groundwater Management in Bangladesh,* Retrieved from http://www.cseindia.org/userfiles/groundwater_management_bangladesh.pdf

Shahid S. (2008). Spatial and temporal characteristics of droughts in the western part of Bangladesh. *Hydrological Processes* **22**(13): 2235–2247.

__________(2010). Rainfall variability and the trends of wet and dry periods in Bangladesh. *International Journal of Climatology,* Wiley Online Library, 30:2299-2313, DOI: 10.1002/joc.2053

Shahid, S., and Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. *Natural Hazards* **46**(3): 391–413.

Studer, R.M., and Liniger, H. (2013). Water Harvesting Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.

Walker, B., Holling, C.S., Carpenter, S.R., and Kinzig, A. 2004. Resilience, Adaptability and Transformability in Socioecological Systems. Ecology and Society, 9(2)

Wasimi, S.A. (2009). Climate Change Trends in Bangladesh. *Proceedings of 2nd International Conference on Water and Flood Management*, 8-10 March 2009, Dhaka, Bangladesh, 1:203-210

Worm, J. and van Hattum, T.(2006). Rainwater harvesting for domestic use. *AGROMISA and CTA / RAIN (Rainwater Harvesting Implementation Network).* Wageningen, The Netherlands

Zhang, Q., Xu C-Y, and Zhang, Z. (2009). Observed changes of drought/wetness episodes in the Pearl River basin, China, using the standardized precipitation index and aridity index. *Theoretical and Applied Climatology* **98**(1-2): 89–99.

7. Safeguarding Wild Plant Genetic Resources of Georgia within the Millennium Seed Bank Partnership

Tsira Pantsulaia-Mikatadze, Sandro Kolbaia, Ana Gogoladze

ABSTRACT:
Working group of the Department of Plant Conservation of the National Botanical Garden of Georgia (NBGG) have been participating in the global Millennium Seed Bank Partnership, led by the Royal Botanic Gardens, Kew since 2005. During the 2005-2018 period, within the scope of MSB-1 and MSB-2, seeds and herbarium samples of more than 1750 plant species and interspecific taxa, belonging to 107 families and 483 genera (more than 41% of Georgia's flora) – 348 endemics of Caucasus and 151 endemics of Georgia, have been secured in the Georgian National Seed Bank (GNSB). Seed Bank data are managed in BRAHMS (Department of Plant Sciences of Oxford University). The collection of wild plant species is accompanied by the comprehensive database of geographical, botanical and habitat information. Later phase involves laboratory treatment and germination/viability testing (at least 500 seeds per species) and the long-term deposition and storage (under -20°C temperature) at the National Seed Bank of Georgia. The duplicates of seed collection and herbarium vouchers are stored at the Millennium Seed Bank of Royal Botanic Gardens, Kew, UK. Germination capacity and viability of collections in GNSB is determined before cold storage of seeds, while at the MSB already banked seeds are tested.

Keywords: Seed bank, ex-situ conservation, plant diversity, botanical garden, genetic resources

Dr. Tsira Pantsulaia-Mikatadze is the head of the Department of Plant Conservation of the National Botanical Garden of Georgia, Tbilisi, Georgia. Head of National Seed Bank of Georgia. Project manager of "Global Tree Seed Bank Project (Garfield Weston Foundation, UK, 2015-2019)", "Ex-situ and in-situ conservation of Prunus microcarpa a threatened species in eastern Georgia (BGCI, UK, 2017-19)", "Saving the Flora of the Caucasus (Royal Botanical Gardens Kew Grants, 2011-20)", "Enhancing Rural Caucasian Community Livilihood through Fruit and Nut Conservation (Darwin Initiative, UK, 2018-21)". Previous projects: "In-situ and ex-situ conservation action for the Georgian almond (Amygdalus georgica) (BGCI, UK, 2014-16)", "Collection of Crop Wild Relatives in Georgia by the National Botanical Garden (NBGG) (Global Crop Diversity Trust, Germany, 2014-16)", "Collection of seeds of native plant species from Georgian flora for ex-situ conservations at the Institute of Botany, Georgia and the Millennium Seed Bank (Royal Botanic Gardens (Kew) Grants UK # 4714 P 4/6, 2005-10)", "Sustainable Use & Conservation of Medicinal plant Resources in the Republic of Georgia (CRDF (U.S.A. Civilian Research & Development Foundation, USA, 2004-06)" etc.

MSc Sandro Kolbaia is the research assistant at the Department of Plant Conservation of the National Botanical Garden of Georgia, Tbilisi, Georgia. Project participant of "Global Tree Seed Bank Project (Garfield Weston Foundation, UK, 2015-2019)", "Ex-situ and in-situ conservation of Prunus microcarpa a threatened species in eastern Georgia (BGCI, UK, 2017-19)", "Saving the Flora of the Caucasus (Royal Botanical Gardens Kew Grants, 2011-20)", "Enhancing Rural Caucasian Community Livilihood through Fruit and Nut Conservation (Darwin Initiative, UK, 2018-21)". Works alongside at the Species Conservation Group NACRES as a habitat and flora specialist in scope of developing the Emerald Network in Georgia. Acquired Bachelor of Ecology from Ilia State University (2010-14) and Master of Plant Sciences from the University of Bonn (2015-18).

Ana Gogoladze is the research assistant at the Department of Plant Conservation of the National Botanical Garden of Georgia, Tbilisi, Georgia. Project participant of "Global Tree Seed Bank Project (Garfield Weston Foundation, UK, 2015-2019)", "Ex-situ and in-situ conservation of Prunus microcarpa a threatened species in eastern Georgia (BGCI, UK, 2017-19)", "Saving the Flora of the Caucasus (Royal Botanical Gardens Kew Grants, 2011-20)", "Enhancing Rural Caucasian Community Livilihood through Fruit and Nut Conservation (Darwin Initiative, UK, 2018-21)". PhD candidate at the Faculty of Natural Sciences of Ilia State University. Acquired Bachelor of Biology and Medicine from Tbilisi State University (1996-2000) and Master of Botany from Tbilisi State University (2000-2002).

1. Introduction

The republic of Georgia has one of the highest concentration of plant species know from any temperate part of the world. Bordered to the north by Russian Federation, to the east by Azerbaijan, to the south by Armenia and Turkey and to the west by the Black Sea, Georgia's 69,700 km^2 are home to an exceptional plant diversity in an area where the European and Asian floras intersect. The Greater Caucasus Mountains traverse northern Georgia, the Lesser Caucasus Mountains cross the southern edge and a rich central valley is bounded by the dry Iori Plateau and Alazani Valley to the east and the humid Kolkheti Plain to the west. This topographic diversity, including mountain peaks that exceed 5,000 meters (Mt. Shkhara, Mt. Mkinvartsveri), coupled with a diverse array of climatic influences, gives rise to a complex mosaic of vegetation zones that support a high diversity of plants.

Georgian flora comprises of the vascular plants grown in wild conditions on the territory of country, comprising 185 families, 1048 genera and 4275 species. High endemism level of Georgian flora reflects its richness - 21 % of the local flora is endemic and consists of about 900 species. Among them about 600 species are endemic to the Caucasus and about 300 are endemic to Georgia (Davliandize *et al.* 2018)

The Caucasus, and Georgia in particular, has been attributed to the world's biodiversity hotspots.

Figure 1: The Republic of Georgia on the world map.

Ex-situ conservation via establishing seed banks and living collections is one of the most efficient and comparatively low-cost method for the protection of plant biodiversity.

The seed bank was founded on behalf of Caucasus Regional Seed Bank (CRSB) in

Georgia in 2001 by the staff members of the N. Ketskhoveli Institute of Botany in collaboration with colleagues from the Missouri Botanical Garden (USA) with financial support from the CRDF (U.S. Civilian Research &Development Foundation). Two joint projects: "Informatics for the Sustainable Use of Plant Genetic Resources in the Republic of Georgia" (2001-2002) and "Sustainable Use & Conservation of Medicinal Plant Resources in the Republic of Georgia" (2004-2006) were accomplished in collaboration with American colleagues. As a result, seeds of 150 endemic and rare species were deposited in the seed bank, the database created using the information system TROPICOS and the results published in Miller 2006.

The Caucasus Regional Seed Bank has been renamed as The National Seed Bank of Georgia (NSB) under The National Botanical Garden's Plant Conservation Department. The former comprises of 2 ha of collection plot with living plants from the Caucasus.

As of partnership with the Millennium Seed Bank of the Kew Botanical Garden: The global project – The Millennium Seed Bank Partnership (MSB) was launched by the Seed Conservation Department of the Royal Botanic Gardens, Kew in 2000. Target of the first stage of the project (MSB-1), that was completed in March of 2010, was to bank the seeds of 10% of the vascular flora of the world (all species from the United Kingdom as well as nearly 24,200 mainly dryland species) at a new storage facility located in the Wakehurst Place, West Sussex, later called the Welcome Trust Millennium Building. The project was also aimed at the development of partnership with organisations in many countries, bilateral research, training and capacity building for the support of plant conservation at a global scale.

Scientists of the Department of Plant Conservation of the N. Ketskhoveli Institute of Botany joined this global initiative in 2005 with the project "Ex-situ conservation of the wild flora of Georgia in the Caucasus Regional Seed Bank (Georgia) and the Millennium Seed Bank (UK) 2005-2010 (N4714 P4/6, 22 August, 2005). Georgia was the first former Soviet country to join the MSB-1. Priority for the project was creation of the seed bank of endemic, rare, threatened, vulnerable and economically important plants.

MSB-1 was completed in March 2010. During the period of 2005-2010, in collaboration with British colleagues within the scope of the MSB-1, seeds and herbarium samples of 848 plant species have been collected, comprising around 21% of Georgia's flora (Mikatadze-Pantsulaia *et al.* 2010).

MSB-2 or MSBP (Millennium Seed Bank Partnership), as is referred the second decade of this global project (2010-2020), aims at conserving seeds of another 15% of world's seed-bearing plants at the Millennium Seed Bank during the current decade and enabling practical use of these seeds for the well-being of mankind.

Staff members of the Department of Plant Conservation of the National Botanical Garden of Georgia together with colleagues from the Institute of Botany of the Ilia State University continue their work under the project „Saving the Flora of the Caucasus" to achieve targets of the second stage of the MSBP (2010-2020).

2. Materials and Methods

Seeds of target species are to be necessarily collected in the wild. For each species a special data sheet is filled out, which, along with geographic and botanical data, contains comprehensive information about the sample, its habitat and the process of collecting.

After the primary processing all these data are transferred into the electronic database – BRAHMS (Botanical Research and Herbarium Management System) and is electronically exchanged with the MSB and MSB DW (Data Warehouse).
The National Seed Bank (NSB) is designed for the long-term storage of seeds. All seed bank procedures are in accordance with international standards and guidelines (Baskin 2001; Smith 2003).
Upon arrival to the seed bank seeds are dried in dry room and then processed (manual cleaning, sorting, removal of infested, damaged or empty seeds, cleaned (if appropriate) using the aspirator (CB-1 Column Blower, Agriculex Inc., Canada), weighted and numbered. Specialists carefully check seed maturity and collection quality – the collection is visually evaluated using the binocular stereoscope (Motic SMZ-161, Hong Kong). Depending on the size of a collection, certain number of seeds are cut tested, as well as, in some cases, stained with tetrazolium chloride (TZ test) for the evaluation of their viability. After the examination and testing of seeds, "adjusted seed number" is determined, considering the percentage of potentially non-viable seeds (empty, half-filled, damaged or infested). Before banking seeds are kept in the dry room at the relative humidity (rH) of 15-20%. Above indicated equilibrium relative humidity is safe level to store seeds at the minus temperature. Dried seeds are placed in aluminium foil bags, sealed using the sealing apparatus (Hulme Martin Heat Sealers Ltd, UK) and banked in the freezer at –20^{o}C. Germination capacity of seeds is tested on Petri dishes on 1% plain agar medium inside the incubator (LMS Ltd, UK) under controlled illumination and temperature regime. Results and conditions of germination tests along with the data of seed processing (cleaning, weighing, cut testing) and relative humidity measurements are transferred to the electronic database (BRAHMS), which automatically calculates percentages of germination and viability.
Germination capacity and viability of collections in NSB is determined before cold storage of seeds, while at the MSB already banked seeds are tested for germination every ten years.

Figures 2, 3: NSB team members assessing the population of target species - Eversmannia subspinosa (DC.) B.Fedtsch. in Vashlovani Nature Reserve, Eastern Georgia (left). Collection process of Caucasian endemic pear species Pyrus takhtadzhianii Fed. in Eastern Georgia (right).

3. Conclusion and Discussion

During the 2005-2018 period, within the scope of MSB-1 and MSB-2, seeds and herbarium samples of more than 1750 plant species and interspecific taxa, belonging to 107 families and 483 genera (more than 41% of the Georgian flora) – 348 endemics of Caucasus and 151 endemics of Georgia, have been secured in the National Seed Bank of Georgia (NSB). Among them are 134 species of woody plants, as well as 168 ssp. of crop wild relatives (CWR) from 298 populations.

The information gathered in the seed bank is managed using the BRAHMS database.

Minimum number of 500 seeds from each species are deposited at the NSB and the corresponding labelled herbarium specimen kept at the National Herbarium of Georgia (TBI). The duplicates of the seed collection and herbarium voucher are sent to the Millennium Seed Bank and Herbarium of the Royal Botanic Gardens, Kew (K).

Under the partnership, the "excess" seeds of the plants of conservation importance are used for building the documented living collections for later use in *in-situ* reintroduction works, scientific research and public awareness.

Figure 4: Seed collecting process of Acer laetum C.A.Mey. at Gombori pass in Eastern Georgia

Figure 5: National Seed Bank facility and equipment.

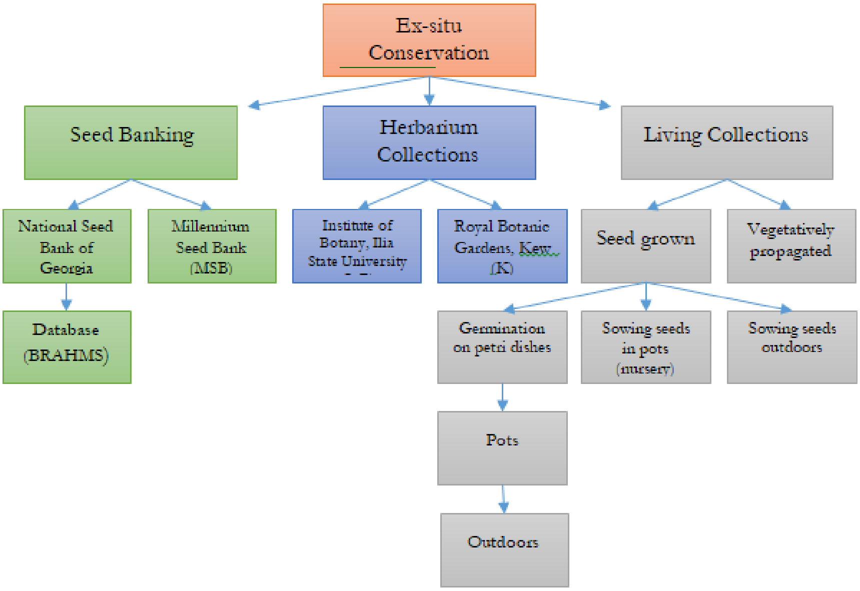


Figure 6: Structure of ex-situ conservation work at the National Seed Bank (NSB) within the Millennium Seed Bank partnership (MSB).

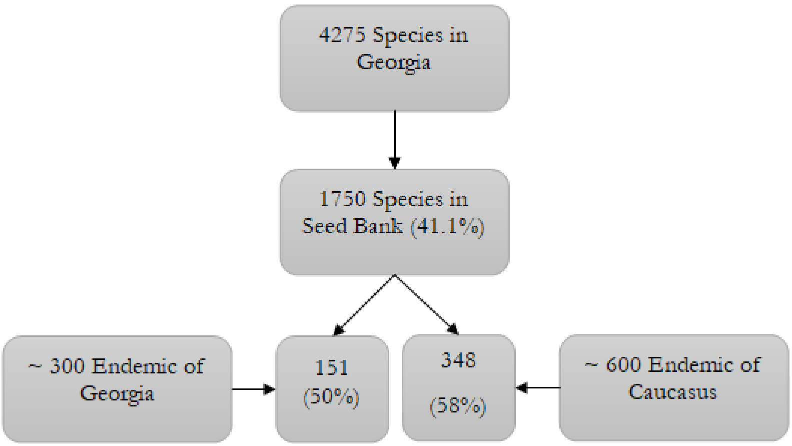


Figure 7: Current state of collections at the National Seed Bank (2005-2018).

4. Acknowledgements

We thank: Staff of the Millennium Seed Bank of the Royal Botanic Gardens, Kew (UK), the Rufford Foundation (UK) and personally Mr. David Hunt (British-Georgian Society, UK).

References

Baskin, C. C. & Baskin, J.M. (2001) Seeds, Ecology, Biogeography and Evolution of Dormancy and Germination. Academic Press, California.

Davlianidze M. and et al. (2018) Nomenclatural Checklist of Flora of Georgia. Ilia State University Institute of Botany, Tbilisi

Miller J.S., McCue K., Consiglio T., Stone J., Eristavi M., Sikharulidze Sh., Mikatadze-Pantsulaia Ts., Khutsishvili M. (2006) Endemic Medicinal Plants of Georgia (Caucasus). 45p.

Mikatadze-Pantsulaia Ts., Barblishvili T., Trivedi C., Kikodze D., Khutsishvili M. (2010) Ex-situ conservation of some endemic and protected plant species in Georgia, Kew Bulletin, 65 (4):643-448.

Mikatadze-Pantsulaia Ts., Barblishvili T., Trivedi C., Faruk A., (2017) Caucasus Regional Seed Bank, Nova Science Publishers Inc. New York, USA

Solomon J., Shulkina T., Schatz E. G. (2014) Red List of the Endemic Plants of the Caucasus: Armenia, Azerbaizan, Georgia, Iran, Russia, and Turkey. Monographs in Systematic Botany from Missouri Botanical

Smith, R. D., Dickie, J. B., Linington, S. H., Pritchard, H. W., & Probert, R. J. (2003). Seed Conservation: Turning Science into Practice. London. The Royal Botanic Gardens, Kew.

Trivedi C. (2012) Seed scientists and horticulturalists working together to conserve threatened Georgian species. Samara, 23 July-December

8. Factors Affecting Adoption of Sustainable Soil Management Practices Among Fluted Pumpkin Vegetable Producers in Ikorodu, Lagos State

Omowumi Ayodele Olowa

ABSTRACT:
Proper soil management is germane to sustainable vegetable production. The greatest threat to sustainable agricultural productivity is the declining soil productivity. The reason for this declining soil productivity might not be unconnected with the soil management practices by farmers. This study attempt to isolate factors that are contributing to vegetable farmers' adoption of soil management practices. Primary data were collected from randomly selected 120 fluted pumpkin vegetable farmers, adopting pre-tested semi-structured interview schedule in Ikorodu Local Government Area. This predicated on the facts that Ikorodu environment seems to be well adapted for fluted pumpkin production as many hectares of land are cultivated to fluted pumpkin by hundreds of small holders. probit regression model was used to isolate factors affecting the adoption of sustainable soil management technology. Overall, the model predicted 85.76%of the sample correctly. The findings of the study revealed that number of economically active family members, household head education, livestock holding, membership in farmer's group and credit availability affects positively whereas, age of household head affects negatively in the adoption of sustainable soil management technology. A unit increased in economically active family members, years of education and livestock standard unit would increase the probability of adoption of technology by 21.3, 5.8 and 7.6% respectively. Likewise, if farmers were made member in the groups and credit made available, the probability of adoption of technology would increase by 46.2 and 46.3% respectively. But a unit increased in the age of household head would decrease the level of adoption by 1.4% indicating old aged farmers do not adopt innovative technologies in agriculture.

Keywords: Lagos, adoption, probit, sustainable soil management, vegetable, fluted pumpkin

Dr. (Mrs) O. A. Olowa, a Nigerian of Ogun State origin, holds a PhD in Agricultural Economics from the University of Ibadan, Nigeria having also bagged a Master and BSc in the same field from the same university. She has many journal publications and conferences paper to her credit. She is a senior Lecturer in the Department of Agricultural Education.

1. Introduction

Degradation of land is a reduction in its productivity that may result from loss, breakdown in soil structure, salinization, water logging, nutrient loss, and pollution from toxic substances. Most of these factors are the result of Agricultural activities (ADB, 1995). The Federal Ministry of Agriculture, (1987) defined soil conservation/management as the wise use of land so that its productivity is kept high over a relatively long period of time. According to their definition, soil conservation encompasses three phases namely: Sustaining the fertility of soil and protection from destruction; studying and planning control measures for degraded soil; and actual reclamation of degraded soil. It has been said that the greatest threat to sustaining agricultural productivity in Nigerian farming is the decline in soil productivity. As a result of this, a number of programmes and policies aimed at promoting soil conservation practices have been mounted by Nigerian government. The common soil management practices among vegetable farmers can be classified into two namely indigenous and non-indigenous practices. Minimum tillage, bush fallow, zero-tillage, shifting cultivation, ridging across the slope and manure/plant residue management are popular indigenous soil management practices while fertilizer use and crop rotation are non-indigenous soil management practice in Nigeria. The greatest threat to sustaining agricultural productivity in Nigerians farming communities is the declining productivity of soil caused by one, Loss of soil fertility due to removal of top soil by agents of soil erosion due to inappropriate land use practices. Two, Loss of soil structure and porosity due to continuous cultivation and laterisation of top soil. As a result of continuous exposure to sun by anthropogenic agents (man and animals) soil water content are continuously reduced during the process. Three, destruction of natural soil structure due to wrong adoption and use of modern technology (e.g. use of heavy farm machines). The spectacular emergence of the problem of soil erosion (including sheet, wind and coastal erosion) in nearly all parts of Nigeria is an attestation of the inappropriate land use practices in many communities (Federal Ministry of Agric., Water Res. and Rural Development, 1987). As far back as 1977, Olayide and Falusi, had observed that the country is under the threat of massive depletion of her soil due to the increasing occurrence of improper farming and cultivation practices which expose the soil to harsh weather conditions. Over 40 years later, the fertility status of Nigeria's soil resources have continued to decline. Despite several uncoordinated attempts to address the problem of land degradation and soil depletion, fluted pumpkin farmers in the southern part of Nigeria have not been too eager to adopt or invest in soil conservation practices introduced to them. Agbamu (1993) after closely studying the soil management practices adoption behaviour of small farmers in Lagos State concluded that the attitude of most farmers in south western Nigeria towards the adoption of soil conservation practices 'has not been encouraging. With the initiation of commercial vegetable cultivation, there have been increasing trend of chemicals use. Excessive application of chemical fertilizers and pesticides thereby causing toxicity of soil. Also, huge amount of money is being spent for the import of chemical fertilizers and pesticides every year.

In spite of massive subsidy regime in the fertilizer supply, small holders cannot afford the quantum of fertilizers required to meeting soil requirement (Subedi et al., 2001). On the other hand, excessive use of chemicals in agriculture is reducing soil fertility. Almost all the soil in Nigeria has become deficient in organic matter due to poor management practices. To cope with the situation of pesticide hazards and environment deterioration, a case for sustainable soil management practice is made in this paper. Sustainable soil management (SSM) practices are compatible with the capabilities of rural communities and smallholder farmers who generally lack capital to buy synthetic pesticides and inorganic fertilizers. In some situations SSM based growers may be less vulnerable to natural and economic risks than conventional farmers since their systems are usually more diversified (Olson et al., 1982). Also, addition to this Nowadays, various areas in the world have faced water logging and salinity problems, which are intensified by a myriad of factors including use of wastewaters for irrigation, unsuitable cropping pattern, torrential rains and floods, lack of sufficient drainage, uncontrolled drainage, lack of adequate knowledge, wrong management decisions, very poor construction and rehabilitation rates of drainage systems, increase of irrigation systems without paying any attention to their adverse impacts on soil and quality of water resources, etc. (Valipour, 2014). Under good soil management practice, fluted pumpkin yield as high as 500-1000 kg/ha and can also be as high as 3-10t/ha depending on the management system. The seed yield can be up to 1.9t/ha derived from 3000 fruits. Hence the need for sustainable management practice for soil.

Although, there are many agricultural technologies nowadays available for farmers which are eco-friendly and sustainable, their use and sustainable adoption is not known. Farmers are adopting such practices whose profitability, sustainability, and viability are alien to them. Poor extension and adoption rate of improved farming technology have been implicated in Nigerian agriculture development. Thus, the general objective of this study is to find out the level of adoption and the major factors influencing adoption of sustainable soil management practice

Specifically, the study seek to:

(i) find the level of adoption of Sustainable Soil Management practice among fluted pumpkin vegetable farmers.

(ii) identify the major factors influencing the level of adoption of Sustainable Soil Management practice.

(iii) isolate the factors influencing adoption of Sustainable Soil Management practice.

2. Methodology

Ikorodu Local government Area (ILGA) is divided into six Local Council Development Areas (LCDAs) namely Ikorodu West, Ikorodu North, Ijede, Igbogbo-Bayeku, Imota and Ikosi-Agbowa. Apart from Ikorodu West with seemingly metropolitan nature, farming activities are carried out extensively in other five LCDAs. Fluted pumpkin farming/production is largely carried out in all the LCDAs but Ijede. All the four LCDAs were covered in the sample survey. Thirty fluted pumpkin farmers were purposively selected in each LCDA. Thus one hundred and twenty farmers were selected. Majority of these *ugu* farmers were full-time producers who have no non-farm activities.

Primary data was collected using semi-structured interview schedule. The instrument elicited information on age, gender, years of experience in vegetable farming, membership of farmers' group, training received or otherwise and on soil management practices. Information were collated on soil management or conservation practices and subjected to adoption index to calculate the level of Sustainable Soil Management (SSM) practice adoption, following Dongol (2004). Thus farmers were categorised into different levels of adoption such as high adoption, medium adoption, and low adoption, based on the derived adoption index. Probit regression model was applied to determining factors affecting level of adoption of SSM practices in this study. The characteristic feature of probit models is that the effect of independent variables on dependent variables is non-linear. It is a statistics model which aims to form a relation between probability values and explanatory variables and to ensure that the probability value remains between 0 and 1. In the Probit model, suppose Y_i be the binary response of the farmers and take only two possible values; Y = 1, if farmer's adoption level is more than 84% and Y = 0, if less than 84% (Bhusal, 2012). Suppose x be the vector of several explanatory variables affecting to the level of adoption and β, a vector of slope parameters, which measures the changes in x on the probability of the farmers to adopt the practice at higher level. The probability of binary response was defined as follows:

$$if Y_i = 1; \Pr(Y_i = 1)$$

$$Y_i = 0; \Pr(Y_i = 0) = 1 - P$$

Where, $Pi = E(Y_i = 1/X)$ represents the conditional mean of Y given certain values of X. According to Nagler (2002) probit model constrains the estimated probabilities to be between 0 and 1 and relaxes the constraint that the effect of the independent variables is constant across different predicted values of the dependent variables. This is normally experienced with the Linear Probability Model (LPM). The advantage of probit model is that it includes believable error term distribution as well as realistic probabilities. There were several factors that affect the level of adoption of the practices at the farm level. Decision to adopt at higher level might be influenced by several socioeconomic, demographic, institutional and financial conditions. The aim of the model is to predict the influence of variables (X) on the probability of adoption of sustainable soil management practices (Y, dependent variables). Accordingly, the probit model estimate the likelihood of farmers adopting SSM practices as a non-linear function of variables. $\Pr(Y=1) = (X\beta)$

2.1 Model specification

The Probit model as specified in this study to analyze factors affecting farmer's level of adoption of sustainable soil management practices was expressed as follows: $\Pr(>84\%=1) = f(b_0 + b_1 X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11})$.

Where, Pr (> 84%) = Probability score of adopting SSM practices

$b_1, b_2 \ldots b_{11}$= Probit coefficient

b_0= Regression coefficient

Table 1. Description and *A Priori* Signs of the variables used in the Probit model.

Variable	Type	Description	Value	Expected sign
Dependent variable Y_i	Dummy	Farmers scoring more than 84% in adoption score.	1 if farmer secured score> 84%; 0 otherwise	
Independent variables				
Economically active members	Continuous	Number of economically active family members in the household (16-59years)		+
Education	Continuous	Years of education of the household head (years)		+
Farm size	Continuous	Total size of cultivated land (Ha)		+
Experience	Continuous	Experience of household head in vegetable farming (Year)		+
Gender	Dummy	Gender of the household head	1 if male; 0 otherwise	+/-
Age	Continuous	Age of the household head (years)		+
Training	Dummy	whether farmers received training from different governmental and non-governmental organization.	1 if farmers received training; 0 otherwise	+
Livestock holding	Continuous	Livestock holding	Livestock Standard Unit, LSU	+
Membership	Dummy	Participation of respondent on SSM farmers group	1 if yes; 0 otherwise	+
Credit	Dummy	Whether farmer had access of credit	1 if farmers had access to credit; 0 otherwise	+ -

3. Results and Discussion

3.1 Socio-demographic characteristics of Fluted pumpkin Farmers

The socio-demographic characteristics of fluted pumpkin vegetable farmers in the study area were summarized in Table 2. As shown in the table, majority of the fluted pumpkin farmers were male (53.45%) with average family size of 6.2. Average age of farmers was 56.2 years. The socio-demographic analysis further showed that 51% were economically active. 86.2% of farmers were male-headed indicative of male dominated farming system in the study area. About 63% were found to be literate with average level of Education (years) of 12. Average land area cultivated was 0.001342ha and only 0.00318ha was under irrigation. This imply that majority of the fluted pumpkin farmers were small holders. Moreover, 62% of the farmers indicated they had received trainings related to sustainable soil management practices facilitated by their group/ union, as majority of them (85.8%) belongs to farmers' group/union. The average livestock holding was 9.12 in the study area.

Table 2: Socio-Demographic Characteristics of Fluted Pumpkin Farmers (N=120)

Characteristics	**Frequency**	**Percentage**	**Mean**	**SD**
Age (Years)			56.2	10.31
Household Head				
Male-headed	103	86.2		
Female-Headed	17	13.8		
Family Size			6.16	3.22
Gender				
Male	64	53.45		
Female	56	46.55		
Educational Level			12.2	2.03
Economically Active	61	51		
Farming related	16.8	7		
Non-Farm	223.2	93		
Training				
Yes	74	62.2		
No	46	37.8		
Membership of Farmers' Group				
Yes	103	85.8		
No	17	14.2		
Average Livestock Holding			9.12	6.7
Average land Cultivated (Ha)			0.001342	0.56

3.2 Soil Conservation/Management Practices among Fluted Pumpkin Farmers

Common soil management practices among fluted pumpkin farmers in Ikorodu are described in Table 3. First, zero tillage, in the study area zero tillage is usually carried out when opening up a new site or returning to an old farmland. The farmers clear the land and the plant residue is left to rot or burnt into ashes. As the table shows, none of the farmer practiced it. Two, fertilizer use. Fertilizer use can be used as a soil conservation practice if it is applied to enable quick growth and vegetation coverage of the soil, thereby reducing soil erosion. However, most farmers in Ikorodu use fertilizer mainly for the purpose of direct supply of needed nutrients for crops growth and yield improvement and not for strict conservation purposes. To the farmers, it cannot be said to be an indigenous soil conservation method. According to them, the essence of soil management is to increase or maintain crop yield levels in the short term. The use of fertilizer was found to be the most prevalent soil management practice in the study area. According to Table 3, all the farmers used fertilizer mainly for the purpose of direct and quick supply of nutrient to growing fluted pumpkin. Even though the farmers did not deliberately set out to apply fertilizer for soil conservation purposes, it is possible that the resultant rapid growth in vegetation resulting from the application will have conservation effect on the soil. Three, Minimum tillage. In the study area, minimum tillage involves the use of hoes to disturb the soil in the process of constructing of beds/heaps. Minimum tillage ranks well as soil conservation practice with fertilizer use, as all the farmers (100%) practiced it. It is actually the most prevalent indigenous method. Their landholdings are rather too small and fragmented for tractor operation. Four, Bush fallowing. This practice involves the abandoning of a cropland for a period of time to revert to bush. Majority (81%) of them did not practice it. Only about 19 percent, majority of which reside in Ikosi-Agbowa LCDA, a very rural environment practiced it. The practice is not prevalent in the study area because of the scarcity of land. Five, Mulching. Mulching is a tillage system that ensures a maximum retention of crop residues or other vegetative materials on the soil surface. As seen in Table 3, about 31% of the farmer were engaged in the practice, while majority (69%) have given up the practice. Mulching is practiced mainly by yam farmers. The practice is not common among fluted pumpkin farmers. Six, Crop rotation. Crop Rotation is a practice of growing different crops, one at a time, in a definite sequence on the same piece of land. The practice is not a popular soil management technique in the study area as almost all (99%) of the farmer were not engaged in the practice. Seven, Manuring/Plant Residue Management. Plant residue management (PRM) involves seeding through the previous crop residue by either burning of residue or incorporation or mulching. Manuring on the other hand is a soil management system of adding refuse from farm animals and plants to the soil in order to supply nutrients required by plaints. Only a small proportion (5.1%) of the farmers was engaged in these practices. About 94.9 percent had given up the practices. Eight, Making Ridges/Heap along/across the slope. This is particularly important in land with sloppy terrain to curb excessive water run-off. Ridging or heaping across the slope is well known as a soil conservation method by the farmer. Only about 8.6 percent of the farmers are currently engaged in the practice. The sloppy location of their farmland pre-dispose them to the practice.

Table 3. Soil Conservation/Management Practices among Fluted Pumpkin Farmers (N=120)

Soil Management Practices	**Frequency**		**Percentage**	
	Yes	**No**	**Yes**	**No**
Zero Tillage	0	120	0	100
Use of fertilizer	120	0	100	0
Minimum Tillage	120	0	100	0
Bush fallowing	23	97	19	81
Mulching	37	83	30.8	69.2
Crop rotation	12	108	1.0	99
Manuring/Plant Residue Management	6	114	5.1	94.9
Making Ridges/Heap along/across the slope	10	110	8.6	91.4

3.3 Scale of Soil management Practice/ Adoption

Table 4 shows the adoption levels of fluted pumpkin farmers when all the soil management practices were bundled together and adoption index was applied following Dongol (2004). As the Table shows, majority of the respondent that is, 44.2 percent had medium level of adoption (exactly 84.5% level) of sustainable soil management practices, while, a very small proportion (18%) was in the high adoption level category; whereas, 37.50% were at low level. The breakdown analysis shows that majority of high adoption of soil management practice were found Ikorodu-North (30%) and Igbogbo-Bayeku (20%) LCDAs. The implication of the results is that soil management/conservation technique adoption/practice rate is very low, as about 81% of the farmers could be classified medium or average and below in their practice of soil conservation on aggregate.

Table 4. Scale of Adoption of Sustainable Soil Management Practices By Respondents

Level of Adoption	Local Council Development Area				Total
	Imota	Ikosi-Agbowa	Ikorodu-North	Igbogbo-Bayeku	
<84.5% (Low)	12 (40)	11(36)	08(26)	14(46)	45(37.5)
=84.5% (Medium)	14 (46)	16(53)	13(43)	10(33)	53(44.2)
>84.5% (High)	04 (13)	03(10)	09(30)	06(20)	22(18.3)
Total	30	30	30	30	120(100)

Figures in Parenthesis are Percentages. Average level of Adoption=84.5%

3.4 Probit Regression Analysis

The results of the Probit regression analysis are shown in Table 5. The adoption level of the farmers in the study area was categorized into binary response by the adoption level of more than 84.5%= 1 and 0 otherwise. The extent to which the probit regression analysis modeled independent variables used in prediction correctly predicted the dependent variable. Overall, the model predicted 85.76 per cent of the sample correctly. Thus the model may be said to be consistent and meaningful. The Wald test (LR chi^2) for the model indicated that, the model had good explanatory power at1% level. The Pseudo R^2 was 0.777. For robust interpretation of the model, marginal effects were derived from the regression coefficients, calculated from partial derivatives as a marginal probability. The outcome is shown in Table 5. Probit regression analysis showed six variables were statistically significant for the level of adoption and they were; *ECONOMICALLY ACTIVE FAMILY MEMBERS, EDUCATION, AGE, LIVESTOCK HOLDING, MEMBERSHIP AND CREDIT*. Five other variables namely experience, occupation, training and gender were statistically non-significant and associated positively with adoption while farm size was negatively correlated (Table 5). The study revealed that, number of economically active family members was positively significant (P<0.05) and holding other factors constant, a unit increase in the number of economically active family members would increase probability of level of adoption by 21.3%. This might be due to the availability of the more labor force in the agricultural activities. Teklewold et al. (2006) reported that higher size of the household reduces labour constraints and influence the adoption of new technology positively.

Table 5. Factors Affecting the Level of Adoption of Sustainable Soil Management Practices in the Study Area

Variable	**Coefficients**	**P>|z|**	**Standard error**	**dy/dx[b]**	**S.E[b]**
Economically active members(No.)	0.950**	0.014	0.385	0.213	0.094
Education (Years)	0.257***	0.008	0.097	0.058	0.029
Farm size (Ha)	0.003	0.935	0.042	-0.001	0.009
Experience (Years)	0.121	0.577	0.217	0.027	0.051
Gender (Dummy)	0.147	0.692	0.692	0.033	0.158
Age of HH (Years)	-0.653**	0.027	0.029	-0.014	0.006
Training (Dummy)	1.013	0.088	0.594	0.272	0.196
Livestock holding (LSU)	0.340**	0.034	0.164	0.076	0.024
Membership (Dummy)	1.918***	0.002	0.624	0.462	0.164
Credit availability (Dummy)	1.637**	0.011	0.644	0.463	0.207
Occupation (Dummy)	0.078	0.914	0.724	0.018	0.172
Constant	-6.121	0.008	2.318		
Summary statistics					
Number of observation(N)	120				
Log likelihood	-18.248				
LR chi2(10)	127.15***	(Prob>chi2 = 0.000)			
Prob>chi2	0.000				
Pseudo R2	0.777				
Cases predicted correctly (%)	85.76				
Goodness of fit test	Pearson chi2 (107) = 76.85.	Prob> chi2 = 0.9877			

*** Significant at P = 0.01; ** significant at P = 0.05. [b]Marginal change in probability (marginal effects after Probit) evaluated at the sample means.

Higher education level of household head gives the ability to interpret and respond to new information much faster than their counterparts with lower education (Feder et al., 1985). The coefficient of level of Education was positive and highly significant (P<0.01). One year increase in Education of farmers would increase the level of adoption by 5.8%. This finding is in consonance with the report of Kattel (2009). Age of farmer was negatively significant (P<0.05). The marginal effect showed a unit increase in the age would decrease the adoption level by 1.4 percent. Similar study by Ghimire and Kafle (2014) showed that age factor negatively affected the adoption of integrated pest management practices in Nepal. This finding is also in tandem with Mussei *et al.*, (2001) and Hussain et al. (2011) where they reported that older farmers do not adopt the innovative technologies like IPM; but contrasted sharply with Chebil *et al.*, (2007) who reported otherwise. Livestock holding was positively significant (P<0.05) and a unit increase in the Livestock holding would increase the adoption level of Soil Management practices by 7.6%. Similar finding was reported by Kudi *et al.* (2011) which contrasted the findings by Dhital (2010). Coefficient of Membership of Farmers' group was positive and highly significant (P<0.01), and if farmers participated in a group related with sustainable soil management practices would increase the probability of adoption level by 46.2%. This might not be unconnected with the facts that, farmers derive improved capacity through their involvement in groups/union activities. Nchinda *et al.* (2010) reported similar findings. Credit Availability was positively significant ($P<0.05$) indicating that if farmers were provided credit facility, adoption of Sustainable Soil Management practice would increase, and at the margin by 46.3%. Tizale (2007), Ghimire B. Dhakal S.C., Sharma S. and Poudel S. (2015) also opined that there is a positive relationship between the intensity of use of various technologies and the availability of credit.

4. Conclusion and Recommendations

The study revealed that the fluted pumpkin farmers were aware of different soil management practices and that adoption of any practice depend on a number of factors which affect the adoption process significantly. The study explore the disposition of fluted pumpkin farmers to common soil management practices. The most common practice was found to be fertilizer use (which is a non-indigenous short-term fertility maintenance practice) and minimum tillage (indigenous short/ medium term erosion control practice); bush fallow (indigenous short/medium term fertility maintenance practice); and zero tillage (indigenous short/medium term erosion control practice) were not popular among the farmers. Other fairly prominent practices include mulching (indigenous short-term erosion control practice). The implication of these findings is that the soil conservation practices that foster long term sustainability goals of soil management such as bush-fallow, crop rotation, manure/plant residue management, and green manuring, are not currently popular among the farmers in the study area. Probit regression result suggested that SSM practices could be well extended only after addressing the different socioeconomic problems of the farmers. Economically active family members, Education of farmers, Age of farmers, Livestock holding, Membership of Farmers' group and availability of Credit to farmers were found as most significant factors affecting adoption of SSM practice in the study area. Based on the fore-going, the following recommendations are proposed. One, Technologies, trainings and credit should be provided to farmers especially as the findings of this study showed that economically active members and availability of credit affects adoption of SSM. This is necessary to protect farmer from dissipated energy over declining production due to soil declining productivity. Two, Adoption of SSM was significantly increased with increase in years of education of farmers. Thus, Government and farmers' group should heighten education and training programmes through extension visit, demonstrations, seminars and workshop etc. for farmers to enhance SSM understanding, practice and dissemination. Three, Farmer's group activities should be encouraged by channeling all agricultural support programmes and facilities through them. The group should be saddled with the responsibility of educating their members on the dangers of excessive reliance on the use of inorganic fertilizers, as well as, the benefits of substituting other soil nutrient-replenishing practices which are more long-term conservation oriented.

References

African Development Bank (ADB) (1995) Country Environmental Profile: Sierra Leone. *Environmental and Social Policy working Paper series No.17. Pp. 50.*

Agbamu, J. U. (1993) "Analysis of farmers' Characteristics Associated with Adoption of Soil Management Innovation in lkorodu Local Government Area of Lagos State. The *Nigerian Journal of Rural Extension and developmentvol.1 Nos. 2 & 3.*

Bhusal D.R (2012). Impact of cattle urine use technology in farm income of the vegetable growers of Dhading district, Nepal. M.Sc. Agriculture Economics Thesis. Institute of Agriculture and Animal Science (IAAS). Rampur, Chitwan Nepal.

Chebil A and Nasr H, Zaibet L (2007). Farmer's willingness to adopt salttolerant forage in south- eastern of Tunisia In: Adding value to the Agro-Food Supply Chain in the Future Euromediterranean Space. Mediterranean Conference of Agro-Food Social Scientists.

Dhital PR (2010). Factors affecting adoption of recommended technology of cauliflower production in Kavre district of Nepal. M.Sc.Agriculture Extension and Rural Sociology Thesis. Institute of Agriculture and Animal Science (IAAS). Rampur, Chitwan Nepal.

Dongol BBS (2004). Extension Education.1st Ed. Dongol Printers 283 p.

Federal Ministry of Agriculture, Water Resource and Rural Development (1987). Soil Conservation Techniques for Small Scale Farming. Prepared by Department of Agricultural Land Resources, for the occasion of world Food Day, 16th October, 1997

Feder G, Just R.E and Zilberman D (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change 33(2):255-298.*

Ghimire B, Kafle N (2014). Integrated pest management practices and its adoption determinants among apple farmers in Mustang, Nepal. *Scholars Journal of Agriculture and Veterinary Sciences 1(2):83-89.*

Ghimire B. Dhakal S.C., Sharma S. and Poudel S. (2015). Factors affecting adoption of sustainable soil management practices among vegetable producers in Dhading, Nepal. *Vol. 13(44), pp. 2510-2515.*

Hattam C (2006). Adopting organic agriculture: An investigation using the theory of planned behaviour. Poster paper prepared for presentation, International Association of Agriculture Economics Conference, Gold Coast, Australia.

Hussain M, Zia S, Saboor A (2011). The adoption of integrated pest management (IPM) technologies by cotton growers in the Punjab. *Soil and Environment 30(1):74-77.*

Kattel RR (2009). The impact of coffee production on Nepali smallholders in the value chain. Institute of Environmental Economics and World Trade, Leibniz Universitate. Hannover, Germany. Kudi T.M, Bolaji M, Akinola M.O and Nasa I.D.H (2011). Analysis of adoption of improved maize varieties among farmers in Kwara State, Nigeria. *International Journal of Peace and Development Studies 1(3):8-12.*

Mussei A, Mwanga J, Verkujil H, Mongi R, Elanga A (2001). Adoption of improved wheat Technologies by small scale farmers in Mbeya District, Southern Highlands, Tanzania. Mexico, D. F.: International Maize and Wheat Improvement Centre (CIMMYT) and the United Republic of Tanzania.

Nagler J (2002). Interpreting probit analysis. New York University. Available at http://www.nyu.edu/classes/nagler/quant2/notes/probit1.pdf.(Accessed on 20/01/2015).

Nchinda V.P, Ambe T.E, Holvoet N, Leke W, Che M.A, Nkwate S.P and Ngassam S.B (2010). Factors influencing the adoption intensity of improved yam (Dioscorea spp.) seed technology in the western highlands and high guinea savannah zones of Cameroon. *Journal of Applied Biological Sciences 36:2389-2402.*

Olayide, S. 0. and Falusi, A. O (1977): "Economic of Soil Conservation and Erosion Control Practices in Nigeria" *in Soil Conservation and management in the Humid Tropics. Eds. D. J. Green land and R. Lai* and Published by John Wesley and Sons, New York.

