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ENERGIZING FUTURES – SUSTAINABLE DEVELOPMENT AND ENERGY IN TRANSITION

Proceedings of the Futures Conference 2018

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TABLE OF CONTENTS

ENERGY FUTURES

INTRODUCTION

University of Turku, Finland Futures Research Centre organized the 19th Futures Conference on 13–14 2018 in Tampere, Finland, under the title "Energizing Futures – Sustainable Development and Energy in Transition''. This publication is the proceedings of the Energizing Futures 2018 conference.

To understand the challenges of the ongoing energy transition process, we need multidisciplinary, multi-level and time-variant analysis of various issues: renewable and non-renewable energy (re)sources, transforming primary energy into energy carriers (fuels, electricity, and heat), energy technologies, impacts (environmental, social, economic, institutional, cultural, etc.) of energy use, energy exports and imports, energy markets and energy price, energy end-use patterns and consumer behavior, energy and resource efficiencies, energy policies, and energy governance. The questions presented for contributions into this conference included the following ones:

- What are the main challenges of sustainable energy futures in an era of increasing uncertainty?
- How to create sustainable energy policies in Europe, and elsewhere in the World?
- What is the role of futures studies in identifying opportunities for a fair, efficient and resilient energy system?

The aim of the "Energizing Futures" was to generate multidisciplinary, stimulating and critical discussions that promotes networking between people from different backgrounds with a common interest towards energy and sustainability in the Future. The conference was supported by the European Commission via the EU Horizon 2020 Research and Innovation Programme under the Grant Agreement No. 649342 EUFORIE. The conference was an important dissemination channel for the results generated in the project "European futures of energy efficiency" (EUFORIE), coordinated by the University of Turku. The conference had a large number of presentations under thematic sessions, and only a part of these presentations are included in this publication. The programme and the presentations of the conference can be viewed on the conference web site: https://futuresconference2018.wordpress.com

The 14 articles included in the proceedings of the Energizing Futures 2018 conference give an useful insight on the large variety of topics dealt with in the Energizing Futures 2018 conference. They are grouped under three major themes: Theory and practice of energy efficiency (five articles), Energy transition in developing countries (four articles) and Energy futures (five articles). I hope that the articles inspire and help the readers to energize the future from their own starting points!

Tampere, 9 October 2019

Dr. Jarmo Vehmas
University of Turku, Finland Futures Research Cente
Chair of the Conference Scientific Committee
Coordinator of European Futures for Energy Efficiency (EUFORIE)

EUFORIE
European Futures for Energy Efficiency

European Commission

SpringerOpen has published a thematic collection that aims to generate multidisciplinary, stimulating and critical discussions on energy futures and transition pathways for the future. Based on the 19th Futures Conference in June 2018, articles in this collection focus mostly on challenges of this transition: www.springeropen.com/collections/enfu

Saving Cooperative Energy: Key Learnings from a European Agro-Food SME Energy Efficiency Project

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Abstract

Saving Cooperative Energy (SCOoPE) is a energy efficiency project aimed at improving energy efficiency at Small- and Midsized Enterprises in the European agri-food industry. The project consists of six key phases: i. Pre-project actor engagement, ii. a desktop phase, iii. a tool development phase, iv. a benchmarking phase, v. a deployment phase, vi. and a communication phase. This article provides an overview of the set-up of the project, as well as a presentation of initial conclusions. The main basis for the conclusions are five performed energy audits of Danish dairy processing plants.

Introduction and Background

> *"The world needs another industrial revolution in which our sources of energy are affordable, accessible and sustainable. Energy efficiency and conservation, as well as decarbonizing our energy sources, are essential to this revolution" (Chu & Majumdar, 2012).*

In 2015, a report from the European Commission's Joint Research Centre showed that the amount of energy necessary to cultivate, process, pack and bring food to citizens' tables in the EU is the equivalent of 17% of EU's gross energy consumption or 26% of EU's final yearly energy consumption (Monforti-Ferrario & Pineda Pascua, 2015). Improving energy efficiency along the food value chain is therefore a vital part of decreasing total European energy use, and an important contribution to the goal of achieving a greener and more sustainable future energy system in Europe. Given the size of the total food value chain, indeed even small improvements significantly advances the green transition of Europe, especially if scalable and repeatable. Considering that energy inputs are also important cost drivers for the agri-food sector, increased energy efficiency simultaneously strengthens Europe's sectoral competitiveness.

However, barriers for this development exists. While investments in energy efficiency may be cost-effective and yield a positive return on investment for the investing company, they are often not implemented. It has been widely recognized since the late 1980s that "*many investments in energy efficiency fail to be made despite their apparent profitability"* (DeCanio, 1993). This has been called the efficiency paradox – generally, it runs counter to economic theory that systematic unexploited profit opportunities persists, yet research on the economics of energy efficiency consistently document this (DeCanio, 1998). This turned out to be also the experience of the SCOoPE-project.