Olson KD, Langley J, Heady EO (1982). Widespread Adoption of Organic Farming Practices: Estimated Impacts on U.S. *Journal of Soil and Water Conservation 37(1):41-45.*

Pandey ND (1995). The impacts of the farmers' practices on soil fertility management: A case study in Dhading Besi area, Middle Mountain Region, Nepal. AIT Thesis No: AE-95-44. Asian Institute of Technology, Bangkok Thailand pp. 47-59.

Shrestha PP, Koirala P, Thakur AS (2010). Knowledge practice and use of pesticides among commercial vegetable growers of Dhading district, Nepal. *Journal of Agriculture and Environment 11:20-25.*

Subedi K.D, Jaisi S, Subedi T.B, Mandal S and Dhital B.K (2001). Gothemaltatha compost mal bewasthapan talim pustika. Sustainable soil Management Programme. SSMP, Bakhundol, Lalitpur, Kathmandu, Nepal 92 p.

Teklewold H, Dadi L, Yami A and Dana N (2006). Determinants of adoption of poultry technology: a double hurdle approach. *Livestock Research for Rural Development 18:3.*

Tizale CY (2007). The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia. Ph.D.Thesis, Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria.

Tripathi BP (2002). Review of acid soil and its management in Nepal. In: Proceedings of the Third National Conference on Science and Technology. Nepal Academy of Science and Technology. Lalitpur, Kathmandu, Nepal.

Valipour M (2014) Drainage, waterlogging, and salinity, *Archives of Agronomy and Soil Science 60(12):1625-1640.*

9. Analysis of the Effects of Direct Payment Subsidies for Environmentally-Friendly Agriculture on Income of Rice Farmers in Shiga, Japan

Danielle Katrina Mallari Santos, Koji Shimada

ABSTRACT:

This study will determine the economic effects of direct payment subsidies for Environmentally-Friendly Agriculture on income of rice farmers in Shiga Prefecture, Japan. It will specifically aim to: (1) analyze the effect of reduced chemical and fertilizer use on income and (2) come up with policy recommendation related to the implementation of direct payment subsidy. Environmentally-friendly agriculture has been promoted for over two decades as a response to the environmental challenges brought by climate change and biological loss. The Japanese government has endeavored to seek appropriate policies which reflect various environmentally-friendly farming practices such as organic farming and reduction of chemicals and fertilizers. The agro-environmental policy in Shiga is one of the earliest and most advanced in Japan. It aims to promote environmentally-friendly agriculture among farmers and to engage various stakeholders to protect the environment using the "Kodawari" slogan for Lake Biwa conservation and eco-farming. Rice as a staple food in Japan, this study will seek to address the notion that output and income of rice farmers receiving direct payment subsidies for agricultural inputs has not increased as evidenced by the study conducted by Kim (2014). In addition, chemical input is higher in Japan than most developed countries, this study will also aim to disprove the findings from the study conducted by Masuda (2016) that the current level of direct payment subsidy has only resulted to economic disadvantages in output for smaller environmental advantages. This study will contribute to the literature by analyzing an unexplored mandate of the direct payment scheme, particularly on the reduced use of chemicals and fertilizers, by explicitly determining the economic effects of the said program on income to determine how the gains from environmentally-friendly agriculture influence farmer's decision to produce.

Keywords: rice, direct payment subsidy, environmentally-friendly agriculture, income

Danielle Katrina Mallari Santos was born on June 02, 1994 and is the eldest child born to Danilo Marcelino Santos and Imelda Mallari Santos. Commonly called as Kat by her friends and classmates, she finished her tertiary education at the University of the Philippines, where she also graduated cum laude. Currently, she is a first year master's student at Ritsumeikan University, taking up Master's in Economic Development. Her research interests include agricultural policies on farm mechanization, rural development, and sustainable development in the agricultural sector.

Koji Shimada, Ph.D., is a professor at Ritsumeikan University. He finished his undergraduate and graduate studies at Kyoto University. Prior to joining Ritsumeikan University in 2003, he had worked for the Ministry of the Environment. He has also held committee positions on various projects regarding the energy and environmental sector. Having such expertise in environmental economics and environmental engineering, he won an award from the Environmental Systems Committee of the Japan Society of Civil Engineering in 2007.

1. Introduction

Climate change affects food production, as agriculture is highly dependent on climate conditions such as temperature, sunlight, and precipitation. According to Stern as cited in Kunimitsu and Kudo (2015), a moderate level of warming of about 2° to 3° C will be beneficial for countries located at higher latitudes. Situated at a relatively higher latitude, it is possible that Japan may benefit from future climate change (Kunimitsu & Kudo, 2015) yet Japan is also a rare developed country located in the Asian Monsoon climate region, making the country vulnerable to the impacts of climate of change (Yamada, 2011). About 70% of the Japanese farmers grow rice (Nikkei, 2017) making it necessary to advance the promotion of sustainable agriculture, particularly in paddy farming, for the protection of the environment and maintenance of biodiversity amidst intensive farming (Chen, Qiu, & Nagata, 2013).

Environmentally-friendly agriculture has been promoted for over two decades as a response to the environmental challenges brought by climate change and biological loss (Chen, Qiu, & Nagata, 2013). The Japanese government has endeavored to seek appropriate policies which reflect various environmentally-friendly farming practices such as organic farming and reduction of chemicals and fertilizers. As early as 1992, efforts to promote the nationwide adaptation of sustainable agriculture have been initiated. It was in the New Policy for Food, Agriculture, and Rural Areas (New Policy) issued by the Ministry of Agriculture, Forestry and Fisheries (MAFF) that environmental issues involving the agricultural sector were formally addressed for the first time in Japan. The importance of considering the environment in agricultural production was also first recognized in the New Policy for Food, Agriculture, and Rural Areas Basic Act in 1999 (New Basic Act). In order to provide countermeasures on the environmental impacts of agriculture, it was in the subsequent New Basic Act that environmentally-friendly agriculture was written as a policy target, together with the creation of the Three Laws on Agro-Environment. In addition, the actual environmental payments at the national level appeared in the Measures to Conserve and Improve Land, Water, and Environment (MCILWE) in 2007 (Yamada, 2011), although establishment of the subsidy system for agro-environmental conservation and direct payments to eco-friendly farmers has not started until 2004 and 2011 respectively (Chen, Qiu, & Nagata, 2013).

The agro-environmental policy in Shiga is one of the earliest and most advanced in Japan starting as early as 2004. It is also known for its uniqueness due to its policy objectives involving the conservation of Lake Biwa, occupying one-sixth of the prefecture's total land area. The prefectural government started the environmentally-friendly certification policy and direct payments to farmers based on agreed stipulations on eco-farming. During this time, there was no mandate on direct payments for eco-friendly farmers from the central government. Under this policy scheme, Shiga Prefecture has implemented projects which aim to promote environmentally-friendly agriculture among farmers and to engage various stakeholders to protect the environment using the *Kodawari* slogan for Lake Biwa conservation and eco-farming (Yamada, 2011).

In 2007, MAFF instituted MCILWE which consist of two levels: the entry level and the advanced level (i.e. the level categorized as the agri-environmental scheme in this study). In the entry level, measures include coordination between farmers and non-farmers in the maintenance of farm roads and agricultural canals while the advanced level include measures to reduce the use of agrichemicals and chemical fertilizers in a "collective manner" by as much as 50%. The collective action for the reduced chemical use can be achieved by either one of the following:

1. At least 50% of the producers contribute to the reduction for each of the environmentally-friendly products; or,
2. At east 20% of the total farmland for all the products and at least 30% of the producers contribute to the reduction cumulatively for all the environmentally-friendly products.

This requirement is known as the "collective action prerequisite" and is key to the collaboration among farmers. Without changing the program certification, the prefectural government successfully transitioned to the national direct payment scheme. This was made possible through various initiatives of the prefectural government such as information sessions for farmers in various parts of the prefecture in 2006, prior to the commencement of the national program. The information sessions also involved the knowledge intermediation on the similarities and differences between the prefectural and national direct payment subsidy schemes. While the national scheme promoted collective actions, this practice was already a norm rather than a burden among farmers for collective use of agricultural inputs has already been in practice for rice cultivation (Nomura et al. 2013 as cited in Kishioka, Nishi, Hashimoto, & Saito, 2017).

In spite of this initiative, adoption of sustainable farming, particularly organic farming, accounts for a small share of the cultivated land in Japan. According to the Japanese Ministry of Agriculture, Forestry, and Fisheries (2015), the share of organic in the domestic production was a mere 0.24% in 2015. While the percentage of land devoted to organic agriculture has been gradually increasing, the share of organic farms remains low at 0.6% of the cultivated lands in Japan (Ministry of Agriculture, Forestry and Fisheries, 2017). Not to mention, the chemical input is higher in Japan compared to most developed countries in Europe.

The contribution of this paper is to focus on an approach to environmentally-friendly agricultural practice which remains to be unexplored, to draw contrasting literatures about measuring the economic effect of direct payment subsidies and similar agro-environmental incentives at a different level of analysis, and show the implications for Shiga Prefecture, where Lake Biwa is located. Lake Biwa is known to suffer from poor water quality due to urbanization. Thus, this study was proposed to investigate the economic returns of the direct payment subsidy program for environmentally friendly agriculture among rice farmers in Shiga Prefecture, Japan .

2. Literature Review

Concerns about the environmental decline and sustainability of conventional agriculture have prompted the introduction of environmentally-friendly agricultural practices. The study conducted by Bravo-Ureta et al. (2005) analyzed the determinants of farm income among farmers who participated in in natural resource management projects in El Salvador and Honduras. The study estimated the farm income function using a three-equation system in which farm income is determined simultaneously by the farmer's production decisions which include soil conservation technologies and cropping system implemented on the farm. The study used a framework which would show the relationships among technology adoption, product diversification, and farm income. Surprisingly, the study also established that one of the factors affecting the household's decision-making process include the socioeconomic and agroecological environment apart from the conventional effects of prices, wages, and input, output, and financial markets. Results showed a significant increase in farm income with the adoption of soil conservation practices and a positive association between output diversification and farm income.

Another environmentally-friendly agricultural practice is the Integrated Pest Management (IPM). The study conducted by Dasgupta et al. (2004) used a survey data to compare the outcomes for farming with IPM and conventional techniques in Bangladesh, using input-use accounting, conventional production functions and frontier production estimation. Results showed that the productivity of IPM rice farming is not significantly different from the productivity of conventional farming in all three models of production. However, the study has emphasized that IPM reduced pesticide costs with no production loss, and appears to be more profitable than conventional rice farming, not to mention the substantial health and ecological benefits that comes with its adoption.

While organic farming has been well established in the West, it is still catching up in Asian countries. The study conducted by Lee et al. (2016) implemented a financial analysis to compare the annual costs and net returns of conventional, partially converted and environmentally friendly farming in Gangwon Province, South Korea. The study selected study areas which are within the watershed of Soyang Lake in Gangwon province, which is the largest reservoir and tributary located North of the Han River in South Korea. As a result of overpopulation, the residents in the downstream area of the watershed utilize the water resource overwhelmingly. Thus, water pollution in surrounding environmentally-sensitive areas, especially in the selected area, is seriously affected by intensive farming, and can seriously damage fresh drinking water use of the citizens. Using the survey data gathered through face-to-face interview with farmers, results showed the emergence of partially-converted farms (PCF) between conventional farms (CF) to environmentally-friendly farms (EFF). Despite the promotion of environmentally-friendly farming, there was a low acceptance of the said farming practice among farmers. Thus the study aimed to identify which farming technique is more profitable by financial analysis and to examine which factors affect the adoption of farming techniques in South Korea using multinomial logistic regression. Results showed that indeed the labor cost of EFF is higher than CF and PCF. On the other hand, with regards to the economic benefits, the net returns per farm and hectare of EFF were higher compared to CF and PCF, when considering the total expenses, annual income and subsidies. Regardless, the results from the study conducted by Kim and Banfill (2011) showed that the subsidies are insufficient to serve as a proper incentive for income compensation to the farming household that implements environmentally-friendly farming households. Although majority of the farmers expressed the opinion that "the program is necessary for continuous management of agriculture even though income is lower". This indicates that farmers accept the long term necessity of environmentally-friendly agriculture.

The inspiration for doing this study is the urgent need to conserve the Lake Biwa, the largest freshwater lake in Japan, for its valuable water resource use for the residents of Shiga Prefecture (Nakano, et al., 2008). Nakano et al. (2008) investigated the effects of natural environments and human activity on Lake Biwa, central Japan. They gathered river samples and analyzed the concentrations of the components (Cl, NO_3, SO_4, Ca, Mg, Na, and K) as well as the pH levels. Results showed that the Water quality of rivers greatly affected by human activity, specifically by industrial and agricultural sectors where the wastewater of the former is discharged directly into the rivers, whereas the wastewater of the latter seeps into the ground and then flows into the rivers.

Owing to the issue on the deteriorating water quality of Lake Biwa, greenhouse gas emissions from rice production has been the target of new research interest. Masuda (2016) examined the economic and environmental effects of the agri-environmental direct payment on the adoption of a measure to mitigate global warming in Japanese rice farms using a combined application of linear programming and life cycle assessment at the farm scale. He focused on the environmentally-friendly agricultural practice of prolonged midseason drainage technique. Results showed that under the current direct payment level, the prolonged midseason drainage technique did not improve the eco-efficiency of Japanese rice farms. In fact, the practice of this technique in environmentally-friendly rice farms caused large economic disadvantages in exchange for small environmental benefits.

3. Theoretical Framework

The theoretical framework of this study is grounded on welfare economics, in which direct payment rewards farmers for taking care of the environment. Farming activities both have a positive and negative effect from its non-tradable output. In any case, there are no markets that exist where third parties can either buy more of the positive externality or buy off some rights to produce less of the negative externality. For instance, conventional farming which employs high level of chemical inputs, higher yield is always associated with higher social costs due to more pollutants being discharged into the environment. However, the resulting external costs such as the water treatment of Lake Biwa, is not accounted for in the production costs of the farmers. On the other hand, environmentally-friendly agricultural practices improve the quality of the agro-ecosystem and thus generate a positive externality (Kim & Banfill, 2011).

Direct payments can theoretically affect agricultural output through a technical efficiency channels. For instance, the study conducted by Fujie (2008), analyzed the behavior of farmers who participated in the environmentally-friendly agricultural product. Results showed that as farmers are more risk averse, the cropping ratio of environmentally-friendly agricultural products decline. However, the direct payment subsidies from environmentally-friendly agriculture increases the cropping ratio of environmentally-friendly agricultural products. In addition, an increase in the unit price of direct payment subsidy, increases the cropping ratio of environmentally-friendly agricultural products, which in turn has an impact on technical efficiency.

Direct payments also modify the wealth of farmers and thus creates the incentive to produce risk averse farmers For instance, Serra, Zilberman, and Gil (2007) as cited in Femenia, Gohin, and Carpentier (2010) considered the case where direct payments have a wealth effect on risk-averse producers leading them to increase their input use.

4. Overview and Implementation Status of the Direct Payment Subsidy for Environmentally-Friendly Agriculture in Shiga Prefecture

Farmers participating in the environmental agricultural direct payment system first make an environmentally-friendly agriculture agreement with the prefectural governor. The main contents of the agreement include:

i. reducing the use of chemical pesticides and fertilizers to less than 50% of the conventional practice;

ii. proper use and management of compost and agricultural wastewater; and,
iii. the agreement period is to be implemented for 5 years.

By signing the agreement and cultivating by the method specified in the production plan submitted to the prefecture, farmers can receive a certificate proving their implementation of environmentally-friendly agricultural cultivation on their products and receive the corresponding subsidies as shown in Table 1.

Table 1. Grant per unit price at the time of establishment of the prefecture independent system in 2004.

		(JPY/10a)
	Unit Price Indicator	Less than 50% of the conventionally used synthetic pesticide and chemical fertilizer
Paddy	Less than 3 ha	5,000
Rice	Over 3 ha	2,500

Source: Morino, 2016

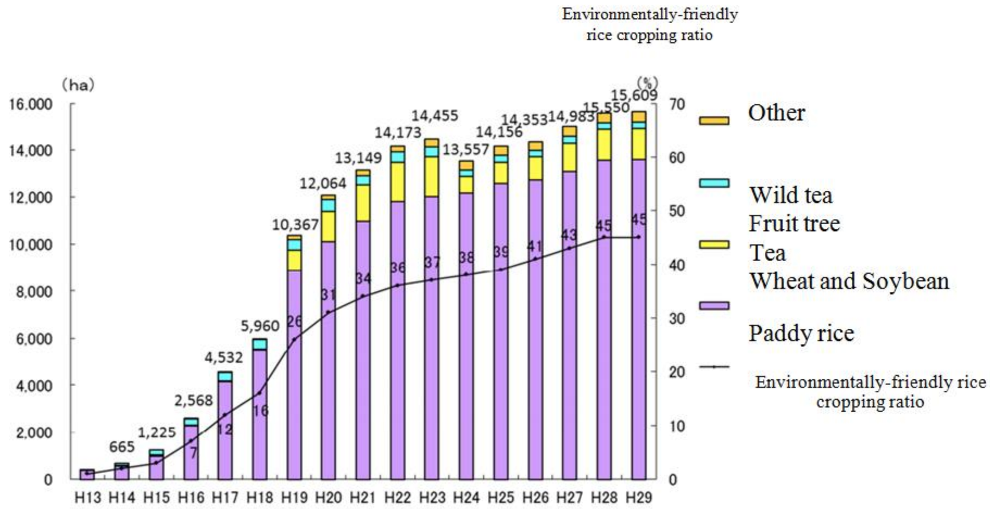
The basis for the computation of the grant per unit price was based from the results of "Shiga Prefecture Environmentally-Friendly Agricultural Income and Expenditure Management", the amount of the difference in cultivation costs between conventional practice and the environmentally-friendly agricultural practice of 50% reduction in synthetic pesticides and chemical fertilizers will be used (Table 2). The total subsidy payment amount is JPY 5,000/10a (Morino M. , 2016). In 2019, a new payment amount was implemented, amounting to JPY 8,000/10a (Shiga Prefecture, 2019b).

Table 2. Calculation basis for paddy rice, 2004.

Income	Environmentally-friendly Cultivation	Agriculture/Conventional
Yield	95.8%	
Selling Price	104.7%	
Gross Revenue	100.3% ≒ 100%	
Production Costs (JPY/10a)		
Organic fertilizer cost	5,090	
Synthetic pesticide cost reduction	3,204	
Labor cost	3,342	
Total production costs	5,228	

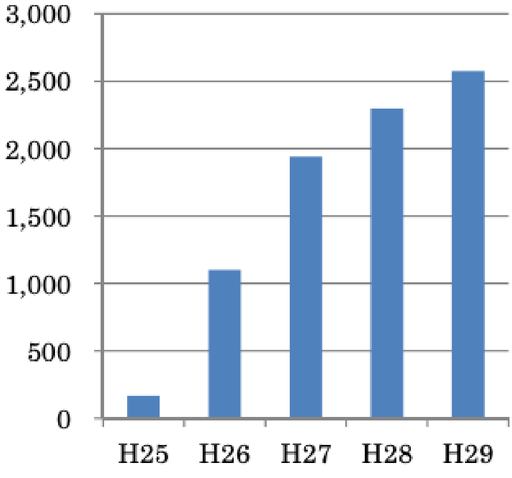
Source: Morino, 2016

According to Shiga Prefecture (2019b) the cultivation area of environmentally friendly agricultural products exceeded 14,000 ha in 10 years from the start of the certification system, but then it decreased temporarily and gradually increased to reach 15,609 ha in 2017. Rice accounted for 45% of the total cultivated area.

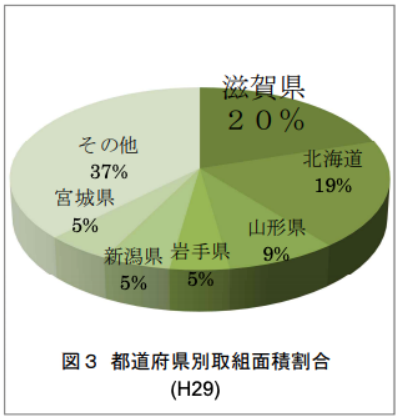


Source: Shiga Prefecture, 2019b
Figure 1. Change in environment-friendly agricultural product cultivation area and environmentally-friendly rice cropping ratio, 2001-2017.

The planting of *Mizukagami,* which is produced entirely through environmentally-friendly agriculture, has been expanded to 2,575 ha (Figure 2). User demand in Kyoto-Osaka-Kobe metropolitan area has also been increasing.
In 2017, the area covered by direct payment subsidy for 20% (Figure 3). Shiga Prefecture has been ranked 1st in terms of environmentally-friendly agriculture implementation in the whole country for 6 consecutive years.



Source: Shiga Prefecture, 2019b
Figure 2. Change in the area (ha] cultivated for Mizukagami in Shiga prefecture, 2013-2017



Source: Shiga Prefecture, 2019b
Figure 3. Area distribution of environmentally-friendly agriculture among prefecture in Japan

The amount of synthetic pesticides used in the prefecture was also reduced by about 40% compared to 2000, and the discharge of total nitrogen from agricultural lands to the Lake Biwa environment was reduced by 18.2% in 2015 (Table 3) .

Table 3. Pollutant load inflow to Lake Biwa, 2017.

	Total N inflow load (kg/day)	Total P inflow load (kg/day)	COD inflow load (kg/day)
2000 fiscal year	2,241	119	5,321
2015 fiscal year	1,834	101	4,611
Reduction Rate (%)	18.2	15.1	13.3

Source: Shiga Prefecture,

5. Comparison between Shiga Prefecture's Environmentally-Friendly Agriculture Rice and Conventional Rice Cultivation

Table 4 shows the comparison between the cost and returns of environmentally-friendly and conventional rice. Results showed that the average planting area remains to be higher for conventional rice. Area cultivated for environmentally-friendly rice remains to be less than a hectare as compared to the conventional rice which is planted to 1.6 hectares. On the other hand, comparing the unit yield, selling price, labor cost, and production cost, the difference between environmentally-friendly and conventional rice is quite large. Conventional cultivation of rice would result in harvesting 1,034 kg/ha more than the environmentally-friendly cultivation of rice through reduced use of synthetic pesticides and chemical fertilizers. In addition, the number of hours for labor has drastically increased to 124 man-hours on a per hectare basis as compared to the 21 man-hours per hectare required for conventional rice cultivation. With the additional cost on labor, the production cost has also increased by 93%, amounting to JPY 1,183,860.00/ha, not to mention the additional input cost due to usage of organic fertilizers to compensate for the 50% reduction in the use of chemical fertilizers and synthetic pesticides. On the contrary, the price difference due to the price premium of environmentally-friendly rice resulted to its higher selling price at JPY 12,983.00/60kg as compared to the selling price of conventional rice amounting to JPY 11,011.00/60 kg .

Table 4. Average difference in planting area, yield, selling price, and management costs between environmentally-friendly and conventional rice, 2017.

	Environmentally-Friendly Rice	Conventional Rice
Average Planting Area (ha)	0.128	1.6
Unit Yield (kg/ha)	4,136	5,170
Selling Price (JPY/60 kg)	12,983	11,011
Man-hour (hr)	124	21
Production Costs (JPY/ha)	1,183,386	1,099,540

Source: Shiga Prefecture, Ministry of Agriculture, Fisheries, and Forestry, 2017.

Partial budget analysis was used to quantify the differences in profitability of environmentally-friendly and conventional rice in Shiga Prefecture. The partial budget is a way of determining whether it is profitable to choose one farming method over the other by considering the difference in costs and benefits among the two farming methods.

Results of the partial budget analysis are shown in Table 5. With the information from the costs and returns analysis in Table 4, the additional costs were calculated by adding the input costs which included cost of organic fertilizer and labor. On the other hand, there was no reduced income since there were no returns that would not be received under the proposed change.

Environmentally-friendly farmers can receive a direct payment subsidy amounting to JPY 80,000.00 per hectare per year. On the other hand, reduced costs included the cost from using synthetic pesticides and chemical fertilizer amounting to JPY 32,040.00 per hectare per year.

The positive side of the change (additional income of JPY 80,000.00 plus reduced costs of JPY 32,040.00) amounted to JPY 112,040.00 per hectare per year. The negative side of the change

(reduced income of JPY 0.00 plus additional costs of JPY 84,320.00) amounted to JPY 84,320.00 per hectare per year. When the positive aspects were compared with the negative aspects, notice that there was a positive difference of JPY 27,720.00 per hectare per year, suggesting that cultivation of rice through environmentally-friendly agriculture can generate a higher income for the farmers.
In order to account for the yield difference due to farming method, the theoretical yield reduction from environmentally-friendly rice cultivation was multiplied to the selling price of conventional rice. According to 胡柏 (2001), the decrease in yield from environmentally-friendly agriculture is about 12% or 620.4 kg/ha (unit yield of conventional rice amounting to 5,170 kg multiplied by 12%). Since the price of rice is JPY 11,011.00/60kg, the value of the yield difference due to farming method amounted to JPY 1,897.56/kg (dividing the 620.4 kg by 60 kg since the selling price of rice is on a per 60 kg basis, and multiplying the resulting yield to the selling price of conventional rice which amounts to JPY 11,011.00/60kg or JPYy183.52/kg). Subtracting this value from the change in net income from Table 5, the change in net income due to the farming method amounted to JPY 25,822.40 per hectare per year. This value assumes that the effect of farming method on the increase in income due to an increase in output is removed and only the effect of subsidy is accounted for.

Table 5. Partial budget analysis for shifting from conventional cultivation to environmentally-friendly cultivation of rice per hectare, per year, Shiga Prefecture, 2017.

Positive Effects	Value (JPY/ha/year)	Negative Effects	Value (JPY/ha/year)
Additional income:		Reduced income:	
Direct payment subsidy	80,000.00	None	0
Total additional income:	80,000.00	Total reduced income:	0
Table 5. Continued…			
Reduced costs		Additional costs:	
Chemical fertilizer and synthetic pesticide	32,040.00	Organic fertilizer	50,900.00
		Labor	33,420.00
Total reduced costs:	32,040.00	Total additional costs:	84,320.00
Total additional income and reduced costs (TAIRC)	112,040.00	Total reduced income and additional costs (TRIAC)	84,320.00
Change in income (TAIRC-TRIAC)		27,720.00	
Less the value of theoretical yield difference due to farming method		1,897.60	
Change in income		**25,822.40**	

Source: Author's estimates, 2019.

6. Summary and Conclusion

The main objective of this study is to determine the economic effects of direct payment subsidies for Environmentally-Friendly Agriculture on income of rice farmers in Shiga Prefecture, Japan. The study had the following as its specific objects: (1) analyze the effect of reduced chemical and fertilizer use on income and (2) come up with policy recommendation related to the implementation of direct payment subsidy. The methods of analysis used included descriptive analysis for describing the implementation of the direct payment subsidy program, costs and returns analysis for comparing the differences in the farm performance of environmentally-friendly farmers and conventional farmers, and partial budgeting for analyzing the changes in costs and returns of environmentally-friendly rice.

The study has concluded that environmentally-friendly agriculture was profitable. Results from the costs and returns analysis and partial budget analysis showed the difference in costs incurred as well as the returns received. Production costs of environmentally-friendly farmers may have been higher than that of conventional farmers but the difference was offset by the direct payment subsidy received. Income obtained from environmentally-friendly rice cultivation remained to be positive, thus it is sufficient to say that income obtained from environmentally-friendly agriculture was higher than the income from conventional farming, isolating the effect of direct payment subsidy rather than the effect of yield difference due to farming method. In addition, the environmentally-friendly farmers have also received a price premium for their rice resulting to its higher selling price.

Based on these findings, it may be concluded that the substitution of environmentally-friendly agriculture for conventional rice farming had resulted to an increased farm income due to the direct payment subsidy received.

7. Recommendation

Since the estimates indicated a higher income, it only signifies that the benefits from environmentally-friendly agriculture were higher than conventional farming. Therefore, environmentally-friendly agriculture is recommended for rice production. Based from the findings of the study, the government should aim to popularize environmentally-friendly agriculture to increase the production of environmentally-friendly products through localized agricultural administration that would dispel the farmer's failure to realize economies of scale due to low income received and high production costs due to high labor requirement and high organic fertilizer cost. Promotion of environmentally-friendly agricultural practice can significantly reduce the external costs such as pollution load to the Lake Biwa ecosystem and increase farm income as well. Direct intervention such as introduction of various technologies that would save costs on applying organic fertilizers to supplement the fertility of the soil as an alternative to chemical fertilizers and synthetic pesticides, and incentives such as direct payment subsidies should be used to induce farmers to adopt environmentally-friendly agriculture.

References

Bravo-Ureta, B. E., Solis, D., Cocchi, H., & Quiroga, R. E. (2006). The impact of soil conservation and output diversification on farm income in Central American hillside farming. Agricultural Economics 35 (2006), 267-276.

Chen, B., Qiu, Z., & Nagata, A. (2013). Review of Sustainable Agriculture: Promotion, Its Challenges and Opportunities in Japan. Journal of Resources and Ecology, 231-241.

Dasgupta, S., Meisner, C., & Wheeler, D. (2007). Is Environmentally-Friendly Agriculture Less Profitable for Farmers? Evidence on Integrated Pest Management in Bangladesh. Review of Agricultural Economics 29 (1), 103-118.

Femenia , F., Gohin , A., & Carpentie, A. (2010). The Decoupling of Farm Programs: Revisiting the Wealth Effect. American Journal of Agricultural Economics Volume 92, Issue 3,, 836-848.

Fujie, T. (2008). Economic Analysis of Agricultural Environmental Policy-Focusing on Environmental Agriculture Direct Payment System in Shiga Prefecture. 『彦根論叢』, No. 370,, 65-85.

Kim, C. G., & Banfill, J. (2011). A Policy Evaluation of Environmental-Friendly Direct Payment Programme in Korea. OECD, Paris, France. [2014-3-20]. Retrieved from http://www.oecd.org/tad/sustainable-agriculture/48170214.pdf

Kunimitsu, Y., & Kudo, R. (2015). Fluctuations in Rice Productivity Caused by Long and Heavy Rain Under Climate Change in Japan: Evidence from Panel Data Regression Analysis. Japan Agricultural Research Quarterly,, 159-172.

Land of Plenty . (2018, Jun 25). Retrieved from Oishi: https://www.oishii.sg/article/4468/

Lee, S., Nguyen, T. T., Poppenborg, P., Shin, H.-J., & Koellner, T. (2016). Conventional, Partially Converted and Environmentally Friendly Farming in South Korea: Profitability and Factors Affecting Farmers' Choice. Sustainability 2016, 8, 704;, 2-18.

Li, X. N., & Li, R. (2013). The Effect of Grain Subsidies on the Production and Farmers' Income in China. 2013 International Conference on Management Science & Engineering (20th), (pp. 2162-2167). China.

Masuda, K. (2016). Optimization Model for Mitigating Global Warming at the Farm Scale: An Application to Japanese Rice Farms. Sustainability, MDPI, Open Access Journal, vol. 8(7), 1-17.

Murathi Kiratu, N. (2014). An Assessment of the Impact of Kilimo Plus Subsidy Program on Smallholder Farmers' Food Security and Income in Nakuru North District, Kenya, Research Theses, 43470, Collaborative Masters Program in Agricultural and Applied Economics.

Morino, K. (n.d.). Wastewater Management in the Lake Biwa Basin. Retrieved from http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0264pdf/ks0264023.pdf

Nakano, T., Tayasu, I., Yamada, Y., Hosono, T., Igeta, A., Hyodo, F., . . . Yachi, S. (2008). Effect of agriculture on water quality of Lake Biwa tributaries, Japan. Science of Total Environment 389 (2008), 132-148.

Nikkei. (2017). Japan to Stop Coddling its Rice Farmers.

Ministry of Agriculture, Forestry and Fisheries. (2017a). Agricultural Production Costs Statistics. Retrieved from http://www.maff.go.jp/j/tokei/kouhyou/noukei/seisanhi_nousan/

Ministry of Agriculture, Forestry, and Fisheries. (2017b). Amount of Rice Harvest in 2017 (Kinki). Retrieved from http://www.maff.go.jp/kinki/press/toukei/seiryu/171205.html

Ministry of Agriculture, Forestry, and Fisheries . (2017c). Amount of Rice Harvested in 2017 (Shiga Prefecture). Shiga, Japan.

Ministry of Agriculture, Forestry, and Fisheries. (2017d). Current Status of Rice Cultivation and Its Problems. Japan.

Ministry of Agriculture, Forestry and Fisheries. (2017e, August). Promotion of Organic Agriculture. Japan.

Ministry of Agriculture, Forestry, and Fisheries. (2017f). Relative Transaction Price and Quantity of Rice Produced in 2017 . Retrieved from http://www.maff.go.jp/j/press/seisaku_tokatu/kikaku/171013.html

Ohmi Rice Promotion Association. (2019). Mizukagami Cultivation Manual. Shiga, Japan.

Shiga Prefecture . (2013). Cultivation Expansion and Stabilization of Taste and Quality of Rice Variety "Mizukagami". Shiga, Japan.

Shiga Prefecture. (2018). Life with Lake Biwaびわ湖と暮らし. Retrieved from https://www.pref.shiga.lg.jp/file/attachment/4037776.pdf

Shiga Prefecture. (2019a). Environmentally-friendly Agriculture Direct Payment Grant (support for cultivation of environmentally-friendly agricultural products). Retrieved from 滋賀県: http://www.pref.shiga.lg.jp/g/kodawari/files/h31kanchokupanfu.pdf

Shiga Prefecture. (2019b). Shiga Prefecture Environmentally Friendly Agriculture Promotion Basic Plan Original Proposal (Draft)滋賀県環境こだわり農業 推進基本計画原案（案）. Retrieved from https://www.pref.shiga.lg.jp/file/attachment/4018774.pdf

Shiga Prefecture. (2019c). Shiga Prefecture Basic Plan 2019. Shiga, Japan.

Yamada, N. (2011). Agro-environmental Policies in Japan and Attendant Challenges: Countermeasures for the Agricultural Sector. In J. Bi , K. Otsuka, J. Ge, & S. Wang (Eds.), Stakeholder Involvement in Water Environment Conservation in China and Japan: Building Effective Governance in the Tai Lake Basin. IDE Joint Research Program Series No.155.

胡柏. (2001). Profit Formation Ability and Formation Condition Analysis of Environmentally-Friendly Rice Cultivation: The Case of Kyushu Region. 農 業 経 済 研 究 第 73 巻， 第 1 号 ., 1-15.

10. Drivers of Land Embodied in International Trade of Rice: The Italian Case Study

Dario Caro, Fabio Sporchia

ABSTRACT:
In the last years, a significant increase of imports of Rice from Cambodia and Myanmar into the European Union has been recorded. In particular, Italian farmers were badly affected by the imports of rice from these two Asiatic countries. Indeed, the European Commission in 2019 has therefore decided to re-introduce specific import duties. In turn, such exported rice corresponds to large quantities of land that are driven by consumption of Asiatic rice in Italy. In this study, we estimate the Virtual Land Trade associated with rice trade between Cambodia and Myanmar to Italy. Our analysis combines physical import data and associated land information. The analysis shows the pro-and-con of these debated trade connections also revealing the effect of replacing the Asiatic import demand with domestic production of rice in Italy in terms of land use. The study is relevant in understanding whether patterns of rice consumption, production and trade represent an efficient, and logical, allocation of natural resources.

Keywords: Virtual land trade; food; consumer awareness; land footprint; agricultural impact; rice; international trade

Dr. Dario Caro is a tenure-track researcher in the Department of Environmental Science at the Aarhus University. He is the co-leader of the Strategic Growth Area "Resource flows in a circular economy" and member of the Advances in Cleaner Production Network. His research focuses on coupling human and natural systems and sustainable systems analysis including energy policy; waste management; pollution and natural resources embodied in international trade and the complex interactions of agriculture/livestock, climate change and global ecology.

Fabio Sporchia was born in 1993. He got his bachelor's degree in biological sciences at University of Milan in 2015. Currently, he is working on his master's degree thesis in ecotoxicology and environmental sustainability at Aarhus University thanks to the Erasmus for traineeship scholarship he was granted by Siena University, where he is currently enrolled. His main interests include food sustainability, GHGs emissions, SDGs and environmental sustainability in general.

1. Introduction

Rice cultivation is responsible for using 11% of global arable land (GRISP, 2013) and the expected population growth (Alexandratos and Bruinsma, 2012) will entail an increase of global paddy extension in the next years. The international trade of rice has substantially increased over the last decades. According to FAO (2019), trade of rice increased by 233% from 1990 to 2016, year in which, around 40 Mt of rice were traded globally. Although Asia has the dominant position in rice production and consumption, rice is also consumed in many countries of other continents. While the international trade of rice may represent a good business for exporter countries, it may also be a disadvantage for domestic producer of importer countries. Indeed, it may involve direct import of rice from countries with lower production costs, environmental commitments and environmental performances. Therefore, international agreements and disciplinary measures should be designed to influence production costs, market prices and environmental sustainability.

In this context, the export of rice from Cambodia and Myanmar to Europe has substantially increased over the last few years. In particular, the export of rice between Cambodia and Myanmar to Italy has represented an interesting case study which has been debated in the last few years. Indeed the import of rice from Cambodia and Myanmar to Italy increased by 77% and 64%, respectively from 2013 to 2016 (FAO, 2019). Above all, in Italy, the question has been raised due to the associated reduction of domestic production of rice. As a consequence, the European Union has recently imposed a tax on rice from Cambodia and Myanmar for three years after an investigation found that a significant increase in imports of the rice from the two countries caused economic damage to European producers (European Commission, 2019). In terms of environmental impact, trade of agricultural products is also a trade of resources (Taherzadeh and Caro, 2019). That is, resources exploited to produce agricultural products in one country such as land energy and water are shipped in other countries to satisfy final consumption of those products. Therefore, such exported rice corresponds to large quantities of resources that are driven by consumption of Asiatic rice in Italy.

The growth of human population, expected to reach 9 billion in 2050, together with competitive land use causes land scarcity (Alexandratos and Bruinsma, 2012). Hence, agricultural influence on the land is intensifying due to an increasing food requirements. Rice is mainly produced for human consumption, which accounts for 78% (GRISP, 2013), and is the staple food for around half of global population. Therefore, its international trade is driven by direct human consumption, which, in turn, depends on the dietary habits.

In recent years, researchers have developed a sustainability indicator named "virtual land trade" (VLT) able to estimate the hidden flows of land if food or other commodities are traded from one place to another (Qiang et al. 2013). The VLT reflects the land embodied in trade of commodities, highlighting how the growing land demand put increasing pressure on local and national land resources because of international demand. Although, some studies have investigated the VLT of different commodities, including rice, at the global level (Zhang et al. 2016), this study aims to focus on a specific, relevant and current case study concerning Italy and the two largest exporters of rice in Italy such as Cambodia and Myanmar.

In particular the objective of this paper is to develop a VLT to estimate the amount of land exported from Cambodia and Myanmar to Italy due to the export of rice during the period 2013-2016. The flows of land embodied in trade of rice between these countries is revealed and discussed. Moreover, the paper the amount of land saved if the Italian import was replaced with a domestic production of rice. The study is relevant in understanding whether patterns of rice consumption, production and trade represent an efficient, and logical, allocation of natural resources.

2. Methods

Virtual land trade of rice (VLT) refers to the rice-specific land use which corresponds to the physical quantity of rice produced for export. For country n the VLT is calculated by multiplying the quantity of rice traded (RT) by rice specific yield (Y) of country n:

$$VLT_{(ne,ni,t)} = RT_{(ne,ni,t)} \times Y_{(ne,t)} \qquad (1)$$

VLT indicates the cropland (ha) traded from exporting country n_e to importing country n_i

in year t. In this paper as exporting country (n_e) we analyzed Cambodia and Myanmar whereas as importing importing country (n_i) Italy. Y indicates the yield of an exporting country n_e in year t. It is estimated as the ratio between the national rice specific area harvested (ha) and the national rice-specific production (tonnes) in the year t:

$Y(n_e,t) = Area\ harvested(n_e,t)\ /\ Production\ of\ rice(n_e,t)$ (2)

The annual rice paddy yield was provided by FAO (2019) as well as the quantity of rice traded.

When we hypothesize a shift in imported rice from Cambodia and Myanmar, we considered the same amount of rice imported from these two countries as domestically produced in Italy. That is, the same amount of rice imported from Cambodia (or Myanmar) is allocated to the domestic production of rice in Italy.

According to FAO (2019), export of rice from Cambodia and Myanmar to Italy started to be significant in 2013. Therefore, results are provided from the period 2013-2016.

3. Results

We find that in 2016, 5270 and 621 ha of land were used for producing rice in Cambodia and Myanmar respectively to be exported in Italy. Overall, in 2016, Italy imported 5890 ha of land from these two countries to satisfy national consumption of rice. During the period 2013-2016 the land exported from Cambodia to Italy increased by 64%. Indeed, in 2013 the amount of exported land was about 3213 ha. In the same period, the exported land from Myanmar to Italy also substantially increased. Indeed in 2013, we record an amount of land exported equal to 32 ha.

However figure 1 shows two different trend associated with Cambodia and Myanmar. The export of rice related land from Cambodia to Italy decreased by 48% from 2013 to 2014 and then significantly increased from 2014 to 2015 (313%). A slight decrease is recorded from 2015 to 2016 (-22%). The export of rice related land from Myanmar to Italy significantly increased from 2013 to 2015 and then decreased (-75%) in the last year analyzed.

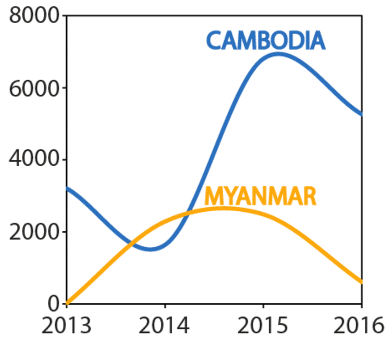


Figure 1: Land embodied in export of rice from Cambodia to Italy (blue line) and Myanmar to Italy (orange line) during the period 2013-2016. Values of land exported are expressed as hectares of land.

Figure 2 shows the land potentially saved when Italian import of rice from Cambodia and Myanmar is replaced with national domestic production. Basically the total amount of imported rice is allocated to the Italian production of rice. This kind of scenario shows if, from a land point of view, the Italian import of rice from Cambodia and Myanmar is advantageous or not compared with the Italian rice production. We find that in each analyzed year, Italy would save land by domestically producing rice instead of importing it from Cambodia and Myanmar. Basically, it implies that production of rice in Italy is more efficient than production of rice in Cambodia and Myanmar in terms of land use. Indeed in 2016, about 2900 ha of land would have been saved with an increase of 71% with respect to the amount of land that would have been saved in 2013 (about 1690 ha). The highest value of land saved is recorded in 2015 (4459 ha).

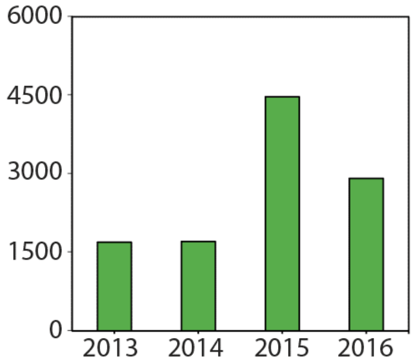


Figure 2: Land potentially saved when the same amount of rice imported from Cambodia and Myanmar is considered as domestically produced in Italy during the period 2013-2016. Values of land potentially saved are expressed as hectares of land.

4. Discussion and Conclusions

This paper has provided two important information. First, as a consequence of export of rice, Cambodia and Myanmar have virtually exported land to Italy during the period 2013-2016. In particular the land exported from Cambodia to Italy is significant and it substantially increased over the years analyzed (Fig. 1). Second, if Italy had domestically produced rice imported from Cambodia and Myanmar, a substantial amount of land would have been saved (Fig. 2). It implies that the production of rice in Italy is more efficient than Cambodia and Myanmar in terms of land use.

The case study presented in this paper is strictly connected with the current political and economic debate around the European import of rice from Asia. In particular, the case of Cambodia and Myanmar has been deeply discussed in Europe over the last year with a special focus on Italy. Indeed, the European Union has recently imposed tariffs on rice from Cambodia and Myanmar in response to a request by the Italian government (European Commission, 2019). In this way, European Union has incentivized Italian local producers to gain protection from the import of rice.

The debate around the tariffs has mainly concerned economic and political aspects. In practice, the reason upon which the tariffs have been levied has been due to the different prices of rice between Italy and the two Asiatic countries. Hence, low-priced imports from Cambodia and Myanmar has been considered the main responsible for difficulties of the Italian rice producers. However, considerations based on environmental issues have been neglected. Nevertheless, to ensure sustainable production and consumption patterns is one of the 17 Sustainable Development Goals (SDG 12) of the 2030 Agenda of Sustainable Development (United Nations, 2015) adopted by 193 Member States of United Nations including Italy, Cambodia and Myanmar.

In this paper, an environmental perspective of the situation is also provided. That is, an evaluation may also be evaluated as a function of the impact on land. In general, growing demand induces growing impacts transferred via international trade. It's therefore necessary to look for a feasible way to prevent it, either acting on the i) reduction of the demand from importing countries that may be incentivized by tariffs (European Commission, 2016); ii) reduction of the impacts in exporting countries. In some cases, the latter might alleviate the high pressure on domestic resources and reduce conflicts for valuable scarce resources (Yao et al. 2019).

Our results have shown that the main driver of land embodied in trade of rice is the trade that is the amount of rice exported from Cambodia and Myanmar to Italy. However, it also depends on the country-specific yield. Figure 2 reveals that Italy, due to a more efficient yield (with respect to Myanmar and Cambodia), would save land by domestically producing rice instead of importing it from the two Asiatic countries. The yield strictly depends on various environmental factors, such as ground composition, land morphology and climate and global rice yield is expected to increase of 12% in the next decade (OECD/FAO, 2018).

From this point of view, the approach of our analysis is relevant because it captures the flows of environmental impact such as land use embodied in trade thus providing information about impacts generated by the final consumer (Italy). This consumer perspective allows understanding the impact associated with the final demand of rice and shows the impact that Italy generates on Cambodia and Myanmar to satisfy its domestic demand. Since an analysis of this sort is able to reveal if it is more advantageous to have rice produced in one country rather than another one, it is reasonable that including the trade flows, it could eventually be used to impose border taxes also based on environmental issues (Caro et al. 2017).

Although it is not an easily implementable solution, another option to reduce the land used for producing rice is to act on the dietary habits. A shift toward a more sustainable products may reduce demand and associated external dependency of rice. In this context, products such as sweet potato and cassava have been investigated as potential substitutes of rice (GRISP, 2013). However, deepened analyses evaluating the overall environmental impacts associated with alternative products are needed. In particular, studies assessing the overall environmental burden related to virtual trade of rice and potential substitutes, including the impacts on land, water and greenhouse gas emissions would provide a complete overview of the situation. Indeed, focusing only on one environmental impact associated with trade of rice such as land represents a limitation of the paper as considerations about potential trade-offs with other relevant environmental impacts are not possible from the current study. Therefore, future analyses should investigate potential trade-offs focusing on the overall environmental impacts embodied in international trade of rice.

References

Alexandratos, N. and J. Bruinsma. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.

Caro D., Frederiksen P., Thomsen M., Pedersen A.B. 2017. Toward a more consistent combined approach of reduction targets and climate policy regulations: The illustrative case of a meat tax in Denmark. Environmental Science and Policy 76, 78-81.

Caro D., Davis S., Kebreab E., Mitloehner F. 2018. Land-use change emissions from soybean feed embodied in Brazilian pork and poultry meat.

European Commssion 2019. EU imposes safeguard measures on rice from Cambodia and Myanmar. Brussels, 16 January 2019. Available at: europa.eu/rapid/press-release_IP-19-427_en.pdf

European Commission 2016. Impacts of EU trade agreements on the agricultural sector. Written by Copenhagen Economics December 2016. Available at: https://ec.europa.eu/agriculture/sites /agriculture/files/external-studies/2016-bilateral-trade-agreements/final-report_en.pdf

FAO (2019). FAOstat 2019. Available at: http://www.fao.org/faostat/en/#home

GRISP 2013. Global Rice Science Partnership. Rice Almanac. 4th Edition, International Rice Research Institute, Los Baños.

OECD/FAO 2018. OECD-FAO Agricultural Outlook 2018-2027, OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome. Available at: https://doi.org/10.1787/agr_outlook-2018-en

Qiang W., Liu A., Cheng S. et al., 2013. Agricultural trade and virtual-land use: The case of China's crop trade. Land Use Policy 33, 141–150.

Taherzadeh O., Caro D. 2019. Drivers of water and land use embodied in international soybean trade. Journal of Cleaner Production 223, 83-93.

Zhang J., Zhao N., Liu X., Liu Y. 2016. Global virtual-land flow and saving through international cereal trade. Journal of Geographical Sciences 26, 619-639.

United Nations 2015. General Assemby. Available at: https://www.un.org/ga/search /view_doc.asp?symbol=A/RES/70/1&Lang=E

Yao X., Yasmeen R., Li Y., Hafeez M., Padda H. 2019. Free Trade Agreements and Environment for Sustainable Development: A Gravity Model Analysis. Sustainability 11, 597.

11. Daily Habits and Energy Consumption: Go to Bed Earlier for Environmental Protection

Shigeru Matsumoto

ABSTRACT:
The reduction of energy consumption in the residential sector is crucial for the mitigation of global warming and thus many researchers have investigated the determinants of household energy consumption from various aspects. However, the impact of time allocation on the energy consumption has not yet examined in previous studies. The main reason for the research delay is the lack of the survey that simultaneously examined time allocation and energy consumption. We conducted an original survey of 547 Japanese households in order to examine whether time allocation affects the household electricity consumption. We divided the time of 2 successive days into 192 time slots and asked the households to choose the behavior of each slot from 20 types of actions prepared. At the same time, we collected socioeconomic and electricity consumption information. After controlling various factors that affect household electricity consumption, we examined whether time allocation determines electricity consumption. Our empirical result reveals that although the husband's bedtime does not affect the electricity consumption, the wife's bedtime affects it. This result suggests that understanding daily habits of people is necessary for proposing effective energy conservation measures.

Keywords: Household Electricity Use, Micro Data, Time Use

Dr. Shigeru Matsumoto is Professor, Aoyama Gakuin University, Japan. He studied on Heiwa Nakajima Foundation Scholarship at North Carolina State University, USA, where he earned his Ph.D. in economics. He also holds his Masters of Environmental Science from Tsukuba University, Japan. His research interest lies in the applied welfare economics, with particular focus on consumer behavior analysis. Major works include "Environmental Subsidies as a Policy Instrument: How did they work in the Japanese market?" (Routledge, Taylor & Francis Group) and "Consumer Perception of Food Attributes" (CRC press) (Editorial book). He published more than 30 articles in English peer-reviewed journals. He is the board member of Society for Environmental Economics and Policy Studies of Japan and a co-editor of International Journal of Economic Policy Studies.

1. Introduction

The residential sector accounts for a large share in the end use of energy in modern society. In 2015, the residential sector held a 25.4% share in energy usage in EU-28, the second largest after the transportation sector (Eurostat 2018). Although the share of the residential sector in energy usage is much smaller, it still accounted for 14.3% in 2014 (Agency for Natural Resources and Energy of Japan 2016). Several developed countries have made a great leap forward in conserving energy in the industrial sector over the last decade. However, this achievement was not mirrored in the residential sector. In EU-28, the final energy consumption of the industrial sector fell by 15.5% and that of the residential sector declined by a mere 3.9% between 2007 and 2015 (Eurostat 2018). In Japan, conversely, the final energy consumption of the residential sector doubled and that of the industrial sector increased only 0.8 times between 1973 and 2014 (Agency for Natural Resources and Energy of Japan 2016). These trends suggest that energy conservation in the residential sector is a pressing policy issue.

A literature review of energy conservation policies revealed that previous policies primarily focused on the diffusion of energy-efficient products. Many governments directed producers to improve the energy efficiency of their products and put in place systems to keep consumers informed about the energy efficiency of products. As a result, energy efficiency of products sold in the market improved notably, and, considering the difference in energy consumption, consumers started to choose more energy-efficient products. Despite this technological progress, households' energy savings have been very modest.

Households are concerned about the expenditure on energy services over a period of time. However, they do not give much thought to the amount of energy used by a specific home appliance. More than 150 years ago, Jevons (1865) asserted that the demand for resources will increase with gradual improvements in their efficiency in using that resource. Furthermore, Khazzoom (1980) argued that energy efficiency increases the stock and utilization of all home appliances. If there is a potential demand for energy services, energy efficiency improvements may not result in reduced entire household's energy consumption. Therefore, to assess the impact of improvement in energy efficiency, we need to know the potential demand for various services.

During times when electricity was not available, people performed specific activities at specific times. Today, however, we have the flexibility to plan various activities as per our convenience. A typical working class individual tends to spend much time outside his or her home and complete household activities in the night. The nighttime shift of household activities appears to affect energy consumption as additional energy is utilized for lighting or heating. Therefore, we expect that a nighttime shift of household activities increases electricity consumption. However, existing studies have not focused on the relationship between time allocation and energy consumption. This paper is aimed at analyzing this relationship through a household survey conducted in Japan.

The remainder of the paper is organized as follows. In Section 2, we briefly review the studies that evaluate the determinants of household energy usage. In Section 3, we summarize the data from our household survey. Section 4 presents the estimation model and reports the empirical findings, and Section 5 concludes the study.

2. Brief Literature Review

Frederiks et al. (2015) reviewed studies that evaluated the determinants of household energy usage and reported that sociodemographic (e.g., income, employment status, dwelling type/size, home ownership, household size, and stage of family life cycle) and psychological factors (e.g., beliefs and attitudes, motives and intentions, perceived behavioral control, cost-benefit appraisals, and personal and social norms) affect household energy usage. However, the impact of both these factors varies widely across studies (Urban and Ščasný 2012).

Almost all studies provide consistent results involving economies of scale in energy usage, stating that electricity usage decreases when the number of family members increase (O'Neill and Chen 2002; Druckman and Jackson 2008; Brounen et al. 2012). This is because family members can share certain energy services. Previous studies also found a positive relationship between income and energy usage. Although energy consumption increases with growth in income, the share of energy expenditure in the total household expenditure decreases. Therefore, the welfare impact of changes in energy prices varies among income classes (Romero-Jordán et al. 2016; Schulte and Heindl 2017). Similarly, most studies found a positive relationship between housing size and energy usage, stating that people living in large houses generally use more energy for daily activities.

Previous studies did not provide consistent results on the impact of education on energy consumption. Although Poortinga et al. (2004) and Nair et al. (2010) found that the educational background influences energy efficiency investments and/or energy-saving practices of individuals, Ritchie et al. (1981) and Gatersleben et al. (2002) did not find similar results.

Similarly, no consistent conclusion with respect to the impact of age on energy consumption was found in previous studies. Fritzsche (1981) analyzed the Consumer Expenditure Survey of US households and reported that an inverted u-shaped curve was found, with energy expenditure being the lowest during the early and late stages of the life cycle. Young people consume more energy because they are active, while elderly people use more energy because they stay home for longer hours. More recent studies, such as those by Brounen et al. (2012), Longhi (2015), and Gram-Hanssen (2013), found that age impacts every energy carrier differently. They found that gas consumption is largely determined by the dwelling conditions, but electricity consumption is less affected by the socioeconomics characteristics of households.

Hori et al. (2013) surveyed five Asian cities and found that the environmental attitudes of subjects influenced their curtailment behavior. In contrast, Trotta (2018) analyzed survey data from Britain and reported that environmental attitudes affect curtailment behavior and small-scale energy-efficient investment decisions but does not impact large-scale energy-efficient investment decisions. Wang et al. (2011) found that social interactions affected the energy-efficient investment decisions in Chinese households. Finally, Nakamura (2013) studied the curtailment behavior of Japanese households after the 2011 earthquake and found that social interaction impacted this behavior.

3. Data

The data used in this study were sourced from an Internet survey firm, Nippon Research Center[13], and the survey was conducted on October 15–16, 2015. Since we expected time allocation to significantly differ between single and married individuals, we focused on married individuals between ages 25 and 64. A total of 546 responses were collected. We allocated respondents in advance to eliminate gender and age bias. Table 1 classifies the respondents. The survey's target area was the Tokyo metropolitan area, and the number of respondents by prefecture was 2, Ibaraki Prefecture; 86, Saitama Prefecture; 85, Chiba Prefecture; 239, Tokyo Special Ward; and 134, Kanagawa Prefecture.

[13] NRC, a full-service marketing research agency established in 1960, engages in consumer marketing and consultation, as well as academic and public opinion polling.

Table 1. Age and Gender of Survey Respondents

Age category	Male		Female	
	Number	Share	Number	Share
25 – 34	55	21.0%	73	25.7%
35 – 44	69	26.3%	69	24.3%
45 – 54	66	25.2%	70	24.6%
55 – 64	72	27.5%	72	25.4%
Total	262	100.0%	284	100.0%

We asked the married couples participating in the survey to maintain a daily record of their activities for two sampling days. We adopted the pre-coded method used in *The Survey on Time Use and Leisure Activity*, the national survey of the Japanese government.[14] We divided two successive days (a 48-hour study period) into 192 (48 h × 4) time slots with 15-minute increments and asked the participants to choose the behavior of each slot from the following preset actions: (1) sleeping, (2) personal care, (3) consuming meals, (4) commuting, (5) working, (6) schooling, (7) housework, (8) nursing, (9) childcare, (10) shopping, (11) commuting, (12) watching television/reading newspaper, (13) relaxing, (14) self-development, (15) undertaking hobbies, (16) playing sports, (17) volunteering, (18) companionship, (19) medical treatment, and (20) others.

Table 2 presents the amount of time that husbands and wives allocated to the 20 activities on average. We classified the activities into two broad categories: outdoor and indoor.[15] We expect the electricity usage to decrease with increase in the time spent on outdoor activities.

[14] *The Survey on Time Use and Leisure Activities* is aimed at obtaining comprehensive data on daily patterns of time allocation and leisure activities. The survey has been conducted every five years since 1976 (Statistics Bureau of Japan 2006).

[15] This classification is not exact. Meals include lunch time taken at work. Although some childcare activities such as bringing children to parks are outdoor activities, childcare is categorized as an indoor activity.

Table 2. Time Allocation of Husband and Wife (Minutes)

	Husband (N = 546)		Wife (N = 546)	
	Average	Standard Deviation	Average	Standard Deviation
Outside activities				
Commuting	92.49	62.84	32.07	51.20
Movement	24.85	52.23	32.06	49.61
Shopping	8.91	22.46	34.86	36.09
Work	479.12	199.81	168.06	210.41
School	1.10	9.95	2.60	10.38
Sports	5.43	22.55	6.36	23.79
Volunteer	0.87	8.74	0.96	8.80
Companionship	8.98	31.58	6.26	24.57
Medical treatment	3.01	26.02	4.37	16.38
Sum	624.75	206.65	287.61	229.70
Inside activities				
Sleeping	415.59	73.80	424.00	76.81
Television/newspaper	85.65	101.36	119.07	117.39
Housework	13.91	42.73	194.30	146.38
Personal care	73.82	65.44	93.52	87.05
Relaxation	71.21	77.40	103.83	98.15
Nurse	0.52	4.56	2.25	10.46
Childcare	8.48	37.61	51.44	118.68
Meal	97.76	44.02	96.91	35.84
Self-development	7.05	31.92	7.90	33.87
Hobby	24.08	61.71	35.63	75.73
Others	17.18	67.14	23.54	53.20
Sum	815.25	206.65	1152.39	229.70
Night time activities between 23:00 pm and 4:00 am	54.01	58.94	45.48	52.53

Table 2 shows that husbands spent 624.75 minutes and wives spent 287.61 minutes outdoors on average. In addition to the 479.12 minutes for work, husbands spent 92.49 minutes on commuting. Although wives spent only 168.06 minutes working on average, they were responsible for most of the shopping. As the survey was conducted on weekdays, husbands and wives spent a small amount of time on other outdoor activities. With respect to indoor activities, husbands and wives slept for about 7 hours and spent 1.6 hours on meals. The table reveals that wives spent more time on personal care and took longer breaks than husbands. However, wives spent much more time on household production activities, such as housework and childcare, than husbands.

In summary, the table indicates that husbands and wives allocate time very differently. Husbands spend much more time on job-related activities, and wives spend more time on household production.

Table 3. Characteristics of households

Variable	Unit	Mean or Share	Standard Deviation
Sampling period			
Metered in September	dummy	0.58	
Electricity usage			
Electricity usage of household	kWh	9.00	4.72
Electricity usage per person	kWh	3.20	1.90
Characteristics of household			
Number of persons in family	person	3.05	0.99
Age of household head	years	46.97	11.13
College husband	dummy	0.72	
College husband	dummy	0.41	
Presence of young person (13-22)	dummy	0.31	
Presence of elderly person (> 65)	dummy	0.06	
Household income	million yen	787.69	668.62
Deposit	million yen	1656.44	3178.18
Loan	million yen	921.57	1637.28
Characteristics of houses			
Floor	m^2	85.35	38.43
Housing tenure	dummy	0.72	0.45
Detached house	dummy	0.42	0.49
Wood house	dummy	0.39	0.49
Old house (built before 2000)	dummy	0.49	0.50
Appliance ownership and usage			
Ampere	ampere	38.50	7.98
Number of ACs	unit	2.63	1.32
Size of the main AC	m^2	17.41	5.16
Intensity of use of the main AC	rarely 1 - always 3	2.65	0.93
Ownership of cloth dryer	dummy	0.49	
Ownership of dish washer	dummy	0.32	

The descriptive statistics of the variables used in the following analysis are listed in Table 3. Tokyo Electric Power Company Holdings bills households in the Tokyo metropolitan area every month. In this survey, we asked participants to enter their billing information. Approximately 58% of the respondents entered information concerning the September metering, while the remaining 42% entered information on the October metering. We initially calculated the daily electricity usage of households by dividing monthly usage by number of usage days. According to our calculations, a household uses 9.00 kWh of electricity on average per day. We then calculated electricity usage per person per day by dividing daily electricity usage by number of members in a family. In this calculation, we excluded family members who live away from home for work, school, and clinical reasons. Figure 1 contains the distribution of electricity usage per person per day. According to our calculations the mean electricity consumption was 3.20 kWh per person per day.

Our main hypothesis is that a person undertaking more activities at nighttime uses more energy. To test this hypothesis, we included the amount of active time from 23:00 pm to 4:00 am for the two sampling days. Although we cannot precisely gauge a subject's lifestyle from their bedtime in the sampling days, we can examine if nighttime activities increase energy consumption.

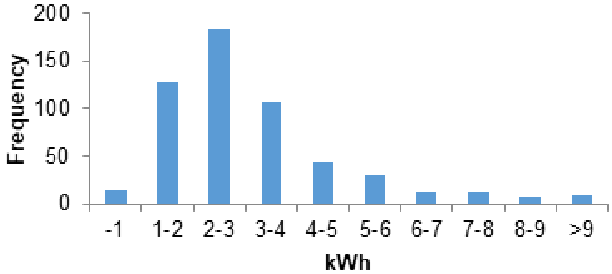


Figure 1. Electricity usage per person per day

We also included the household characteristics that previous studies found to affect household electricity usage. We first took account of the size of the families. As presented in Table 3, each family had 3.05 members on average. In the survey, we asked the respondents about their educational background and found that 72% of the husbands and 41% of the wives had attended a university. The share of college graduates in our survey is higher than the national average because our sampling area is within the metropolitan region. In our data, 31% of the households included young people between ages 13 and 22, and 6% of the households included elderly people over 65 years of age. The annual household income obtained from this survey was 7.88 million yen, which is higher than the average annual income of the Tokyo metropolitan area of 6.06 million yen (Ministry of Health, Labour and Welfare 2016), probably because our survey focused on households with married couples. Matsumoto (2016a) reports that the level of household saving determines the appliance ownership. In the survey, we asked respondents about their deposits and loans.

Families using many appliances at the same time require a high ampere rate. We asked households about their contract ampere and included their responses in the following analysis to control for the appliance ownership effect. The number of contract amperes in our survey was 38.50 on average. We also took account of the ownership of air conditioners (ACs), cloth dryers, and dishwashers. According to Matsumoto's (2016b) conditional demand analysis, the ownership of these appliances affects the electricity usage of households. We also took into account the number, size, and usage of ACs. Table 3 reveals that while each household owned 2.65 AC units on average, only 49% of households owned cloth dryers and 32% owned dishwashers.

Previous studies reported that the characteristics of housing affect energy usage. In this study, we asked participants about floor size, ownership, type, make, and year of construction. The floor area of the average house was 83.35 m^2. Approximately 72% of respondents owned their houses, 42% lived in detached houses, 39% lived in houses made of wood, and 49% lived in houses constructed before 2000.

4. Empirical Model and Result

To evaluate the impact of nighttime activity, we estimated the following semi-log electricity demand function:

$$\ln y_i = \alpha + \alpha_{SEP} SEP_i + \sum_k \beta_k x_{ki} + \sum_l \gamma_l h_{li} + \alpha_{AMP} AMP_i + \sum_m \eta_m z_{mi} + \sum_s \theta_s \ln t_{si} + \sum_p \lambda_p p_i + \varepsilon_i$$

Here, y_i is the per capita, per day electricity consumption of household *i*, SEP_i is the dummy variable for the September metering, and AMP_i is the number of contract amperes. Following the specifications of previous studies, we include household characteristic variable x, housing characteristic variable h, and appliance condition variable z. Our main variable, t_s, measures the nighttime activity time of spouse *s*. We include prefecture dummies p to consider the prefecture fixed effect. The last term ε_i is an error term.
The estimation result is presented in Table 4. The dummy variable for the September metering becomes positive and statistically significant, suggesting that households use more energy in the September metering period than in the October metering period. Several household characteristic variables become statistically significant. The number of members in a family becomes negative and significant. Since the dependent variable is the electricity consumption per person per day, the result implies that economies of scale exist in household energy usage. We also confirmed that the age composition of a household affects electricity usage. Specifically, electricity usage increases as the age of the household head increases. The presence of young or senior members in a family also increases electricity consumption. Education level was not found to meaningfully affect electricity usage. Furthermore, we found that income did not affect household electricity usage but wealth did. Households with large deposits were found to use less electricity. Since the age of the household head is controlled for, we expect this variable to serve as a behavior variable. The above results imply that thrifty households also save energy.
We found that living in a large house results in more electricity consumption. According to our estimations, a 1% increase in the house size raises electricity usage by 0.145%. Although some previous studies reported that owners and renters behave differently, we did not observe any difference in the electricity usage of these two groups. We also found that individuals living in wooden buildings consumed less electricity.
The contract ampere variable becomes positive and significant. As mentioned before, households using many appliances at the same time need a high contract ampere. Therefore, the variable of contract ampere gauges the number of home appliances owned and the result suggests that households having many appliances consume more electricity. We also obtained the expected results for a series of AC variables. As the number of ACs increases, electricity consumption goes up. This effect is magnified if households use large ACs frequently. We found that the ownership of cloth dryers increases electricity consumption but that of dishwashers does not.
We included the total occupied time in the analysis.[16] Although we obtained the expected positive sign for this variable, it did not become statistically significant. Finally, the variable of wives' nighttime activity became significant, while that of husbands' did not. Hence, only wives' nighttime activity is associated with electricity usage. This difference is explained by the fact that wives still undertake most of the household work in Japanese households, a conclusion supported by the results in Table 2. Table 4 shows that a 1% increase in wives' nighttime activity increases electricity usage by 0.033%. Based on this estimation, reducing nighttime activity by an hour would decrease electricity consumption in an average size household by 0.14 kWh (= (60/45.48) × 0.033 × 3.12) per day. Since an average household uses about 8.99 kWh of electricity per day, approximately 1.51% of the daily electricity

[16] Total occupied time is the aggregate amount of time in which at least one family member is in the house.

usage can be saved by advancing the bed time by an hour.

Table 4. Determinants of household energy consumption

	Coefficient	Standard error
Constant	-0.452	(0.373)
Sampling period		
Metered in September	0.115***	(0.036)
Characteristics of household		
Number of persons in family	-0.277***	(0.023)
Age of household head	0.009***	(0.002)
Presence of young person	0.071**	(0.032)
Presence of elderly person	0.148**	(0.073)
College husband	-0.051	(0.041)
College wife	-0.036	(0.040)
Log of household income	0.043	(0.031)
Log of household deposit	-0.029***	(0.009)
Logo of household loan	-0.007	(0.006)
Characteristics of house		
Log of floor area	0.145*	(0.078)
Housing tenure	-0.057	(0.053)
Detached house	0.115	(0.095)
Wood house	-0.187**	(0.079)
Old house	-0.044	(0.039)
Appliance ownership and usage		
Contract ampere	0.005**	(0.002)
Number of ACs	0.082***	(0.020)
Size of the main AC	0.005*	(0.003)
Intensity of use of the main AC	0.115***	(0.019)
Ownership of cloth dryer	0.110***	(0.041)
Ownership of dish washer	0.030	(0.046)
Time allocation		
Total occupied time	0.007	(0.006)
Husband nighttime activity	-0.004	(0.011)
Wife nighttime activity	0.033***	(0.012)
Adjusted R^2	0.447	

Note. *, **, *** indicate statistically significant results at 10%, 5%, and 1%, respectively.

5. Conclusion

In this study, we surveyed 547 Japanese households to examine whether time allocation affects their electricity consumption. Our empirical result reveals that electricity consumption rises with an increase in wives' nighttime activity. Shifting the time of household work from day to night would increases household energy consumption. Many power companies reduced electricity charges for nighttime to equalize the usage of electricity. However, since such a discount encourages shifting housework to later in the evening, it may increase energy consumption. This study suggests that understanding the daily habits of people is necessary to propose effective energy conservation measures.

6. Acknowledgements

The author received financial support from the Japan Society for the Promotion of Science KAKENHI (Grant number: 26340119) and the Environment Research and Technology Development Fund (2-1707) of the Environmental Restoration and Conservation Agency of Japan.

References

Agency for Natural Resources and Energy of Japan. (2016). http://www.enecho.meti.go.jp/about/whitepaper/2016html/ accessed 16/04/2018.

Brounen, D., Kok, N., and Quigley, J.M. (2012). Residential energy use and conservation: economics and demographics. *European Economic Review*, 56, 931–945.

Druckman, A. and Jackson, T. (2008). Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. *Energy Policy* 36, 3177–3192.

Eurostat. (2018). Consumption of Energy. http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy accessed 11/04/2018.

Fritzsche, D.J. (1981). An analysis of energy consumption patterns by stage of family life cycle. *Journal of Marketing Research*, 18, 227–232.

Gram-Hanssen, K. (2013). Efficient technologies or use behavior, which is the more important when reducing households' energy consumption. *Energy Efficiency*, 6, 447–457.

Hori, S., Kondo, K., Nogata, D., and Ben, H. (2013). The Determinants of Household Energy-Saving Behavior: Survey and Comparison in Five Major Asian Cities. *Energy Policy*, 52, 354–362.

Khazzoom, D.J. (1980).–Economic implications of mandated efficiency standards for household appliances. *Energy Journal*, 1, 21–40.

Longhi, S. (2015). Residential energy expenditures and the relevance of changes in household circumstances. *Energy Economics*, 49, 440–450.

Fritzsche, D.J. (1981). An analysis of energy consumption patterns by stage of family life cycle. *Journal of Marketing Research*, 18, 227–232.

Frederiks, E.R., Stenner, K., and Hobman, E.V. (2015). The socio-demographic and psychological predictors of residential energy consumption: a comprehensive review. *Energies*, 8, 573–609.

Gatersleben, B., Steg, L., and Vlek, C. (2002). Measurement and determinants of environmentally significant consumer behavior. *Environmental Behavior*, 34, 335–362.

Jevons, W.S. *The Coal Question*, 3rd edition. Augustus M. Kelley, New York; 1865 [1965].

O'Neill, B.C., and Chen, B.S. (2002). Demographic determinants of household energy use in the United States. *Population and Development Review*, 28, 53–88.

Matsumoto, S. (2016a). Household Income Structure and Electrical Appliance Ownership: Evidence from Japanese National Household Survey. *International Journal of Energy Economics and Policy*, 6 (1), 14–19.

Matsumoto, S. (2016b). How do household characteristics affect appliance usage? application of conditional demand analysis to Japanese household data. *Energy Policy*, 94, 214–223.

Ministry of Health, Labour and Welfare. (2016). Basic Survey on Wage Structure.

Nakamura, H. (2013). Effects of Social Participation and the Emergence of Voluntary Social Interactions on Household Power-Saving Practices in Post-disaster Kanagawa, Japan. *Energy Policy*, 54, 397–403.

Nair, G., Gustavsson, L., and Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. *Energy Policy*, 38, 2956–2963.

Poortinga, W., Steg, L., and Vlek, C. (2004). Values, environmental concern, and environmental behavior: a study into household energy use. *Environment and Behavior*, 36, 70–93.

Ritchie, B., McDougall, G., and Claxton, J. (1981). Complexities of household energy consumption and conservation. *Journal of Consumer Research*, 8, 233–242.

Romero-Jordán, D., del Río, P., and Peñasco, C. (2016). An analysis of the welfare and distributive implications of factors influencing household electricity consumption. *Energy Policy*, 88, 361–370.

Schulte, I. and Heindl, P. (2017). Price and income elasticities of residential energy demand in Germany. *Energy Policy*, 102, 512–528.

Statistics Bureau of Japan. (2016). Outline of the 2016 Survey on Time Use and Leisure Activities. www.stat.go.jp/english/data/shakai/ accessed 06/03/2018.

Trotta, G. (2018). Factors Affecting Energy-Saving Behaviours and Energy Efficiency Investments in British Households. *Energy Policy*, 114, 529–539.

Urban, J. and Ščasný, M. (2012). Exploring domestic energy-saving: the role of environmental concern and background variables. *Energy Policy*, 47, 69–80.

Wang, Z., Zhang, B., Yin, J., and Zhang, Y. (2011). Determinants and Policy Implications for Household Electricity-Saving Behaviour: Evidence from Beijing, China. *Energy Policy*, 39, 3550–3557.

12. Impact of the Renewable Energy Development in Lithuania‘S Energy Economy

Rita Bužinskienė

ABSTRACT:
Renewable energy plays substantial role in energy economy and it is the major source for the economic development of any country. This paper investigates the energy development from renewable energy sources theoretic framework and uses annual data of 2006 – 2016 to measure energy development in Lithuanian's energy sector. The research methods used in the paper include the collection of primary and secondary information sources and quantitative data, which are then used for comparative analysis. Assessing the development of renewable energy in the energy sector are used various economic indicators. The impact of renewable energy sources in the energy sector are determine by using linear regression model. The purpose – evaluation of the impact of development renewable energy sources in the energy sector. This paper is characterized by scientific novelty as it involves a very scarce research problem in Lithuanian‘s energy sector, assessing the development of the impact from renewable energy sources. Renewable energy sources have a multiplier effect in spurring the economy and the development of not only the energy sector but also all the supporting activities related to such industry. Impact of the development of renewable energy is one of the factors that develop the quality of technology innovation development.

Keywords: Renewable energy sources, development, innovation, effect of renewable energy, energy sector

Dr. Rita Bužinskienė is associate professor of Siauliai State College, Lithuania. As a researcher, she published more than 15 scientific articles in various scientific publications and databases of scientific information. She has read presentations at International Conferences in Latvia, Turkey, Belarus and others countries. At 2013 years she trained at Anadolu universities, in Turkey. Since 2000 she has experience in finance and accounting. Research direction: investigates of the use of renewable energy sources; development of the energy independence strategy; impact of knowledge generating investment on GDP growth; determination of the value of intangible assets in the companies; evaluation of structure of financial and non-financial information of intangible assets and etc.

1. Introduction

Lithuania, as in the whole of the European Union (EU), is discussing a strategy for reducing the impact of climate change. Members of the international community agree that reducing greenhouse gas emissions to the atmosphere is necessary to avoid dangerous climate change. The Energy Independence Strategy‘2020 reveals that the key priorities include energy security, diversification of energy supply, energy efficiency and integration of Lithuania‘s energy network with the energy systems of the European Union. It requires each EU Member State to introduce energy efficiency obligation schemes and policy tools to increase the efficiency of energy use in households, industry and the transport sector. These targets to help the EU achieve a more competitive, secure and sustainable energy system and to meet its long–term 2050 greenhouse gas reductions target. According to them, in the long term, it will be necessary to significantly reduce global emissions, in order to avoid dangerous climate change. The EU is committed to 2050 to reduce its emissions by 80 – 95% compared to the 1990 level if developed countries work together to bring about similar efforts. The strategy sends a strong signal to the market, encouraging private investment in new pipelines, electricity networks, and low-carbon technology (2030 Energy Strategy; Directive 2012/27/EU, FMEAE 2014; REY 2016, BEM 7; ECR 2017). Renewable energy plays a substantial role in the energy economy and it is the major source for the economic development of any country. The Energy Law of the Republic of Lithuania defines energy as a branch of the state economy, which includes energy activities, including energy exploration, extraction, recycling, production, storage, transportation, transmission, distribution, supply, trade, marketing and/or operation of energy facilities and equipment (Law of LR Energy, No. IX-884, 2002). All this shows that energy is one of the important economic objects occupying strategically important areas of activity. The energy sector as an object of research occupies an important position in scientific terms. One of the widest research objects is renewable energy resources. The majority of scientists appreciate the impact of these resources on economic growth in different foreign countries. Research by scientists has revealed these results: 1. Soava and *et al.* (2018), analyzed the relationship between economic growth and renewable energy consumption, using data for 28 countries of the European Union over the period 1995-2015. The results of the study showed that renewable energy consumption has a strong positive impact on economic growth. 2. Oguz and Aslan (2013), analyzed the relationship between energy consumption and economic growth for 22 Organisation for Economic Co-operation and Development (OECD) countries over the period 1960–2005. The results of the study showed that while in most cases there is a strong relationship that starts from economic growth to energy consumption, the strongest relationship from energy consumption to economic growth is shown only for Iceland and Portugal. 3. Maradin *et al.* (2007), found that renewable energy technologies (RET) have a multiplier effect in spurring the economy and the development of not only the energy sector but also stimulates economic growth. 4. Apergis and Payne (2012), analyzed bidirectional causality between renewable energy consumption and economic growth exists in both the short and long run in the period 1990–2007, 80 OECD countries. 5. Gan and Smith (2011), found, that GDP promotes renewable energy development, whereas R&D investment, energy prices and CO2 emissions cannot promote (1994–2003, 26 European countries) and others. However, there is a lack of research into the benefits of the development of renewable energy resources for energy economic activity. This paper investigates the energy development from renewable energy sources theoretic framework and uses annual data of 2004 – 2016 to measure energy renewable resources development in Lithuanian's energy economy. Assessing the development of renewable resources in the energy economic activity is created energy efficiency model. Processes in the Energy Efficiency Model illustrate the importance of the development of renewable energy sources and the efficiency of the energy sector, which raises a problematic question: what renewable energy resources affect energy economic activity in order to ensure efficiency in the energy sector. How to improve the performance of the energy sector to maximize the energy benefits of developing renewable energies. The energy economy efficiency is measured in economic indicators: energy productivity and energy intensity. The impact of renewable energy resources on the energy economy is determined by using a linear regression model.

The purpose – evaluation of the impact of renewable energy resources on the efficiency of the energy economy.

The research methods used in the paper include the collection of primary and secondary information sources and quantitative data, which are then used for comparative analysis.

2. The Tendency of Lithuanian's Energy Economy Indicators

Lithuania's National Energy Strategy has a legally binding target, in the year 2020, the share of renewable energy would account for at least 23% of the total final energy consumption of the country, and the share of renewable energy would account for at least 10% of final energy consumption in the transport sector (ECC 2017). It can be noted that in 2014, 23% of the total number of people in the EU was reached (Figure 1).

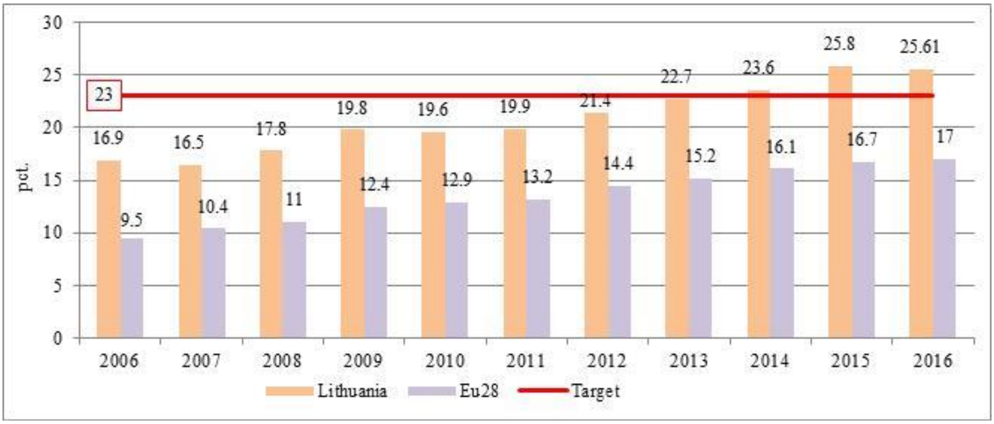


Fig.1. Energy production using renewable energy resources, % Sources: Eurostat

According to the results, energy production using renewable energy resources growth about 8,71 percentage points (p. p.) in Lithuania during the 10 years. The renewables accounted for 25,61 % of final energy consumption compared to EU 28 members state 17 % in 2016, representing more than 86 % of the 2020 target. In the future, Lithuania's objective is to achieve a 30% share of renewables in the final energy consumption balance in 2020; a 45% share of renewables in the final energy consumption balance in 2030; and 80% share of renewables in the final energy consumption balance in 2050.

Another indicator is the share of renewable energy in gross final energy consumption by sector. The analysis shows that EU28 members states in the electricity sector, the share of renewable energy the during 2006 – 2016 years went up from 15,4 % to 29,6 %, in the transport sector went up from 2,5 % to 7,1 %., 7,1% and in the heating sector in the same period, the share of renewable energy went up from 11,4 % to 19,6 % (Table 1).

Table 1. Share of renewable energy in gross final energy consumption by sector, %

Indicators	Lithuania			EU28		
	2006	**2011**	**2016**	**2006**	**2011**	**2016**
RES-share in the general electricity, %	4	9	16,8	15,4	19,7	29,6
RES-share heating and cooling,%	29,2	32,8	46,5	11,4	15,6	19,6
RES-share in transport, %	1,9	3,8	3,6	2,5	4	7,1

Sources: Eurostat

According to the results, in 2016 the largest increase in renewable energy capacities was in electricity and heating and cooling sectors — in comparison to 2006, respectively it went up by 12,8 p. p and 17,3 p.p. (Lithuania). The smallest increase in renewable energy capacities was in the transport sector – in comparison to 2006, respectively it went up by 1,7 p.p. (Lithuania). Lithuania's results show that RES –share in the heating and cooling sector is higher than the EU 28 member states, respectively, i.e. about 26,9 p.p. (2016). In 2050, the objective is Lithuania would have to produce about 70% of its own heat and electricity, while the share of green energy in transport should reach 50%.

Renewable energy sources are understood as inexhaustible energy resources, they are continually renewed and coming from natural sources: wind, wave, tidal, solar, aerothermal, geothermal, hydrothermal and ocean, hydropower, bioenergy, biomass, biofuel, landfill gas, wastewater treatment gas, and biogas and so on. Here is a list of the main types of practically utilized alternative energy sources (Table 2).

Table 2. Conversion of renewable energy

Renewable sources of energy	**Conversion**
Wind	Electricity
Solar	Heating / cooling, electricity
Biomass	Heating / cooling, transport, electricity
Water	Electricity
Geothermal energy	Heating / cooling, electricity

Sources: John 2004; Ma L et al. 2009; Heal 2010; Lund 2010; Law on Renewable Energy, 2011; Miškinis et al. 2014; International Energy Agency 2015; Hagen 2016; Marčiukaitis et al. 2016.

We can see five main types of renewable energy are important for our energy sector: Wind is the motion of air molecules can be harvested in wind turbines that spin the shaft of electric generators or in windmills; Sunlight is the solar photon flux can be converted to heat, electricity or chemical energy; Biomass is organic materials can be used for cooking and heating, as well as to produce electricity and liquid transportation fuels. In the transport sector two types of biofuels are used as fuel from biomass: biodiesel and bioethanol; Water is the potential and kinetic energy of flowing water can be tapped to produce electricity or mechanical tasks; Earth's internal heat (Geothermal energy) can be used for heating and electricity production.

Lithuania's governments aim to increase the efficiency of the energy economy. Two key indicators are used for energy efficiency: energy productivity and energy intensity. *The energy intensity* does give some indication of how efficiently economies are able to harness primary energy. Improving energy intensity is important as it encourages more energy economic activity and GDP growth. Low energy intensity is desirable as it indicates an effective energy infrastructure. *The energy productivity* identifies to what extent there is a decoupling between energy consumption and economic growth. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP (Figure 2) (Štreimikienė *et al.* 2016).

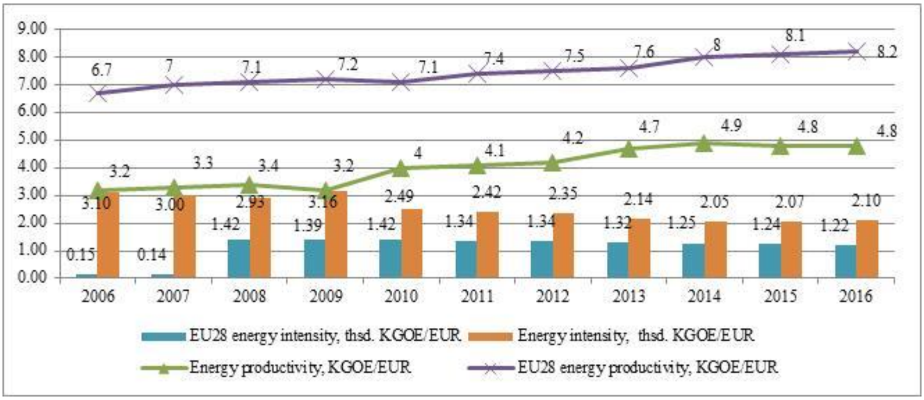


Fig.2. Energy intensity and Energy productivity in Lithuania Sources: Eurostat

According to the results, we can see that Lithuania's' energy intensity decreased 1,0 thsd. TOE/EUR from 2006 till 2016, since entering the EU however economic crisis had a negative impact and energy intensity started to increase (EU28 increased 1,07 thsd. TOE/EUR). The trend of energy intensity decrease can be noticed following the recovery from the economic crisis in 2010. Lithuania's energy productivity was grown up by 1,6 KGOE/EUR (EU28 increased 1,5 KGOE/EUR). These results show that energy productivity increased at the same time when the Gross domestic product (GDP) during 2006–2016 years had risen position in Lithuania 41 %. Comparing these indicators between them, we can see, that energy intensity is inversely related to energy productivity; that is the bigger the energy productivity of a given process, the smaller its energy intensity.

As mentioned earlier, there is a lack of research to assess the impact of the development of renewable energy resources on the efficiency of the energy economy. In view of this, an energy efficiency model has been developed.

3. Methodology

In this study, the energy efficiency model shown in Figure 3 is selected as a framework and theoretical starting point in understanding the ongoing processes between the energy sector and the development of renewable energy resources, using key energy economy indicators to measure the performance of the energy economy.

The proposed energy efficiency model includes the entire energy economy that reveals how the energy sector provides secure, efficient, environmentally friendly energy production, supply and transfer to consumers. The development of renewable energy resources depends on the ability of the energy sector to invest in new technologies that save energy. Another strategically important aspect of energy is to ensure the need for other industries to consume energy from renewable resources. The main economic indicators of energy productivity and energy intensity illustrate the efficiency of the energy economy. These indicators reveal the effect of the use and development of renewable energy resources, which provides continuous feedback on the efficient growth of the energy sector.

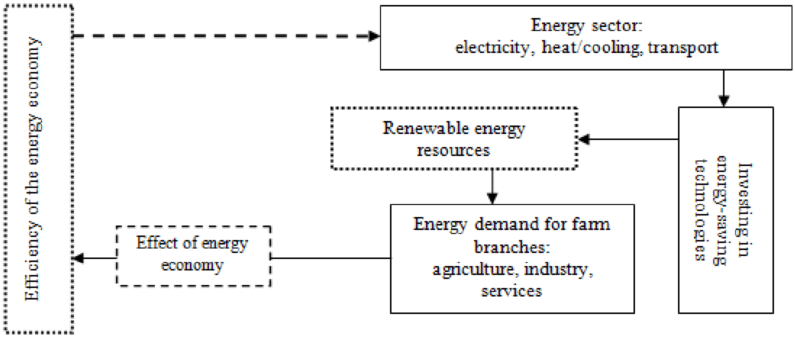


Fig 3. Energy-Efficiency Model, Sources: created by the author

In order to test the energy efficiency model practically, a multi-linear linear regression method is chosen. This method allows you to control many other factors that simultaneously affect a dependent variable. This is important both for verifying the validity of the economic theory and for assessing the effectiveness of ongoing economic activity when the study is based on non-experimental data. Multiple regression provides links between two or more independent variables. The regression analysis model allows predicting variable values from independent variable values (Forsströmet *et. al.* 2011; Wooldridge, 2010; Čekanavičius and Murauskas 2001).
The standard expression of a multiple linear regression model is:

$$Y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + e_i \, ; \qquad (1)$$

Here: Y – dependent variable; β_0, β_1, β_2, ..., β_k *– model coefficients (not known in advance, they are found by the least squares method and by checking the hypothesis about the suitability of the model);* x_1, ..., x_k *– analyzing factors;* e_i *– accidental error. Multiple regression model assumptions:* e_i *– normal distributed random values; all* e_i *averages are zero, that is* $e_i = 0$*; all* e_i *variances are equal to an unknown number* σ^2*; all* e_i *independent.*

In the analysis of the impact of renewable energy resources development on the energy sectors, two economic indicators have been chosen: energy productivity and energy intensity. These indicators point to the level of achievement of the country's energy economy (Table 3).

Table 3. Energy economy indicators

INDICATORS	DESCRIPTION
Energy productivity	It is an indicator of the amount of economic output that is derived from each unit of energy consumed. Economy-wide energy productivity is generally measured as the national gross domestic product (GDP, in millions of dollars) divided by petajoules (PJ) of primary energy consumed.
Energy intensity	It is a measure of the energy inefficiency of an economy. It is calculated as units of energy per unit of GDP. Energy intensity is the ratio between gross inland energy consumption (GIEC) and gross domestic product (GDP), calculated for a calendar year.