Barriers to energy efficiency has been defined as 'a postulated mechanism that inhibits investments in technologies that are both energy efficient and (at least apparently) economically efficient.' (Sorrell et al., 2000; Trianni & Cagno, 2012). Energy efficiency barriers may be economic, information-related, organisational, behavioural, competence-related, technology-related, or due to a lack of awareness (Trianni et al., 2016). It is widely assumed that smaller organisations face larger barriers for energy efficiency, as these may particularly lack the required economic, technical, informational and organisational capacities to secure energy efficiency.

There are more than 23 million Small- and Medium-sized Enterprises (SMEs) in the EU, representing more than 99% of all European undertakings and generating 60% of the GDP in the EU (Fresner et al., 2017). While these SMEs are often not energy intensive, the sheer magnitude of the sector makes it imperative to provide constructive energy efficiency solutions helping to overcome noted barriers. Many of these small- and medium-sized enterprises in Europe are part of the agri-food sector. These agri-food SME's are the focus of the European energy efficiency project Saving Cooperative Energy (SCOoPE)[1] which forms the basis of this paper. While the project functions primarily as an action research project directly raising awareness and promoting energy efficiency investments in more than 80 production sites across Europe, the study also reveals insights into several relevant research areas, including i. The current level of energy efficiency at an actual operational level across various food industry subsectors across Europe, ii. Examinations of the practically attainable energy efficiency potential across various agri-food sectors in Europe, iii. How to overcome energy efficiency barriers for SMEs in order to secure implementation of possible energy efficiency investments.

As the project is still ongoing, this paper will focus mainly on the setup of the project as well as initial experiences. While the overall project covers several agri-food sectors, the focus of this article is primarily the dairy sector. This is due to the focus of the Danish Agriculture & Food Council within the project. In most European member states, and in Europe as a whole, the dairy sector is simultaneously one the largest food industry sectors in terms of turnover, and one of the most energy-intensive (Ramirez et al., 2006; Bühler et al., 2018). In USA, the dairy sector consumes about the 13 percent of the total electricity use in the food industry, as well as about 13 percent of the total natural gas use (Masanet et al., 2014). A majority of this consumption happens at farm level; however, the energy used for dairy processing is also substantial. Unsurprisingly, energy efficiency at dairy processing plants remains a target of academic attention (e.g. de Lima et al., 2018; Bühler et al., 2018; Moejes & Boxtel, 2017; Finnegan et al., 2017; Soufiyan et al., 2017).

Dairy processing takes place in many regions around the world and in developing countries may contribute to larger shares of the national economic and environmental footprints. This is one of the reasons for the broad, and rising, academic attention. On a general note, the organisational capacity for capturing energy efficiency may generally be smaller developing regions, with greater opportunities for energy efficiency improvements. For these rural areas around the world, increased food industry energy efficiency are important elements of sustainable development, reinforcing not only sustainability, but also economic development. For the study of sustainable development and sustainable futures, understanding the barriers and the opportunities for energy efficiency projects in agri-food SMEs is therefore highly relevant, and the communication of positive experiences of these projects a means of generating positive impact.

Material and Methods

Saving Cooperative Energy (SCOoPE) is funded (2016–2019) by the European Commission's Horizon 2020-programme as part of a call promoting market uptake of energy efficiency[2]. The main aim of SCOoPE is to identify and deploy cost-efficient energy efficiency solutions for small- and midsized agri-food cooperatives. The project also provides valuable results regarding current industrial energy performance in the agri-food sector, general barriers for energy efficiency improvements in SMEs, and of regulatory differences within the EU.

The project directly engages 81 processing plants in the food value chain across seven European countries. The plants work within the agri-food sectors of crop drying, meat and poultry, dairy, and fruit

[1] This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agremeent N° 695985.
[2] H2020-EE-2015-3-MarketUptake, grant agreement No. 695985.

and vegetables transformation, and they are located in Denmark, France, Greece, Italy, Portugal, Spain, and Sweden. The Danish Agriculture & Food Council is a project partner, coordinating energy audits in 5 Danish dairies.

Figure 1. *Locations and sectors of 81 involved production sites (SCOoPE, 2018).*

The stated objective at the start of the project was to reduce energy consumption directly with between 10% and 15% by implementing cost-effective energy solutions in these 81 businesses, and to achieve this without any decrease in the production capacity of the companies.

A large majority of the businesses are small- and midsized companies, and a majority of companies involved function as cooperatives, although both large companies and private companies are also been involved. The five Danish dairies range in size from 6 employees to 235 employees which is representative for the range of almost all business involved in the project.

All agri-food companies involved in the project were actively engaged prior to the project. In practice, this pre-project phase was challenging, but broad involvement of SME-business was crucial to the development of the project. At the beginning of the project, energy consumption data was collected for all involved companies in order to make a benchmark before the identification and deployment of energy efficiency measures.

The initial energy consumption for the 81 production plants involved in the project amounted to about 850 GWh per year. The total CO2-emissions derived from this initial energy consumption is an estimated 160.000 tons CO2e/year based on the electricity carbon intensity measurements of Moro & Lonza (2018). Achieving the project targets of 10–15% reductions of energy consumption would therefore reduce the global CO2-emissions by 15.000–20.000 tons CO2e/year.