Although most of these energy indicators measures are not directly connected with the renewable energy sector, economic synergies exist between efficiency improvements and renewable energy. Synergies exist between energy intensity and energy productivity can support increased renewable energy deployment. The development of these indicators as a driving force promotes the growth of the country's economy through activities developed by the efficiency of the energy sector activities. Creation of the model for assessment of the impact of renewable energy resources development on the energy economy activities (Table 4).

Table 4. Description of the variables for the analysis of the impact of renewable energies on the energy economy

NOTATION OF VARIABLE	METHOD OF INDICATOR	
*Energy productivity, KGOE	Economic output / Energy used	Dependent variable
**Energy intensity, KGOE	Gross inland energy consumption / Gross domestic product	
Share of renewable energy from wind sources, %	Gross inland consumption of wind, thsd. TOE / Gross inland consumption of renewable energies, thsd. TOE x 100%	Independent variable
Share of renewable energy from solar sources, %	Gross inland consumption of solar, thsd. TOE / Gross inland consumption of renewable energies, thsd. TOE x 100%	
Share of renewable energy from hydro sources, %	Gross inland consumption of hydro, thsd. TOE / Gross inland consumption of renewable energies, thsd. TOE x 100%	
Share of renewable energy from geothermal sources, %	Gross inland consumption of geothermal, thsd. TOE / Gross inland consumption of renewable energies, thsd. TOE x 100%	
Share of renewable energy from biomass sources, %	Gross inland consumption of biomass, thsd. TOE / Gross inland consumption of renewable energies, thsd. TOE x 100%	

**Euro per kilogram of oil equivalent (KGOE); ** Kilograms of oil equivalent (KGOE) per thousand euro;*

The multi–regression model requires the reliability of the results obtained to be verified, and therefore the reliability of statistical data is used (Table 5).

Table 5. Reliability tests for the regression model

Indicators	Reliability test	Description
Pearson'correlation coefficient	If [0,9; 1] - very strong correlation; [0,7; 0,89] - strong correlation; [0,4; 0,69] - medium correlation; [0.2; 0,39] - weak correlation; [0; 0,19] - very weak correlation	The correlation coefficient is a criterion for the quantification of linear dependency between variables or a measure of the strength of a relationship.
Determination coefficients R^2	If $R^2 \geq 0{,}20$ or adjusted $R^2 \geq 0{,}25$, the model is appropriate	The determination coefficient acquires values from the interval [0, 1]. The higher the coefficient value, the better the data model.
ANOVA p-value	If $p < 0{,}05$ or df > 0, the model is appropriate	It shows whether the model has a regressor associated with the dependent variable.
Multicolinearum	If VIF > 4 or tolerance < 0,25 the	Shows the correlation of

Indicators	Reliability test	Description
(Value of Variance Inflation Factor (VIF))	problem of multicolinearity . Variable Tolerance = *1/VIF*.	independent variables included in the model, do they not correlate with each other. The dependency is only related to the dependent variable.
Autocorrelation (Durbin-Watson (DW) test)	If p-value > 0,05, it is correlation is not statistically significant (no autocorrelation). It may vary from 0 to 4. The closer 2, the less likely it is that there is autocorrelation between residual errors.	Checking for a dependent variable *Y* during the period t does not correlate with error t-1 in the period.

The correlation coefficient itself is simply a way to describe how two variables vary together, so it can be computed and interpreted for any two variables. Correlation computes the value of the Pearson correlation coefficient. Its value ranges from –1 to +1. The determination coefficient can be interpreted as the ratio of the part of the variance explained by the regression model to the whole dispersion. The value of the determination coefficient must be bigger than 0,20, and the value of the corrected determination factor (Adjusted R square) must be bigger than 0,25, then the regression model is considered appropriate. Anova p-value indicates the evaluation of a variable communication model. If this value is less than 0,05, this confirms the suitability of the model. When verifying that the independent variables are not multicolored, whether there is a strong correlation between them, the variance inflation factor (VIF) is calculated. When there is a strong correlation between the variables, there is a problem with the so-called multicollinearity. Such multipolarity means that in the regression model, leaving the variable and the variables with which it correlates, there may be a problem of forecast stability. Multipolarity is checked by the value of VIF statistics: if VIF> 4, then independent variables in the model correlate. Instead of using VIF, it is possible to use the indicator - tolerance. There are several tests to check the correlation of errors (Autocorrelation). One of them is Durbin-Watson's (DW) test. Autocorrelation means that model errors are related to each other. Durbin - Watson criteria statistics vary from 0 to 4. The absence of correlation means that the size of DW statistics is close to 2. If DW is close to 0 or 4, it can be said that e_i and e_{i-1} high enough correlation.

4. Empirical Results

At the initial stage of the analysis of the impact of renewable energy sources on the energy economy, the correlation between the variables has been established, there was a problem with multicollinearity because the dispersion reduction factor was bigger than 4 (VIF > 4). In this situation, the regression model created cannot be realized to support the conclusions. There are several ways to solve multicollinearity problems: *1. Removal of one or more strongly correlated factors if they overlap each other, it describes the same characteristics of the analyzed factor; 2. Inclusion of additional data (an increase of the sample); 3. Data Correction: Multiple Linear Multiple Variables Used.*

In this study will use first ways to solve multicollinearity problems (Table 6).

Table 6. The problem of multicolinearity

Renewable sources	Wind	Solar	Hydro	Geothermal	Biomass
Wind	×	˅	˅	˅	
Solar	˅	×	˅		
Hydro	˅	˅	×	˅	˅
Geothermal	˅		˅	×	˅
Biomass			˅	˅	×
Results of multicolinearity					
Wind	= (solar, hydro, geothermal)			≠ (biomass)	
Solar	= (wind, hydro)			≠ (geothermal, biomass)	
Hydro	= (wind, solar, geothermal, biomass)				
Geothermal	= (wind, hydro, biomass)			≠ (solar)	
Biomass	= (hydro, geothermal)			≠ (wind, solar)	

˅ - *it means no multicollinearity problem; empty field means multicollinearity problem.*

Table 6 shows four restrictions of this study: 1. Wind correlates with biomass; 2. Solar correlates with geothermal and biomass; 3. Geothermal correlates with solar; 4. Biomass correlates with wind and solar. It can be noticed that only hydro consumption does not correlate with other renewable energy resources. In view of these constraints, there are three combinations of renewable energy resources:1. Y_1 *= f (hydro, biomass, geothermal; 2.* Y_2 *= f (hydro, wind, solar); 3.* Y_3 *= f (hydro, geothermal, wind).* Three models (M1, M2, M3) have been realized when analyzing the effect of composite combinations (Y_1, Y_2, Y_3) on energy productivity value (Table 7). The question posed by the study can be answered: What is the effect of the value of the combinations (Y_1, Y_2, Y_3) on energy productivity *? What* (Y_1, Y_2, Y_3) combinations are best for energy productivity growth?

Table 7. Empirical results of energy productivity

Model	Dependent variables	Independent variables	Pearson' correlation coefficient	R Square	Adjusted R Square	Durbin-Watson (DW)	Collinearity Statistics	
							Tolerance	VIF
1	Energy Productivity	Hydro	.948	.898	.864	1.604	.691	1.448
		Biomass					.719	1.390
		Geothermal					.526	1.902
2		Hydro	.950	.903	.871	1.508	.359	2.785
		Wind					.316	3.165
		Solar					.373	2.680
3		Hydro	.943	.889	.853	1.656	.473	2.113
		Geothermal					.696	1.438
		Wind					.380	2.634

Based on the data in Table 7, the correlation coefficient between the first model (M1 = 0,948), the second model (M2 = 0,950), the third model (M3 = 0,943) and the energy productivity level show a very strong positive relationship. The corrected determination coefficient for the first model (M1 = $R2$ = 0,864), the second model (M2 = $R2$ = 0,871) and the third model (M3 = $R2$ = 0,853) show that the variables included in the model explain respectively: 86,4%, 87,1%, 85,3% energy productivity indicator spread. This accounts for more than 25 percent. This means that the model is suitable for data. Empirically tested models (M1, M2, M3) have no multicolinearity (VIF <4) and autocorrelation (DW test p > 0.05). The three models implemented meet all the requirements and can be used to formulate the conclusions of the study. The following is a dispersal analysis (ANOVA) (Table 8).

Table 8. Disperse analysis (Anova)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.693	3	2.231	26.439	.000[a]
	Residual	.759	9	.084		
	Total	7.452	12			
2	Regression	6.731	3	2.244	27.986	.000[a]
	Residual	.722	9	.080		
	Total	7.452	12			
3	Regression	6.628	3	2.209	24.128	.000[a]
	Residual	.824	9	.092		
	Total	7.452	12			

Based on Table 8, F statistics and significance are interpreted. $Fkrit.$ (3,9) and this statistic is significant because $p < 0,05$. It can be said that all three of the regression models that have been created are aligned and chosen correctly.

Table 9. Summary of energy productivity results

Model		Unstandardized Coefficients	Standardized Coefficients	t	Sig.	95.0% Confidence Interval	
		B	Beta			Lower Bound	Upper Bound
1	(Constant)	34.699		7.360	.000	24.035	45.364
	Geothermal	-.815	-.135	-1.058	.318	-2.559	.928
	Biomass	-.317	-.750	-5.974	.000	-.437	-.197
	Hydro	-.263	-.236	-1.607	.143	-.633	.107
2	(Constant)	2.838		3.678	.005	1.093	4.583
	Wind	.281	.785	4.536	.001	.141	.422
	Solar	1.027	.260	1.408	.193	-.624	2.678
	Hydro	.073	.065	.385	.709	-.355	.501
3	(Constant)	3.189		4.194	.002	1.469	4.909
	Wind	.327	.914	5.672	.000	.197	.458
	Geothermal	-.627	-.104	-.784	.453	-2.437	1.183
	Hydro	.020	.018	.099	.924	-.434	.473

The results in Table 9 showed that the expressions of all three models have a significant effect on the value of energy productivity, but this effect is manifested in different directions. Combination of the first model (M1) growth of 1 % reduce the value of energy productivity, respectively: Geothermal 0,815 %, Biomass 0,317 %, Hydro 0,263 %. Combination of the second model (M2) growth of 1 % increase the value of energy productivity, respectively: Wind 0,281%, Solar 1,03%, Hydro 0,073%. Combination of the third model (M3) growth of 1 % increase energy productivity, respectively: Wind 0,327 % and Hydro 0,20 %, but Geothermal decreased energy productivity by 0,627%

The results showed, that the impact of all models on energy productivity can vary: M1 model: Geothermal ± 1,63%, Biomass ± 0,63%, Hydro 0,53%; M2: Wind ± 0,28 %, Solar 2,05%, Hydro 0,15 %; M3 model: Wind ± 0,26 %, Geothermal ± 1,25 %, Hydro 0,04 % at 95 percent of the probability.
Three models (M1, M2, M3) have been realized when analyzing the effect of composite combinations (Y_1, Y_2, Y_3) on energy intensity value (Table 7). The question posed by the study can be answered: What is the effect of the value of the combinations (Y_1, Y_2, Y_3) on energy intensity? *What* (Y_1, Y_2, Y_3) combinations are best for energy intensity growth?

Table 10. Empirical results of energy intensity

Model	Dependent variables	Independent variables	Pearson' correlation coefficient	R Square	Adjusted R Square	Durbin-Watson (DW)	Collinearity Statistics	
							Tolerance	VIF
1	Energy Intensity	Hydro	.907	.822	.763	1.259	.691	1.448
		Biomass					.719	1.390
		Geothermal					.526	1.902
2		Hydro	.902	.814	.752	1.372	.359	2.785
		Wind					.316	3.165
		Solar					.373	2.680
3		Hydro	.906	.820	.760	1.346	.473	2.113
		Geothermal					.696	1.438
		Wind					.380	2.634

Based on the data in Table 10, the correlation coefficient between the first model (M1 = 0,907), the second model (M2 = 0,902), the third model (M3 = 0,906) and the energy productivity level show a very strong positive relationship. The corrected determination coefficient for the first model (M1 = $R2$ = 0,763), the second model (M2 = $R2$ = 0,752) and the third model (M3 = $R2$ = 0,760) show that the variables included in the model explain respectively: 76,3%, 75,2%, 76,0% energy intensity indicator spread. This accounts for more than 25 percent. This means that the model is suitable for data. Empirically tested models (M1, M2, M3) have no multicolinearity (VIF <4) and autocorrelation (DW test p > 0.05). The three models implemented meet all the requirements and can be used to formulate the conclusions of the study. The following is a dispersal analysis (ANOVA) (Table 11).

Table 11. Disperse analysis (Anova)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32941.795	3	10980.598	13.890	.001[a]
	Residual	7115.080	9	790.564		
	Total	40056.875	12			
2	Regression	32621.068	3	10873.689	13.161	.001[a]
	Residual	7435.807	9	826.201		
	Total	40056.875	12			
3	Regression	32845.707	3	10948.569	13.665	.001[a]
	Residual	7211.168	9	801.241		
	Total	40056.875	12			

Based on Table 11, F statistics and significance are interpreted. $Fkrit.$ (3,9) and this statistic is significant because $p < 0{,}05$. It can be said that all three of the regression models that have been created are aligned and chosen correctly.

Table 12. Summary of energy intensity results

Model		Unstandardized Coefficients	Standardized Coefficients	t	Sig.	95.0% Confidence Interval	
		B	Beta			Lower Bound	Upper Bound
1	(Constant)	-1896.668		-4.156	.002	-2928.926	-864.410
	Geothermal	59.476	.135	.797	.446	-109.283	228.236
	Biomass	22.330	.721	4.351	.002	10.720	33.940
	Hydro	17.814	.218	1.125	.290	-18.003	53.631
2	(Constant)	329.450		4.206	.002	152.277	506.624
	Wind	-22.055	-.840	-3.503	.007	-36.297	-7.813
	Solar	-23.481	-.081	-.317	.758	-191.050	144.088
	Hydro	-.138	-.002	-.007	.994	-43.606	43.330
3	(Constant)	326.717		4.594	.001	165.828	487.607
	Wind	-23.264	-.886	-4.308	.002	-35.481	-11.048
	Geothermal	46.377	.105	.620	.551	-122.929	215.683
	Hydro	-2.528	-.031	-.135	.896	-44.963	39.907

The results in Table 12 showed that the expressions of all three models have a significant effect on the value of energy intensity, but this effect is manifested in different directions. Combination of the first model (M1) growth of 1 % increase the value of energy intensity, respectively: Geothermal 59,5 %, Biomass 22,3 %, Hydro 17,8 %. Combination of the second model (M2) growth of 1 % reduce the value of energy intensity, respectively: Wind 22,1 %, Solar 23,5 %, Hydro 0,138 %. Combination of the third model (M3) growth of 1 % reduce energy productivity, respectively: Wind 23,3 % and Hydro 2,5 %, but Geothermal increase energy intensity by 46,4 %.

The results showed, that the impact of all models on energy productivity can vary: M1 model: Geothermal ± 118,95%, Biomass ± 23,22%, Hydro 35,63 %; M2: Wind ± 44,11%, Solar ± 92,75%, Hydro 0,28 %; M3 model: Wind ± 46,53 %, Geothermal ± 92,75 %, Hydro 5,06 % at 95 percent of the probability.

Comparing the results of the study, it can be seen that the combination of RE resources created by the M2 model is one of the best ways to increase the efficiency of the energy economy (Table 13).

Table 13. Summary of regression analysis results

Model	Energy Productivity	Energy Intensity	Findings
M1	Decrease (-)	Increase (+)	unsuitable
M2	Increase (+)	Decrease (-)	suitable
M3	Increase (+) Decrease (-)	Increase (+) Decrease (-)	partly suitable

The combination of the M2 model has been identified as a significant combination of renewable energy (RE) resources, having the highest and most direct impact on energy efficiency and energy intensity. Using the RE combination of the Model 2, energy productivity increased and energy intensity reduced. This means that a lower value of energy intensity and a higher value for energy productivity increase the efficiency of the energy economy. The combination of the M1 model is not appropriate because the combination of RE resources in this model reduced energy productivity and increased energy intensity. This means that this combination of RE resources for the energy economy is not beneficial. The combination of the M3 model is only partially appropriate, as each RE resource has a different impact on energy productivity and energy intensity indicators, and therefore cannot deliver more efficient performance than the M2 model.

5. Discussion

It can be noted that the identified combinations are most suitable for electricity because these resources can be easily converted to electricity. For the heating/cooling sector, these combinations are not suitable because solar, geothermal and biomass cannot be used together. These resources correlate with each other, which reduces the energy economy efficiency. In order to determine which of these resources the best to choose for the efficient operation of the energy sector, it is necessary to carry out additional studies that are not dealt with in this article. In fact, biomass resources are used only in the transport sector. This resource includes the potential for the use of various local resources: straw, wood, waste, etc. However, this study also does not study which of the local resources is the most suitable for use in the transport sector and further research should be carried out.

6. Conclusions

To sum up, renewable energy resources are the key to green energy, which occupies an important position in the energy economy. It is a promising energy sector where this sector plays an important role: electricity, heat/cooling, and transport. The development of this area in Lithuania should receive much more attention. The analysis of the development of Lithuanian renewable energy resources revealed that the production of energy using RE resources is increasing every year and has exceeded the established EU28 average. From 2014 Lithuania has achieved its target (energy production from RE resources by 23% by 2020) and this figure was 23,6%. Two indicators were selected for energy efficiency: energy productivity and energy intensity. In Lithuania, energy productivity, compared to EU28, was less than 3,4 KGOE/EUR. All this shows that the demand for energy resources has increased due to the inefficient use of energy resources in production processes. In Lithuania, the energy intensity compared to the EU28 countries was 0,88 thsd. KGOE/EUR is lower, this is a positive trend as much less energy is consumed in the production of one product than the EU28 average.

Initial research showed that RE resources cannot use available at the same time, because they compete with each other: Wind with biomass; Solar with geothermal and biomass; Geothermal with solar; Biomass with wind and solar. Only hydro can be used with other resources. Against this background, three renewable energy (RE) resource combinations have been developed to assess the impact on the efficiency of the energy economy performance. For this study used two indicators energy productivity and energy intensity. The study has shown that the combination of the model M2 RE resources is one of the most appropriate choices. Model M2 has a positive impact on the efficiency of the energy economy because it increased energy productivity and reduced energy intensity. This means that a lower value of energy intensity and a higher value of energy productivity can ensure to grow up the efficiency of the energy economy. Using the model M1 RE resource combination was determinate, that this model has a negative effect and it is not beneficial to the energy economy. The combination of the model M3 RE resources is only partially appropriate, because it has different effects on energy productivity and energy intensity indicators, and therefore cannot ensure the growth of energy economy performance.

References

Apergis, N. and Payne, J.E. 2012. Renewable and non-renewable energy consumption-growth nexus: evidence from a panel error correction model. Energy Economics, Vol. 34, No. 3, 733–738

BEM (Baltic Energy Market). Interconnection Plan GRIP 2017. https://www. entsog. eu/public /uploads/ files/ publications/GRIPs/2017/entsog_BEMIP_GRIP_2017_Main_web_s.pdf

Čekanavičius, V., Murauskas, G. 2001. *Statistika ir jos taikymai I.* Vilnius: TEV. *http://stat.vadoveliai lt/files/ STAT1SV_DEMO.pdf*

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012http://eur-lex.europa.eu/ LexUriServ /Lex Uri Serv.do?uri =OJ:L:2012: 315: 0001 : 0056:EN:PDF

ECC (European Commission. Communication from the commission to the european parliament, the council, the european economic and social committee, the committee of the regions and the european investment bank), Third Report on the State of the Energy Union, 2017. https://ec.europa.eu/commission/sites/beta-political/files/annex-3-progress-national-energy-climate-plans_en.pdf

ECR (European Commission. Communication from the commission to the European parliament, the council, the European economic and social committee, the committee of the regions and the European investment bank, Third Report on the State of the Energy Union). 2017. https://ec.europa.eu/commission/sites/beta-political/files/annex-3-progress-national-energy-climate-plans_en.pdf

Energy Strategy 2030. https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy

FMEAE (The Federal Ministry for Economic Affairs and Energy). 2014. Renewable Energy Sources in Figures. https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/renewable-energy-sources-in-figures-2014.pdf?__blob=publicationFile&v=3

Forsström, J., Lahti, P., Pursiheimo, E., Rämä, M., Shemeikka, J., Sipilä, K., Tuominen, P., Wahlgren, I. 2011. Measuring energy efficiency. VTT TIEDOTTEITA – RESEARCH NOTES 2581. ISSN 1455-0865 https://www.vtt.fi/inf/pdf/tiedotteet/2011/T2581.pdf

Gan, J.B. and Smith, C.T. 2011. Drivers for renewable energy: a comparison among OECD countries. Biomass and Bioenergy, Vol. 35, No. 11, 4497–4503.

Hagen K. D. *Introduction to Renewable Energy for Engineers*. 2016. Weber State University. ISBN-13: 978-0133360868.

Heal G. 2010. Reflections – The Economics of Renewable Energy in the United States // *Review of Environmental Economics and Policy, Winter*. Vol. 4. 1. 139–154.

International Energy Agency. 2015. *Energy and Climate Change*. IEA Publications. Paris: Cedex. P. 446. ISSN: 2074-3974. https://www.iea.org/publications/freepublications / publication/WEO2015 Special Reporton Energyand Change.pdf

John S. *Sustainable Biomass: A Systems View*. 2004. USDOE/NASULGC Biomass and Solar Energy Workshops

John S. *Sustainable Biomass: A Systems View*. 2004. USDOE/NASULGC Biomass and Solar Energy Workshops

Law of Energy No. IX-884. 2002. https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.167899

Lietuvos Respublikos atsinaujinančių išteklių energetikos įstatymas. Lietuvos Respublikos Seimas, 2011 m. gegužės 12 d. Nr. XI-1375. https://www.e-tar.lt/portal/lt/legal Act/TAR.FC7 AB69BE291 /pPk MV Hzker

Lund H. *Renewable Energy Systems: The Choice and Modeling of 100% Renewable Solutions*. Amsterdam, Boston (Mass.): Elsevier. 2010. P. 275. ISSN 2283-9216.

Lund H. *Renewable Energy Systems: The Choice and Modeling of 100% Renewable Solutions*. Amsterdam, Boston (Mass.): Elsevier. 2010, 275. ISSN 2283-9216.

Ma L., Li Z., Fu F., Zhang X., Ni W. 2009. Alternative energy development strategies for China towards 2030. *Frinties of Energy and Power Engineering in China,* Vol. 3. No. 1, 2–10. ISSN 1673-7393.

Maradin, D., Cerović, L., Mjeda, T. 2017. Economic Effects of Renewable Energy Technologies. Our economy, Vol. 63, no. 2, 49-59.

Marčiukaitis M., Dzenajavičienė E. F, Kveselis V., Savickas J., Perednis E., Lisauskas A., Markevičius A., Marcinauskas K., Gecevičius G., Erlickytė-Marčiukaitienė R. Atsinaujinančių energijos išteklių naudojimo Lietuvoje patirtis, reikšmė ir siekiai. *Energetika*. 2016. T. 62. Nr. 4. P. 247–267. ISSN 0235-7208.

Miškinis V., Galinis A., Konstantinavičiūtė I., Lekavičius V. 2014. Energijos vartojimo Lietuvoje ir ES šalyse tendencijos. Energetika, T.60. Nr.2, P. 96-112.

Oguz, O., Aslan, A. 2013. Renewable energy consumption–economic growth nexus in Turkey. Renewable and Sustainable Energy Reviews, Vol. 28, 494-499.

REY (Renewable Energy Yearbook). 2016. http://www.taastuvenergeetika.ee/wp-content/ uploads/ 2017/08 / Renewable-energy-yearbook_2016.pdf

Soava, G., Mehedintu, A., Sterpu, M., Raduteanu, M. (2018). Impact of renewable energy consumption on economic growth: evidence from European Union countries. Technological and Economic Development of Economy, Vol. 24, 3, 914–932. ISSN 2029-4913

Štreimikienė D. Wadim A. Strielkowski B, Bilan Y. C, Mikalauskas I. 2016. Energy dependency and sustainable regional development in the Baltic States - a review. *Geographica Pannonica,* Vol.20, Issue 2, 79-87.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data*. The MIT Press Cambridge, Massachusetts London, England. http://www.ipc-undp.org /evaluation /apoio / Wooldridge%20-%20Cross-section%20and%20Panel%20Data.pdf

13. Electricity Access Thresholds for Meeting Non-Energy SDG Targets

Robert Brecha

ABSTRACT:
Access to sufficient amounts of energy is a prerequisite for development of human well-being. Analysis presented in this paper shows that multiple sustainable development targets are linked to per capita access to electricity in particular and demonstrate a threshold behavior below which sustainable development targets have not been met historically. The present work relates to the broad literature on the Sustainable Development Goals (SDGs), recognizing the interconnectedness of energy access (SDG7) and other development goals. Although targets are provided for each of the 17 goals, not all targets are quantified, leaving room for ambiguity in fulfilling, for example, the goal of "ensuring access to affordable, reliable, sustainable and modern energy for all." The focus of this work is an extension of our finding that a per capita societal electricity consumption thresholds of about 400kWh is strongly related to meeting outcomes for health indicators related specifically to SDG targets. In this contribution we further examine this quantitative relationship between electricity access as correlated with education, sanitation, food security and health outcomes, posing the question in the form, "Below what minimum societal per capita access to electricity is a country very unlikely to meet SDG targets?"

Keywords: Electricity access; energy; SDG; health; education; sanitation; food security

Dr. Robert Brecha is visiting scientist at the Berlin think tank Climate Analytics, supported by a EU Marie Skłodowska Curie Fellowship. Since 1993 he has been at the University of Dayton (Ohio, USA) where he is Professor of Physics and of Renewable and Clean Energy Program, and was founding coordinator of the Sustainability, Energy and the Environment (SEE) initiative from 2007 - 2015. From 2006-2017 he was a regular visiting scientist at the Potsdam Institute for Climate Impact Research (PIK) in Germany, including one year as a Fulbright Fellow (2010-2011). From Janary – December 2018 he was a visiting scientist at Climate Analytics as and from June –December 2018 served as Acting Head of Energy System Modeling. His research publications focus on energy efficiency in buildings, climate change mitigation strategies, and energy needs for sustainable development.

1. Introduction

Energy access plays a key role in economic and human development, as exemplified in Sustainable Development Goal (SDG) 7: "ensure access to affordable, reliable, sustainable and modern energy for all." At the same time, it is recognized that access to energy is not an end in itself, but rather that there are important links between access to sustainable modern energy and the achievement of other SDGs. There is a large literature on both requisite levels of energy access (Krugman and Goldemberg 1983; Goldemberg et al. 1985; Sathaye et al. 2011; S Pachauri et al. 2012; Nussbaumer, Bazilian, and Modi 2012; Bhatia and Angelou 2015; Rao and Pachauri 2017; Pelz, Pachauri, and Groh 2018; Jain and Shahidi 2019), especially at the household level (Shonali Pachauri and Spreng 2002; S. Pachauri et al. 2004; Shonali Pachauri et al. 2013; Groh, Pachauri, and Rao 2016), as well as a growing literature on SDG synergies (and less commonly, mutual barriers) (Collste, Pedercini, and Cornell 2017; Weitz et al. 2017; Taylor et al. 2017; McCollum et al. 2018).

In this paper we go beyond the qualitative linkages between energy access and other SDGs and look at development indicator data for most countries, examining how specific levels of average per capita annual energy (or electricity) consumption is correlated with achieving specific SDG quantitative targets.

2. Energy Access and Human Development

The Human Development Index (HDI) is one measure of average quality of life for a country (UNDP 2016). Expressed on a scale between 0 and 1, the HDI is a composite index of economic wealth, education, and health indicators. Human Development Index data from the United Nations Development Programme form part of the Human Development Report published each year. Data for both the overall index as well as for the individual components are publicly available (at http://hdr.undp.org/en/content/human-development-index-hdi). For the present work, chosen years for the HDI are matched to the years for which energy data are available, usually 2014. A plot of HDI values vs. final energy consumption per person (IEA 2016) as shown in Fig. 1 results in a characteristic trend toward higher levels of HDI with greater energy consumption, at least for lower levels of HDI. Beyond a certain level (greater than an HDI of about 0.8 and final energy consumption of 50GJ per capita annually), however, increased energy consumption does not correlate with an increase in well-being. The diamonds in Fig. 1 represent a snapshot of HDI values in the year 2014 for 142 countries for which both HDI and final energy data were available. The United Nations Development Programme considered ranges of human development (2014): <0.55, low (12% of world population); 0.55-0.70, medium (37%); 0.70-0.80, high (31%); >0.80, very high (20%).

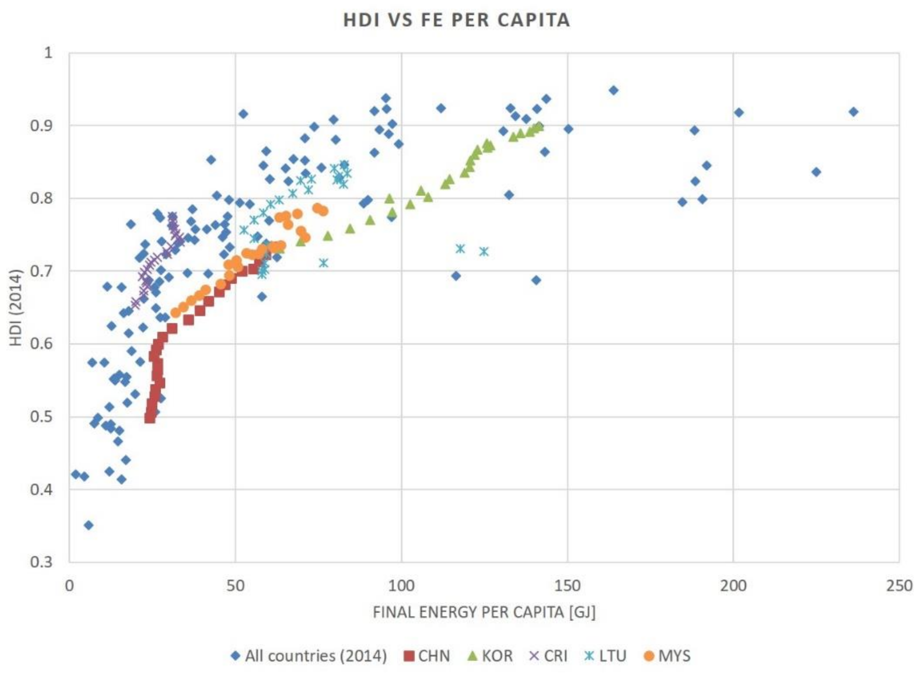


Figure 1 - Human Development Index as a function of per capita final (i.e. useful) energy. The diamonds are a snapshot of all countries with available data in the year 2014. The other series are for selected individual countries in one-year steps from 1990 to 2014. Individual countries are China, Korea, Costa Rica, Lithuania and Malaysia. Sources of data: UN Development Programme, http://hdr.undp.org/en/content/human-development-index-hdi and International Energy Agency, http://wds.iea.org/wds/ReportFolders/ReportFolders.aspx?CS_referer=&CS_ChosenLang=en and World Bank, World Data Indicators, http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators#

The low-energy, low-HDI end of the scale is most crucial, and leads to the framing we use in what follows. No country at a "very high" level of HDI (above 0.8) has an average availability of final energy of less than 40 GJ per person per year[17]. (In the US, final energy consumption is approximately 200GJ.) Furthermore, we can look at these data to see how several individual countries develop over time (represented by the time series of symbols from 1990-2014), and find that they follow a path that moves through stages represented by the snapshot of countries today, tracking from the lower left toward the upper right of the plot.

3. HDI and Electricity Consumption

We further narrow our focus to electricity, as the most modern and flexible of energy sources, and examine individual components of the HDI (GDP, life expectancy, years of schooling). The relationship between the Human Development Index (HDI) and per capita electricity consumption is shown in Fig. 2. Data for 172 countries are shown in Fig. 2a, representing about 97% of the world's population for which data on both HDI (vertical axis) and per capita electricity consumption (kWh per person per year, horizontal axis) are available for the year 2014[18]. From Fig. 2b, it appears that achieving an HDI of greater than 0.7 is inconsistent with having per capita electrification of less than 1000 kWh annually. This set of countries represents about 42% of the world's country population. Looking even further (Fig. 2c), countries with greater than 400 kWh per capita are likely to have an HDI >0.55, and those with access less than ~400kWh/capita all have an HDI of <0.6 (Fig. 2d). It is these countries that are the focus of this paper. We choose the value of 400 kWh as a marker based not only on this observation of data, but also on previous work we have done looking at achievement of SDG numerical targets for health indicators (Brecha 2019). Approximately 15% of the world's population lives in countries with access to less than an average of 400 kWh per capita, representing at least one billion people.

---

[17] In energy units, 40 GJ is approximately 11,000 kWh, or one "tonne of oil equivalent (toe)". An average power of 1kW is equivalent to an annual energy consumption 8760 kWh. To the level of precision needed here, we can consider 40GJ per capita and 1 toe and 1kW to all be equivalent expressions for the same level of energy access.

[18] Wealthy countries, as represented by the Organization for Economic Cooperation and Development (OECD) have per capita annual electricity consumption of >5000 kWh, with an average of over 8000 kWh/person/year, with the United States at more than 12,000kWh/person/year (average value including all sectors of the economy)

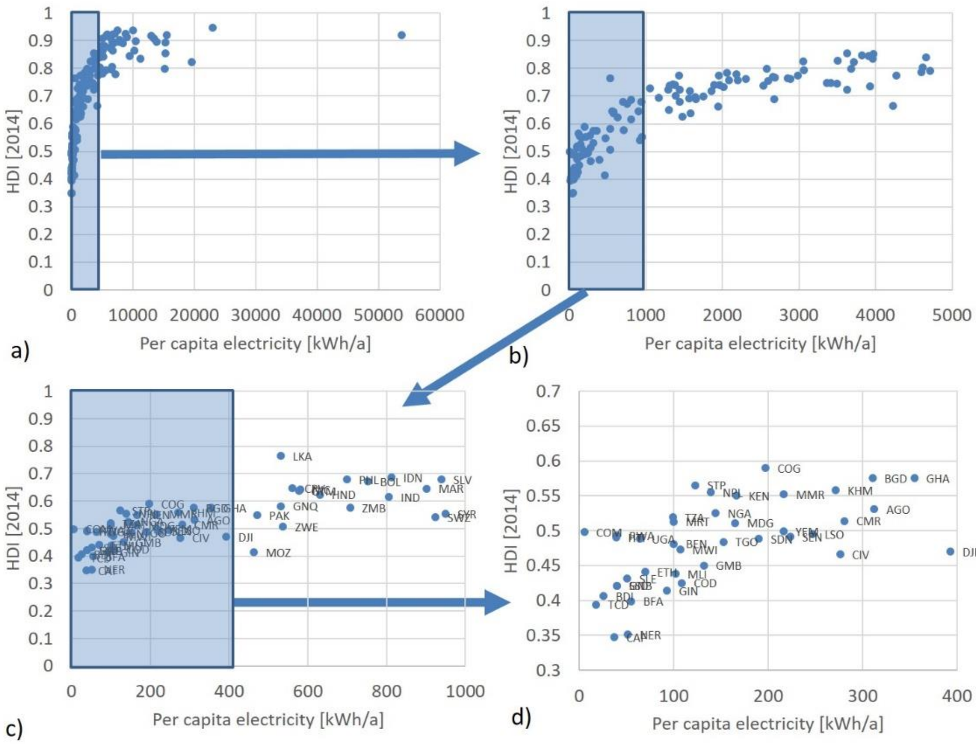


Figure 2 - Human Development Index as a function of per capita electricity consumption in kWh per year [kWh/a]. Each point represents one country with data from 2014. Source: World Development Indicators, http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators# and http://hdr.undp.org/en/content/human-development-index-hdi

4. Education, Health, Wealth, and Life Expectancy

One component of the HDI is mean years of schooling. Access to education is also addressed by SDG 4, to "ensure inclusive and quality education for all and promote lifelong learning" (UN General Assembly 2015), with targets involving universal access, literacy and numeracy, and appropriate facilities. Fig. 3a shows histograms for mean years of schooling (UNDP 2016), with different country groups divided by per capita electricity consumption (World Bank 2017). No country with electricity access lower than 400 kWh per capita has more than primary school education levels on average. In contrast, countries with greater than 400kWh of per capita average annual electricity consumption are very unlikely to average less than nearly eight years of schooling (Education Index of 0.6-0.7). Given that one specific target for SDG 4 is "By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education," it appears that only countries with more than at least 400 kWh of per capita annual electricity consumption meet that target.

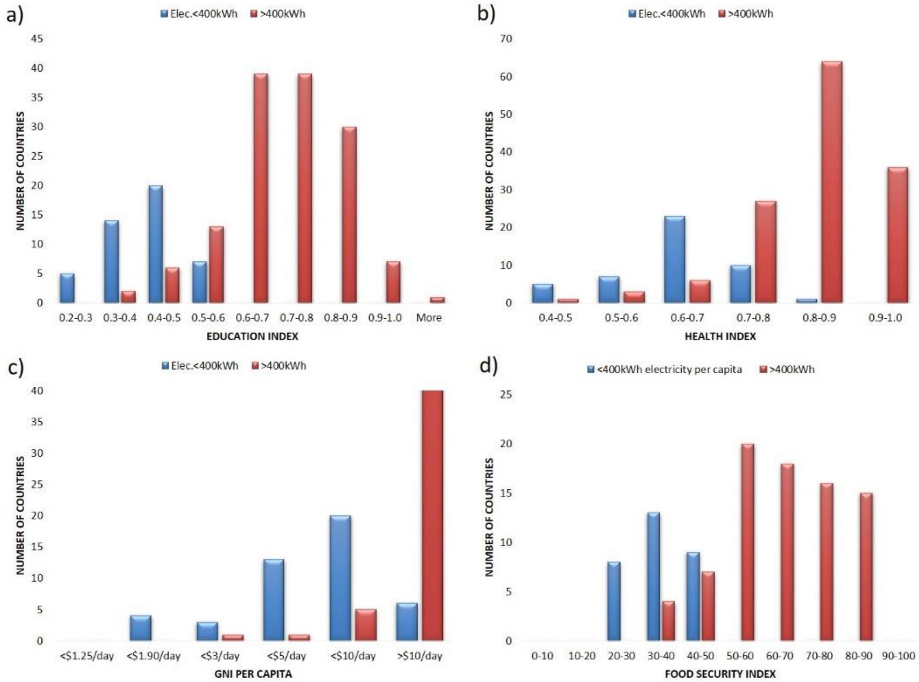


Figure 3 – a) Education index (mean and expected years of schooling) for different electricity consumption ranges. b) Histogram of the number of countries with different ranges of life expectancy at birth. c) Per capita Gross National Income (GNI) for different electricity consumption groups. d) Global Food Security index for 111 countries. Countries are grouped by how much electricity is consumed on average per capita per year. Groups of countries are those with <400kWh per capita average annual consumption (blue bars), and those with >400kWh (red bars). Data from UNDP, http://hdr.undp.org/en/data, for food security, from http://foodsecurityindex.eiu.com/.

In Fig. 3b the world is again divided into countries that have, on average, access to either less than or more than 400kWh/person/year. If a country has access to less than 400kWh of electricity per person, it is highly likely that the average life expectancy at birth is greater than 70 years. Average life expectancy at birth is between 70-85 years for those with higher electricity access. In addition to being a component of HDI, life expectancy links energy access to SDG3, "Ensure healthy lives and promote well-being for all at all ages." Our previous work has made this linkage more explicit and forms the basis for the threshold electricity consumption level used here. (Brecha 2019)

Fig. 3c is a histogram of the different electricity-consumption groups, each divided into bins corresponding to different per capita incomes. Of countries with per capita GNI corresponding to less than $5/day (more than twice the poverty definition of $1.90/day), 90% have average per capita electricity consumption under 400kWh/year. Conversely, of those countries with per capita GNI greater than $10/day, only 5% have <400kWh/year electricity consumption. The GNI measure also corresponds to an augmented version of SDG1, to "end poverty in all its forms, everywhere" (UN General Assembly 2015). For comparison, Italy has a GNI per capita of ~$100/day, the United States about 50% more than that.

As another example, SDG 2 calls for the world to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture," with targets to "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round" and "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons." One way to expressing these targets is in terms of the Global Food Security Index[19] an aggregate index on a scale of 0-100, with components of availability, affordability and quality, the familiar pattern from other development indicators appears. We see in Fig. 3d that no country with less than 400kWh per capita electricity consumption achieves a food security index value of >50, whereas those countries with higher per capita electricity consumption are very unlikely to have a low food security index (under 50).

5. Energy Requirements for All Those with Less than 400 kWh per Capita Average Societal Access

The population in 2015 for those countries with less than 400kWh per capita electricity consumption is 920 million. The UN projects in its "medium variant" scenario an increase in population to 1.6 billion in 2030 for these same countries (UN Dept of Economic and Social Affairs 2017). Countries currently with less than 400 kWh per capita electricity consumption have an average of about 170kWh per capita, so total electricity consumption for the 920 million people in these countries is 160 billion kWh (160 TWh or Terrawatt-hours) as shown in Fig. 4 where curve a) is a plot of cumulative electricity consumption as a function of cumulative total population ends at the point (920[million], 160[TWh]). Taking as a target that each of these countries should have an average per capita electricity consumption of 400kWh by 2030 leads to curve b) in Fig. 4, which shows for this simplified example a total consumption of 640 TWh, representing a compounded annual growth rate of 9.3%/year. Curve c) in Fig. 4 is simply the 9.3% yearly exponential increase in per capita electricity consumption from its current level to the target level in the year 2030, with population instead of time as the abscissa.

The International Energy Agency (IEA) in its 2017 World Energy Outlook Special Report on Energy Access (IEA 2017) focuses mainly on household electricity (and cooking energy) access, while acknowledging the importance of access to modern sources of energy for productive needs such as the services discussed above. The "Energy for All" scenario looks at providing access at the initial level of 250 kWh per rural household (and 500 kWh for urban households) with a gradual increase thereafter, such that universal access is achieved by 2030. Compared to the baseline "New Policies Scenario" the more ambitious scenario results in additional demand of 119 TWh of electricity demand by 2030, at an additional cumulative investment cost of $391 billion, or an average of $28 billion per year. The latter represents 1.7% of annual global energy system investments. (IEA 2017)

[19] http://foodsecurityindex.eiu.com/

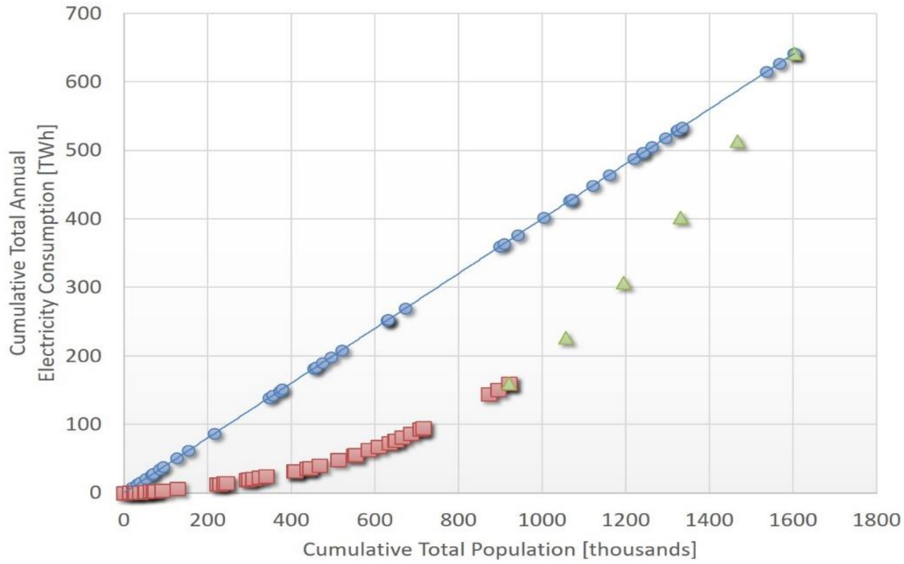


Figure 4 - Cumulative electricity consumption as a function of cumulative population for all countries with <400kWh per capita average annual consumption.