The distribution of initial energy consumption and derived CO2-emissions is seen below in Figure 2.

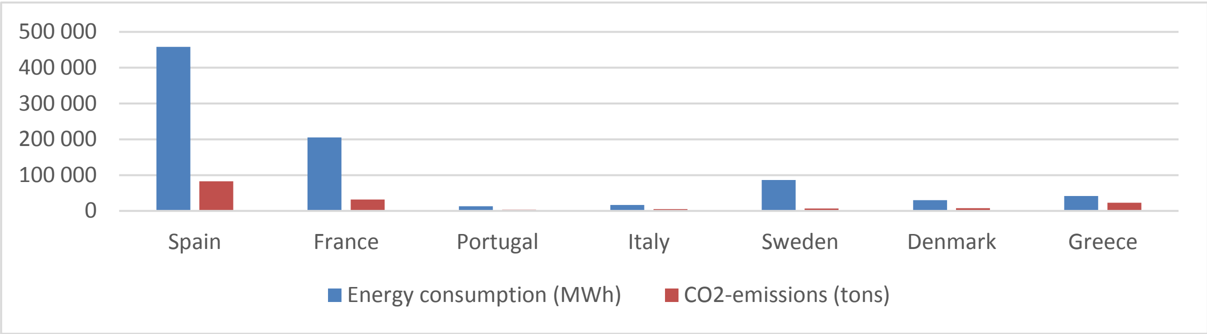

Figure 2. *Initial energy consumption and CO_2-emissions from the 81 production sites.*

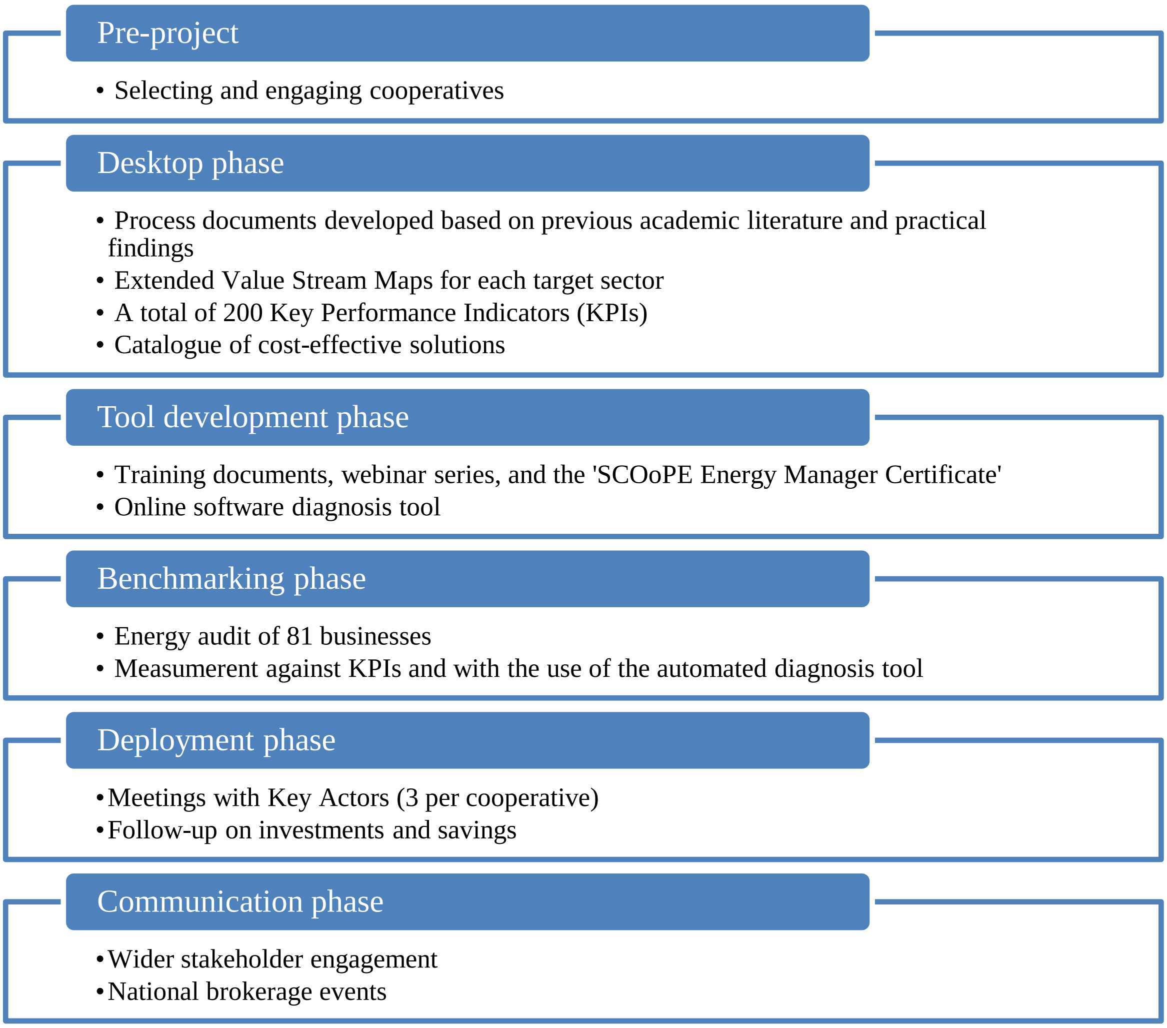

Figure 3*. Phases of the SCOoPE-project.*

After initiation of the project, tasks and actions related to five general project phases, described in Figure 3. Each phase was included and designed in order to minimise various energy efficiency barriers and effectively reduce potential transaction costs for the involved SMEs as much as possible.

First, detailed information on sectorial production processes was developed based on previous literature. For each target sector Extended Value Stream Maps (EVSMs) was developed using “Lean and green"-methodology (for methodological descriptions, see e.g. Hartini et al., 2017; Dhingra et al., 2014). The ESVMs for crop drying, dairy industries, meat and poultry, and fruit and vegetables transformation are available on the SCOoPE-project website[1]. The ESVMs were used to develop a set of more than 200 Key Performance Indicators (KPIs), thereby providing benchmarks for energy efficiency. The final key output of the initial desktop phase was a detailed catalogue of cost-effective technological solutions and available best practices, collecting possible measures within one common document with preliminary information on economics and technology-providers included.

Through the *tool development phase* a series of training documents were provided in order to qualify energy auditors. In total 12 online webinars were developed and subtitled into the eight European languages of the project with a certification scheme for viewers, who passed a final test[2].

The core of the SCOoPE-project was the *benchmarking phase* with execution of energy audits. Energy audits have been shown by many previous studies to be important energy efficiency instruments (see e.g. Schleich, 2004, Fresner et al., 2017), and after the adoption of the Energy Efficiency Directive audits are now mandatory for large companies (non-SMEs) in the European Union. For the SCOoPE-project each energy audit consists of at least two visits, measurement of the collected data against the literature-based set of KPIs, proposals of selected improvement measures, and a presentation of an executive report directly to the senior management of the business audited.

During the *deployment phase* suggested energy efficiency measures are elaborated. In order to maximise the realisation of investments and savings, the project includes the organisation of meetings between the involved cooperatives and so-called Key Actors. Key Actors are providers of e.g. technology or financing, and a project hypothesis is that this direct and targeted linking between the food SMEs and possible solution providers can be a key step for reducing transaction costs and increasing energy efficiency investments.

Finally, a key aim of the project is the *dissemination* of the learnings to a wider group of food value chain businesses. Since each sector of the European food value chain consists of large number of small- and medium-sized enterprises with, to some degree, comparable production processes, identified relevant cost-effective solutions for the 81 production sites will be expected to be repeatable elsewhere. If this scalability is harnessed, the overall impact of the project can be substantial, and disseminating the collected experiences to right target groups is integral for this purpose. In addition to extensive use of electronic media channels, the execution of multiple brokerage events is underlined.

Results

This section focuses on the experiences of Danish Agriculture & Food Council (DAFC), which are specific to the Danish part of the project.

The first hurdle of the project was the selection and engagement of cooperatives to be involved in the project. DAFC is a member organisation representing hundreds of companies involved in the agri-food sector, in addition to a majority of Danish farmers. With the use of intermediaries as contact points for individual food industry business sectors, the DAFC contacted more than 50 companies inviting them to be involved during the preparation of the project. However, most member cooperatives did not see the need to participate in a Europe-wide project, preferred to pursue their own investment projects, or considered the necessary in-kind contribution (ie. the time consumption of the project) to be greater than its benefits.

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[1] https://scoope.eu/publications-reports/
[2] It is possible to watch the webinar and gain the SCOoPE Energy Manager Certificate through https://scoope.eu/scoope-energy-manager-webinars/

In reality, even the offer of targeted energy audits provided at no direct financial cost for the company proved to be something of a hard sell. Seven dairies showed interest in participating in the project proposal. One dairy dropped out of the project before the project was initiated, while another later declined its participation after a change of ownership. In the end, only five Danish dairies was audited and benchmarked. This whole engagement process prior to the actual assessment of energy efficiency potentials seemed to affirm many of the conclusions from previous studies on energy efficiency barriers of Small- and Midsize Enterprises.

From the dialogue with potential participants, it was clear that in order to engage participation in energy efficiency projects (and, eventually, in investments), a directed marketing effort underling how this supplements and benefits their existing daily operations is needed. Making general conclusions, SME industrial managers did not necessarily show much interest in green transition, unless this strengthens the existing core business. However, the response to the project was unequivocally supportive – even those declining participation clearly perceives of energy efficiency as positive.

The auditing and benchmarking was done by a subcontracted engineering consultancy, Viegand & Maagøe[1], selected after a competitive tender process. All auditing visits and final presentation visits took place September 2017 – February 2018.

The five final executive reports include a total of 42 proposed energy efficiency measures. The proposed measures are clustered along several general themes, shown below in Figure 4.