Furthermore, the additional access to electricity for 674 million people by 2030 compared to the New Policy Scenario implies approximately 175 kWh per capita per year access. For the example we have given above, and current consumption levels across the energy-poor countries, approximately two times as much would be needed to satisfy the goal of reaching 400 kWh per capita electricity availability. The IEA estimates from their modeling that additional investments of $391 billion are necessary for their goal; a rough extrapolation would double this to $800 billion in cumulative investments by 2030, or ~$60 billion per year, representing approximately 3.5% of global investment in energy systems. (IEA 2017)

6. Discussion

Countries with average per capita electricity consumption of less than 400kWh per year have uniformly poor human development indicators, and few if any at this level of consumption meet SDG targets for health, wealth, education, sanitation or food security. On the other hand, this can be expressed by stating, from the same data, that there are relatively few countries with average electricity access of >400kWh per capita that have an average number of years of education less than eight, or life expectancy at birth of less than 70 years, or high mortality rates for women, infants or young children. For reference, 400 kWh per capita is approximately one-fifth the level of electricity use in the US in 1950; the SDG indicators for life expectancy and average educational attainment are roughly those for the US at that time as well. If it is possible to achieve society-wide targets at lower levels of electricity consumption, then it must be shown how that is to be accomplished. For example, efficient appliances and lighting may contribute to lowering the bar for energy-related indicators. It is also clear that energy access must

be planned and implemented in a systemic fashion so that household and productive uses are addressed effectively; in that sense, it is also important to consider SDGs that support the goals and targets discussed here: SDG 9 - Industry, Innovation and Infrastructure; SDG 16 - Peace, Justice and Strong Institutions; and SDG 17 - Partnership for the Goals. One possible objection to this analysis is that electricity access has been chosen as the independent variable, but that other variables could have been chosen. In other words, energy access might be just a proxy for "wealth" or GNI/capita. In fact, the two are closely related. Interestingly, the threshold behavior identified in our previous work (Brecha 2019), from which we derive the per capita consumption level of approximately 400kWh used in the present analysis, is not as evident as a function of GDP as it is in terms of electricity access. Additionally, it is possible to construct causal chains showing that it truly is energy access that is a key to achieving these (and possibly other) SDGs, and not just increase in wealth. Although there is the potential for conflicts between SDGs (Stechow et al. 2016; McCollum et al. 2018; Nilsson, Griggs, and Visbeck 2016; Weitz et al. 2017) clear connections have been made by others between access to electricity in support of achieving other goals (McCollum et al. 2018).
In Table 1 we compile linkages between the SDGs considered in this paper and access to electricity (and more broadly, other modern energy sources). The examples here are mainly based on McCollum et al. In that work, there are also potential negative aspects of energy access, depending on the particular sources used; here we are concerned mainly with the implications for having access to enough electricity (and at the relatively low levels correlated with achieving SDG targets).

Table 1 - Summary of key synergies between access to electricity and other SDGs, focusing on the causal connections

SDG 1 - Poverty	SDG 2 - Hunger	SDG 3 - Health	SDG 4 - Education	SDG 6 – Water and Sanitation
Modern energy (electricity) fundamental for development	Energy access can help reduce post-harvest losses	Electricity allows storage of medicine and vaccines	Lighting allows more opportunity for studying at home	Electricity can allow access to pumping for safer drinking water
Access to electricity (and other modern energy) frees up time and other resources	Food preservation improved by access to electricity	Improved lighting and equipment power in clinics	Electricity in schools provides better lighting and information technology access	Electricity access will allow for desalination to enhance scarce water resources
		Better food preservation contributes to better health outcomes		Power needed for water treatment

In conclusion, access to modern energy systems, and primarily to electricity, is strongly linked to being able to achieve targets set for many Sustainable Development Goals. Although gains in efficiency in the future as well as some geographical and country-specific factors may affect the exact level of consumption, we have shown here that below a societal level of 400 kWh per capita annually, very few countries have been able to meet SDG targets. Furthermore, even this relatively meager amount of electricity is higher than what is projected for 2030 in international modeling efforts. Therefore, either higher levels of electricity access must be assumed for models to be consistent with the SDGs, or else it is necessary to demonstrate how the SDGs can be achieved without that level of access to modern energy.

7. Appendix: Data Sources

Human Development Index data are from the United Nations Development Programme as part of the Human Development Report published each years. Data for both the overall index as well as for the individual components are available at http://hdr.undp.org/en/content/human-development-index-hdi. For the present work, chosen years for the HDI are matched to the years for which energy data are available, usually 2014.

Specific data sets used are:

Human Development Index (HDI)	http://hdr.undp.org/en/indicators/137506	S1, S2
Life expectancy at birth	http://hdr.undp.org/en/indicators/69206	S4
Mean years of schooling	http://hdr.undp.org/en/indicators/103006	1
Gross national income (GNI) per capita	http://hdr.undp.org/en/indicators/141706	
Final energy use [GJ]	IEA Energy Balances	S1

Data for other indicators are taken from the World Bank database of World Development Indicators (WDI) that can be found at https://data.worldbank.org/indicator. Specific indicators used here are:

Indicator name	Indicator code	Fig.
Electric power consumption (kWh per capita)	EG.USE.ELEC.KH.PC	S2
Energy use (kg of oil equivalent per capita)	EG.USE.PCAP.KG.OE	
GDP per capita, PPP (constant 2011 international $)	NY.GDP.PCAP.PP.KD	S3
Maternal mortality ratio (modeled estimate, per 100,000 live births)	SH.STA.MMRT	2a
Mortality rate, under-5 (per 1,000 live births)	SH.DYN.MORT	2c
Mortality rate, neonatal (per 1,000 live births)	SH.DYN.NMRT	2b
Life expectancy at birth, total (years)	SP.DYN.LE00.IN	
Access to clean fuels and technologies for cooking (% of population)	EG.CFT.ACCS.ZS	
Improved sanitation facilities (% of population with access)	SH.STA.ACSN	2d
Population, total	SP.POP.TOTL	

Population data, both current and projected increases, are taken from the United Nations World Population Prospects 2015 update, POP/DB/WPP/Rev.2015/POP/F01-1.

For many African countries, the WDI database does not include per capita electricity consumption. To fill in these gaps, the United Nations Environment Programme *Atlas of Africa Energy Resources* was used (UNEP 2017) as were data from the United States Energy Information Administration (https://www.eia.gov/).

References

Bhatia, M, and N Angelou. 2015. "Beyond Connections - Energy Access Redefined." Technical report 008/15.

Brecha, R.J. 2019. "Threshold Electricity Consumption Enables Multiple Sustainable Development Goals." *Submitted to Nature Sustainability*.

Collste, David, Matteo Pedercini, and Sarah E. Cornell. 2017. "Policy Coherence to Achieve the SDGs: Using Integrated Simulation Models to Assess Effective Policies." *Sustainability Science*, July. https://doi.org/10.1007/s11625-017-0457-x.

Goldemberg, T.B. Johansson, A.K.N. Reddy, and R Williams. 1985. "Basic Needs and Much More with One Kilowatt per Capita." *Ambio*, 1985.

Groh, Sebastian, Shonali Pachauri, and Narasimha D. Rao. 2016. "What Are We Measuring? An Empirical Analysis of Household Electricity Access Metrics in Rural Bangladesh." *Energy for Sustainable Development* 30 (February): 21–31. https://doi.org/10.1016/j.esd.2015.10.007.

IEA. 2012. *Energy Balances of Non-OECD Countries - 2012 Edition*. International Energy Agency, Paris.

———. 2017. "World Energy Outlook Special Report on Energy Access." International Energy Agency.

Jain, Abhishek, and Tauseef Shahidi. 2019. "Guiding Action: A User Centric Approach to Define, Measure and Manage Electricity Acces." *Economics of Energy & Environmental Policy* 8 (1): 19–32.

Krugman, H., and J Goldemberg. 1983. "The Energy Cost of Satisfying Basic Human Needs." *Technological Forecasting and Social Change*, 1983.

McCollum, David L, Luis Gomez Echeverri, Sebastian Busch, Shonali Pachauri, Simon Parkinson, Joeri Rogelj, Volker Krey, et al. 2018. "Connecting the Sustainable Development Goals by Their Energy Inter-Linkages." *Environmental Research Letters* 13 (3): 033006. https://doi.org/10.1088/1748-9326/aaafe3.

Nilsson, Måns, Dave Griggs, and Martin Visbeck. 2016. "Map the Interactions between Sustainable Development Goals." *Nature* 534 (June): 320–22.

Nussbaumer, Patrick, Morgan Bazilian, and Vijay Modi. 2012. "Measuring Energy Poverty: Focusing on What Matters." *Renewable and Sustainable Energy Reviews* 16 (1): 231–43. https://doi.org/10.1016/j.rser.2011.07.150.

Pachauri, S, A Brew-Hammond, Douglas F. Barnes, D.H. Bouille, S Gitonga, V Modi, G Prasad, A Rath, and H Zerriffi. 2012. "Chap. 19 - Energy Access for Development." In *Global Energy Assessment—Toward a Sustainable Future*, 1401–58. Cambridge: Cambridge University Press and International Institute for Applied Systems Analysis.

Pachauri, S., A. Mueller, A. Kemmler, and D. Spreng. 2004. "On Measuring Energy Poverty in Indian Households." *World Development* 32 (12): 2083–2104. https://doi.org/10.1016/j.worlddev.2004.08.005.

Pachauri, Shonali, Bas J van Ruijven, Yu Nagai, Keywan Riahi, Detlef P van Vuuren, Abeeku Brew-Hammond, and Nebojsa Nakicenovic. 2013. "Pathways to Achieve Universal Household Access to Modern Energy by 2030." *Environmental Research Letters* 8 (2): 024015. https://doi.org/10.1088/1748-9326/8/2/024015.

Pachauri, Shonali, and Daniel Spreng. 2002. "Direct and Indirect Energy Requirements of Households in India." *Energy Policy* 30 (6): 511–23.

Pelz, Setu, Shonali Pachauri, and Sebastian Groh. 2018. "A Critical Review of Modern Approaches for Multidimensional Energy Poverty Measurement." *Wiley Interdisciplinary Reviews: Energy and Environment* 7 (6): e304. https://doi.org/10.1002/wene.304.

Rao, Narasimha D, and Shonali Pachauri. 2017. "Energy Access and Living Standards: Some Observations on Recent Trends." *Environmental Research Letters* 12 (2): 025011. https://doi.org/10.1088/1748-9326/aa5b0d.

Sathaye, Jayant, Oswaldo Lucon, Atiq Rahman, John Christensen, Fatima Denton, Junichi Fujino, Garvin Heath, et al. 2011. "Renewable Energy in the Context of Sustainable Development." In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C.von Stechow (Eds)]*. Cambridge, UK, and New York, NY, USA: Cambridge University Press. https://ipcc.ch/pdf/special-reports/srren/Chapter%209%20Renewable%20Energy%20in%20the%20Context%20of%20Sustainable%20Development.pdf.

Stechow, Christoph von, Jan C. Minx, Keywan Riahi, Jessica Jewell, David L. McCollum, Max W. Callaghan, Christoph Bertram, Gunnar Luderer, and Giovanni Baiocchi. 2016. "2 °C and SDGs: United They Stand, Divided They Fall?" *Environmental Research Letters* 11 (3): 034022. https://doi.org/10.1088/1748-9326/11/3/034022.

Taylor, Peter G., Kathleen Abdalla, Roberta Quadrelli, and Ivan Vera. 2017. "Better Energy Indicators for Sustainable Development." *Nature Energy* 2 (8): 17117. https://doi.org/10.1038/nenergy.2017.117.

UN Dept of Economic and Social Affairs. 2017. "World Population Prospects 2017." 2017. https://esa.un.org/unpd/wpp/.

UN General Assembly. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjZ-7PBusnRAhXEyyYKHakDAKcQFggsMAE&url=http%3A%2F%2F www.un.org%2Fsustainabledevelopment%2Fdevelopment-agenda%2F&usg=AFQjCNHsy UhLC3HVpbu5w-C-YGkRRxPc2Q&sig2=kJReLwsoSiwm_A94lwWYRw.

UNDP, ed. 2016. *Human Development for Everyone*. Human Development Report 2016. New York, NY: United Nations Development Programme.

UNEP. 2017. *Atlas of Africa Energy Resources*. Nairobi, Kenya: United Nations Environment Programme. http://hdl.handle.net/20.500.11822/20476.

Weitz, Nina, Henrik Carlsen, Måns Nilsson, and Kristian Skånberg. 2017. "Towards Systemic and Contextual Priority Setting for Implementing the 2030 Agenda." *Sustainability Science*, September. https://doi.org/10.1007/s11625-017-0470-0.

World Bank. 2017. "World Development Indicators." Database. World Development Indicators. 2017. https://data.worldbank.org/data-catalog/world-development-indicators.

14. Integrating Energy Markets in the Wider Europe - The Eastern Dimension

Afroditi Semkou, Elias Andreadis, Elias Kolovos

ABSTRACT:
This paper is to examine the extent of integration between the regional energy markets of the Member States of the European Union and the countries of the wider Europe with special attention to the Eastern Partnership. Therefore, whether the aforementioned energy markets are in a position to conform to the acquis communautaire and ensure the security of energy supply to the EU in affordable prices. We will record what needs to be done for the integration of these regional energy markets with the EU common market and specifically: (a) the legal framework of the Eastern European non-EU regional energy markets, from the perspective of energy, trade and free competition. The impediments integration is facing and under which circumstances can it be achieved. (B) The required infrastructure and connectivity networks necessary to be completed in order to allow the utilization of the energy reserves in the third countries and the network connection of these third countries with the EU. The designated Trans European Network Strategy regarding the sectors of electricity, natural gas, oil and the Projects of Common Interest currently being constructed in Eastern Europe. (C) The promotion of investments that needs to be carried out in the wider European countries in order to ensure security of energy supply of the EU in the long term. The various forms of cooperation agreements between Georgia, Moldova, Ukraine, Armenia, Belarus and Azerbaijan with the EU and their contribution to the promotion of energy investments and the interconnection of cooperation agreements with the Energy Community.

Keywords: EU, Eastern Europe, Free Trade Agreements, Infrastructure, TEN – E, PCI, Promotion of Investments

Afroditi Semkou is an Attorney-at-Law and a PhD Candidate, who studied law in the Aristotle University of Thessaloniki, then acquired an LL.M from the International Hellenic University, School of Business Adminitration and Legal Studies, in the field of Transnational and European Commercial Law, Mediation, Arbitration and Energy Law and is now a PHD Candidate of the Aristotle University Thessaloniki, School of Law, Measures distorting competition in the energy sector". Afroditi Semkou has worked as an academic assistant of the Aristotle University of Thessaloniki, specifically assisting the MSc Law & Engineering for Energy. She has published a Comment on C-429/2014 European Court of Justice Case, titled as Damages due to passenger delay in the context of carriage by airplane, Monthly Legal Magazine on Applications of Civil & Civil Procedural Law, Publication 10/2016, p. 888-896, Publication: Nomiki Bibliothiki and she has participated in (1) 2nd Energy Union Future Leaders Academy, hosted by the Greek Energy Forum and in (2) Energy Conference "Renewable Energy Sources & Markets of South-East Europe",hosted by the International Hellenic University with the participation of the National Regulatory Authority for Energy, Presentation Title: Recent Developments in Empowering Consumers within the markets of South-East Europe: from end-user to prosumer.

Elias Andreadis is an Attorney-at-Law and a PhD Candidate, who studied law in the Aristotle University of Thessaloniki, School of Law then acquired an LL.M from the Aristotle University of Thessaloniki, School of Law, Field of International Law and is now a PHD Candidate of the Aristotle University Thessaloniki, School of Law, on the topic «Contracting for international energy infrastructure projects». Elias is working for the UNCHR in Thessaloniki, Greece and has been the coach of The third globally awarded team of the Aristotle University of Thessaloniki in the 9th Frankfurt Investment Arbitration Moot Court – March 2015.

Elias Kolovos is an Attorney-at-Law and a PhD Candidate, who studied law in the Aristotle University of Thessaloniki, School of Law then acquired an LL.M from the Democritus University of Thrace, School of Law, Field of International Law and is now a PHD Candidate of the Aristotle University Thessaloniki, School of Law, on the topic Protection and expropriation measures regarding foreign investment in Free Trade Agreements.

1. Introduction

Energy access plays a key role in economic and human development, as exemplified in Sustainable Development Goal (SDG) 7: "ensure access to affordable, reliable, sustainable and modern energy for all." At the same time, it is recognized that access to energy is not an end in itself, but rather that there are important links between access to sustainable modern energy and the achievement of other SDGs. There is a large literature on both requisite levels of energy access (Krugman and Goldemberg 1983; Goldemberg et al. 1985; Sathaye et al. 2011; S Pachauri et al. 2012; Nussbaumer, Bazilian, and Modi 2012; Bhatia and Angelou 2015; Rao and Pachauri 2017; Pelz, Pachauri, and Groh 2018; Jain and Shahidi 2019), especially at the household level (Shonali Pachauri and Spreng 2002; S. Pachauri et al. 2004; Shonali Pachauri et al. 2013; Groh, Pachauri, and Rao 2016), as well as a growing literature on SDG synergies (and less commonly, mutual barriers) (Collste, Pedercini, and Cornell 2017; Weitz et al. 2017; Taylor et al. 2017; McCollum et al. 2018).

In this paper we go beyond the qualitative linkages between energy access and other SDGs and look at development indicator data for most countries, examining how specific levels of average per capita annual energy (or electricity) consumption is correlated with achieving specific SDG quantitative targets.

2. Energy Access and Human Development

The Human Development Index (HDI) is one measure of average quality of life for a country (UNDP 2016). Expressed on a scale between 0 and 1, the HDI is a composite index of economic wealth, education, and health indicators. Human Development Index data from the United Nations Development Programme form part of the Human Development Report published each year. Data for both the overall index as well as for the individual components are publicly available (at http://hdr.undp.org/en/content/human-development-index-hdi). For the present work, chosen years for the HDI are matched to the years for which energy data are available, usually 2014. A plot of HDI values vs. final energy consumption per person (IEA 2016) as shown in Fig. 1 results in a characteristic trend toward higher levels of HDI with greater energy consumption, at least for lower levels of HDI. Beyond a certain level (greater than an HDI of about 0.8 and final energy consumption of 50GJ per capita annually), however, increased energy consumption does not correlate with an increase in well-being. The diamonds in Fig. 1 represent a snapshot of HDI values in the year 2014 for 142 countries for which both HDI and final energy data were available. The United Nations Development Programme considered ranges of human development (2014): <0.55, low (12% of world population); 0.55-0.70, medium (37%); 0.70-0.80, high (31%); >0.80, very high (20%).

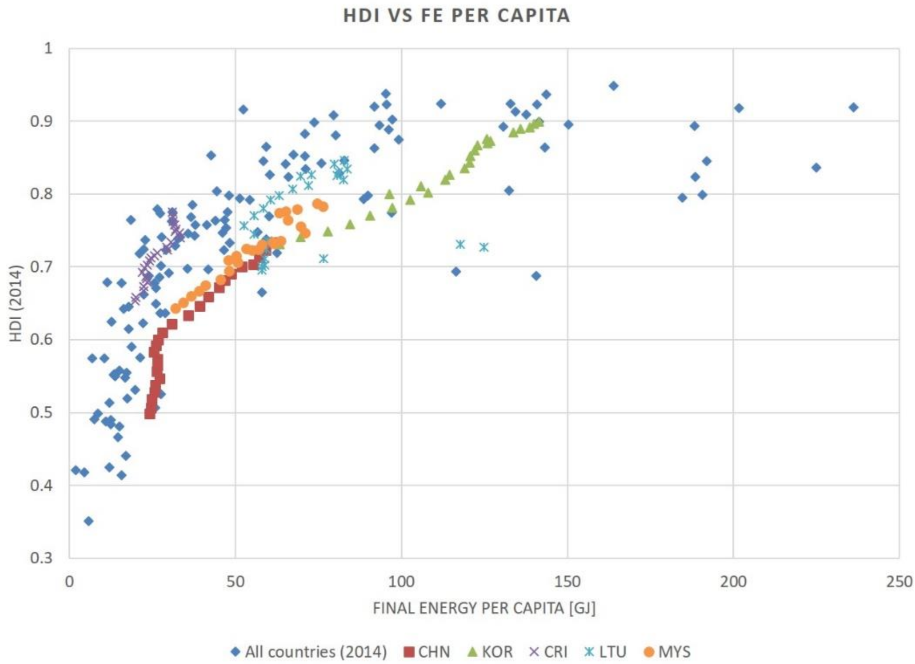


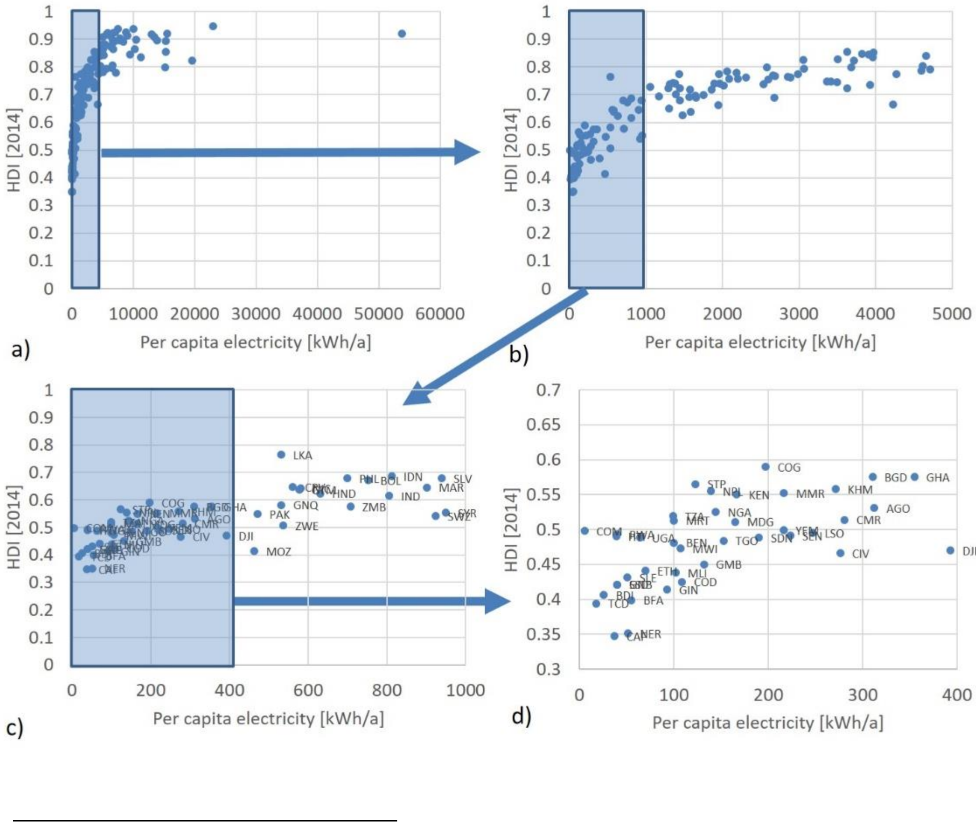
Figure 1 - Human Development Index as a function of per capita final (i.e. useful) energy. The diamonds are a snapshot of all countries with available data in the year 2014. The other series are for selected individual countries in one-year steps from 1990 to 2014. Individual countries are China, Korea, Costa Rica, Lithuania and Malaysia. Sources of data: UN Development Programme, http://hdr.undp.org/en/content/human-development-index-hdi and International Energy Agency, http://wds.iea.org/wds/ReportFolders/ReportFolders.aspx?CS_referer=&CS_ChosenLang=en and World Bank, World Data Indicators, http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators#

The low-energy, low-HDI end of the scale is most crucial, and leads to the framing we use in what follows. No country at a "very high" level of HDI (above 0.8) has an average availability of final energy of less than 40 GJ per person per year[20]. (In the US, final energy consumption is approximately 200GJ.) Furthermore, we can look at these data to see how several individual countries develop over time (represented by the time series of symbols from 1990-2014), and find that they follow a path that moves through stages represented by the snapshot of countries today, tracking from the lower left toward the upper right of the plot.

3. HDI and Electricity Consumption

[20] In energy units, 40 GJ is approximately 11,000 kWh, or one "tonne of oil equivalent (toe)". An average power of 1kW is equivalent to an annual energy consumption 8760 kWh. To the level of precision needed here, we can consider 40GJ per capita and 1 toe and 1kW to all be equivalent expressions for the same level of energy access.

We further narrow our focus to electricity, as the most modern and flexible of energy sources, and examine individual components of the HDI (GDP, life expectancy, years of schooling). The relationship between the Human Development Index (HDI) and per capita electricity consumption is shown in Fig. 2. Data for 172 countries are shown in Fig. 2a, representing about 97% of the world's population for which data on both HDI (vertical axis) and per capita electricity consumption (kWh per person per year, horizontal axis) are available for the year 2014[21]. From Fig. 2b, it appears that achieving an HDI of greater than 0.7 is inconsistent with having per capita electrification of less than 1000 kWh annually. This set of countries represents about 42% of the world's country population. Looking even further (Fig. 2c), countries with greater than 400 kWh per capita are likely to have an HDI >0.55, and those with access less than ~400kWh/capita all have an HDI of <0.6 (Fig. 2d). It is these countries that are the focus of this paper. We choose the value of 400 kWh as a marker based not only on this observation of data, but also on previous work we have done looking at achievement of SDG numerical targets for health indicators (Brecha 2019). Approximately 15% of the world's population lives in countries with access to less than an average of 400 kWh per capita, representing at least one billion people.



21 Wealthy countries, as represented by the Organization for Economic Cooperation and Development (OECD) have per capita annual electricity consumption of >5000 kWh, with an average of over 8000 kWh/person/year, with the United States at more than 12,000kWh/person/year (average value including all sectors of the economy)

Figure 2 - Human Development Index as a function of per capita electricity consumption in kWh per year [kWh/a]. Each point represents one country with data from 2014. Source: World Development Indicators, http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators# and http://hdr.undp.org/en/content/human-development-index-hdi

4. Education, Health, Wealth, and Life Expectancy

One component of the HDI is mean years of schooling. Access to education is also addressed by SDG 4, to "ensure inclusive and quality education for all and promote lifelong learning" (UN General Assembly 2015), with targets involving universal access, literacy and numeracy, and appropriate facilities. Fig. 3a shows histograms for mean years of schooling (UNDP 2016), with different country groups divided by per capita electricity consumption (World Bank 2017). No country with electricity access lower than 400 kWh per capita has more than primary school education levels on average. In contrast, countries with greater than 400kWh of per capita average annual electricity consumption are very unlikely to average less than nearly eight years of schooling (Education Index of 0.6-0.7). Given that one specific target for SDG 4 is "By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education," it appears that only countries with more than at least 400 kWh of per capita annual electricity consumption meet that target.

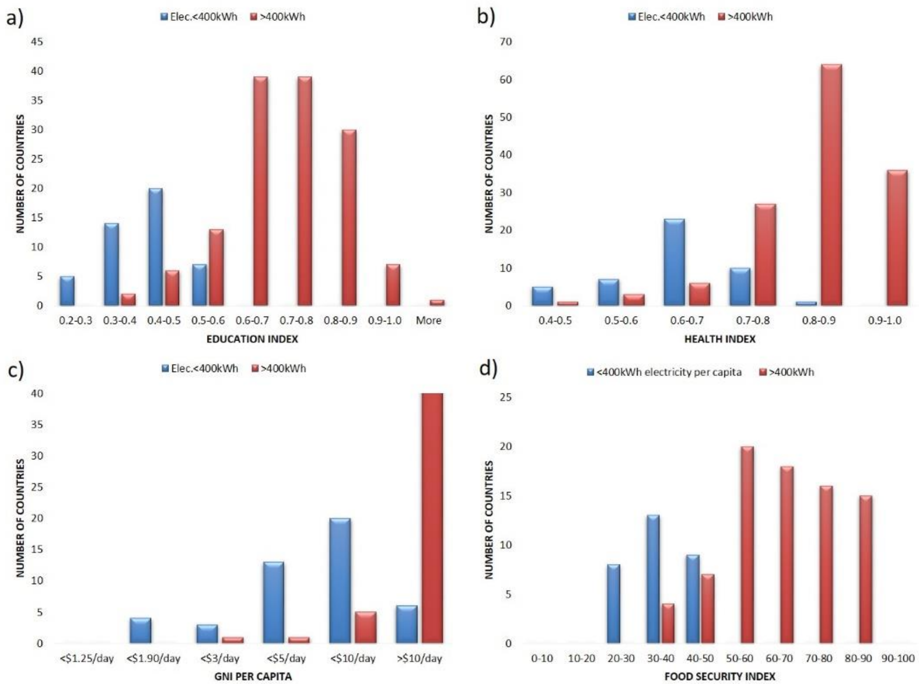


Figure 3 – a) Education index (mean and expected years of schooling) for different electricity consumption ranges. b) Histogram of the number of countries with different ranges of life

expectancy at birth. c) Per capita Gross National Income (GNI) for different electricity consumption groups. d) Global Food Security index for 111 countries. Countries are grouped by how much electricity is consumed on average per capita per year. Groups of countries are those with <400kWh per capita average annual consumption (blue bars), and those with >400kWh (red bars). Data from UNDP, http://hdr.undp.org/en/data, for food security, from http://foodsecurityindex.eiu.com/.

In Fig. 3b the world is again divided into countries that have, on average, access to either less than or more than 400kWh/person/year. If a country has access to less than 400kWh of electricity per person, it is highly likely that the average life expectancy at birth is greater than 70 years. Average life expectancy at birth is between 70-85 years for those with higher electricity access. In addition to being a component of HDI, life expectancy links energy access to SDG3, "Ensure healthy lives and promote well-being for all at all ages." Our previous work has made this linkage more explicit and forms the basis for the threshold electricity consumption level used here. (Brecha 2019)

Fig. 3c is a histogram of the different electricity-consumption groups, each divided into bins corresponding to different per capita incomes. Of countries with per capita GNI corresponding to less than $5/day (more than twice the poverty definition of $1.90/day), 90% have average per capita electricity consumption under 400kWh/year. Conversely, of those countries with per capita GNI greater than $10/day, only 5% have <400kWh/year electricity consumption. The GNI measure also corresponds to an augmented version of SDG1, to "end poverty in all its forms, everywhere" (UN General Assembly 2015). For comparison, Italy has a GNI per capita of ~$100/day, the United States about 50% more than that.

As another example, SDG 2 calls for the world to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture," with targets to "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round" and "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons." One way to expressing these targets is in terms of the Global Food Security Index[22] an aggregate index on a scale of 0-100, with components of availability, affordability and quality, the familiar pattern from other development indicators appears. We see in Fig. 3d that no country with less than 400kWh per capita electricity consumption achieves a food security index value of >50, whereas those countries with higher per capita electricity consumption are very unlikely to have a low food security index (under 50).

5. Energy Requirements for All Those with Less than 400 kWh per Capita Average Societal Access

The population in 2015 for those countries with less than 400kWh per capita electricity consumption is 920 million. The UN projects in its "medium variant" scenario

[22] http://foodsecurityindex.eiu.com/

an increase in population to 1.6 billion in 2030 for these same countries (UN Dept of Economic and Social Affairs 2017). Countries currently with less than 400 kWh per capita electricity consumption have an average of about 170kWh per capita, so total electricity consumption for the 920 million people in these countries is 160 billion kWh (160 TWh or Terrawatt-hours) as shown in Fig. 4 where curve a) is a plot of cumulative electricity consumption as a function of cumulative total population ends at the point (920[million], 160[TWh]). Taking as a target that each of these countries should have an average per capita electricity consumption of 400kWh by 2030 leads to curve b) in Fig. 4, which shows for this simplified example a total consumption of 640 TWh, representing a compounded annual growth rate of 9.3%/year. Curve c) in Fig. 4 is simply the 9.3% yearly exponential increase in per capita electricity consumption from its current level to the target level in the year 2030, with population instead of time as the abscissa.
The International Energy Agency (IEA) in its 2017 World Energy Outlook Special Report on Energy Access (IEA 2017) focuses mainly on household electricity (and cooking energy) access, while acknowledging the importance of access to modern sources of energy for productive needs such as the services discussed above. The "Energy for All" scenario looks at providing access at the initial level of 250 kWh per rural household (and 500 kWh for urban households) with a gradual increase thereafter, such that universal access is achieved by 2030. Compared to the baseline "New Policies Scenario" the more ambitious scenario results in additional demand of 119 TWh of electricity demand by 2030, at an additional cumulative investment cost of $391 billion, or an average of $28 billion per year. The latter represents 1.7% of annual global energy system investments. (IEA 2017)

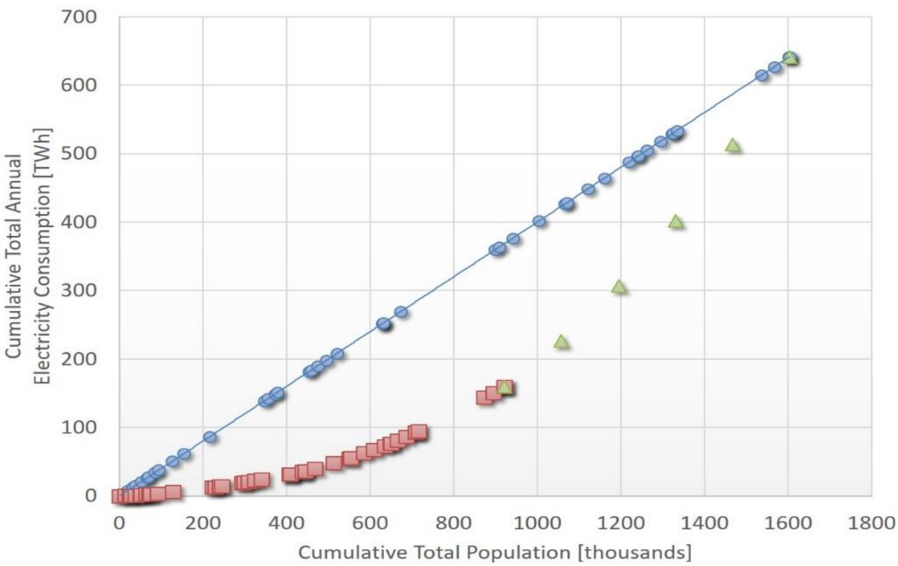


Figure 4 - Cumulative electricity consumption as a function of cumulative population for all countries with <400kWh per capita average annual consumption.

Furthermore, the additional access to electricity for 674 million people by 2030 compared to the New Policy Scenario implies approximately 175 kWh per capita per year access. For the example we have given above, and current consumption levels across the energy-poor countries, approximately two times as much would be needed to satisfy the goal of reaching 400 kWh per capita electricity availability. The IEA estimates from their modeling that additional investments of $391 billion are necessary for their goal; a rough extrapolation would double this to $800 billion in cumulative investments by 2030, or ~$60 billion per year, representing approximately 3.5% of global investment in energy systems. (IEA 2017)

6. Discussion

Countries with average per capita electricity consumption of less than 400kWh per year have uniformly poor human development indicators, and few if any at this level of consumption meet SDG targets for health, wealth, education, sanitation or food security. On the other hand, this can be expressed by stating, from the same data, that there are relatively few countries with average electricity access of >400kWh per capita that have an average number of years of education less than eight, or life expectancy at birth of less than 70 years, or high mortality rates for women, infants or young children. For reference, 400 kWh per capita is approximately one-fifth the level of electricity use in the US in 1950; the SDG indicators for life expectancy and average educational attainment are roughly those for the US at that time as well. If it is possible to achieve society-wide targets at lower levels of electricity consumption, then it must be shown how that is to be accomplished. For example, efficient appliances and lighting may contribute to lowering the bar for energy-related indicators. It is also clear that energy access must be planned and implemented in a systemic fashion so that household and productive uses are addressed effectively; in that sense, it is also important to consider SDGs that support the goals and targets discussed here: SDG 9 - Industry, Innovation and Infrastructure; SDG 16 - Peace, Justice and Strong Institutions; and SDG 17 - Partnership for the Goals.
One possible objection to this analysis is that electricity access has been chosen as the independent variable, but that other variables could have been chosen. In other words, energy access might be just a proxy for "wealth" or GNI/capita. In fact, the two are closely related. Interestingly, the threshold behavior identified in our previous work (Brecha 2019), from which we derive the per capita consumption level of approximately 400kWh used in the present analysis, is not as evident as a function of GDP as it is in terms of electricity access. Additionally, it is possible to construct causal chains showing that it truly is energy access that is a key to achieving these (and possibly other) SDGs, and not just increase in wealth. Although there is the potential for conflicts between SDGs (Stechow et al. 2016; McCollum et al. 2018; Nilsson, Griggs, and Visbeck 2016; Weitz et al. 2017) clear connections have been made by others between access to electricity in support of achieving other goals (McCollum et al. 2018).

In Table 1 we compile linkages between the SDGs considered in this paper and access to electricity (and more broadly, other modern energy sources). The examples here are mainly based on McCollum et al. In that work, there are also potential negative aspects of energy access, depending on the particular sources used; here we are concerned mainly with the implications for having access to enough electricity (and at the relatively low levels correlated with achieving SDG targets).

Table 2 - Summary of key synergies between access to electricity and other SDGs, focusing on the causal connections

SDG 1 - Poverty	SDG 2 - Hunger	SDG 3 - Health	SDG 4 - Education	SDG 6 – Water and Sanitation
Modern energy (electricity) fundamental for development	Energy access can help reduce post-harvest losses	Electricity allows storage of medicine and vaccines	Lighting allows more opportunity for studying at home	Electricity can allow access to pumping for safer drinking water
Access to electricity (and other modern energy) frees up time and other resources	Food preservation improved by access to electricity	Improved lighting and equipment power in clinics	Electricity in schools provides better lighting and information technology access	Electricity access will allow for desalination to enhance scarce water resources
		Better food preservation contributes to better health outcomes		Power needed for water treatment

In conclusion, access to modern energy systems, and primarily to electricity, is strongly linked to being able to achieve targets set for many Sustainable Development Goals. Although gains in efficiency in the future as well as some geographical and country-specific factors may affect the exact level of consumption, we have shown here that below a societal level of 400 kWh per capita annually, very few countries have been able to meet SDG targets. Furthermore, even this relatively meager amount of electricity is higher than what is projected for 2030 in international modeling efforts. Therefore, either higher levels of electricity access must be assumed for models to be consistent with the SDGs, or else it is necessary to demonstrate how the SDGs can be achieved without that level of access to modern energy.

7. Appendix: Data Sources

Human Development Index data are from the United Nations Development Programme as part of the Human Development Report published each years. Data for both the overall index as well as for the individual components are available at http://hdr.undp.org/en/content/human-development-index-hdi. For the present work, chosen years for the HDI are matched to the years for which energy data are available, usually 2014.
Specific data sets used are:

Human Development Index (HDI)	http://hdr.undp.org/en/indicators/137506	S1, S2
Life expectancy at birth	http://hdr.undp.org/en/indicators/69206	S4
Mean years of schooling	http://hdr.undp.org/en/indicators/103006	1
Gross national income (GNI) per capita	http://hdr.undp.org/en/indicators/141706	
Final energy use [GJ]	IEA Energy Balances	S1

Data for other indicators are taken from the World Bank database of World

Development Indicators (WDI) that can be found at https://data.worldbank.org/indicator. Specific indicators used here are:

Indicator name	Indicator code	Fig.
Electric power consumption (kWh per capita)	EG.USE.ELEC.KH.PC	S2
Energy use (kg of oil equivalent per capita)	EG.USE.PCAP.KG.OE	
GDP per capita, PPP (constant 2011 international $)	NY.GDP.PCAP.PP.KD	S3
Maternal mortality ratio (modeled estimate, per 100,000 live births)	SH.STA.MMRT	2a
Mortality rate, under-5 (per 1,000 live births)	SH.DYN.MORT	2c
Mortality rate, neonatal (per 1,000 live births)	SH.DYN.NMRT	2b
Life expectancy at birth, total (years)	SP.DYN.LE00.IN	
Access to clean fuels and technologies for cooking (% of population)	EG.CFT.ACCS.ZS	
Improved sanitation facilities (% of population with access)	SH.STA.ACSN	2d
Population, total	SP.POP.TOTL	

Population data, both current and projected increases, are taken from the United Nations World Population Prospects 2015 update, POP/DB/WPP/Rev.2015/POP/F01-1.
For many African countries, the WDI database does not include per capita electricity consumption. To fill in these gaps, the United Nations Environment Programme *Atlas of Africa Energy Resources* was used (UNEP 2017) as were data from the United States Energy Information Administration (https://www.eia.gov/).

References

Bhatia, M, and N Angelou. 2015. "Beyond Connections - Energy Access Redefined." Technical report 008/15.

Brecha, R.J. 2019. "Threshold Electricity Consumption Enables Multiple Sustainable Development Goals." *Submitted to Nature Sustainability.*

Collste, David, Matteo Pedercini, and Sarah E. Cornell. 2017. "Policy Coherence to Achieve the SDGs: Using Integrated Simulation Models to Assess Effective Policies." *Sustainability Science*, July. https://doi.org/10.1007/s11625-017-0457-x.

Goldemberg, T.B. Johansson, A.K.N. Reddy, and R Williams. 1985. "Basic Needs and Much More with One Kilowatt per Capita." *Ambio*, 1985.

Groh, Sebastian, Shonali Pachauri, and Narasimha D. Rao. 2016. "What Are We Measuring? An Empirical Analysis of Household Electricity Access Metrics in Rural Bangladesh." *Energy for Sustainable Development* 30 (February): 21–31. https://doi.org/10.1016/j.esd.2015.10.007.

IEA. 2012. *Energy Balances of Non-OECD Countries - 2012 Edition.* International Energy Agency, Paris.

———. 2017. "World Energy Outlook Special Report on Energy Access." International Energy Agency.

Jain, Abhishek, and Tauseef Shahidi. 2019. "Guiding Action: A User Centric Approach to Define, Measure and Manage Electricity Acces." *Economics of Energy & Environmental Policy* 8 (1): 19–32.

Krugman, H., and J Goldemberg. 1983. "The Energy Cost of Satisfying Basic Human Needs." *Technological Forecasting and Social Change*, 1983.

McCollum, David L, Luis Gomez Echeverri, Sebastian Busch, Shonali Pachauri, Simon Parkinson, Joeri Rogelj, Volker Krey, et al. 2018. "Connecting the Sustainable Development Goals by Their Energy Inter-Linkages." *Environmental Research Letters* 13 (3): 033006. https://doi.org/10.1088/1748-9326/aaafe3.

Nilsson, Måns, Dave Griggs, and Martin Visbeck. 2016. "Map the Interactions between Sustainable Development Goals." *Nature* 534 (June): 320–22.

Nussbaumer, Patrick, Morgan Bazilian, and Vijay Modi. 2012. "Measuring Energy Poverty: Focusing on What Matters." *Renewable and Sustainable Energy Reviews* 16 (1): 231–43. https://doi.org/10.1016/j.rser.2011.07.150.

Pachauri, S, A Brew-Hammond, Douglas F. Barnes, D.H. Bouille, S Gitonga, V Modi, G Prasad, A Rath, and H Zerriffi. 2012. "Chap. 19 - Energy Access for Development." In *Global Energy Assessment—*

Toward a Sustainable Future, 1401–58. Cambridge: Cambridge University Press and International Institute for Applied Systems Analysis.

Pachauri, S., A. Mueller, A. Kemmler, and D. Spreng. 2004. "On Measuring Energy Poverty in Indian Households." *World Development* 32 (12): 2083–2104. https://doi.org/10.1016/j.worlddev.2004.08.005.

Pachauri, Shonali, Bas J van Ruijven, Yu Nagai, Keywan Riahi, Detlef P van Vuuren, Abeeku Brew-Hammond, and Nebojsa Nakicenovic. 2013. "Pathways to Achieve Universal Household Access to Modern Energy by 2030." *Environmental Research Letters* 8 (2): 024015. https://doi.org/10.1088/1748-9326/8/2/024015.

Pachauri, Shonali, and Daniel Spreng. 2002. "Direct and Indirect Energy Requirements of Households in India." *Energy Policy* 30 (6): 511–23.

Pelz, Setu, Shonali Pachauri, and Sebastian Groh. 2018. "A Critical Review of Modern Approaches for Multidimensional Energy Poverty Measurement." *Wiley Interdisciplinary Reviews: Energy and Environment* 7 (6): e304. https://doi.org/10.1002/wene.304.

Rao, Narasimha D, and Shonali Pachauri. 2017. "Energy Access and Living Standards: Some Observations on Recent Trends." *Environmental Research Letters* 12 (2): 025011. https://doi.org/10.1088/1748-9326/aa5b0d.

Sathaye, Jayant, Oswaldo Lucon, Atiq Rahman, John Christensen, Fatima Denton, Junichi Fujino, Garvin Heath, et al. 2011. "Renewable Energy in the Context of Sustainable Development." In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C.von Stechow (Eds)]*. Cambridge, UK, and New York, NY, USA: Cambridge University Press. https://ipcc.ch/pdf/special-reports/srren/Chapter%209%20Renewable%20Energy%20in%20the%20Context%20of%20Sustainable%20Development.pdf.

Stechow, Christoph von, Jan C. Minx, Keywan Riahi, Jessica Jewell, David L. McCollum, Max W. Callaghan, Christoph Bertram, Gunnar Luderer, and Giovanni Baiocchi. 2016. "2 °C and SDGs: United They Stand, Divided They Fall?" *Environmental Research Letters* 11 (3): 034022. https://doi.org/10.1088/1748-9326/11/3/034022.

Taylor, Peter G., Kathleen Abdalla, Roberta Quadrelli, and Ivan Vera. 2017. "Better Energy Indicators for Sustainable Development." *Nature Energy* 2 (8): 17117. https://doi.org/10.1038/nenergy.2017.117.

UN Dept of Economic and Social Affairs. 2017. "World Population Prospects 2017." 2017. https://esa.un.org/unpd/wpp/.

UN General Assembly. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjZ-7PBusnRAhXEyyYKHakDAKcQFggsMAE&url=http%3A%2F%2F www.un.org%2Fsustainabledevelopment%2Fdevelopment-agenda%2F&usg=AFQjCNHsy UhLC3HVpbu5w-C-YGkRRxPc2Q&sig2=kJReLwsoSiwm_A94lwWYRw.

UNDP, ed. 2016. *Human Development for Everyone*. Human Development Report 2016. New York, NY: United Nations Development Programme.