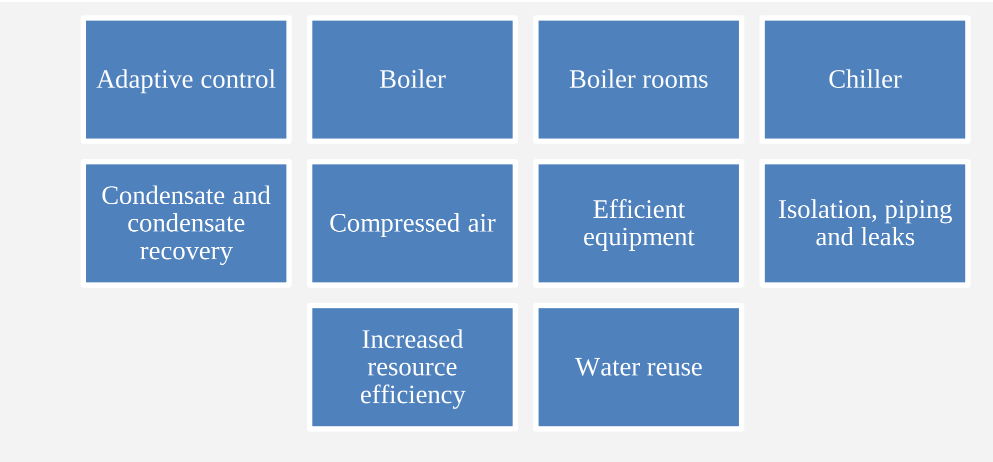

Figure 4. *Energy efficiency measures identified after energy audits.*

The identified possible energy efficiency measures are in line with the previous academic literature on energy efficiency in the dairy industry (e.g. Masanet et al., 2014). The reports included detailed proposals on measures for total possible savings of 1225 MWh/year, representing about 4% of the total energy consumed at the audited plants.

The total amount of recommend savings was lower than the intended project energy consumption reduction target of 10–15%. This may be explained by the fact that all five examined Danish plants measured well against the project KPIs. The actual energy consumption for all five plants was, in almost all cases, lower even than the suggested 'best KPI' which should represent the top 10% for an indicator in a given sector.

In other words, the participating Danish dairies proved that they were comparatively energy efficient already at the onset of the project, and the potential for additional cost-effective measures was therefore relatively low.

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[1] http://www.viegandmaagoe.dk/en/

However, the energy audits still revealed several very low-hanging fruits. As an example, there were several cases of lack of isolation on heat piping systems. The investments needed to remedy this may be in the magnitude of hundreds of euros, so this oversight is hardly due to economic barriers. For one of the plants a detailed investment calculation of securing isolation for every inch of piping systems documented payback times of not much more than one year.

The audits also showed the necessity of a holistic approach to energy efficiency. Increased resource efficiency with reduced waste, water reuse, usage of residual products, condensate recovery etc. were suggested as key avenues of improvement. However, implementation of these measures might require changes of existing operation procedures, which can necessitate more considerations on behalf of the dairy company before implementation. One dairy plant is currently considering a major remodelling of the plant using the conclusions from the energy audit as part of the inputs for the consideration. This also shows the importance of considering energy efficiency potentials not only of improvements of existing production processes, but also the potential gained by possible changes of processes or of process reconfigurations.

In our opinion, the Danish energy audits indicated a need for better integration of “resource efficiency” thinking and concepts of circular economy thinking than often showed in the academic energy efficiency literature. The burgeoning interest in the Lean and Green-methodology might be a fruitful avenue for this integration, as piloted in this project. We hope to be able to further evaluate this conclusion, as the results of the entire SCOOPE-project become available.

A final result came from the brokerage events associated with the project. As the results of the project was communicated by the energy auditors, other dairy plants started to show interest in the project. As originally hoped, it appears that the experiences of the project might be transferable to industry operations with similar production processes. Simultaneously, it was clear that some SME managers showed significantly greater interest *post-project* when it was more immediately clear how *they* might benefit from the results. Considering the current state of the dialogue, it is likely that some SMEs, who previously declined the offer of a free (ie. project-financed) energy audit, might now *pay* for a similar audit. This again suggests to us that, at least for operations of a certain size, economic barriers may not (always) be the biggest hurdle for getting industrial companies interested in energy efficiency considerations.

Discussion and Conclusions

The transition to a low carbon future is among the core themes of futures research. Improved energy efficiency is one of the major tools needed to unlock this more sustainable future. Understanding barriers for energy efficiency – and finding novel ways of overcoming these barriers – is therefore an important part of the field concerned with socio-technical transitions and transitions to more sustainable socio-technical systems (Hyytinen & Toivonen, 2015).

The prevailing literature on barriers for energy efficiency considers economic, technical and information-related barriers. These have all been reaffirmed during the course of the SCOoPE-project. Even if technological improvements are available and cost-effective, there is little guarantee for their market uptake. Actions undertaken to strengthen energy efficiency in small- and midsized companies (voluntarily) must therefore be tailored to the specific contexts of the receiving organisations.

The SCOoPE-project has put considerable emphasis on capacity building. This includes educating energy efficiency auditors, developing free energy efficiency diagnosis tools, and a series of webinars all available (subtitled) in the local languages of the project. The capacity building of intermediaries, as well as the language-specific material, are means to this end: Tailoring of information to specific contexts. Even with the project design aimed at securing this, there was still challenges in engaging SMEs, as well as a need to adapt the project after initiation in order to match specific needs and requests of the involved organisations.

However, the experience of SCOoOE is that piloting projects, such as this, can be an effective way of demonstrating value for money for SMEs, and that the presentation of successful pilot projects may be a way of generating increasing interest in energy efficiency potentials.

As for the Danish energy audits, at least three main conclusions are drawn:

- Even in industrial companies outperforming energy efficiency KPI's, low hanging fruits were identified.
- In line with the previous academic literature on energy efficiency in dairy industries, major targets for potential improvement projects relate to the efficiency of the boiler, the boiler room, compressed air systems, chillers, and condensate recovery. While the examined dairies in general had made investments in adaptive controls, there were still identified further potential investments in this regard. As the project shows, digitalisation can be a key driver for improved energy efficiency.
- Certain improvement suggestions related to better general resource efficiency, for which improved energy efficiency would be a positive side effect. The project thus demonstrated both how auditing for energy efficiency might have other significant positive effects beyond issues related to energy use, while the audits simultaneously showed the need for looking at broader operational issues in order to optimize energy efficiency.

While the project is not yet finished, there seems to be a risk that investment targets at least for the Danish plants are not met. This is in part due to a high initial level of energy efficiency. However, the audits did generate new knowledge for the involved actors, and this function as important input for future transformation projects within the plants and within the dairy processing sector in Denmark.

Finally, the project may offer significant positive benefits beyond its involved stakeholders. A tangible project-wide outcome has been the development of significant amounts of material, which is now accessible at the project website. As almost all material, including the capacity building webinar series on energy efficiency in the agri-food industry, is available in English, Spanish, French, Italian, and Portuguese, the material is easily accessible for large audiences also outside the European Union. We are therefore hopeful that the material will be utilized in order to generate significant positive impacts on sustainable development even beyond the project lifetime. While the detailed energy audit reports remain confidential, the authors here can also be contacted for more direct information on energy efficiency improvement projects in the dairy industry or the other agri-food industries in the project.

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Assessing energy efficiency improvements, energy dependence and CO_2 emissions in the European Union using a decomposition method

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Abstract

The objectives of this study are to provide new insights on (i) the levels of energy efficiency improvements achieved by the EU over the period 1995–2015 by employing a decomposition analysis approach – Logarithm Mean Divisia Index – and using disaggregated final energy consumption data, (ii) the progress of the EU towards the energy efficiency target set for 2030, and (iii) the energy security and climate benefits associated with energy efficiency improvements.

The results show that from 1995 to 2015, efficiency allowed the EU to save approximately 235 Mtoe of final energy. Additionally, energy efficiency improvements reduced the EU's dependence on energy imports at the average rate of 1% per year, saved 811 MtCO2, and contributed to achieving 52.5% of the energy efficiency target set for 2030.

Introduction and Background

On December 11, 2018, the European Parliament and the Council set a binding 32.5% energy efficiency target for 2030 (Directive (EU) 2018/2002). The energy efficiency target is set by using the Price-Induced Market Equilibrium System (PRIMES) model that simulates demand and supply behaviour by agent (sector) under different assumptions regarding economic development, emissions and other policy constraints, technology changes and other drivers. However, the way the target is defined and determined presents several limitations. First, the PRIMES model calculates primary and final energy savings rather than the reduction in energy use due to energy efficiency improvements. While achieving efficiency typically implies saving energy, the opposite is not necessarily true; reductions in energy consumption can be driven by several other factors, such as structural changes towards less energy-intensive industries and lower economic activity. Second, the energy efficiency target is based on a theoretical percentage of future primary energy use rather than absolute energy savings. Given the complexity of the energy system, many factors driving future energy supply and demand, such as macroeconomics, oil prices, technology improvements, and policies, may follow unexpected trajectories. Consequently, the actual energy supply and demand can significantly differ from the projections. Third, although the projections of energy demand, supply, and prices have been periodically updated (2009, 2013, and 2016), the energy savings for 2030 are still calculated using the 2007 PRIMES baseline projections. Thus, a portion of the 32.5% target could be achieved because of structural changes to the EU economy resulting from the recession of 2008 rather than renewed measures to reduce energy use. Additionally, the impact of the latest EU policy measures such as the Energy Performance of Buildings Directive (2010/31/EU) and the Energy Efficiency Directive (2012/27/EU), is not considered.

Against this background, the aims of this study are to provide an indication of the energy savings driven by energy efficiency improvements in the European Union during the period 1995–2015 and track the progress towards the 2030 energy efficiency target by employing a decomposition analysis approach and using disaggregated final energy consumption data.