UNEP. 2017. *Atlas of Africa Energy Resources*. Nairobi, Kenya: United Nations Environment Programme. http://hdl.handle.net/20.500.11822/20476.

Weitz, Nina, Henrik Carlsen, Måns Nilsson, and Kristian Skånberg. 2017. "Towards Systemic and Contextual Priority Setting for Implementing the 2030 Agenda." *Sustainability Science*, September. https://doi.org/10.1007/s11625-017-0470-0.

World Bank. 2017. "World Development Indicators." Database. World Development Indicators. 2017. https://data.worldbank.org/data-catalog/world-development-indicators.

15. Waste to Energy Financial Model Design Based on Resident Participation

Farizal, Nadya Amalin, Amar Rachman

ABSTRACT:
This study designed a financial model for utilizing municipal solid waste (MSW) to generate energy based on resident participation. This effort is crucial since in many cases a government has some competing programs to be funded on its limited money. This makes a public project does not receipt enough funding to run the best option available or even the project sometime has not funded at all. On the other side, regulation and social responsibility factors inhibit private sector to invest their money on it. Based on willingness to pay research conducted at the City of Depok, it was shown that the residents are willing to spend their money to get a better MSW treatment through funding a Sustainable Modular Landfill Gas Plant project. A financial model developed for the project showed that the project is feasible. The project gave a positive net present value and internal rate of return greater than the average Indonesian bank interest rate; that is 13.87% for no electricity discounts scenario and 13.73% for electricity discount scenario. Further analysis showed that the minimum number of resident to participate on the project are 7% and 51% of the total Depok household, respectively.

Keywords: Financial model, waste to energy, landfill gas plant project, net present value, internal rate of return

Farizal, PhD is Lector (comparable to Assistant Professor) at Department of Industrial Engineering, Universitas Indonesia, Indonesia. His research is on renewable energy planning and optimization. He has developed a model to select suitable energy sources among available renewable energy sources using quantitative and qualitative methods, conducted energy demand forecast and oil consumption forecast. Currently, his focus is on municipal solid waste (MSW) to energy. He has conducted a complete research on MSW utilization started from MSW potency research, MSW plant location determination, MSW collection routing determination, MSW plant financial model, and MSW plant business model. Currently, he also serves as editorial board of Makara Journal of Technology (MJT).

Nadya Amalin was a former master student of Department of Industrial Engineering, Universitas Indonesia who conducted resident based financial model under Farizal, PhD supervision. She completed her bachelor degree from department of Chemical Engineering, University of Diponegoro, Indonesia. She is currently works as consultant at Veda Praxis.

Ir. Amar Rachman, MEIM is former Lektor Kepala (comparable to Associate Professor) of Department of Industrial Engineering, Universitas Indonesia. He completed his Master from KU Leuven, Belgium. His research focuses on optimization and modeling. He served as Co-Supervisor of Ms. Amalin master thesis research.

1. Introduction

Economic growth and population increment will directly affect energy consumption (Tiess and Mujiyanto, 2013). Indonesian population increases from 237.6 million in 2010 to 260 million in 2017 (Indonesia Investments, 2019). In the last ten years (2003-2013), energy consumption in Indonesia has increased from 79 million TOE to 134 million TOE which means it grows on average 5.5% per year (DEN, 2014). Electricity, as a form of energy, consumption continues to increase every year with an average rate about 7.2% per year. However, electricity power generation capacity grow only on average by 5.1% per year (DEN, 2014). This fact shows there is a shortage of electricity in Indonesia. Meanwhile, another problem faced by Indonesian government is municipal solid waste (MSW) management. MSW will continue to be produced as long as human beings exist. According to Sudrajat (2007) the waste volume produced is proportional to the number of the population. Lack of management of liquid and solid waste management system in Indonesia, could pose many significant threats to human health and the environment.

Indonesian government has made a target that energy mix in 2015 will consist of 25% of renewable energy and 75% of fossil energy. Whereas in 2010 the target of using renewable energy as the main energy source is only 5% (EMR, 2013). One of potential bioenergy technology in Indonesia is biogas. The use of bioenergy technology can improve human welfare because it can improve the city sanitation, reduce smoke, better lighting, and job creation (Amiguna and Blottnitz, 2009). Bioenergy can also improve the quality of the environment because it can improve water quality, conserve resources, especially trees, and reducing green house gas (GHG) emissions (Amigun et al, 2008).

One possible way to treat MSW that can reduce environmental impact significantly and simultaneously provide benefit in the form of energy is developing landfill gas plant; commonly referred as landfill gas, LFG. According to Yazdani et al (2006), methane gas (CH_4) and carbon dioxide (CO_2) are two dominant gases produced at the landfill as the waste decomposed. It is approximated that 45-60% of the gases produced are methane and 40-60% are carbon dioxide. These two gases are GHG sources. Fortunately, methane gas can be used as feed stock to generate electricity. According Tasri and Susilawati (2014), applying landfill gas technology is a proper way for treating MSW in Indonesia.

Economic analysis for waste to energy (WtE) program has been widely applied in some countries and also with variety of existing technologies. WtE economic analysis by comparing two technologies, inceneration and landfill gas technology, for processing MSW in Thailand conducted by Menikpura et al (2014). Comparison of the two WtE technologies also have been done by Dong et al (2014) by comparing indicators of environmental, economic, and energy. Xin-gang et al (2015) conducted an economic analysis by calculating investment cost as the feasibility indicator of investment in WtE inceneration technology. While Johari et al (2012) analyzed the economic benefits and environment of landfill gas in Malaysia. Inceneration indeed can generate more electricity than the landfill gas plant, but it also requires a greater operational cost and gives by products of ash that can create air pollution (Menikpura et al, 2014; Dong et al, 2014; Xin-gang et al, 2015).

Even tough utilization of LFG is one of best solution for a better waste management and simultaneously solves the energy problem in Indonesia. But due to one reason or another, the government does not eagerly utilize this approach to its around four hundred landfills (Trisyanti and Helmy, 2015). On the other side, regulation and social consideration are not allowed private investors either. However, Farizal et al (2019) showed an alternative way to fund LFG. On their research, based on Willingness to Pay (WTP) survey they developed, at the City of Depok, Depok residents were willing to donate their money to get a better MSW management through constructing a sustainable landfill gas plant (SLFG) project at their district. This study developed financial model based on resident participation of the project, showed the reliability of the funding source and calculated the minimum resident participation required to make sure the project run appropriately.

2. Methodology

Since sources, including money, are not unlimited, every project should be analyzed before implemented. Study to analyze whether a project is attracted and profitable is economic feasibility study. For the purposes, methods to evaluate a project worthiness are Net Present Value, Internal Rate of Return, External Rate of Return, and Payback Period (Canada, et al 2005). Among the methods, due to its simplicity, NPV is the most popular one to used.

Net Present Value Analysis. This analysis calculates net revenues of the whole life of the project and then equates the value to its present value. A project is considered profitable and worth to do if the NPV is greater than 0 (or positive). If there are several competing alternative investment projects, the best alternative is the one with the highest NPV. NPV is calculated using the following formula:

$$\text{NPV} = I + \sum_{n=1}^{n} \left(\frac{An}{L(1+r)^n} + \frac{Vn}{L(1+r)^n} \right) \qquad (1)$$

Where I is investment, r is rate of return, An is cash flow/proceed, n is time when the cash flow occurs, and Vn is salvage value of investments at the end of economic period

Internal Rate of Return Analysis. Instead of calculating the NPV in the term of money earned, IRR basically calculates the percentage of profit of the project. A project is accepted if its IRR is greater than MARR (Minimum Attractive Rate of Return) set by the company. MARR is usually set a bit higher than the interest the company pay to the lender for financing their project. IRR can also be interpreted as the discount rate that produces zero NPV as shown at the formula below.

$$\sum_{n=1}^{n} PW_n\,(pos) - PW_n\,(neg) = 0 \qquad (2)$$

Sensitivity Analysis. The calculation using one or more methods mentioned above uses data that most of the time are estimated (or predicted). in reality, assumptions and estimations are not free from errors or mistakes. A project is also facing risks that sometimes not seen in advance. Sensitivity analysis is the way to check how a factor(s), for instance cost, profit, project life time, influence the outcome of the calculation. Sensitivity analysis gives an interval outcome of the calculations, instead of a single number, so project decision maker will have the minimum (the least) and the maximum results of the project.

3. Sustainable Landfill Gas Plant Model

Landfill gas plant (LFG) is a facility that collects methane gas produced from decomposition of MSW dumped at a landfill. LFG uses the collected gas to generate electricity. LFG facility is consisted of gas collection system, gas treatment system, and electricity generation system. Scheme of a typical LFG is shown in Figure 1.

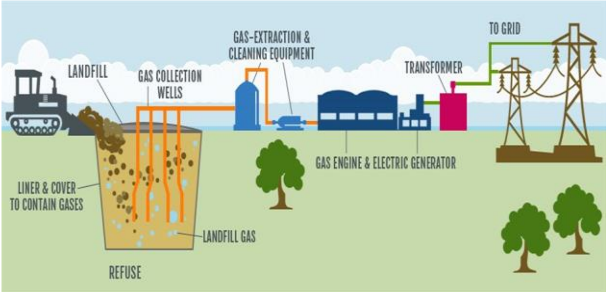


Figure. 1. Landfill Gas Plant Scheme (US EPA, 2010)

Unlike ordinary landfill that collects MSW for a certain period of time and closed when its capacity reached a maximum point. Proposed LFG model on this study is designed to be a sustainable facility in the sense that the landfill will be used to dump MSW and generate electricity forever. Even thought the plant life time is around 20 years (US EPA, 2015), but the LFG itself will never be closed. Once a plant is about to be decommissioned, another LFG is erected as a new plant at the adjacent area and start to produce electricity. This practice is repeated until a newer landfill opens at the first landfill site and a newer LFG erected. Sustainable landfill plant (SLFG) model was developed by Ardiansyah (2014). Landfill gas plant (LFG) will be used as a power plant with gas engine as its power generation. The selection of gas engine as power generation is because for generating 1 MW electricity, needs an input approximately 0.4 to 1.6 millions ft^3 per day with a composition of 50% methane. As addition, gas engine is commonly used as power generation for LFG, especially in America (US EPA, 2015).

Landfill gas processing will be done in a sustainable manner in which land use of landfill will increase at a time until it settles. MSW will be collected during the next three years and one year used for the construction of power generation facilities. Gasses production will be started in the first year until the 25th year. During the production, the landfill continues to open up a new landfill of the same size every three years. Table plan activities for SLFG development model are shown in Table 1.

Table 3. Activities Plan of Sustainable Landfill Gas Plant

Aktivitas	Time (Year)																													
	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Landfill Preparation	A			B			C			D			E			F			G			H			A					
Piling Up Waste																														
Landfill Gas Construction																														
LFG Production																														

In addition, it is assumed in this study that a landfill will only produce methane for 15 years, although actually the anaerobic reaction of MSW produces methane landfill within 20 years period (US EPA, 2015). This assumption was done because according to the Nevada Department of Taxation (2010) and US EPA (2015), the age of the gas collection equipment has a useful life of 15 years. Thus, the model Landfill gas will be made with the assumption that a landfill cell will contribute to generate gas to be processed into electricity for 15 years. Meanwhile, at the age of 20 years, a landfill cell can be excavated to be stockpiled garbage again. Waste buried in landfills will undergo anaerobic process and will shrink by 25% from the previous volume of waste mound after 20 years (US

EPA, 2015).
The calculation of estimated methane gas production and electricity potential will use US EPA model; i.e Landgem v-302 that already used in many LFG projects calculation in America. For applying SLFG model, the model is implemented to MSW management at the City of Depok. A suburban of Jakarta that just has one landfill at Cipayung site (Farizal and Tammarar, 2018). It is estimated that the average electricity generated at Cipayung was 5.62 MW. For this purpose, the ideal gas engine capacity to used is 6 MW. Pattern of methane gas produced at landfill gas from year-0 production to year 25 is shown in Figure 2.

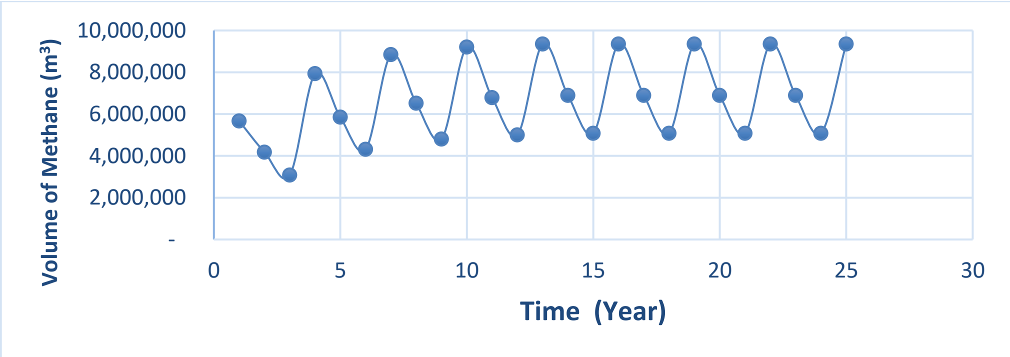


Figure 2. Sustainable Landfill Gas Methane Production Model

Compare to ordinary LFG, sustainable landfill gas plant offers some advantage such as producing a more stable and more amount of methane gas and the facility is sustainable. However, SLFG undoubtedly needs more funding than the ordinary one. The cost will consist of investment costs, and operation and maintenance costs. The initial investment cost required in development LFG consists of landfill gas system components and installation costs. Projected investment costs needed for LFG in the City of Depok are shown in Table 2. Meanwhile, the operation and maintenance costs will consist of labor costs, utilities' costs, and maintenance costs. As shown in Table 1, the investments are made gradually for each cell of the landfill. Each year will be required different operational costs until the 13th year. In the year 13 of production, there will be 5 landfill cells operating annually. Total annual operation cost of 5 active landfill cells is summarized in Table 3.

Table 4. Total Investment Cost of 8 Cells of Sustainable Landfill Gas Plant

Component	Quantity	Unit Price (IDR)	Total Price (IDR)	Reference
Land Preparation (m^3)	10,080,000	27,330	275,486,803,200	KPU (2012)
Gas Collection & Flare system (Acre)	124.54	351,188,907	43,737,389,572	EPA (2015)
Treatment system (ft^3/min)	926.43	15,149,325	14,034,716,554	EPA (2015)
Electricity generation (kW)	6,000	999,205	5,995,231,200	EPA (2015)
Geomembran capping and Instalation (m^2)	100,000	60,798	61,284,585,600	Duffy (2016)
Electricity Power Distribution (Unit)	1	2,003,774,360	2,003,774,360	Maxpower Indonesia
Leachate removal system (Acre)	124.54	105,736,000	13,168,458,717	Duffy (2016)
Total			**415,710,959,203**	

Table 5. Operations & Maintenance Costs of 5 Active Landfill Cells per Year

Component	Quantity	Unit Price (IDR)	Total Price (IDR)	Reference
Gas Collection & Flare system (Acre)	124.54	980,535,782	76,323,017,701	EPA (2015)
Treatment system (ft^3/min)	926.43	1,790,375	1,658,648,320	EPA (2015)
Electricity generation (kW)	6,000	2,478,981	14,873,883,120	EPA (2015)
Leachate removal system (Acre)	124.54	15,660,400	1,218,975,417	Duffy (2016)
Operator & staff (person)	43	32,460,000	1,395,780,000	Ardiansyah (2014)
Supervisor (person)	1	42,198,000	42,198,000	Ardiansyah (2014)
Waste pile up cost			1,345,508,750	DKP (2015)
Waste Collection cost			17,759,895,625	DKP (2015)
Total			**114,617,906,934**	

SLFG Cash Flow. Cash flow indicates of the amount of cash spent and earned in the future. It provides useful information report to users in evaluating the changes of company's net worth. Cash flow projections in this study will be made with the calculation of revenues and costs incurred during the life time of SLFG, which is 25 years. Cash flow scenarios were created with some conditions described below:

First, based on SLFG model described in Table 1, the construction of a landfill cell consists of the cost of land excavation, investment and installations of capping on the base and the surface of landfill, as well as the installation of leachate treatment system. The investment of land excavation and the installation of capping and leachate treatment system also occurred in year 2, 5, 8, 11, 14, 17. While the excavations in the 20th year will just consist of land excavation cost which has shrunk by 25%. Meanwhile, the installation of gas collection system occurred in year 3, 6, 9, 12, 15, 18, 21.

Second, depreciation used in this study is based on Indonesia Ministry of Finance Regulation No. 21/PMK.01/2010 about Taxation and Incentives for Renewable Energy Sources Utilization Activities. The depreciation model will be Straight Line Model at 12.5% of the investment cost of equipments. It is applicable only for the first 8 years of the equipments being installed.

Third, gas collection system equipments at a landfill cell operate only for 15 years. From the year 15th until 20th, a landfill cell will not generate gasses since the lifetime of the gas collection equipments has assumed already finished in 15th year. Thus, operating costs are calculated based on the number of landfill cells and the equipments currently active in certain year.

Fourth, on the year 16th there will be an investment again for buying new gas engines and new treatment systems.

Fifth, according to PMK No. 21/PMK.011/2010 about Taxation and Customs Facilities for Renewable Energy Utilization Activities, taxable income in the first 6 years of operation get 30% deduction of net income; it is charged 5% per year for 6 years. Meanwhile, the income tax is 25%.

Sixth, the cost of land acquisition to build a landfill gas facility will be assumed provided by City government as according to Presidential Decree Regulation No. 18/2016 about The Accelerated Development of Waste To Energy.

Seventh, this study will be done in 2 scenarios of calculation.

a. Cash flow scenario without electricity discount offer.

- Operational cost is the cost of the equipment operated actively in certain year.
- The cash in flow consists of electricity sales (the price is according to PerMen No. 44/2015), Carbon Development Mechanism (CDM) incentives, and resident funding

participations from the 4th parts of WTP questionnaire survey results (Farizal, et al 2019).
b. Cash flow scenario with electricity discount offer.
- Operational cost consists of the cost of the equipment operated actively in certain year and the electricity discount for the participate residents (Farizal, et al 2019).
- The cash in flow consists of electricity sales (according to PerMen No. 44/2015), CDM incentives, and resident funding contributions from the 5th parts of WTP questionnaire survey results.

4. Results and Discussion

4.1 Economic Feasibility Analysis

Based on the assumptions and data described earlier, a financial model has been developed with Excel. Financial worthiness calculation results of Sustainable Landfill Gas Plant (SLFG) of the City of Depok are summarized in Table 4.

Table 6. Feasibility Indicator of SLFG Project in the City of Depok

Feasibility Parameter	Without electricity discounts offer	With electricity discounts offer
NPV (IDR)	2,175,023,689,760	1,780,943,573,848
IRR (%)	13.91	13.77

Table 4 shows that both scenarios of SLFG have a positive NPV at the bank rate of on average is 11%. From the IRR view, the rates are higher than MARR, i.e. 13.91% and 13.77% for without and with discount, respectively. These results indicate that the residence based SLFG is economically acceptable in both cash flow scenarios. From the Indonesian Financial Statistics (BI, 2016), MARR from 2010 to 2016 is between 9.86% - 13,58%.
Furthermore, Table 4 shows that both results, the NPV value and IRR from scenario with electricity discount offer are less than scenario without electricity discounts offer. Although the nominals of WTP with discount offer scenario are significantly higher than the nominals of WTP without electricity discount offer. This is due to the electricity discount scenario has extra operational costs per year; i.e. electricity discount given to to 88% of Depok citizens who agreed to participate. However, the NPV value is still large enough as 1,780,943,573,848 IDR. Besides that, the implementation of the scenario will give economic benefit to the participants, in the form of electricity discounts, that in turn will drive more Depok resident to participate and to donate.

4.2 Sensitivity Analysis

This sensitivity analysis is used to determine the effect of changes in the number of participants in the funding program towards the NPV value. The results are displayed on Figures 3 and 4.
Figure 3 shows that in the scenario without a discount, NPV generated by the project is linear to the number of participant willing to pay. This means that the more the participants', the greater the NPV. The graph also shows that when the number of participants is reduced even by 90%, the NPV is still positive. The NPV will be negative with the amount of 163,397,319,787 IDR if the participant withdrawal completely from

the program. Figure 3 shows that the cut off number of participant to get the NPV zero is 7% of the total household. So, as long as the funding participant is greater than 7% this scenario is still attractive to do.

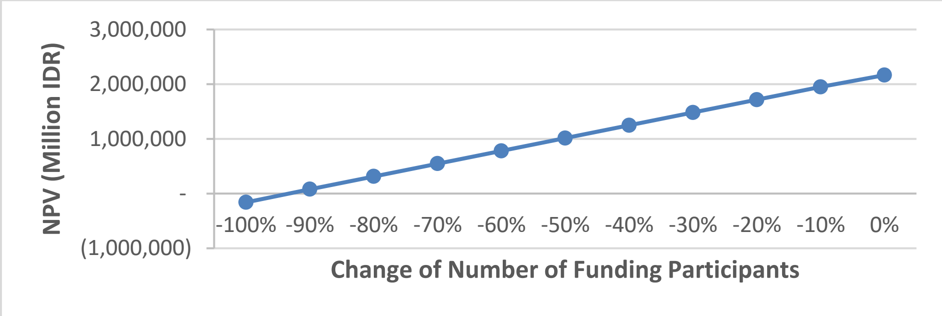


Figure 3. Change of Number of Funding Participants to NPV on Without Electricity Discount Offer Scenario

Figure 4 is for the scenario with electricity discount offer. The chart says that if the number of participant is reduced by 50%, the NPV will be negative with value of 33,003,959,977 IDR. The discounts offered cause the operational costs much higher than the previous model. Figure 6 shows when the number of participants was reduced by 49%, or only 51% participants the NPV will be 0. This means this scenario must keep the number of participant slightly more than 51% in order to be profitable.

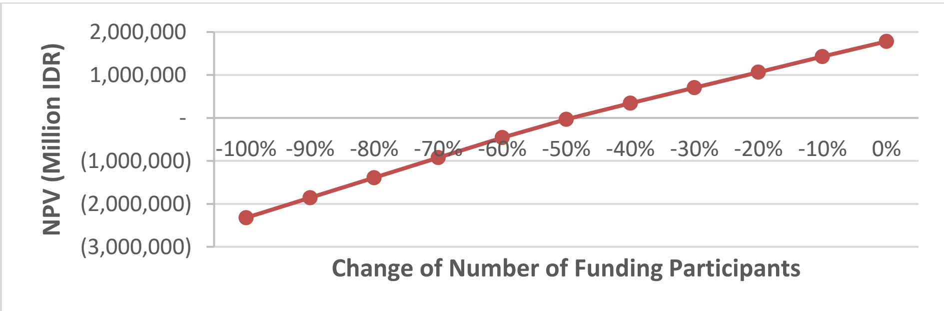


Figure 4.Change of Number of Funding Participants Towards NPV on With Electricity Discount Offer Scenario

The composition of minimum number of participants for without discount scenario and with discount scenario is shown in Table 5. The table shows that the biggest number of participant belongs to the group with the lowest amount of contribution; i.e. 80,000 IDR per month.

Table 7. Composition of the Minimum Number of Funding Participants

Without electricity discounts		With electricity discounts	
Value (IDR) /Month	Participants (%)	Value (IDR) /Month	Participants (%)

20,000	1,3	80,000	33.2
50,000	3,5	100,000	10.6
80,000	0,8	150,000	4.4
100,000	0,9	200,000	2.7
200,000	0,5		
Total	7%	Total	51%

The impact of changing the value of the WTP to the NPV produces a similar results as the impact of changing the number of participants to the NPV. Composition of minimum value and its percentage is shown in Table 6. The table indicates that the lowest and highest contribution for without discount scenario can reduce to 1,050 IDR and 14,000 IDR, respectively to make the NPV still positive. While for with discount scenario, the lowest and the highest contribution just can reduce close to half of the original contribution in order to keep the NPV positive. The lowest and the highest donation can go down to 40,800 IDR and 102,000 IDR, respectively.

Table 8. The Minimum Number of WTP value Compositions

Without electricity discounts offer		**With electricity discounts offer**	
Value (IDR) /Month	**Participants (%)**	**Value (IDR) /Month**	**Participants (%)**
1,050	16	40,800	57
3,500	43	51,000	18
5,600	10	76,500	8
7,000	11	102,000	5
14,000	6		
Total/ Year	22,987,609,914	Total/ Year	259.087.867.520

5. Conclusion

Based on the calculation results through the financial model developed, both scenarios of resident based funding of sustainable landfill gas plant are good to go. They give a positive NPV values and good IRRs. The IRRs exceed the bank interest rate (MARR) that never more than 13.58%. In this case, the IRR values are 13.91% and 13.77% for the investment scenario without electricity discounts and the investment scenario with electricity discounts, respectively. The minimum number of participant funding for without electricity discount scenario is 7% of total household of the City of Depok. While for the scenario with electricity discount, the number of participant is at least 51%.

6. Acknowledgment

This work has been supported partially by PITTA B 2019 Grant funded by DRPM Universitas Indonesia under contract No. NKB-0731/UN2.R3.1/HKP.05.00/2019.

Reference

Amigun, B. and Blottnitz, H.V. (2009). Capital cost prediction for biogas installations in Africa: Lang factor approach Authors. *Environmental Progress and Sustainable Energy*, 28, 134-142.
Amigun, B., Sigamoney, R., and Blottnitz H.V. (2008). Commercialisation of biofuel industry in Africa: A review. *Renewable and Sustainable Energy Reviews*, 12, 690–711.
Ardiansyah, S. (2014). *Analisis Model Pembangunan Pembangkit Listrik Tenaga Sampah Berkelanjutan*. Unprinted Bachelor Thesis. Universitas Indonesia, Fakultas Teknik, Jakarta. In Indonesia language
BI (2016). *Statistik Ekonomi and Keuangan Indonesia*. Jakarta: Bank Indonesia. In Indonesian language
BPS (2014). *Depok Dalam Angka 2014-2015*. Depok: Baand Pusat Statistik. In Indonesia language
Canada, J.R., Sullivan, W.G., Kulonda, D.J., and White, J.A. (2005). *Capital Investment Analysis for Engineering and Management*. 3rd ed. Pearson-Prentice Hall, Upper Saddle River, NJ
DEN (2014). *Energy Outlook 2014*. Jakarta: Dewan Energi Nasional Republik Indonesia. In Indonesia language
DKP (2015). *Mengenal Lebih Dekat TPA Cipayung Kota Depok*. Depok: Dinas Kebersihan and Pertamanan Kota Depok. In Indonesian language
Dong, J., Chi, Y., Zou, D., Fu, C., Huang, Q., and Ni, M. (2014). Energy, environment, economy assessment of waste management systems from a life cycle perspective: Model development and case study. *Applied Energy*, 114, 400–408.
Duffy, Andiel P. (2016). *Landfill Economics Part 2: Getting Down to Business*. The Journal for MSW Professional
EMR (2013). *Hand book of energy and economic statistic of Indonesia*. Jakarta: Kementerian Energi and Sumber Daya Mineral.
ESDM (2013). *Peraturan Mentri ESDM No. 44 Tahun 2015 Tentang Pembelian Tenaga Listrik oleh PT. PLN dari Pembangkit Listrik Berbasis Sampah Kota.* Jakarta: Kementrian Energi and Sumber Daya Mineral. In Indonesian language
Farizal, Amalin, N., and Rachman, A. (2019). A new funding scheme for MSW management to support WtE program. International Conference on Advances in Energy Systems and Environmental Engineering (ASEE 19). Wroclaw, Poland
Farizal and Tammarar, E. (2018). Tipping fee determination to support the waste to energy concept at the city of Depok, Indonesia. Proceeding of Conference on Emerging Energy and Process Technology (CONCEPT) 7, UTM. https://doi.org/10.1051/e3sconf/20199001007
Johari, A., Ahmed, S.I., Hashim, H.,Alkali, H., and Ramli, M. (2012). Economic and environmental benefits of landfill gas from municipalsolid waste in Malaysia. *Renewable and Sustainable Energy Reviews*, 16, 2907– 2912.
Indonesia Investments. (2019). https://www.indonesia-investments.com/culture/population/item67. Accessed 25/06/2019.
KEMENKEU (2009). *PMK No. 21/PMK.01/2010 Tentang Pemberian Fasilitas Perpajakan and Kepabeanan*. Jakarta: Kementrian Keuangan. In Indonesian language
KPU (2012). *Pedoman Bahan Konstruksi Bangunan and Rekayasa Sipil*. Jakarta: Kementrian Pekerjaan Umum. In Indonesian language
Lu, W., Peng, Y.,Webster, C., and Zuo, J. 2015. Stakeholders' willingness to pay for enhanced construction waste management: A Hong Kong study. *Renewable and Sustainable Energy Reviews*, 47, 233–240.
Menikpura, S.N.M., Arun, J.S., and Bengtsson, M. (2014). Assessment of environmental and economic performance of Waste-to-Energy facilities in Thai cities. *Renewable Energy*, 86, 576-584.
Nevada Department of Taxation. (2010). *Personal Property Manual 2011-2012*. Division of Assessment Standards, Department of Taxation, Carson City.
Sudrajat, H. R.(2007). *Mengelola Sampah Kota*. Penebar Swadaya. Jakarta. In Indonesia language
Tasri A. and Susilawati, A. (2014). Selection among renewable energy alternatives based on a fuzzy analytic hierarchy process in Indonesia. *Sustainable Energy Technologies and Assessments*, 7, 34–44.
Tiess, G. and Mujiyanto, S. (2013). Secure energy supply in2025: Indonesia's needfor enenergy policy strategy. *Energy policy*, 61, 31–41.
Trisyanti, D. and Helmy, M. (2015). World waste to energy city summit. London, UK. INSWA
US EPA (2010). *Landfill gas Energy Project Development Handbook, Landfill Methane Outreach Program*. Washington, D.C: United States Environmental Protection Energy, Climate Change Division
US EPA (2015). *Landfill gas Energy Project Development Handbook, Landfill Methane Outreach Program*. Washington, D.C: United States Environmental Protection Energy, Climate Change Division.

Xin-gang, Z., Gui-wu, J., Ang, L., and Ling, W. (2015). Economic analysis of waste-to-energy industry in China. *Waste Management*, 48, 604–618.

Yazdani, R., Kieffer, J., Sananikone, K., and Augenstein, D. (2006). *Final Technical Progress Report - Full Scale Bioreactor Landfill for Carbon Sequestration and Greenhouse Emission Control.* Yolo County Public Works, California.

16. Intricate Analysis of Potential Materials for Sustainable Product Development

Sachin Kumar, Anchit Goel, Gaurav Kumar Singh

ABSTRACT:
Raw materials are scarce and are exponentially depleting. Material usage and product disposal both lead to improvidence of raw ingredients for products. We use materials for manufacturing new products while simultaneously throwing away used non-biodegradable products which pollute the environment. The world of designing and manufacturing needs to use new material(s) which can be selected using the methodology proposed in the research text. To select the best material for a product, its environmental impact, cost and properties that decide the quality of a product are plotted in a 3 dimensional space. Now the threshold limit of quality defining properties is obtained through experimentation. Cutoff cost is decided through market research and then environmental impact is minimized. The material beyond the cutoff planes is rejected and the best among the remaining materials is selected. The product developed using this method for material selection will contain the negative environmental impact during manufacture, use and expenditure of used products and thus helping sustainable development.

Keywords: Sustainability, Life Cycle Analysis, Material selection, Cost optimization, Environmental Repercussion, Mechanical properties

Mr. Sachin Kumar is an undergraduate student of Department of Mechanical Engineering, National Institute of Technology Karnataka, India. Executive member of The Institute of Engineering and Technology NITK. Dedicated research enthusiast in environmental sustainability, clean energy and its optimization.

Mr. Anchit Goel is an undergraduate student of Department of Civil Engineering, National Institute of Technology Karnataka, India. Executive Member of Indian Society for Technical Education, NITK. Student Member of American Society of Civil Engineers NITK Chapter. Research student in seismic retrofitting methods, sustainable and environment friendly construction techniques.

Mr. Gaurav Kumar Singh is an undergraduate student of Department of Mechanical Engineering, National Institute of Technology Karnataka, India. Active pursuer in the field of eco friendly product development, its cost efficiency and mechanical properties of materials.

1. Introduction

Climate change is one of the major problems faced by all living creatures. For past decades the climate has been changing drastically. And due to this change, the lives of trillions of living species on earth are in danger. Even the extinction of species could result in a misbalance of the whole eco-system. All this is due to the pollution caused by the products that we manufacture and use in our daily lives. These products cause pollution during manufacturing and even after their use. The increase in population results in increasing demand for products for daily use. The increase in products manufactured per year increases pollution. Used products that don't degrade cause large heaps of waste which again pollutes the land.

Raw materials are exponentially depleting and the extraction of these raw materials is becoming difficult, costly and emissive. These emissions are harmful to the environment and all living species. Also, the better quality of the product would imply long term use and hence lesser waste/disposal. This decrease in lesser consumption of products would

result in lesser manufacturing and raw material extraction. Hence better quality products will reduce the harmful effect on the environment and help in the conservation of crucial raw materials for future generations. Also, the product must have a low cost in order to sell out. A sustainable product has no use if it is costly as it won't sell out.
For the above reasons, a better way to select materials for a product is needed. For a product to be sustainable, material, design and manufacturing process selection are the major aspects that should be focused. Hence for sustainable product development, a simultaneous study of product's properties, cost, and environment effect during its life cycle are needed. In practical engineering, these aspects are evaluated separately and their effect on each other is not considered. Hence a new approach with a simultaneous complex study of these factors needs to be carried out for sustainable product development. This new approach evaluates the values of each factor considering cost, quality, and environmental impact separately and then a combined comparative study of these values for all potential materials is carried out to select the best among all.

2. Generation of Standard Equations to Evaluate Sustainability of a Product

The science of material selection involves the evaluation and comparison of many parameters. The most important among them is the cost of manufacturing and the quality of the product. Due to depleting resources and increasing population, a new parameter is added to make the process more sustainable. This new parameter represents the environmental effect of material during its life cycle. It can be represented in the form of cost to the environment. The value of this parameter represents the cost that could reverse the environmental impact during the materials life cycle. This is evaluated using Life Cycle Analysis (LCA). LCA involves emissions caused by product/material during its complete life cycle i.e. from the extraction of raw material to dispose of/recycle of material.
To represent the quality of the product, one or more specific properties of the product are considered. For example, a spacecraft material should be light and temperature resistant. So, the property that should be considered is the material's density and melting point. Hence the quality parameter for this product should be equivalent to the density of the material used to manufacture this product. The third parameter represents the cost of the manufacturing of the product. This includes raw material cost and manufacturing cost. Raw material cost includes the cost of extraction/recycling and transportation. Whereas manufacturing cost includes labor cost and power cost.

2.1 Cost of product

A traditional way to analyze the cost of the product is to simply add total money spent to manufacture a product. A cheaper product might cost very much in the long term. Products made of different materials have a different lifespan. So, the cost of owning a product for a specific period of time should depend not only on the cost of the product but also on the lifespan of the product. Hence the traditional method to analyze the total cost of the product is not fair to products made of different materials. Therefore, a new method is required to calculate the total cost of the product. The total cost of the product calculated should incorporate the lifespan of the product, recyclability ratio and recycling cost of one product. The lifespan of a product is actual time (in years) until the failure of the product. The expected value of lifespan can be predicted using analysis and simulation software for the design and each material. Recyclability ratio is the fraction of total material in a product that can be recycled. Recycling cost is the amount of money spent to recycle material from a used product.

For the first cycle of the product, the cost of the product is a function of raw material cost per product and manufacturing cost per product only. Hence

$$C_1 = R + M$$

For further cycles of product, recyclability is also considered. Hence

$$C_2 = r + (1-\propto).R + M$$

Therefore a combined equation to calculate the cost of the product for N years can be written as

$$C = R + M + [r + (1-\propto).R + M].\frac{N-L}{L}$$

$$C = \propto.R - r + [r + (1-\propto).R + M].\frac{N}{L}$$

Where

C_1 is the cost of a product in its first lifespan

C_2 is the cost of the first recycled product

C is the cost to keep a product in the market for N years

R is the cost of raw material used in a product

M is the manufacturing cost per product

r is the cost to recycle one product

α is the recyclability ratio

L is the lifespan of a product

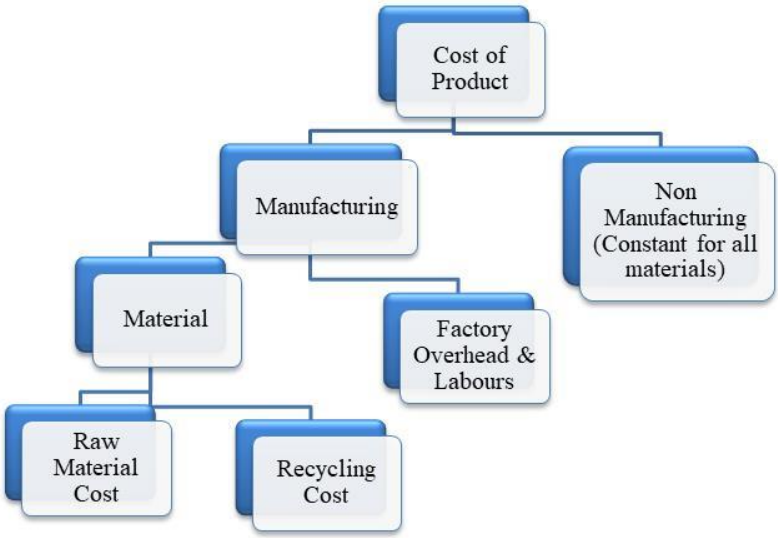


Fig1. Cost of product

2.2 Properties of material

Properties of material are also very important and considered equally important in the process of material selection. Properties of material are classified in two groups i.e. (a) properties that define the lifespan of the product and (b) properties that define the quality of the product in its lifespan. Group (a) properties are used to predict the lifespan of the product which is then used to calculate the cost of the product. Whereas, properties of the group (b) are directly used in the process of material selection. These properties are used to discard materials using cutoff for each.

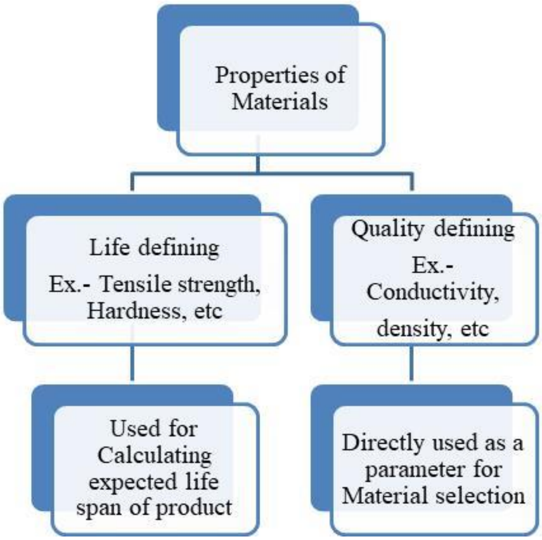


Fig2. Properties of material

2.3 Environmental impact of product

Products can be very harmful to the environment and these environmental impacts are very difficult to recover from. Products are harmful to the environment at every stage in their entire life cycle. Hence it is most important to minimize these impacts. To minimize these impacts, careful selection of design, material, manufacturing process and recycling process is required. In the process of material selection, various calculations and estimations are required. These calculations are carried out using Life Cycle Analysis (LCA). LCA is used to analyze total emissions made during the complete life cycle of the product. The life cycle of the product involves the extraction of raw materials from their natural state, manufacturing processes, the complete lifespan of the product and recycling/dispose of the product.

During the extraction of raw material, different harmful gases and solid are emitted. Different materials have different quality and quantity of these emissions. Therefore different materials have different environmental impacts even before their use in a product. All materials have different mechanical properties, castability, and machinability. So, all materials consume different amounts of energy during the manufacturing phase. The energy consumed also has some environmental impact as not all of the energy is clean. So the higher the energy consumption, the higher is the environmental impact. The development of correlation for the environmental cost is similar to the equation generated for the cost of the product. Therefore, a final equation to calculate the environmental cost of the product can be written as,

$$C_{env} = E + M_{env} + (1-\alpha).D + [r_{env} + (1-\alpha).E + M_{env} + (1-\alpha).D].\frac{N-L}{L}$$

$$C_{env} = \propto . E - r_{env} + [r_{env} + (1-\propto). E + M_{env} + (1-\propto). D]. \frac{N}{L}$$

Where,
C_{env} is the environmental cost of the product
E is the environmental cost during the extraction of raw material
M_{env} is the environmental cost during the manufacturing of the product
α is the recyclability factor
r_{env} is the environmental cost during recycling
D is the cost to dispose of non-recyclable product material
L is the lifespan of the product

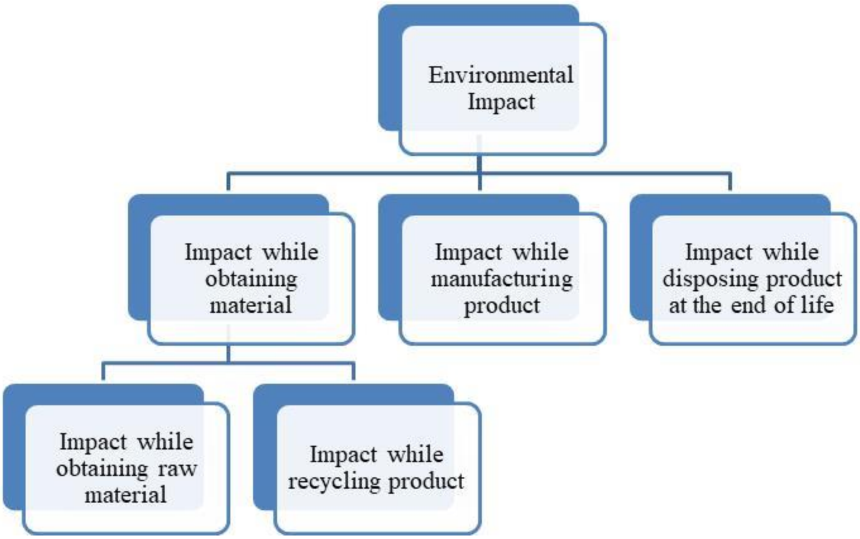


Fig3. Environmental impact

3. Illustration of Methodology

The sustainability parameters calculated using standard equations are used to select the best among potential materials for a product. All potential materials are plotted on a three-dimensional graph with each sustainability parameters on each axis of the graph. Materials might have different values of sustainability parameters depending on composition, temperature, etc, therefore the position of each potential material can be represented using a point, line or a solid on the three-dimensional graph.

Table 1: Potential materials, cost and density

Material	Cost(USD per pound)	Density(lb/in^3)
Aluminum	0.30	0.098
Iron/Steel	0.24	0.284
Titanium	30	0.161
Zinc	1.05	0.258
Magnesium	2.10	0.064
copper	1.80	0.323

Now the cutoff value of each sustainability parameter is used to discard material from the list of potential materials for the product. The cutoff value for the cost of the product is calculated with the help of market research based on demand and availability of the product in the market. The cutoff value of quality defining properties is obtained by performing experimental and analytical studies using different simulation and analysis software. Deciding cutoff values of environmental cost is the most difficult part. It depends on the environmental policies of the particular nation. The methodology is explained below using an example.
Ideal material for an aircraft skin would be light, cheap and one that causes less pollution. Potential materials for an aircraft are aluminum, steel, titanium, zinc, magnesium, and copper. Table 1 shows the cost and density of these materials. Each material among these has a different impact on the environment due to different emissions and energy consumption during extraction and manufacturing. The cost of the product is based on the amount of material used and manufacturing cost. The amount of material used would be different for each material as a fixed volume material is required but the density of each material is different. Also, simulation software like Ansys is used to calculate the expected life span of the plane. The property considered for the selection would be the density of the material.
Now to calculate environmental impact, emissions during extraction and energy consumption during manufacturing are considered. Also, recyclability of metals is considered. Using the generalized equation for each parameter, the values of each parameter are calculated and plotted on a 3d plot. And different planes representing the cutoff values of each parameter are drawn. Materials outside the required are discarded.

4. Summary and Conclusion

Raw materials on our planet are limited but the population is not. Also, the extraction of rare raw materials causes more pollution. To avoid environmental pollution and scarcity of raw materials a new methodology for material selection is required that considers the cost and quality of the product as well as the environmental impact of the product for a specific material.
This research work presents a methodology for the selection of best material among potential materials. Three different parameters such as the cost of the product, properties of the product and environmental impact of a product in its life span have been considered for the selection of material. All potential materials were plotted on a three-dimensional space with each axis representing one parameter. Cutoff values of each parameter were decided based on simulations, market analysis and environmental policies of the particular nation. Materials outside these cutoff limits were discarded.
This research is just the beginning and does not present a solution to the problem specific to a product. Each product follows a different life cycle, extraction, and manufacturing process. Hence further research should be carried out to a specific field. Recycling and disposing of are also the processes that should be studied and further research should be carried out in these areas.