The advantage of the decomposition analysis is that it disentangles and separates variations in actual energy consumption over time into changes of economic activity, structure, and energy intensity. By isolating the changes in energy intensity (at disaggregated level) from other factors affecting changes in energy consumption, it is possible to estimate the amount of energy saved due to energy efficiency improvements. Isolated energy efficiency improvements achieved between 2005 and 2015 are then assessed against the historical 2005 final energy consumption level that is used as the reference year for the energy efficiency target that has been set for 2030. By tracking the energy savings due to energy efficiency improvements (alone), it is possible to obtain a clearer understanding of the actual progress of the EU towards the energy efficiency target and the remaining gap to be bridged by 2030. In addition, to account for economy-wide benefits, simple formulae are used to estimate to what extent energy efficiency improvements between 1995 and 2015 were translated into energy security and climate benefits.

This study is particularly timely given the recent EU energy efficiency policy developments and the broader discussion concerning moving towards a secure and low-carbon economy. Without a proper measurement of the underlying drivers of energy consumption, it is impossible to evaluate energy efficiency improvements and some benefits at the top of the European policy agenda. Distinguishing the levels of causation driving the variation in energy consumption and the sectors/sub-sectors driving energy efficiency could provide a lever or opportunity for policies to exert influence. The results might also influence future discussions regarding the appropriate level of the energy efficiency target that should be adopted by the EU in 2030, which could strongly affect future investments and policies at the EU and national level and the achievement of the energy security and climate change goals.

Material and Methods

The dataset is composed of the final energy consumption by sector (industry, transport, residential, services, agricultural) and sub-sector/end-use (e.g., chemical industry, cars, space heating, etc.) of the European Union. In addition, data about passengers and goods traffic, the number of households, the stock of dwellings permanently occupied, the floor area of dwellings, the stock of large appliances, and CO_2 emissions are collected. The primary data source is the Odyssee database. Odyssee data are complemented with data on the value-added and energy dependence of the European Union taken from the World Bank and Eurostat database, respectively. The data cover the period from 1995 to 2015 for the European Union.

The Logarithmic Mean Divisia Index I (LMDI-I) decomposition approach is employed to estimate the level of energy efficiency improvements in the European Union.

The decomposition analysis separates and quantifies the impacts of the individual factors (‘effects’) of changes in economic activity, structure, and energy intensities on the final energy consumption (Ang 2015, 233-238) in each sector of the European Union from 1995 to 2015. The three main factors resulting from the decomposition analysis are as follows: (i) activity, that is, the basic human or economic actions that drive energy use in a particular sector (e.g., the value-added output in the industrial or service sectors); (ii) structure, which reflects the mix of activities within a sector that can affect how energy is used (e.g., the share of production represented by each sub-sector of industry); and (iii) intensity, that represents the energy use per unit of activity, such as the ratio between the energy consumption and the gross value added in the industrial sector or the ratio between the energy consumption and the floor area in the residential sector for space heating. For each sector and/or sub-sector/end-use an indicator for ‘activity’, ‘structure’, and ‘intensity’ is constructed.

Among the different decomposition methods – the Laspeyres method, the Paasche index, the Fischer Ideal, the Logarithmic Mean Divisia Index I (LMDI-I), and the Logarithmic Mean Divisia Index II (LMDI-II) – the Logarithmic Mean Divisia Index in the additive form (LMDI-I) presents several advantages and it is therefore used in this study. Ang (2015, 233–238) and Ang & Wang (2015, 67–76) by comparing all of the different approaches concluded that the Logarithmic Mean Divisia Index in the additive form (LMDI-I), is the 'best' decomposition method due to its theoretical foundation, adaptability, easy usage and result interpretation. In particular, the LMDI-I (i) passes a number of basic tests for a good index number; (ii) is 'perfect' (no residual); and (iii) is easy to use, as the formulae take the same form irrespective of the number of explanatory factors.

Assuming that V is an aggregate composed of n factors (x_1,x_2,…,x_n) and that from period 0 to T the aggregate changes from V^0 to V^T, the objective is to derive the contributions of n factors to the change in the aggregate, which can be expressed as follows:

$$\Delta V_{tot} = V^t - V^0 = \Delta V_{x_1} + \Delta V_{x_2} + \ldots + \Delta V_{x_n} \quad (1)$$

$$\Delta V_{x_k} = \sum L\,(V_i^t, V_i^0)\ln\left(\frac{x_{k,i}^T}{x_{k,i}^0}\right)$$

where i indicates the five sectors (industry, transport, residential, services, and agriculture), k indicates the explanatory factors (activity, structure, and intensity) and *L*(*a, b*) = (*a* − *b*)/(ln *a* − ln *b*) is the logarithmic mean of two positive numbers, i.e., a and b, which in this case, are the aggregates of the final energy consumption during years 0 and T that are used as the weighting function in LMDI-I (additive form). The IDA identity can be expressed as follows:

$$E = \sum_i E_i = \sum_i Q\,\frac{Q_i}{Q}\,\frac{E_i}{Q_i} = \sum_i Q\,S_i I_i \quad (2)$$

where *E* is the total energy consumption, *Q* is the overall activity level, E_i is the energy consumption of sector *i,* Q_i is the activity level of sector *i,* S_i is the structure (activity share) of sector *i,* and I_i is the energy intensity of sector *i.*