References

M. F. Ashby, Material Selection in Mechanical Design. 4th ed. Oxford: Butterworth-Hienemann; 2010.
P. Stoffels, J. Kaspar, D Baehre, M. Vielhaber, Holistic material selection approach for more sustainable products, 2017
Y. Brechet, D. Bassetti, D. Landru, L. Salvo, Challenges in material and process selection, 2001
F. Giudice, G. La Rosa, A. Risitano, Material selection in the Life-Cycle Design process: a method to integrate mechanical and environmental performances in optimal choice, 2005
Lennart Y. Ljungberg, Material selection and design for development of sustainable products, 2007
Y. M. Deng, K. L. Edwards, The role of material identification and selection in engineering design, 2007
Rosy W. Chen, D. Navin-Chandra, T. Kurfess, F. Prinz, A systematic methodology of material selection with environmental consideration, 1994
J. Kaspar, M. Vielhaber, Cross-component systematic approach for lightweight and material oriented design, 2016
M. F. Ashby, Y. J. M. Brechet, D. Cebon, L. Salvo, Selection strategies for materials and processes, 2004
E. A. Starke, J. T. Staley, Application of modern aluminum alloys to aircraft, 1996

17. Environmental Sustainability at the Olympic Games: Comparing Rio 2016 and Tokyo 2020

Kathryn Rowberg, Meg Rincker

ABSTRACT:
The modern Olympic Games have evolved from events fostering international peace and goodwill to showcases of athleticism and commercialism. More recently sustainability became a pillar of the Game site selection process. This paper focuses on two Olympic Games: Rio 2016 (completed) and Tokyo 2020 (upcoming). The goals of Sustainability Plans and pre-game reports for the two Olympic sites are analyzed using weighted summation method of Multi-attribute Value theory and the framework of environmental, economic and social-cultural sustainability, with emphasis on environmental sustainability. Post-game analysis and legacy stories are reviewed for Rio 2016. Application of legacy stories to future Olympics sites is examined. Last, Rio 2016 and Tokyo 2020, in terms of actual and anticipated success in sustainability initiatives, are compared for the impact these two Games may have on future Olympic Game sites.

Keywords: Sustainable development, environmental sustainability, Olympics, Rio 2016, Tokyo 2020

Kathryn Rowberg is an Associate Professor of chemistry at Purdue University Northwest. She earned a BA and PhD in chemistry and a Juris Doctorate. She is a member of the Indiana Bar Association and was awarded the Kohlhoff Award for Excellence in Environmental Law. At Purdue University Northwest, her research groups have worked on diverse projects: monitoring residual herbicide in caves, identifying persistent organic pollutants in sediments, quantifying microplastics in regional waterways, modelling estrogenic activity in compounds, and predicting aquatic phototoxicity in emerging pollutants using computational methods. Professor Rowberg spent two years as a Fulbright Fellow in Addis Ababa, Ethiopia, teaching and directing research for a master's student and one semester as a Fulbright Fellow in Iceland teaching and working on their environmental chemistry curriculum.

Professor Meg Rincker, Purdue University Northwest, Hammond Indiana USA Meg Rincker earned her PhD in political science from Washington University in Missouri. She currently is Professor of Political Science at Purdue University Northwest. Rincker taught International Organizations/Model United Nations for eight years and her students are participants at the regional Model United Nations conference. Her research publications include health politics, public policy, gender and multi-level governance.

1. Introduction

Although the ancient Olympic Games (OG) were religious festivals and displays of political might, when Pierre de Coubertin founded the Modern Olympic games in Rome in 1896, he envisioned athletic competition transcending military competition between states and leading to international cooperation. Hosting the Olympic and Paralympic games can raise a country's international visibility and prestige--particularly so if the country has not hosted before.

Efforts to reform the bidding and hosting process appear to solve some problems while creating others. For example, in preparation for the 1976 Summer Games, Montreal proudly unveiled its Big "O" Stadium costing $1.5b USD. Today, colloquially known as the Big "Owe," it costs $32m USD a year just to maintain it. Only tearing it down would cost more than the maintenance (Todd, 2016, July 7). In response to such overspending, the 1984 Los Angeles Games restructured the Olympic financial model, requiring that multi-million dollar Official Olympic sponsors, or multinational corporations, pay a larger share of the short-term costs of hosting the Games. This model, combined with a sharp jump in television broadcast revenue made L.A. the only city to turn a profit hosting the Olympics, finishing with a $215m US operating surplus (McBride, 2018). Unfortunately, this strategy shuts out local businesses who could benefit from sales (Boykoff, 2016) and leads to a sort of iron-triangle cooperation between the city, country and International Olympic Committee (IOC), and corporate sponsors who maintain complete brand control in the Olympic Economic zone (Sinclair, 2012).

Anti-Olympic groups ask, How sensible is the overall project of the OG? Why should they be held in different cities, saddling generations with pollution, garbage, excess capacity and debt just to pay for buildings used for only two months (Bray 2011)? Should developing countries be pressured to host when they have other priorities (Bray, 2011)? For too long, those who have to deal with the tax burden, inconvenience and garbage associated with hosting an OG, are those who fail to reap actual benefits from hosting.

The opening ceremonies of the XXXII Olympiad will be held in Tokyo, Japan from 24 July to 9 August 2020. These games will include a record 207 Nations, 12,000 athletes, and 324 events in 33 sports (IOC, n.d.) with the paralympics to follow. The average country cost to host a Summer OG is $5.2b US. This includes building stadiums and arenas for athletic events, constructing hotels for tourists, updating transportation for spectators, dealing with garbage, pollution, and traffic created by anticipated 920,000 visitors to Japan each of the 20 days of the games (Osada *et al.*, 2016). Ticket sales, advertising, and athlete fees of $0.6m US do not cover these costs. As a backdrop, Tokyo 2020 OG is situated in a country associated with leading the global community on dealing with climate change. The 1997 Kyoto Protocol set in motion the most comprehensive and proportional plan to get countries to commit to reducing their greenhouse gas emissions (United Nations Framework Convention on Climate Change, 1998).

Compare this projected record attendance with the reality of the Rio 2016 Games, which have been criticized for the poor water conditions for athletes, over-focus on planting trees and emphasis on having athletes eat low on the food chain in the Olympic Village for a green sustainability strategy. Yet, Rio itself was host to the Earth Summit in 1992 to discuss climate change. The non-binding documents signed at the Earth Summit included what would come to be called Agenda 21 (Guthoff, 2017). The UN defines Agenda 21 as "a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment "(World Commission on Environment and Development, 1992). Over the long term, Rio may benefit enormously from being the first Latin American OG host outside of Mexico City in 1968. This paper describes the evolution of an agenda to make the OG environmentally sustainable, and to create a screening assessment of the relative success of activities in connection with the Rio 2106 OG and the upcoming Tokyo 2020 OG.

2. International Conferences and Mainstreaming of Sustainability into the OG

Sustainability is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 16). Domestic environmental groups, as well as international organizations like the United Nations (UN), have forced sustainable development onto the international agenda, including at events like the Olympic Games. Specifically, the UN states that "sustainable development seeks to achieve, in a balanced manner, economic development, social development and environmental protection" (World Commission on Environment and Development, 2015). The UN has shown its commitment to sustainability, despite having other top global priorities. Sustainability was present within the eight Millennium Development Goals formed by the United Nations in the Millennium Summit in 2000 for evaluation by 2017. Specifically, Goal #7 was ensure environmental sustainability. Moving forward to 2015, the UN articulated 17 Sustainable Development Goals (SDGs), which are development principles with targets that all 194 member states should seek to meet by 2030. In particular, Rio considered UN SDGs 7, 9, 12, 13, 15, and 17 to create focus areas of infrastructure and natural sites, sourcing and resource management, and address mobility and climate change, but as mentioned previously Brazil did not perform well on Goal 6 Clean water and Sanitation.

In IOC documents, the current meaning of sustainability has evolved to include the amalgamation of environment, economic and social issues, but the origin of this emphasis is traced back to IOC's presence at the 1992 UN Earth Summit in Rio de Janeiro where Agenda 21 was formed, a plan for worldwide sustainable development. Activists and leaders or advocacy coalitions in the global environmental community are key forces (Keck & Sikkink, 1998), pushing for other international organizations like the IOC to adopt sustainability. By 1996 the IOC revised the Olympic Charter to enumerate the importance of sustainable development in the Olympic Movement (OM; IOC, 1996, p.11). From this inauspicious beginning, the concept of sustainable development in the OG evolved to include terms such as sustainability, green legacy, low carbon, zero waste, biodiversity protection, water conservation, net zero energy and zero impact (Ross & Leopkey, 2017).

Tracing the evolution of the concept of sustainability requires chronology gymnastics due to multi-year lag time from IOC pronouncement to bidding on and hosting an OG. Ross and Leopkey trace the evolution of environmental practices of the OM into three phases: environment, sustainability and zero impact. Several examples are especially pertinent. Beginning in 1997 with the newly added sustainable development clause in the Olympic Charter, Olympic bids contained sections dedicated to sustainable development and environmental protection leading to Athens 2004. In 1999, after the IOC adopted Agenda 21 sustainability development principles and added bid recommendations of environmental restoration, Torino added a green legacy to its bid for the 2006 Olympics (Ross & Loepkey, 2017).

Although it appears the IOC is setting the pace, in reality the bidding cities 'upped the ante' on sustainable development in each subsequent bid of host an OG. In 1997 Torino added a social component to sustainability, while Helsinki's bid suggested developing assessment. However, it wasn't until 2000 that the IOC instituted the Olympic Games Impact Program to assess sustainable development at the OG. After that announcement, Sochi 2014 used the environmental standards of the World Health Organization for assessment. In 2003, Vancouver's 2010 bid expanded Torino's 1997 bid containing the social aspect of sustainability to include financial, economic, social and environment aspects of sustainability (Ross & Loepkey, 2017). These bids reflect the effort of OG candidates to articulate meaningful attributes of sustainable development with each successive bidding city furthering the meaning of sustainability. Presently the internationally recognized pillars of sustainable development are environment, socio-cultural and economic. The IOC declined to mandate specific sustainability goals for an OG bid, and instead stated that it will work with the candidate city to develop a sustainability strategy aligned with the five IOC sustainability focus areas, establish a sustainability management system, and deliver sustainability reports (IOC, 2017a).

In 2005, London announced its bid to host in 2012 and used the phrases low carbon, zero waste, and protection of biodiversity. In 2009, Rio de Janeiro's bid for 2016 OG included the concepts of water conservation, renewable energy, carbon neutrality. In 2013, Tokyo's 2020 bid listed zero waste and restoration of urban nature (Ross & Loepkey, 2017). All these bids occurred by 2013, yet it was not until 2014 that the IOC published Agenda 2020 which included two broad recommendations for sustainability at the OG: include sustainability in all aspects of the OG and include within the OM's daily operation (IOC, 2015). Since then, the IOC recognized that "sustainability is a continually evolving and changing process" (IOC, 2017, p. 49) and committed to reviewing its sustainability strategy every four years. With the implementation of Global Reporting Initiative (which set standards for reporting principles for defining report content and quality) examination of plans, efforts, applications and fulfillment of strategic goals for sustainable development is more feasible than ever (IOC, 2011). The IOC uses the post-games reports to commit to Agenda 2020, namely to ensure post-Games monitoring of the Games legacy. Although this will be expected for the 2024 OG, it is likely that prior OG will voluntarily make efforts in this area. Rio 2016 has yet to submit a post-games report.

The Rio 2016 Games were heralded as most sustainable in their planning, and carbon neutrality through reforestation, but were still criticized for overemphasis on tree planting, the fact that some projects were not completed on time meaning construction for naught, and a dam failure that led to arsenic leeching in a river. But undoubtedly, the most egregious issue at the Rio 2016 Games was the poor water quality encountered by swimmers and athletes using aquatic vessels such as sailboats, canoes, sculls in Guanabara Bay (Guthoff, 2017). Post-games analyses by the sport federations generated a water quality management plan with common guidelines (standards and testing protocols) for future host cities. They predict that following such a plan will secure good water quality for the athletes and for the city afterwards (IOC, 2017b).

3. Environmental Sustainability incorporated into Rio 2016 and Tokyo 2020 Plans

In 2014, the International Olympic Committee (IOC) published Olympic Agenda 2020 (IOC, 2015), listing 40 recommendations to address concerns of credibility, youth games and sustainability. Two recommendations emphasized sustainability—in OG and OM. These two reflected the United Nations Millenium Development Goal #7 Ensure environmental stability (UN, 2000). Furthering this effort, the UN adopted Agenda 2030 creating 17 sustainable development goals (SGDs; World Commission on Environment and Development, 2015) and recognized the powerful role of sport in this quest. Then in 2016, the IOC addressed how it would contribute to the 2030 Agenda and SDGs at the Olympic Games in the IOC Sustainability Strategy. Pointedly, the IOC expected to "include sustainability in all aspects of the Olympic Games and within the Olympic Movement's daily operations" (IOC, 2017a).

Although Rio 2016 was selected as a host city in 2009, much earlier than the IOC move towards environmental sustainability, the candidature application for Rio 2016 included several aspects of sustainability. In *Live Your Passion: Rio 2016 Candidate City* (Rio, 2009), the areas of focus for the environmental and sustainability plans were listed as water conservation, renewable energy, carbon neutral Games, and waste management and social responsibility. After further deliberation, the sustainability management plan listed nine dimensions of environmental sustainability: 1. Water treatment and conservation 2. Environmental awareness 3. Use and management of renewable energy 4. Games neutral in carbon, air quality and transport 5. Protection of soils and ecosystems 6. Sustainable design and construction 7. Reforestation, biodiversity and culture 8. Shopping and ecological certification 9. Solid waste management (Rio 2016 Bid Committee, 2008, volume 1, page 92.). The IOC comments on the candidature file indicated that Brazil had small cars using ethanol, taxis using methane, signed the Kyoto Protocol, had acceptable air quality (with a few exceptions for particulate matter) and the drinking water quality was acceptable (IOC, 2009).

Similarly, this paradigm shift of sustainable development occurred after Tokyo offered the bid in 2009 and candidature file in 2011 for the 2020 Olympics Games. However, Tokyo's bid included its sustainability concept of "Be better, together-For the people and the planet." Tokyo was elected to be the host city for the 2020 Olympic games in 2013, a year before IOC adopted the Olympic Agenda 2020. Nevertheless, in the High-level Sustainability Plan (Tokyo Organising Committee for the Olympic and Paralympic Games, 2016), Tokyo 2020 had fully embraced sustainable development in five main sustainability issues: climate change; resource management; natural environment and biodiversity; human rights, labor rights and fair business practices; and involvement, cooperation and communication. By July of 2016, the Tokyo 2020 Action and Legacy Plan promised gains in sports and health; urban planning and sustainability; culture and education; economy the technology; and recovery, nationwide benefits and global communications. One example is the goal of using recycled metals from donated electronics in the creation of the Olympic medals. Not only were the metals recycled instead of landfilled, but the project generated enthusiasm and buy-in from around the nation.

To address the unsustainable high cost of OG, the IOC published the New Norm (IOC, 2018a) which provided 118 measures to increase cost-effectiveness and transfer of services from game to game. In October 2018, the Executive Board meeting reported that by applying around 90 of the New Norm measures, Tokyo 2020, would be saving $4.3b USD through the review of the Venue Master Plan and from the operational budget (IOC, 2018b, October 4). Unfortunately, this was too late for Rio 2016.

This paper therefore compares the sustainability efforts of the Olympics Games in Rio 2016 and Tokyo 2020 with respect to the environmental hub of sustainability. We report for both Rio 2016 Games and the Tokyo 2020 Games sustainability initiatives in the following nine dimensions: water treatment and conservation; environmental awareness; use and management of renewable energy; games neutral in carbon, air quality and transport; protection of soils and ecosystems; sustainable design and construction; reforestation, biodiversity and culture; shopping and ecological certification; and solid waste management.

4. Method

Sustainability assessment must address several factors, most notably for this assessment: level of analysis desired (screening or evaluative), objectives to assess, attributes to examine, and weighting of the attributes (van Hervejnin, n.d.). The purpose of this assessment is to provide early feedback on environmental activities/events and provide input for refining the bidding process for the OG hosts. To assess environmental sustainability, an evaluation table or matrix was created using the Rio's environmental sustainability dimensions (Rio Bid Committee, 2008, volume 1, page 92) as the objectives (heading in the appendix).

Below each heading, activities (or events) were listed which impacted the heading and were scripted to represent positive weight (w_i = +1) or negative weight (w_i = -1) with regards to performance or completion of the sustainability dimension. Normal font was positive weight and italics was negative.

In this study, a simplified weighted summation methodology was used. Because this is a screening analysis, the weighs were a direct estimation of the magnitude of the effects of the activity and listed as either '0' for prior to event, '1' for moderate effect or '2' for strong effect with the value given in parentheses after the activity. A simple ternary weight system was chosen due to the timing of the assessment. Rio 2016 has yet to complete a final post-game report to use in this analysis; therefore, items for Rio in the matrix come from their bid, pre-game report and from media reporting. Similarly, Tokyo 2020 has yet to host the OG and complete a final post-game report (anticipated in 2023) to use in this analysis. Likewise, items in the matrix for Tokyo come from their bid, pre-game report and from media reporting.

The weighted sums for each issue were calculated using the formula:

$$weighted\ sum = \sum_{i=1}^{N} w_i\, v_i \qquad \text{equation 1.}$$

With N being the number of activities, w_i as the weight of the activity i and v_i as the value of activity i.

The weighted sums were listed immediately below each objective in the appendices. The total of the weighted sums is the score for environmental sustainability and was listed below the name of the Olympic Games host city in each appendix.

5. Results

Appendix 1 is an evaluation matrix for Rio 2016 which lists both positive and negative attributes for each of the nine environmental sustainability dimensions. The weighted sum for each dimension was determined and the sum of these is the score of 8 for Rio 2016 using this environmental sustainability assessment. Appendix 2 follows the same evaluation matrix format for Tokyo 2020 which scored 16 in this environmental sustainability assessment. These scores are temporal and will change as more information is released and as events occur. For Rio 2016, the score of 8 may change when more information is released, especially a post-games report. Tokyo 2020 Games have not happened yet, but many environmental activities are already implemented and have value assigned to them. After the games occur, the value of the other activities can be estimated.

6. Discussion

The nine sustainability dimensions for Rio 2016 (Rio 2016 Organising Committee for the Olympic and Paralympic Games, 2013, p.10) were used as the objectives for two main reasons. First, acting rationally, the Rio 2016 Games should choose dimensions for sustainability in which it could reasonably expect to advance some sort of policy goal. We recognize that different countries might pursue different policies within these dimensions, based on their unique characteristics and comparative advantage, but in this screening assessment was recorded as the presence or absence of policy initiatives in each of the nine dimensions.

Second, even though Brazil is an emerging economy and Japan is a highly developed economy, it struck us as more reasonable to impose Rio's framework on Tokyo than retroactively imposing a framework Tokyo chose on Rio. Finally, when developing frameworks like sustainability strategies for international law, research and policy evaluation must include both developed and developing countries in order to be effective. This case selection strategy is employed in other research. For example, if International Organizations claim that decentralization is a good institutional reform for promoting women, then research testing that proposition must be carried out in a variety of countries (see Rincker, 2017), not just advanced industrialized democracies but a range of countries.

For Rio 2016, the score of 8 represents a rough estimate of the assessment of the environmental sustainability at the Olympics. For Tokyo 2020, the score of 16 is larger; however, none of the values are normalized so direct comparison is not as important as reviewing the strengths and weakness of the attributes for the dimensions. For example, Tokyo may thrive under additional scrutiny and address some areas that are unaddressed or negatives. In fact, Tokyo did address the unfair practices associated with forest products it imported (Tokyo Organising Committee of the Olympic and Paralympic Games, 2019). We would expect Tokyo 2020's sustainability strategy to be more comprehensive than Rio's based on disparate wealth levels, Tokyo learning from the Rio Games and the recommendations in the New Norm (IOC, 2018a). The New Norm was published after Rio 2016 yet the recommendations it provided might have benefitted Rio. Tokyo 2020 estimates it will shave $4.3b US from its expenditures through implementing several of the recommendations (IOC, 2018b).

Bidding itself is subject not only to coercive pressures from the IOC but also mimetic and normative pressure from other candidate and host cities (Ross & Loepkey, 2017). In the excitement of being the first South American country to host the Olympics, environmental goals in the Rio bid may have been an unrealistic reach. The impression of Rio's polluted waterways may cast a pale on the positive legacy of cleaner water. Although not reaching the bid goal of 80%, by the time of the Olympics, the percentage of treated sewage rose from 12 to 60% (Clarke, 2016, March 9). Perhaps the lesson here is to give credit to a bidding city which is more realistic concerning changes and dedicated to a legacy of continuing improvement.

The term 'resilience' is not coined, yet is demonstrated by the appearance of the Tokyo 2020 Olympic flame in regions recovering from the Great East Japan earthquake of 2011. Resilience is an aspect of sustainability and recognition should be given to people who "overcome difficulty and show persistence" (Tokyo Organising Committee for the Olympic and Paralympic Games, 2019). Rio, in retrospect, mustered resilience dealing with both the Zika virus and an economic downturn around the time of the Olympics. These extenuating circumstances are not included in this sustainability assessment, but likely should be.

Last, the nine dimensions are not totally independent from one another. Reflecting the environment itself, there is spillover in one negative dimension to other dimensions, such as Tokyo 2020 not sustainably sourcing its timber. The weighted sums should be analyzed for redundancy to determine if an attribute has more impact than expected.

7. Conclusion

A weighted sum assessment of the dimensions of the Rio 2016 and Tokyo 2020 Olympic Games suggest scores of 8 and 14, respectively. These scores are temporal and will change as event happen and information is released. Both games have completed several outstanding activities related to environmental sustainability and also have experienced problems with environmental quality or unfair practices. It is noteworthy that over previous games, Rio 2016 and Tokyo 2020, located in countries that have played leading roles in setting the international environmental agenda, still have much to do to give the Olympic Games a legacy of sustainability.

References

Boykoff, Jules. (2016). *Power games: A political history of the Olympics.* Verso: New York.

Bray, Ellen. (2011). The curse of good hospitality: Why developing countries shouldn't host international sporting events. *SAIS Review of International Affairs, 31*(1), 99-102.

Cashman, Richard (2002). Impact of the games on Olympic host cities. Retrieved from http://www.dormivigilia.com/wp-content/uploads/2010/01/cashman.pdf

Clarke, Liz. (2016, Mar 9), USOC, athletes navigate questions swirling around Rio's contaminated waters. *Washington Post.* Retrieved from https://www.washingtonpost.com/sports/olympics/us-athletes-focused-on-medals-not-water-quality-ahead-of-rio-olympics/2016/03/09/def96766-e63b-11e5-b0fd-073d5930a7b7_story.html?utm_term=.780deadbc126

Goldblatt, David. (2016). *The games: A global history of the Olympics.* W.W. Norton & Company: New York.

Guthoff, Ian. (2017). Creating a sustainable Olympic games. *Syracuse Journal of International Law and Commerce, 44*(2), 355-375.

IOC. (n.d.). Tokyo 2020. Retrieved from https://www.olympic.org/tokyo-2020

IOC. (1996). *Olympic charter.* Lausanne: Author. Retrieved from https://www.olympic.org/olympic-studies-centre/collections/official-publications/olympic-charters

IOC. (2009). *Report of the 2016 IOC evaluation commission: Games of the XXXI Olympiad*. Lausanne: Author.

IOC. (2011). *Technical manual on Olympic games impact (5th Ed.).* Lausanne: Author.

IOC. (2015). Olympic agenda 2020: Implementation plan. Lausanne: Author. Retrieved from https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/Documents/Olympic-Agenda-2020/Olympic-Agenda-2020-Implementation-Plan-2015-and-Beyond.pdf

IOC. (2017a). Sustainability strategy. Lausanne: Author. Retrieved from https://www.olympic.org/~/media/Document%20Library/OlympicOrg/Factsheets-Reference-Documents/Sustainability/IOC-Sustainability-Strategy-Long-version-v12.pdf?la=en

IOC. (2017b). IF-Sustainability Case Study. Water Quality Working Group. Retrieved from https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/IOC/What-We-

Do/celebrate-olympic-games/Sustainability/Case-Studies/2017/IF%20SCS-WATER%20QUALITY.pdf#_ga=2.126667780.84412320.1538766550-601309461.1538168927

IOC (2018a). *Olympic agenda 2020: Olympic games: the new norm*. Lausanne: Author.

IOC. (2018b). Olympic agenda 2020 and its new norm save Tokyo 2020 USD 4.3 billion. *Olympic news*. Retrieved from https://www.olympic.org/news/olympic-agenda-2020-and-its-new-norm-saves-tokyo-2020-usd-4-3-billion

Keck, Margaret E. and Sikkink, Kathryn. (1998). *Activists beyond borders: Advocacy networks in international politics*. Cornell University Press.

McBride, James. (2018). The economies of hosting the Olympics. Retrieved from: https://www.cfr.org/backgrounder/economics-hosting-olympic-games

Osada, Mitsuhiro, Ojima, Mayumi, Kurachi, Yoshiyuki, Miura, Ko & Kawamoto, Takuji. (2016). Economic Impact of the Tokyo 2020 Olympic Games. Retrieved from https://www.boj.or.jp/en/research/brp/ron_2016/data/ron160121b.pdf

Rincker, Meg. (2017). *Empowered by design: Decentralization and the gender policy trifecta*. Temple University Press.

Rio 2016 Bid Committee. (2008). *Rio 2016 candidature file*. Rio de Janiero: Author.

Rio 2016 Organising Committee for the Olympic and Paralympic Games. (2013). Sustainability management plan: Rio 2016 Olympic and Paralympic games. Retrieved from: http://www.climateaction.org/images/uploads/documents/sustainability_management_plan_aug2013.pdf

Ross, Walker J & Leopkey, Becca. (2017). The adoption and evolution of environmental practices in the Olympic Games. *Managing Sport and Leisure*, *22*(1), 1-18.

Sinclar, Ian. (2012). *Ghost milk: Recent adventures among the future ruins of London on the eve of the 2012 Olympics*. Faber and Faber: London.

Todd, Jack. (2016, July 7). The 40-year hangover: How the 1976 Olympics nearly broke Montreal. Retrieved from https//www.theguardian.com/cities/2016/jul/06/40-year-hangover-19760olympic-games-broke-montreal-canada

Tokyo Organising Committee of the Olympic and Paralympic Games (TOCOG). (2016). *High-level Sustainability Plan*. Tokyo: Author. Retrieved from https://tokyo2020.org/en/games/sustainability/data/sus-plan-EN.pdf

Tokyo Organising Committee for the Olympic and Paralympic Games (TOCOG). (2019). *Sustainability Progress Report: Tokyo 2020*. Tokyo: Author. Retrieved from https://tokyo2020.org/en/games/sustainability/report/data/tokyo2020-games-sus-report_EN.pdfor

United Nations Framework Convention on Climate Change. (1998). Kyoto protocol. Retrieved from http://kyotoprotocol.com/resource/kpeng.pdf

UN. (2000). UN Millennium Declaration. UN: Author. Retrieved from https://www.un.org/millennium/declaration/ares552e.pdf

van Hervejnin, Marjan (n.d.). Weighted summation (WSum). Retrieved from http://www.ivm.vu.nl/en/Images/MCA2_tcm234-161528.pdf

World Commission on Environment and Development. (1992). *Agenda 21*. UNCED: Author. Retrieved from https://sustainabledevelopment.un.org/outcomedocuments/agenda21

World Commission on Environment and Development. (1987). *Our common future*. Oxford: Oxford University Press.

World Commission on Environment and Development, (2015). Transforming our world. The 2030 agenda for sustainable development. UN General Assembly: Author. Retrieved from https://www.unfpa.org/resources/transforming-our-world-2030-agenda-sustainable-development

Appendix 1. Evaluation Matrix for Rio 2016

	Water Treatment and Conservation	**Environmental Awareness**	**Use and management of renewable energy**	**Games neutral in carbon, air quality and transport**	**Protection of soils and ecosystems**	**Sustainable design and onstruction**	**Reforestation, biodiversity and culture**	**Shopping and ecological certification**	**Solid Waste management**
Rio 2016	-1 Clean up	5 Sustainably	1 Cleaner fuels	1 Cleaner fuel for	-1 "Clean	0 Maracana	0 Reforestation	2 All permanent venues	1 Clean up of

Score of 8	pollution and trash from waterways including Guanabara Bay and rivers (1) Add drainage, sewage and water recycling capabilities (1) *Polluted Guanabara Bay had high level of viruses (1)* *High concentrations of untreated sewage in the bay (1)* *Low treatment of sewage in outlying areas of Guanabara (1)*	sourced fish for athletes (1) Meat produced on farms that didn't clear cut (1) Medals from recycled materials (1) Sustainability education activities (1) Sustainability training program for workforce (1)	for Olympic/ Paralympic fleet (1)	Olympic/Paralympic fleet (1) Improvement of public transit including bus, metro, BRT, and bike lanes (1) Optimize transport of materials (1) *Carbon footprint: Promised 3.6m tonnes CO2 reduction, achieved around 1.6m tonnes (2)*	Games' and reforestation initiatives (1) *Construction of golf course on Marapendi Nature Preserve (2)*	Stadium, Rio de Janeiro Rational use of resources, efficiency and minimization of environmental impact in venue design and construction (including recycled materials, greenhouse gas emissions, water use, environmental impact, and spills) (1) Venues remain nearly empty or not utilized post-games (1)	at Barra and Deodoro Sites and Community based reforestation in Rio: Green Capital Programme (1) Clean Games Initiative (coordination of several environmental groups) (1) *8 million trees planted not 36 million promised (2)*	built by municipal government will receive LEED certification from Brazil's PROCEL (1) Forest management and timber sourcing will be certified by FSC, INMETRO/CERFLOR, or PEFC (1)	dump sites (1) Alignment and implementation of waste management plans for construction and responsible management and treatment of solid waste from the games (1) *Failure to Clean Guanabara Bay (1)*

Appendix 2. Evaluation Matrix for Tokyo 2020

	Water Treatment and Conservation	**Environmental Awareness**	**Use and management of renewable energy**	**Games neutral in carbon, air quality and transport**	**Protection of soils and ecosystems**	**Sustainable design and construction**	**Reforestation, biodiversity and culture**	**Shopping and ecological certification**	**Solid Waste management**
Tokyo 2020 **Score of 14**	1 Improve water circulation in the city (1) Recycled use of rainwater in venues (0) Cleaning and management of Tokyo Bay and rivers and Restoration of water in parks including Kokyo Gaien National Park (Imperial Palace) (1) *Mixed - bacteria levels of Tokyo Bay very high at present but plan in place to screen bacteria (1)*	4 Medals made from recycled cell phones (1) Recycled dinnerware in the Olympic Village (0) Implementation of reuse and recycling project for purchased goods and materials (1) Promotion of activities to increase climate change awareness (1) Improving green spaces to promote human interaction with nature (1)	2 Powering the Olympic Village with Hydrogen (0) Promotion recycled materials such as timbers for consumption (1) *Timbers not sustainably sourced initially (1)*	1 Hydrogen fuel cell cars (0) Powering the Olympic Village with Hydrogen (0) Introduction of systems for sharing data on the environment, including the weather and air quality (1)	1 Sustainable sourcing for procurement (0) Management of chemicals in items produced/ given at the games (0) Use of low-emission and low-noise type construction machineries (1) *Timbers not sustainably sourced (1)*	2 New National Stadium, Harajuku (0) Strategic planning to use existing venues (accounting for 60% of venues) (1) High Environmental Performance in New Venues (including recycling materials, installation of renewable energy sources such as geothermal, solar power and passive design, and lumber relay, rank 'S' in CASBEE assessment) (1)	0 Resources obtained from forests and oceans must be ones which are collected and cultivated using resource conservation Measures (1) 'Greening' at venues and development/ upkeep of green spaces around the metropolitan area (0) Combating of Invasive Species (0) *Exploitation of tropical rainforests (1)*	2 Sustainable Sourcing Code (1) Tokyo GAP certificate system (1) New venues must rank 'S' in CASBEE assessment (1) *Timbers not sustainably sourced (1)*	1 Goal of 'Zero Wasting' (0) Reduction of the edible part of food waste by optimized management systems (0) Reduction of the production of new items by using rentals and leases to procure items (1) Recycle of food waste (0) Reuse or recycle of construction wastes (0)

18. Current and future prospects of small hydro power plants. Opportunities and risks

Aranit Shkurti

ABSTRACT:
Small hydro power plants can be an alternative source of electrical energy due to several advantages like minimum maintenance and operating costs, well established technology, opportunity to balance the supply, positive socio-economic impact on rural isolated areas etc. Unlike large plants, small hydropower installations can have a minimum impact on the water ecosystems avoiding to exploit local resources. Overall, 15000 MW of hydroelectric resources have been identified in Albania, whereas, approximately 31% of the identified resources are operational, with 4500 MW of installed hydroelectric power. This paper describes the state of the art of the small hydropower concessions in Albania. The key factors that are taken under consideration are: the return of the investment, the nature and scale of impacts on local communities, and then the extent to which small hydropower might be considered distinct from other energy sectors in terms of externalities that they can generate.

Keywords: Small hydropower plants, externality, rural communities, utilities.

Dr. Aranit Shkurti is an Assistant Professor of Statistics, College of Engineering and Technology, American University of the Middle East, Kuwait. More than 10 years of Experience in the field. PhD University of Rome, "La Sapienza", Italy.

1. Introduction

In recent years, power generation by hydro power plants in Albania has undergone considerable changes. The government has agreed to increase the share of renewable energy under the Energy Community Treaty to 38% by 2020 (EES, Groningen, & 2013). Anyway the transport system is heavily relying on fossil hydrocarbon fuels and the trend is not improving at all. From the other side the hydroelectric power generation is a positive record in Europe, more for the legacy of the past rather than the current investments, given the dependence of the Hydro power plants on the system by 97%.

This is due to socio-economic reasons, but also for simple hydro meteorological reasons, Albania has one of the highest freshwater resources per capita in Europe. In this context, it is important to remember that this cumbersome relationship between water and energy must be modified in the future, in order to avoid unbalancing the entire energy system in the case of a simple dry season.

On the governmental level, the ministry responsible for the energy and electricity-related issues in Albania, is the Ministry of Economy, Trade and Energy (METE). The National Agency of Natural Resources (AKBN) is an institution organizationally-dependent on the METE which is responsible for the usage of the natural resources such as hydrocarbons, mining and energy and develops and implements the energy policies (AKBN, 2010). The Energy Regulatory Entity (ERE) is an independent

body created in 19951. The ERE's role is to maintain a balance between the different energy actors in Albania while ensuring the protection of interest of the electricity consumers. The state-owned Albanian Energy Corporation (KESH) went through a structural change in 2001 and formed the production division, the transmission division (OST) and the distribution division (OSSH) (EES, Groningen, & 2013).
In this study we take in consideration the contribute of small hydropower plant, here refers to less than 10MW installed capacity. Small hydro projects, similarly to larger plants, have a wide range of levelized cost of electricity due to its sensitivity to the plant capacity factor and the cost of capital. The range can be from a minimum of 35 USD/MWh up to and possibly exceeding 230 USD/MWh (IEA, 2012)

2. The current structure of the Energy Market

KESH (*Korporata Elektroenergjitike Shqiptare*) is the largest energy company in Albania with state-owned capital with the public service obligation according to DCM No. 244 dated 30.03.2016[23], responsible for the maintenance and operability of the existing hydro power plants of the Drin river cascade. KESH has undergone a series of fundamental transformations since 2000, by converting, from a vertically integrated company (beginning in 1957), to a company that presently focuses on the power generation and trade. By operating 79% of the generation capacity in the country, KESH supplies about 70-75% of the customers' demand for electricity, provides the energy needed to cover the losses in the transmission grid, as well as guarantees the security of the Albanian energy system through balancing energy and auxiliary services.

[23] http://www.kesh.al

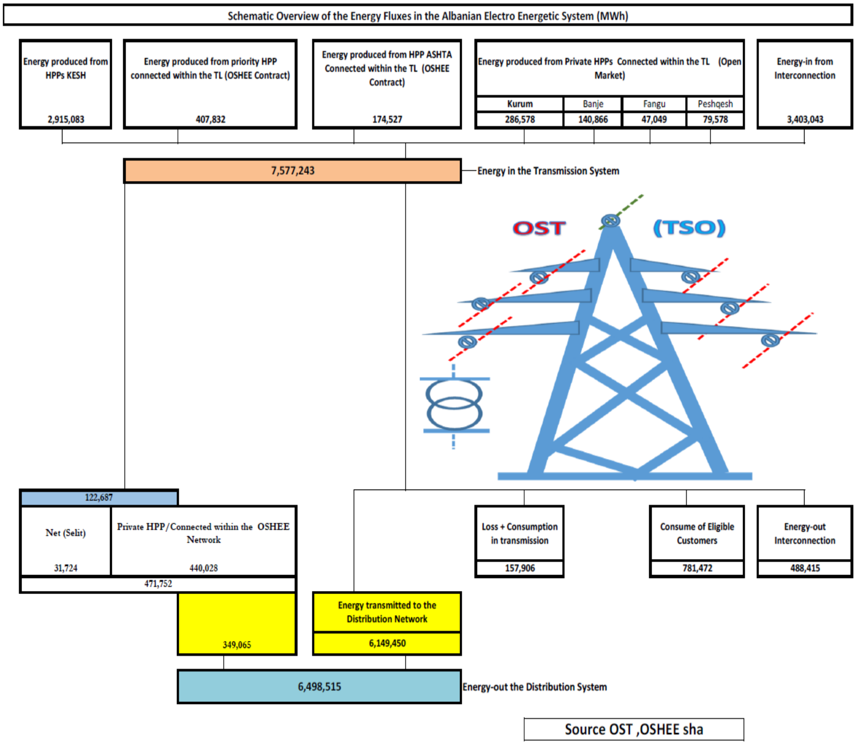
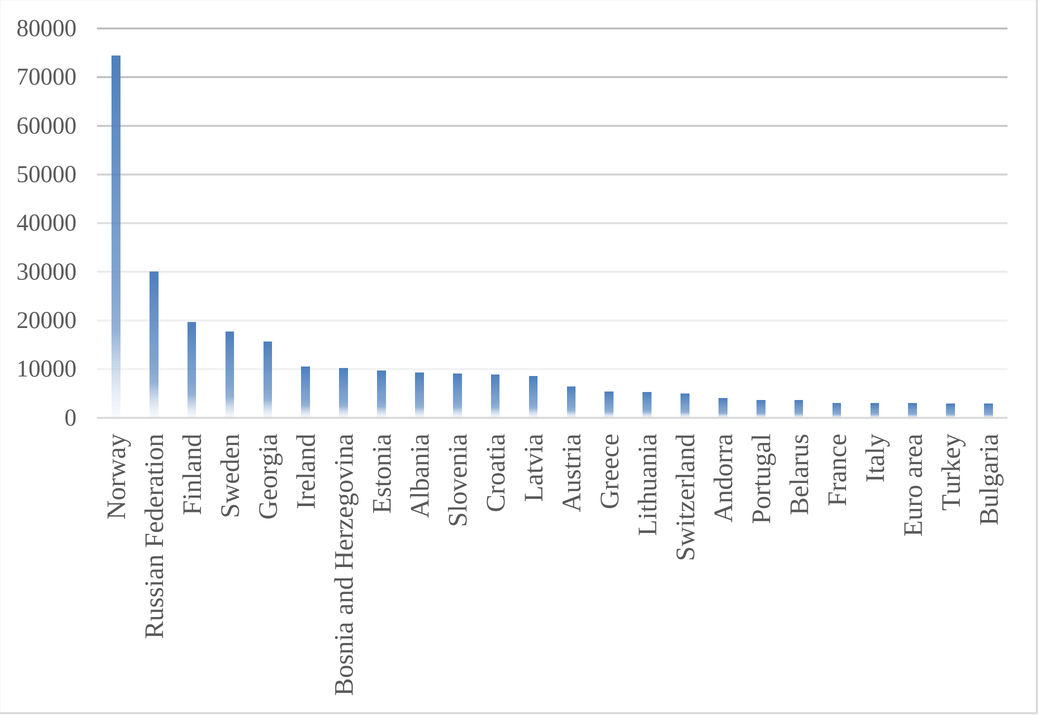


Figure 1. Schematic overview of the Energy fluxes in the Albanian Electro Energetic System. Source: www.kesh.al

3. The Market potential

A series of studies carried out by the World Bank (Gummer, 2002, Kiris, & 2002) on the generation sector identified a series of hydro power generation projects that can be implemented in the next years. In order to have a clear view of the volume of energy needed to meet the needs of the country, the study considered a scenario of increased demand pursuing the current trend.

The hydropower potential of the country is quite impressive, and ranks among the top European countries in matter of freshwater resources So far a series of operators have expressed interest in investments in the electro-energy field. Mainly these are direct investments to small and medium-sized plants. In today's date approximately approx. 213 concessions for the construction of plants up to 50 MW. So far 148 of them are operational.



Renewable internal freshwater resources per capita (cubic meters), Year 2014.
Source: Food and Agriculture Organization, AQUASTAT data.

In addition to the construction of new power plants, KESH the state owned Energy company must also take care of the maintenance of existing ones, which are often in precarious situations. It is important to remember that water power plants need special protection for the danger they can present to civilian populations.

In the formulation of development strategies in the division of generation, we must bear in mind the characteristics of the Albanian system, such as, the disproportionate relationship between the HPP / TPP production capacity, the concentration of generation sources in the North and consumers in the South. In the past 15 years a lot of investment in the sector, were pushing toward a positive attraction for FDI in general and Energy sector in particular (EES, Groningen, & 2013). Anyway the lack of guaranties from the Government have created a lot of conflicts like the CEZ (Czech Energy Company)

The organization of the energy market to operate on a medium-long term path needs access to third parties as soon as possible, free to stipulate bilateral contracts with local operators. This environment must guarantee energy producers the right to choose the counterpart, without restricting the offer to the distribution monopoly (OSSH).

These arguments highlight the difficulty of entering the energy market by operators and foreign capital.

Moreover, the public transmission operator (OST) must guarantee the flows in the network without placing preference constraints for the local market. All these operations must be supervised by the Public Authority for Electricity Regularization (ERE). Given the peculiarity of the energy asset and the very fragile balance of its marketing, only these guarantees can push foreign investors to venture into the Albanian business.

In previous years, many international consortia have expressed interest in the construction of hydro power plants, but also thermoelectric plants, putting into place contract formats of the IPP type. Subsequently potential investors requested long-term PPA contracts, first with KESH and then with OSSH. These agreements are essential in ensuring the financing of the investment schemes.

Project funding is considered a very promising alternative for projects funded minimum for a period of 10 years (Xhafa, 2009). The way this contracts can be developed will be dictated by the circumstances of energy consumption in the Albanian market, but also the local one. In this context, the PPA agreements come into play, in order to guarantee the marketing of energy also in neighboring countries, including Italy.

The investor should be guaranteed to provide detailed financial reports annually, aimed at a climate of mutual transparency. PPA contracts can be flexible in minimum guarantees from the Albanian government, as long as they meet debt repayment and equity participation in order to secure financial participation (Shumka, Shuka, BALWOIS, & 2010).

4. **Methodology**

To evaluate the ongoing performance of the HPPs in Albania a time series of past 5 years were considered. The hydro power plants were divided in three categories

a) Big HPPs with installed capacity of more or equal to 100MW
b) Medium HPPs with installed capacity of in between 10 to 100MW
c) Small HPPs with installed capacity of less than equal to 10MW

The data were downloaded from the Energy Authority web page ere.gov.al
The following formula was applied to calculate the Annual Capacity factor

$$CF = \frac{AG}{IC * 8760}$$

Where

CF – Capacity Facotr
AG – Actual generated Energy

IC – installed capacity
8760 = total hours in one year

The aim of the study is to compare the capacity factor in % of the Small HPP with Big HPPs
Assumptions to be adopted before going further with the analysis are:
1. Same monthly precipitation map.
Not significant differences in the monthly average distribution of precipitations.
2. Same Technology within groups.
Not significant differences within the factor load of big HPPs and the Factor Load of Small HPPs

Table 1. Capacity Factor calculation for Big, Medium and Small Hydropower Plants in the period 2014-2018

Big Power Plants	2014	2015	2016	2017	2018
Actual Generation	3,408,549	4,451,975	5,091,617	2916990	5850932
Installed Capacity	1350	1350	1350	1350	1350
Capacity Factor	**28.82%**	**37.65%**	**43.05%**	**24.67%**	**49.48%**

Medium Power Plants	2014	2015	2016	2017	2018
Actual Generation	819,709	926,613	1382940	1134522	1958137
Installed Capacity	320	337	443	567	614
Capacity Factor	**29.24%**	**31.39%**	**35.64%**	**22.84%**	**36.41%**

Small Power Plants	2014	2015	2016	2017	2018
Actual Generation	436173	487082	615312	471751	743,083
Installed Capacity	153	208	227	228	240
Capacity Factor	**32.54%**	**26.73%**	**30.94%**	**23.62%**	**35.34%**

Source: ere.gov.al Annual report

Data show some some differences between in the efficiency of the Big, Medium and Small Power plants in the years 2016 and 2018, anyway overall the differences are not statistically significant following the ANOVA results of Table 2). We can conclude that there are significant differences (p-value=0.037) in the production of electricity in between the years, but not in between the type of HPPs. (p-value=0.461)

Table 2. ANOVA Results of Capacity Factor differences

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Years	0.018348	4	0.004587	7.594539	0.037464
Type of HPP	0.000401	1	0.000401	0.663565	0.461022
Error	0.002416	4	0.000604		
Total	0.021165	9			

5. Conclusions

Collecting the conclusions of the study, in correspondence with the characteristics of the system mentioned above it is possible to reach these results:

Benefits of Small HPPs:

- Relatively same operational efficiency as big HPPs.
- minimum maintenance and operating costs,
- well established technology,
- opportunity to balance the supply,
- positive socio-economic impact on rural isolated areas etc.
- Unlike large plants, small hydropower installations can have a minimum impact on the water ecosystems avoiding exploiting local resources. In addition to this, all the investments in the southern part of the country report advantages on the energy transmission side. As for the other HPPs, these are more expensive than the petroleum distilled TECs.
- No security issues for civil engineering works. No big dams and no risks of floodings.

Some other important considerations to be mentioned when we consider the small HPPs are that Hydro Power is not the only renewable energy source, and consequentially a total dependency on water resources is somekind dangerous for the stability of the energy system. Basically, diversification of energy sources is quite important in the overall energy balance.

Adaption of small HPPs requires increased controls on quantity, quality and timing of water flows, required to sustain freshwater and estuarine ecosystems, human livelihoods and well being that depend on these ecosystems.

The Albanian legislation has substantially converged the UE regulations and directives, but there is a big gap in the application of the rules, specially concerning the environmental impact of the small HPPs.

Finally the energy market place has no guarantees for the small HPP, because the prices are still fixed by the public corporate KESH.

In addition to national production, in the analysis of the development scenarios it is also possible to introduce elements in a more extended context for future research.

References

Bogdani, M., of, A.-I.-S., & 1997, u. (n.d.). Catastrophic floods and their risk in the rivers of Albania. *books.google.com*.

EES, A., Groningen, U., & 2013, u. (n.d.). Renewable energy scenarios for Albania. *Citeseer*.

Flåten, M. (2015). Stress Induced Stability Assessment of the Underground Caverns for Moglicë Hydropower Project, Albania.

Gummer, J., 2002, H.-K., Kiris, u., & 2002, u. (n.d.). The refurbishment of four main hydro power plants in Albania. *researchgate.net*.

Gummer, J., 2007, H.-H., Granada, u., Spain, u., October, u., & 2007, u. (n.d.). Lessons to be learnt from the Drin River Cascade Rehabilitation Project in Albania–. *researchgate.net*.

Gummer, J., Austria, H.-H., & 2005, u. (n.d.). Vau i Dejes hydro-mechanical rehabilitation on the Drin River in Albania. *researchgate.net*.

Hamududu, B., Energies, A., & 2012, u. (n.d.). Assessing climate change impacts on global hydropower. *mdpi.com*.

Hearn, G., Engineering, R.-Q., & 2018, u. (n.d.). Using stereo aerial photography and satellite InSAR to help assess slope hazards for a hydropower project in mountainous southern Albania. *qjegh.lyellcollection.org*.

Karaj, S., Rehl, T., Leis, H., energy, J.-R., & 2010, u. (n.d.). Analysis of biomass residues potential for electrical energy generation in Albania. *Elsevier*.

Lehner, B., Czisch, G., Policy, S.-E., & 2005, u. (n.d.). The impact of global change on the hydropower potential of Europe: a model-based analysis. *Elsevier*.

McDonald, K., Bosshard, P., environmental, N.-J., & 2009, u. (n.d.). Exporting dams: China's hydropower industry goes global. *Elsevier*.

Prillwitz, F., Al-Ali, S., …, T.-…., & 2007, u. (n.d.). Simulation Model of the Hydropower plant Shkopeti. *pdfs.semanticscholar.org*.

RESOURCES, I.-W., & 2016, u. (n.d.). albania. *climatelinks.org*.

Shumka, S., Shuka, L., BALWOIS, S., & 2010, u. (n.d.). Rivers water life and the responses of possible hydropower's to be constructed in the water courses of Vjosa, Semani and Drini in Albania. *researchgate.net*.

Xhafa, B. (2009). Financial Appraisal on a Hydropower Plant. A Case Study in Albania.

19. Challenges and Solutions for Organizational Design in Urban Digitalization

Máté Csukás, Viktor Bukovszki, András Reith

ABSTRACT:
Digitalization in cities – often branded as smart city (SC) transition – carry the potential for highly inclusive, evidence-based decision making in urban planning, responding to the increasing pressures cities face. However, investments have thus far failed to deliver the expected impacts, thus the attention of the discourse is turning towards organizational structures to overcome complexity, scalability, and procedural challenges of SC transition. This study outlines the barriers inherent in common organizational models (public sector, private-supplier, academic-professional) to SC transition, and makes the case for alternative models, through an extensive literature review, a series of focus groups with key stakeholders involved in SC transition. The paper concludes with showcasing how a nested platform model based on open innovation and a lean approach to urban planning could overcome organizational barriers – using the work in progress, validated design features of a novel organizational model.

Keywords: urban planning, platform, open innovation, assessment, smart city, organizational models

Máté Csukás is a PhD student and research assistant, Corvinus University of Budapest, Hungary. Member of University Research Group where investigates on aspects of developing a smart, sustainable and inclusive society: social, technological, innovation networks in employment and the digital economy.

Viktor Bukovszki is a consultant at ABUD Mérnökiroda, Budapest, initiating and assisting research and development projects if the field of Smart City. He is an interdisciplinary researcher with special focus on the social performance on space.

Dr. András Reith PhD is the CEO and founder of ABUD Mérnökiroda, Budapest. He is an active architect and researcher, he has promoted sustainable design for two decades. His special fields of expertise are Integrated Design Process, ClimaDesign®, specialized façade design, design and consultancy of Net-Zero energy developments, and design in accordance with LEED, BREEAM and DGNB. He is an expert reviewer of the fifth report of UN IPCC (Intergovernmental Panel on Climate Change), a leading author of the Climatic and Energy Concept of the Budapest Urban Development Concept and former president of the Hungary Green Building Council.

1. Introduction

The increasing rate of population growth and concentration has resulted in mounting demands in resources in cities amidst a global effort to sustainably meet these demands, mitigating and adapting to environmental, economic and social pressures (United Nations Human Settlements Programme, 2009). Many cities in the EU seek to cope with these challenges through a smart city (SC) approach to urban planning and management (UPM), referring to the uptake of cutting edge ICT (mostly data-driven) solutions to inform and integrate problem-solving in urban processes (Manville et al., 2014; Ruhlandt, 2018).

Although such digitalization in cities carries the potential for highly inclusive, evidence-based decision making in UPM, investments have thus far been slow to deliver the expected impacts (Barns, 2018). Various frameworks, methodologies, and supporting tools have been developed by academia, the public sector, and suppliers to support SC implementation, each with their specific limitations. Supplier-driven frameworks are too narrow in scope, focusing on urban subsystems relatable to their products and services (Robinson, 2015), (Barns, 2018). City-based and some academic frameworks are too specific to a type of city (Manville et al., 2014; Shen, Jorge Ochoa, Shah, & Zhang, 2011); or to a discipline (Bibri & Krogstie, 2017a); while broader frameworks are too generic and abstract (Klopp & Petretta, 2016). The utilization of urban data itself is limited to indicator listing, without analytic and decision-support functionalities for UPM (Mori & Christodoulou, 2012; Nordregio, 2004). On the other hand, the mismatch of a fast-paced SC market supply and a slow-to-react demand in UPM is driving cities into ad-hoc investments. It is therefore important to investigate why SC frameworks fail to enable transition on the cities side.

One possible explanation for the lack of progress is the cross-cutting nature of its challenges. SC transition challenges can be classified as problems of sociotechnical scalability, the complexity of the subject matter, and procedural difficulties (Dezi, Pisano, Pironti, & Papa, 2018; C. Lim, Kim, & Maglio, 2018a; Nel, du Plessis, & Landman, 2018; Offenhuber & Schechtner, 2018; Reed, 2008; Vanolo, 2014; Zhang et al., 2017). Each of these axes combines social and technical aspects. First, sociotechnical scalability refers to challenges rooted in the addition of more and more people, organizations, information, and hardware in UPM. On the one hand, various data producing and processing systems and actuators need to be interoperable, and the data models integrated (C. Lim, Kim, & Maglio, 2018b).

On the other hand, it is challenging to identify, address, empower stakeholders, and incentivize them to participate in a multi-actor decision-making process (Offenhuber & Schechtner, 2018). It is not apparent which information will be crucial for whom (Reed, 2008), how knowledge is diffused (Dezi et al., 2018), how security is ensured (Zhang et al., 2017) and how the power asymmetries in delicate social structures translate to a more digitalized UPM (Vanolo, 2014). Second, complexity challenges stem from cities being multidimensional complex adaptive systems with deeply interconnected subsystems and interdependent actors (Nel et al., 2018), which is difficult to formalize in a digital environment. Moreover, practical SC implementation must overcome a standardization - customization problem: the breadth of contextual information used in UPM inhibits the replicability and mainstreaming of approaches to practical SC implementation (Manville et al., 2014). Finally, procedural difficulties refer to unpreparedness in the planning process: failure to link urban data to users (Badii et al., 2017), lack of methods to consider city goals and outcomes (Yigitcanlar et al., 2018), a lack of data-based services (Aguilera, Peña, Belmonte, & López-de-Ipiña, 2017), and lack of tools supporting planning (Mora, Deakin, & Reid, 2018).

Scalability, complexity, and procedural challenges cannot be solved through technological innovation alone. Indeed the attention of SC discourse is turning towards organizational structures to deliver transition (Ruhlandt, 2018). Academia, supplier, and public sector governed SC frameworks are sharing one particular attribute: they were initiated, sponsored and maintained and used by single or few entities, even if the development itself was a result of a collaborative effort. The goal of this study is to make a case for an alternative organizational composition based on collaborative networks that are better suited to deliver SC transition. More specifically, the goal of this study is to answer: are there barriers inherent in the conventional organizational models meeting the challenges of SC transition? If so, do an alternative, collaborative network models exist to overcome these barriers?

2. Methodology

SmartCEPS (Smart City Evaluation Platform and Services) is an ongoing research work, intending to develop and roll out a data-driven, scalable, evidence-based, participatory decision-support system for UPM in small and medium-sized cities. It consists of (1) an urban data analytics toolbox, (2) a methodology to use urban data analytics in multi-actor UPM, (3) a virtual marketplace of ICT solutions with urban applications. SmartCEPS is a multi-stakeholder service actively involving municipalities, technology suppliers, citizens, sectoral urban specialists, and generalist consultants – with the business model being training and supplying these generalist consultants. This paper presents the management, particularly the organizational challenges of an application of an innovative data-driven urban planning service and methodology that involves the orchestration of a wide range of urban stakeholders.

The research has three distinct phases. As a first step, an extensive literature review was undertaken to identify challenges of SC transition, regarding (1) multi-stakeholder ecosystems, (2) data-driven applications, (3) knowledge-intensive innovative services, and (4) urban planning. Key ideas were revealed during an inductive category development procedure (Mayring, 2000). After processing about 50% of selected papers, revision of categories and pre-validation of findings begun in the next phase. Three separate focus group sessions were conducted, with a selected group of experts, from

the three most essential stakeholder categories: city managers, urban planning professionals, and technology suppliers. These events aimed to validate, check the reliability, and formulate new categories of organizational challenges. They were semi-structured to allow the identification of additional concepts. Next, information gathered in these events was processed, parallel with the remaining literature, and findings were incorporated into the category development task.
After the categories were finalized, organizational barriers were distributed to their respective stakeholder groups, which served as a problem space for designing the organizational framework of SmartCEPS. Finally, the design decisions in the corresponding solution space were validated in follow-up focus groups, and the proposed organizational concept has been revised accordingly.

3. Results

Organizational barriers manifest differently among the three main stakeholders involved: (1) public, (2) private and (3) professional, while some (4) general barriers are not unique to any of them. Table 1 summarizes the organizational barriers to SC transition.

3.1 Public organizational barriers

In this paper, we partly adopt the stakeholder classification of Ruhlandt (Ruhlandt, 2018), including public, private, academic, and civic. Public stakeholders are described as "institutions", "public subject", "government agencies", "political leadership and administrative proponents" in the literature. Category development process identified that public organizational barriers fall into the following groups: Management, Power & influence, Networks, and Innovation.
In governance, the capacity to adapt and integrate is mentioned to be a critical barrier to the SC transition. Given the volatility of the SC market and urban pressures in general, the need for dynamic control mechanisms is accentuated (O'Reilly & Tushman, 2008). The current practice in Europe is characterized by weak convergence and integration mechanism among interventions, a failure to realize the added value offered by coordination of resources and from the joint efforts of stakeholders (Praharaj, Han, & Hawken, 2018). Both barriers are connected to an authoritative governance approach which fails to enable knowledge, resource, and responsibility pooling (Sørensen & Torfing, 2018). According to interviewed city managers, such approach also results in trading evidence-based planning with political struggles when resources are constrained, which leads to inertia against any public innovation both in the leadership and down the chain of command. The lack of collaborative governance and planning is seen as a critical obstacle to an SC-ready level of adaptive and integrative capacity.
Incapable organizational structures hinder the SC transition. Despite the high relevance, there were participants from all stakeholder groups, who expressed concerns about the viability of their respective organizational background, to be able to address all the needs of SC transition. Especially the 'old' structure of city governance that operates in these "byzantine labyrinth" of silos, requires cross-organizational management. Roles and responsibilities must be clearly defined in the case of external and internal transactions as well. Again, a non-technological, but management and planning problem was identified as a problem for the transition. Without cross-departmental governance, collaboration with various stakeholders cannot be guaranteed (Whyte et al., 2014). It is also a vital issue, mentioned by city managers, that their processes are slow and inefficient, due to the lack of inter-departmental connections.
Furthermore, SC project and developments usually realized in a multi-collaborative (open) environments, where the roles and responsibilities of city managers are challenging to determine (Angelidou, 2014). These difficulties can include their position or even their authority. Some practitioners from technology provider companies mentioned that in many cases, negotiations fail because they do not meet with the right person who is qualified to understand the subject matter but also has the authority to make decisions. In other cases, city managers are afraid to decide on specific issues because of a risk aversive culture inherent in the public sector (Sørensen & Torfing, 2018).
The threat to power and influence is also an often-mentioned factor across different groups. It is also a general hindering factor for organizations that face changes and resist them. Some stakeholders or departments might play a more prominent role in the transition, while others' are excluded or oppressed. Participants perceive that there are beneficiaries but also disadvantages, which can cause stress in and in-between organizations. That is an excellent reason to adopt an inclusive and

participative SC design. Otherwise, the particular power dynamics of longstanding stakeholders are invoked, causing tensions in the city, inevitably hindering SC development.

Inability to properly engage stakeholders is a distinct category of organizational barriers. It is the responsibility of SC developers to design and implement meaningful public-private partnerships, which will function as a sustainable ecosystem (Vanolo, 2014). They have to take the role of stakeholder leadership, because they are the most credible actor, with legitimacy. Engagement of relevant ecosystem participants is a very challenging task because they must be provided with viable incentives to stimulate them. In most SC investments and development processes, practitioners feel as if there are always important actors who are not at the table. There is a knowledge gap among relevant actors. This collaborative thinking is also real for the co-initiation of participatory processes (Daniell et al., 2010). If SC transition is not co-initiated from the bottom-up, it is met with resistance or indifference (Sørensen & Torfing, 2018). SC success is very vulnerable to the degree of public engagement. The knowledge gaps above have spillover effects on the collaboration as well. Beside others, civic engagement is of the highest importance in SC development. Despite its perceived importance, citizen involvement is still not an integral part of the practice. There are several platform-based ICT solutions for this challenge – i.e., Citizen Relationship Management (CRM), Knowledge Hub, but currently, they are not appropriately informed, have no agency in decision-making, and treated mostly as sources of information at best (crowdsensing).

Another critical category in public services is connected to innovation. One significant capability of public actors in SC transition is to combine the innovativeness of a diverse group of stakeholders, through partnerships. The resulting interactions will be the source of creativity and novel solutions (Anttiroiko, 2016). Urban openness degree enables a user (citizen)-driven innovation in existing and new services. Similarly, to governance barriers, there is an utmost need for multi-stakeholder management. Table 1 below collects the identified public barriers.

Table 1: Public Organizational Barriers (Source: own edition)

Public Organizational Barriers			
Management	*Power & influence*	*Networks*	*Innovation*
– Lack of coordination mechanisms – Authoritative strategic approaches – Lack of horizontal integration (functional silos)	– Conflict of interests – Power asymmetries – Resistance to change	– Underperforming collaborative design – Insufficient collaborative capabilities – Lack of co-initiation	– No mutual learning and knowledge diffusion practices – Lack of innovation capabilities – Closed organizational design – Inadequate learning from peer cities

3.2 Private organizational barriers

Private organizations are mostly described as firms and enterprises, but also industry, or market (Ruhlandt, 2018). Many 'general' organizational barriers identified in the case of public and professional actors are also recognizable in this group. It is challenging for companies to align their value-creating processes into the SC transition context. As mentioned before, the immaturity and complexity of the concept force ventures to focus on particular domains of SC within their preexisting competencies, they while they lack a holistic view, and the capacity to thrive with such a context-dependent value offering as smart cities. Both the literature and the city manager focus group identified technology push from companies (Angelidou, 2015). Today, cities and technology providers do not speak a common language regarding technology and social outcomes of SC developments. There is a massive gap between vision and implementations, causing stress between the two actors (Bibri, 2018).

Furthermore, sales processes are not efficient because of different organizational structures. Private organizations - despite the high expectations – are still exploring the market, accumulating investments, and expect high growth in the future. Vendors claim that advanced and sophisticated technologies are inadequate to gain user satisfaction in realistic SC environments. In an unstandardized market, where individual cases require a high-level specification, successful implementation of tech solutions is very challenging, particularly the design, optimization, and requirement checks.

Another significant organizational barrier is related to collaboration, knowledge diffusion, and innovation. Competitive strategies of the private sector result in wasted resources on rivalry and conflicts, but which is more critical, limited exchange of knowledge (Sørensen & Torfing, 2018). Taking into account the complexity of urban challenges and requirements, the absence of mutual learning jeopardize the highly desired innovation capabilities. Ad-hoc approaches are present in case of private actors as well. They deploy technologies and solutions that become available with technological advancement, but without an adequately demonstrated customer need and value proposition. Table 2 below sums up the identified private organizational barriers.

Table 2: Private Organizational Barriers (Source: own edition)

Private Organizational Barriers	
Competitive drive	*Innovation & Technology*
−Product focus over needs −Biased assessments	−Closed innovation process −Applicability over real needs

Distortions between technology push and application pull results in a mismatch between supply and demand. The imbalance is partly because of the difficulty to articulate SC expectations in terms of product specification (Bukovszki, Apró, Khoja, Essig, & Reith, 2019). Suppliers also find it challenging to create new products and services for specific city needs, as they are more inclined to work with their existing portfolios. They experience considerable tension between standardization and customization because there are trade-offs between these two categories: cities require solutions that are entirely based on their local particularities, but firms want to commercialize efficiently scalable products. In the case of private and professional groups, there is an 'oversupply' because supplier driven SC frameworks are designed around the products and services offered by the issuing companies.

3.3 Professional organizational barriers

Private organizations are mostly described as universities and research bodies in the literature (Ruhlandt, 2018). Practitioners – i.e., consultants may also be treated in this category. Many organizational barriers of professional actors are related to knowledge diffusion and capabilities. Until now, there is no common understanding of the SC concept, which makes the interpretation and practical intervention challenging for firms. Results of the focus group with professionals also confirm this status, showing that SC is a fuzzy concept; everyone sees a different meaning in it. The interpretation of smart cities today is a capability that requires immersive knowledge. Otherwise, the adverse effects – i.e., technology dependence, exclusion of social impacts will prevail (Yigitcanlar et al., 2018). UPM is interdisciplinary, and SC frameworks either represent a single dimension, field, discipline, or they become too vague when trying to be holistic (Bibri & Krogstie, 2017b; Sabatini-Marques, da Costa, Chang, Yigitcanlar, & Selig, 2018). Furthermore, SC development is still treated as an outcome, not as a planning process. Table 3 below collects the identified professional organizational barriers.

Table 3: Professional Organizational Barriers (Source: own edition)

Professional Organizational Barriers		
Dissension	*Collaboration*	*Operational*
– Biased assessments Disciplinary complexity & immaturity – Fragmented knowledge generation – Biased interpretations	– Closed innovation process – Applicability over real needs	– Lack of actionable outputs – Missing practice-oriented qualifications – Focus only on outcomes

Similarly, to public organizational barriers, resistant to change is also a phenomenon among professional stakeholders' group. During the focus group session, they were conflicted with data-driven planning approach, opposing their current practice. In academic publications, there is a myriad of SC indicator systems. Problem is with their practical usability, the difficulty of transposing theory to practice. They provide good descriptions, but no executable programs (Mori & Christodoulou, 2012). This challenge is an organizational barrier because relevant actors work independently. Horizontal action among practitioners is desired. Focus group participant also expressed that SC frameworks choose between offering comparability and accuracy, since adding more and more contextual information is needed during the planning process (standardization and customization conundrum) (Bukovszki et al., 2019). Another issue is ad-hoc approaches, which is closely related to the lack of inter-organizational collaboration and meaningful engagement of stakeholders. Ad-hoc approaches make it risky to correctly identify and select interventions that can deliver the desired complex socio-spatial outcomes. Table 4 below summarizes the identified generic barriers.

Table 4: Generic Organizational Barriers (Source: own edition)

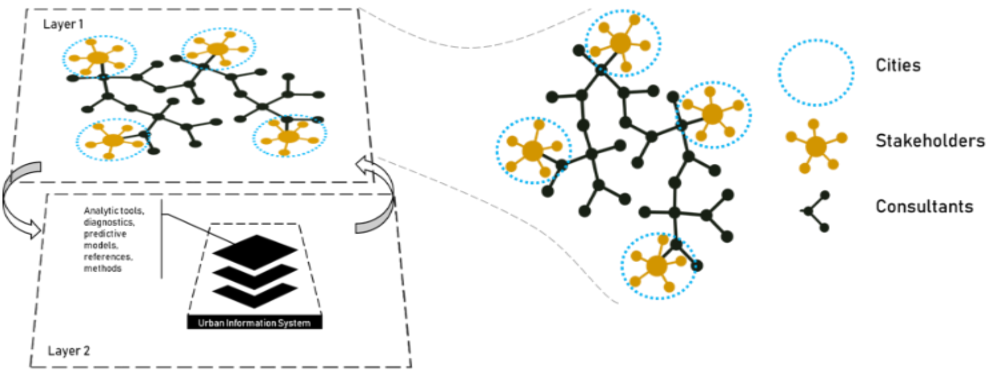
Generic Organizational Barriers	
Management	*Cultural*
– Too large number heterogeneous of actors – Interdependencies (system complexity) – Communication channels (information flow)	– Divergent value perspectives – Different frames of reference – Different mindset

4. Discussion of a Proposed Model: Urban Planning Platform

In this chapter, we are going to describe our proposed model and how it can address the previously identified organizational barriers. The diversity of stakeholders and technological solutions require new models of cooperation to parallel regulate urban actors by governance but provide an innovative, evolving environment at the same time. The authors argue, that the SC transition has a fundamentally a disruptive nature, transforming existing markets and conventional organizational or business structures, which will eventually create new public- and technology management models. In such an environment, the knowledge-intensive digital transformation of cities requires open innovation models - with particular attention to the inflows and outflows of knowledge (Chesbrough & Brunswicker, 2014) – because of the challenges posed by the unique urban features, multi-collaborative environments, and immaturity of the market. The proposed model is a platform that facilitates an open innovation network, with a Community of Innovation (CoI) (M. Lim & Ong, 2019) and Technology Matchmaking mechanism. The adoption of platform thinking to urbanism and particularly smart cities is getting more and more attention in the literature, as a solution for participatory innovation (Anttiroiko, 2016), mediating public-private partnerships (van der Graaf & Ballon, 2019), or delivering services (Rajakallio, Cuthbertson, Pulkka, & Junnila, 2018). Platforms contend the linearity of existing SC developments, facilitating space for interdependencies, increasingly dominating the urban landscape. Platform-based ecosystems, as demonstrated in the, e.g., high tech industry that they are capable of orchestrating a diverse group of innovative actors towards a common goal with a set of rules and incentives, surpassing the traditional organizational boundaries (Gawer & Cusumano, 2014). The SmartCEPS urban planning platform incorporates the design and value creation logic of platforms.

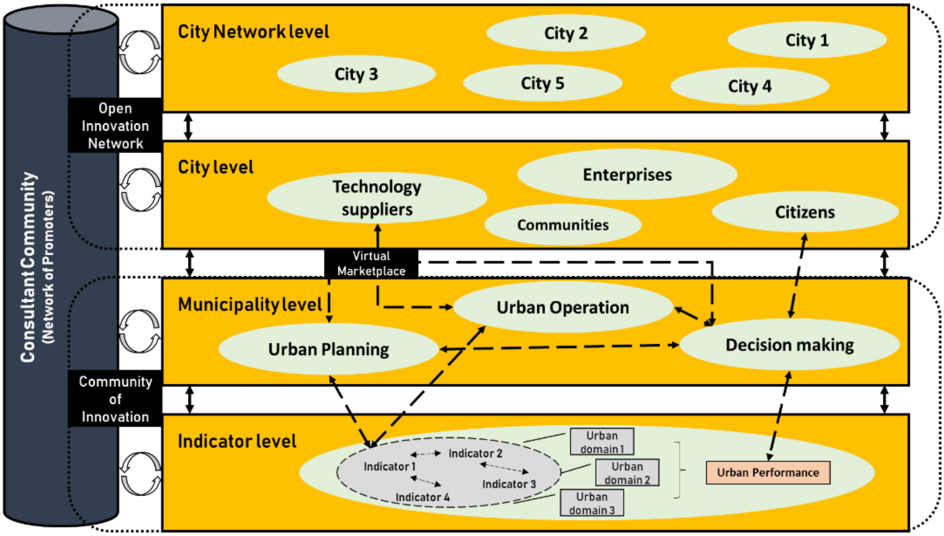
4.1 Platform attributes

The SmartCEPS platform architecture is nested, comprising of two layers. The first layer would function for UPM. It is a discourse in a network of stakeholders, municipal admin, specialist professionals, solution providers, data-producing infrastructure, and peer cities. Orchestration and leadership of the ecosystem would be carried out by a certified consultant network, with a lean project management approach, meaning with early and persistent user-oversight minimizing waste. The second layer would be an urban information system, continuously developed by a discourse in a network of urban professionals. This layer would be a cooperative platform, which is managed and improved by the SmartCEPS consultant community through the platform's infrastructure. This second layer hosts content creation and curation for the analytic tools supporting multi-actor collaboration on the first layer, which would enable a procedure where new technological solutions and concepts evolve from bottom-up collaborations among various stakeholders. Monitoring of urban performance and correcting deviations from urban planning goals makes it possible for a city-level cybernetic control (Carver & Scheier, 2012). The figure 1 below illustrates the layers of the platform architecture.



1. Figure: SmarCEPS Platform Layers (Source: own edition)

The first layer facilitates the core interaction of transacting urban performance data that is generated by the city assessment framework. Key actors are consultants, a community of certified professionals, city managers, who initiate joining the platform, civic community, participating in whole of the process and technology suppliers, who contribute to the materialization of the proposed solutions. Knowledge is exchanged among actors to collaboratively (1) diagnose city problems and define strategic priorities (2) propose and select policy and urban development (3) invest in SC applications of ICT solutions. The principal value proposition of the platform is solving the organizational barriers by translating different actor frames of reference to a standardized data model and vice versa. As this value depends on the accuracy of underlying models, the SmartCEPS consultants are incentivized to actively contribute to the second layer, which in this sense is an open innovation platform. More accurate diagnostic, predictive models, references, increasingly sophisticated methods to transfer contextual information to global models boost both the individual and collective value of the consultants. Figure 2 below is intended to explain the multi-collaborative and multi-level characteristic of the proposed model.



2. Figure: High-level platform architecture with stakeholder relations (Source: own edition)

SmartCEPS Urban Planning Platform adopts conditions for value creation in the following way:

Modularity: the proposed model consists of self-functional components that are separately upgradable, contributing to the adaptability of the system. Modules are the (a) Consultancy network, which is a community of certified SC professionals, who are bounded by shared frames of references; (b) Virtual Marketplace that is an expanding network of technology provider firms; (c) urban analytics toolset, which facilitates a common 'language' to communicate urban problems in-between multiple stakeholders, and to be evolved by the community.

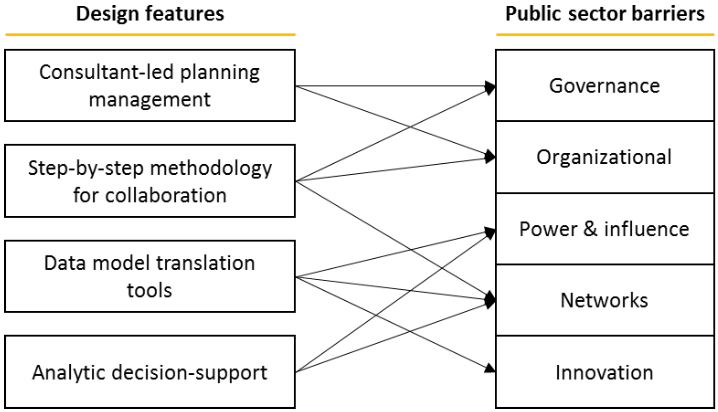
Customizable standardization: the platform is using common standards to assess cities, formulate action plans, and initiate action in practice, based on the analytics and translation of urban performance data. However, the more in-depth data content is built up iteratively by UPM stakeholders during the planning process, ensuring customizability.

Complementarity: complementarity manifests in both actions and technical systems as well. First, consultants work together with public administration and professionals to design interventions that are co-initiated and validated by citizens, which are realized by private companies. Second, from the technical system point of view, city assessments provide each city an 'algorithm', a set of data that define the city, which translates to the Virtual Marketplace in the form of interventions.

Connectivity: coordination and management of each module and the stakeholders are assigned to city dedicated consultants who act as 'conductors', or community managers of the urban planning ecosystem. Inputs and outputs are all shared and accessible by users on the SmartCEPS platform infrastructure. System components are connected in an integrative way.

4.2 Overcoming organizational barriers

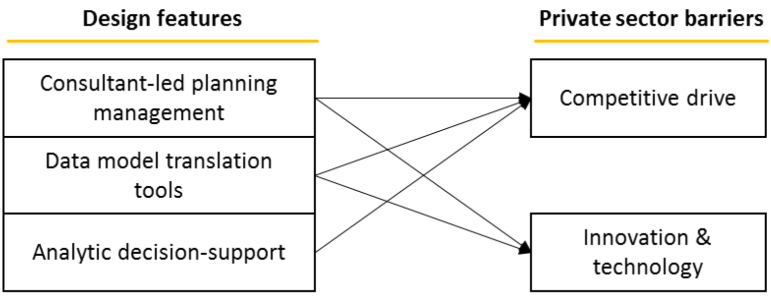
Public organizational barriers: The ecosystem creation is in the heart of the proposed model, where new channels are established, through a common language to cooperatively initiate solutions, implement existing products/services and capitalize on the competences in the local ecosystem. The consultants provide management in the process, following municipality goals. They take multiple roles – e.g., promoting the network, managing the community, enabling knowledge flows. They act as conductors of the discourse, encompassing specialists, municipal managers, civic communities, and other stakeholders. Consultants are trained to use and interpret data and analytics to evolve and expand this discourse. UPM platform layer establishes new connections in the departmental and stakeholder network. Responsibilities are assigned in the design process, and consultants provide leadership, capacities, and bridge knowledge gaps. The platform facilitates the creation and accessibility of continuous feedback from the consulting community on the interactions, synergies, contextual factors, impacts of urban development and policy recommendations, in a shared urban performance architecture, which ensures the integrative nature of the platform. Figure 3 visualizes the identified challenges and the offered solutions of the platform in the public sector.



3. Figure: design features overcoming public barriers (Source: own edition)

Collaboration and co-initiation are ensured by step-by-step methodology, identifying crucial multi-stakeholder decision points, modules to outline stakeholder impacts and to involve relevant stakeholders. Through the information system reference projects are linked to context, goals, city performance. They are described with a universal language and shared underlying data. Latent city relationships – i.e., similarity, complementarity can be defined because of continuous monitoring with a shared reference frame and underlying data, operated by a network of consultant professionals.

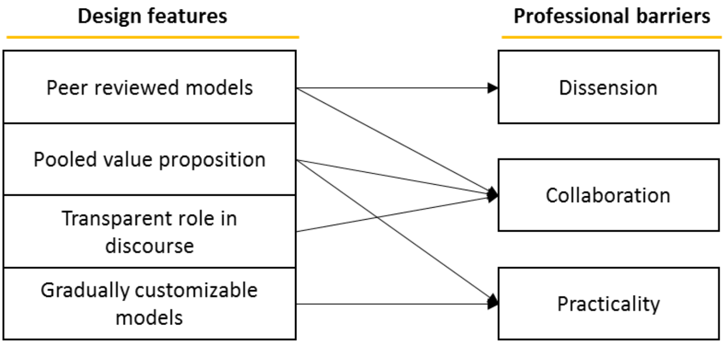
Private organizational barriers: the Virtual Marketplace (VM) module of the platform is intended to resolve the tension between the technology push and application pull forces, providing a convenient, yet efficient forum for companies to register their products or solutions, directly linked to the potential impact on the cities' algorithms – meaning the quantified effect of the solutions. Mediation creates matchmaking between cities and companies, in a way that the platform translates problems and needs into solution (innovation) requests, decomposing them into specific impact measures. These indicators transcribe to specific technical descriptions, disseminating requests through the network. VM enables a more accurate presentation of products and services in terms of urban performance, while the consultant network specifies city needs in term of technology solutions. Figure 4 illustrates the identified challenges and the offered solutions of the platform in the private sector.



4. Figure: design features overcoming private barriers (Source: own edition)

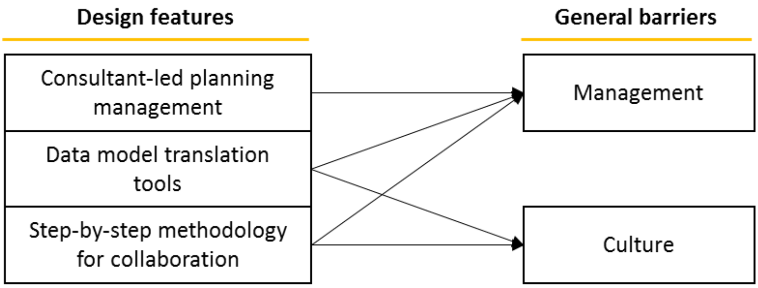
Professional barriers: the SmartCEPS platform is centred on urban performance, translated to different actors' perspectives by common standards and modules. Discourse is not running on obscure conceptualizations and inauthentic approaches, but on performance-based analytics that increases transparency. Platform modules support data analytics in an open innovation framework, continuously peer-reviewed, updated, and developed by a wide range of dedicated professionals.

Mutual learning incentivized by providing an integrative and scalable, yet city-specific service model, that is globally transferable. The urban information system module is gradually customized during the planning process from global standards maintained by a community of consultants. Protocols to integrate consultant feedback into different layers of standards - i.e., global, context-bound, city-specific. Figure 5 illustrates the identified challenges and the offered solutions of the platform in the professional-academic sector.



5. Figure: design features overcoming professional barriers (Source: own edition)

Generic barriers: VM module address interoperability issues, and in the planning process, additional costs of possible incompatibilities are taken into account. Different levels of the assessment provide flexibility in a data-scarce and information divided environment. Missing or insufficient values are imputed. The dedicated consultants individually address the peculiarities of the local data environment. Organizational and cultural differences are aligned by using urban data and analytics to support inter-stakeholder discourse, which is the core competence of SmartCEPS consultants. Methodologies and tools to translate among frames of reference are added to the system and are continuously developed by the consultants. Figure 6 illustrates the identified challenges and the offered solutions that are non-specific to any target groups.



6. Figure: design features overcoming generic barriers (Source: own edition)

5. Conclusion

The platform framework is shown to be a viable organizational model for SC transition because such a transformation is reliant on long-term, cross-cutting, and cross-sectoral collaboration. In the design study, this is achieved by positioning SC transition as a continuous self-reinforcing protocol for the day-to-day process of UPM.

SmartCEPS is a nested platform for collaborative planning on the first layer, and the continuous evolution of underlying methods and models on the second layer. The backbone of the first layer is the translation of stakeholder frames of reference to a

standardized, open-ended, dynamic model of urban performance, which allows for more transparent participation at lower transaction costs. The second layer creates a plus-sum game to continuously evolve and adapt the supporting tools for UPM, by pooling the value proposition of professionals while rewarding active contributors, thus for the first layer. It is notable, however, that the SmartCEPS design is limited in addressing increased data security needs (due to more interactions), it has a high entry barrier for many stakeholders to participate, and is disruptive to conventional deliberative processes – all of which are consequences of a collaborative UPM process.
The SmartCEPS project will continue with demonstrating its design in real-life experiments, but further research will be needed to expand on the trade-offs and minimal entry criteria of a platform-based UPM.

Acknowledgements

The SmartCEPS project has received funding from the European Union's Eurostars-2 joint programme with co-funding from European Union Horizon 2020 research and innovation programme under reference no. E! 10243/14/Q. Project no. NEMZ_15-1-2016-0028 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the NEMZ-15 funding scheme.

References

Aguilera, U., Peña, O., Belmonte, O., & López-de-Ipiña, D. (2017). Citizen-centric data services for smarter cities. *Future Generation Computer Systems*, *76*, 234–247. https://doi.org/10.1016/j.future.2016.10.031
Angelidou, M. (2014). Smart city policies: A spatial approach. *Cities*, *41*, S3–S11. https://doi.org/10.1016/j.cities.2014.06.007
Angelidou, M. (2015). Smart cities: A conjuncture of four forces. *Cities*, *47*, 95–106. https://doi.org/10.1016/j.cities.2015.05.004
Anttiroiko, A. V. (2016). *City-as-a-platform: The rise of participatory innovation platforms in finnish cities. Sustainability (Switzerland)* (Vol. 8). https://doi.org/10.3390/su8090922
Badii, C., Bellini, P., Cenni, D., DIfino, A., Paolucci, M., & Nesi, P. (2017). User Engagement Engine for Smart City Strategies. *2017 IEEE International Conference on Smart Computing, SMARTCOMP 2017*. https://doi.org/10.1109/SMARTCOMP.2017.7947059
Barns, S. (2018). Smart cities and urban data platforms: Designing interfaces for smart governance. *City, Culture and Society*, *12*(December 2016), 5–12. https://doi.org/10.1016/j.ccs.2017.09.006
Bibri, S. E. (2018). *Smart Sustainable Cities of the Future*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73981-6
Bibri, S. E., & Krogstie, J. (2017a). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society*, *31*, 183–212. https://doi.org/10.1016/j.scs.2017.02.016
Bukovszki, V., Apró, D., Khoja, A., Essig, N., & Reith, A. (2019). From assessment to implementation: design considerations for scalable decision-support solutions in sustainable urban development. In *Central Europe towards Sustainable Building*. Prague: Unpublished.
Carver, C. S., & Scheier, M. F. (2012). Cybernetic Control Processes and the Self-Regulation of Behavior. *The Oxford Handbook of Human Motivation*, (May 2018), 1–29. https://doi.org/10.1093/oxfordhb/9780195399820.013.0003
Chesbrough, H., & Brunswicker, S. (2014). A Fad or a Phenomenon ? The Adoption of Open Innovation Practices in Large Firms. *Research-Technology Management*, (March-April), 16–25. https://doi.org/10.5437/08956308X5702196
Daniell, K. A., White, I., Ferrand, N., Ribarova, I. S., Coad, P., Rougier, J., … Burn, S. (2010). Co-engineering Participatory Water Management Processes : Theory and. *Ecology And Society*, *15*(4), 1–38.

Dezi, L., Pisano, P., Pironti, M., & Papa, A. (2018). Unpacking open innovation neighborhoods: le milieu of the lean smart city. *Management Decision*, *56*(6), 1247–1270. https://doi.org/10.1108/MD-04-2017-0407

Gawer, A., & Cusumano, M. A. (2014). Industry Platforms and Ecosystem Innovation. *Journal of Product Innovation Management*, *31*(3), 417–433. https://doi.org/10.1111/jpim.12105

Klopp, J. M., & Petretta, D. (2016). Can we actually agree on indicators to measure urban development?

Lim, C., Kim, K.-J., & Maglio, P. P. (2018a). Smart cities with big data: Reference models, challenges, and considerations. *Cities*, *82*, 86–99. https://doi.org/10.1016/j.cities.2018.04.011

Lim, M., & Ong, B. Y. (2019). Communities of innovation. *International Journal of Innovation Science*, IJIS-09-2017-0086. https://doi.org/10.1108/IJIS-09-2017-0086

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J. K., Thaarup, R. K., … Kotternik, B. Mapping Smart Cities in the EU (2014). European Union. https://doi.org/10.1017/CBO9781107415324.004

Mayring, P. (2000). Qualitative Content Analysis Philipp Mayring 3 . Basic Ideas of Content Analysis. In *Forum Qualitative Sozialforschung* (Vol. 1, p. 10).

Mora, L., Deakin, M., & Reid, A. (2018). Smart-City Development Paths: Insights from the First Two Decades of Research. In *Green Energy and Technology* (Vol. 8, pp. 403–427). Elsevier. https://doi.org/10.1007/978-3-319-75774-2_28

Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). *Environmental Impact Assessment Review*, *32*(1), 94–106. https://doi.org/10.1016/j.eiar.2011.06.001

Nel, D., du Plessis, C., & Landman, K. (2018). Planning for dynamic cities: introducing a framework to understand urban change from a complex adaptive systems approach. *International Planning Studies*, *23*(3), 250–263. https://doi.org/10.1080/13563475.2018.1439370

Nordregio. Potentials for polycentric development in Europe Co-financed by the European Community through the Interreg III ESPON (2004). Stockholm.

O'Reilly, C. A., & Tushman, M. L. (2008). Ambidexterity as a dynamic capability: Resolving the innovator's dilemma. *Research in Organizational Behavior*, *28*, 185–206. https://doi.org/10.1016/j.riob.2008.06.002

Offenhuber, D., & Schechtner, K. (2018). Improstructure - an improvisational perspective on smart infrastructure governance. *Cities*, *72*, 329–338. https://doi.org/https://doi.org/10.1016/j.cities.2017.09.017

Praharaj, S., Han, J. H., & Hawken, S. (2018). Towards the right model of smart city governance in India. *International Journal of Sustainable Development and Planning*, *13*(2), 171–186. https://doi.org/10.2495/SDP-V13-N2-171-186

Rajakallio, K., Cuthbertson, R., Pulkka, L., & Junnila, S. (2018). Creating urban platforms — Opportunities and challenges for innovation in commercial real estate development. *Cities*, *77*, 92–103. https://doi.org/https://doi.org/10.1016/j.cities.2018.01.016

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Robinson, R. (2015). 6 inconvenient truths about Smart Cities. Retrieved from http://theurbantechnologist.com/2015/02/15/6-inconvenient-truths-about-smart-cities/

Ruhlandt, R. W. S. (2018). The governance of smart cities: A systematic literature review. *Cities*, *81*(October 2017), 1–23. https://doi.org/10.1016/j.cities.2018.02.014

Sabatini-Marques, J., da Costa, E. M., Chang, D. L., Yigitcanlar, T., & Selig, P. M. (2018). Knowledge-based, smart and sustainable cities: a provocation for a conceptual framework. *Journal of Open Innovation: Technology, Market, and Complexity*, *4*(1). https://doi.org/10.1186/s40852-018-0087-2

Shen, L. Y., Jorge Ochoa, J., Shah, M. N., & Zhang, X. (2011). The application of urban sustainability indicators - A comparison between various practices. *Habitat International*, *35*(1), 17–29. https://doi.org/10.1016/j.habitatint.2010.03.006

Sørensen, E., & Torfing, J. (2018). Co-initiation of Collaborative Innovation in Urban Spaces. *Urban Affairs Review*, *54*(2), 388–418. https://doi.org/10.1177/1078087416651936

United Nations Human Settlements Programme. (2009). *Planning Sustainable Cities: Global Report on Human Settlements 2009*. (N. D. Mutizwa-Mangiza, Ed.). London: Earthscan/ UN-HABITAT. https://doi.org/https://doi.org/10.1002/psp.616

v. d. Graaf, S., & Ballon, P. (2019). Navigating platform urbanism. *Technological Forecasting and Social Change*, *142*(December 2017), 364–372. https://doi.org/10.1016/j.techfore.2018.07.027

Vanolo, A. (2014). Smartmentality: The Smart City as Disciplinary Strategy. *Urban Studies*, *51*(5), 883–898. https://doi.org/10.1177/0042098013494427

Whyte, J., Hart, T., Yanrong, K., Lei, Z., Cai, C., Yuming, G., … Ying, C. (2014). EU-China Smart and Green City Cooperation " Comparative Study of Smart Cities in Europe and China " - White Paper - prepared for Ministry of Industry and Information Technology (MIIT) DG CNECT , EU Commission with China Academy of Telecommunications Res, (March).

Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., da Costa, E. M., & Yun, J. J. (2018). Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities*, *81*, 145–160. https://doi.org/https://doi.org/10.1016/j.cities.2018.04.003

Zhang, K., Ni, J., Yang, K., Liang, X., Ren, J., & Shen, X. S. (2017). Security and Privacy in Smart City Applications: Challenges and Solutions. *IEEE Communications Magazine*, *55*(1), 122–129. https://doi.org/10.1109/MCOM.2017.1600267CM