The three explanatory effects in the additive form are calculated as follows:

Activity effect: $$\Delta E_{act} = \sum_i L(E_i^T, E_i^0)\ln\left(\frac{Q^t}{Q^0}\right) \quad (3)$$

Structure effect: $$\Delta E_{str} = \sum_i L(E_i^T, E_i^0)\ln\left(\frac{S_i^t}{S_i^0}\right) \quad (4)$$

Intensity effect: $$\Delta E_{int} = \sum_i L(E_i^T, E_i^0)\ln\left(\frac{I_i^t}{I_0^t}\right) \quad (5)$$

The isolated energy intensity changes in each sector (e.g., industry, transport) and sub-sector/end-use (e.g., chemical industry, rail transport, water heating) can then be used as a proxy for energy efficiency improvements. Although it is not possible to observe the physical quantities that define an 'efficiency' in the engineering sense, by building up from the disaggregated data and incorporating changes in other explanatory factors, the measures of intensity more closely approximate changes in the underlying efficiency of energy use.

The difference between the total energy consumption in *T* and the total energy consumption in 0 is equal to the sum of the three effects (no residual) as follows:

$$\mathrm{E^t} - \mathrm{E^0} = \Delta\mathrm{E_{tot}} = \Delta\mathrm{E_{act}} + \Delta\mathrm{E_{str}} + \Delta\mathrm{E_{int}} \quad (6)$$

Given the availability of balanced time-series data, chaining decomposition is preferred to non-chaining decomposition. The advantage of the chaining analysis is that the results reflect year-to-year changes. It also makes full use of the data and it is more flexible in terms of application.

To track the progress towards the efficiency target established for 2030, the estimated energy efficiency improvements from 2005 to 2015 are compared to the historical 2005 final energy consumption levels. Consistent with other climate and energy targets, the European Commission, the European Parliament and the Council of the European Union translated the PRIMES projected energy reduction target into a reduction target compared to 2005 as the reference year for energy efficiency. Specifically, to achieve the energy efficiency target established for 2030 the final energy consumption needs to be approximately 20% lower than the historical final energy consumption in 2005 (The European Parliament and the Council of the European Union 2018, Directive (EU) 2018/2002).

Finally, to better understand the role played by energy efficiency in increasing the levels of energy security, a gross inland energy consumption coefficient is constructed. This coefficient is the result of the ratio of the total gross inland energy consumption to the final energy consumption of the EU during the period 1995–2015 as follows:

$$\beta_t = \frac{\mathrm{E_{g,t}}}{\mathrm{E_{f,t}}} \quad (7)$$

where β_t is the yearly gross inland energy coefficient, and $E_{g,t}$ and $E_{f,t}$ are the gross inland and final energy consumption levels of the EU on a yearly basis (*t*=1996, 1997…2015), respectively. Then, the yearly gross inland energy coefficient is multiplied by the annual amount (Mtoe) of energy saved due to energy efficiency improvements ($\overline{Eff_t}$) to obtain an estimate of the yearly average gross inland energy saved ($\overline{E_{gsav,t}}$) as follows*:*

$$\overline{\mathrm{E_{gsav,t}}} = \beta_t * \overline{\mathrm{Eff_t}} \quad (8)$$

Then, the notional percentage variation in energy dependence from 1995 to 2015 in the absence of energy efficiency improvements $\overline{\%E_{d,t}}$, is estimated as follows:

$$\overline{\%E_{d,t}} = \frac{(MtE_{d,t} - \overline{E_{gsav,t}})}{E_{g,t}} * (100) \quad (9)$$

where $MtE_{d,t}$ is the amount of Mtoe imported each year, $\overline{E_{gsav,t}}$ is the yearly average gross inland energy (Mtoe) saved due to energy efficiency improvements, and $E_{g,t}$ is the total (yearly) gross inland energy consumption.

As many European energy importing countries do not have the resource capacity to expand domestic production to meet the increased demand, for simplicity, it is assumed that all gross inland energy that is not saved due to energy efficiency improvements is imported. The results provide an estimate of the hypothetical variation in the EU's energy dependency in case there were no energy efficiency improvements - *ceteris paribus*.

To evaluate the impact of energy efficiency improvements on the emissions of the European Union, a yearly CO_2 emissions coefficient is constructed for each sector. The CO_2 emissions coefficient is multiplied by the amount of energy saved due to energy efficiency improvements (each year) to provide an estimate of the yearly average CO_2 emissions saved. Therefore, $\lambda_{i,t}$, which is the average CO_2 coefficient in sector *i* (industry, transport, services, residential, or agriculture) on a yearly basis *t*, is calculated as follows:

$$\lambda_{i,t} = \frac{\overline{ECO_{2,i,t}}}{\overline{E_{i,t}}} \quad (10)$$

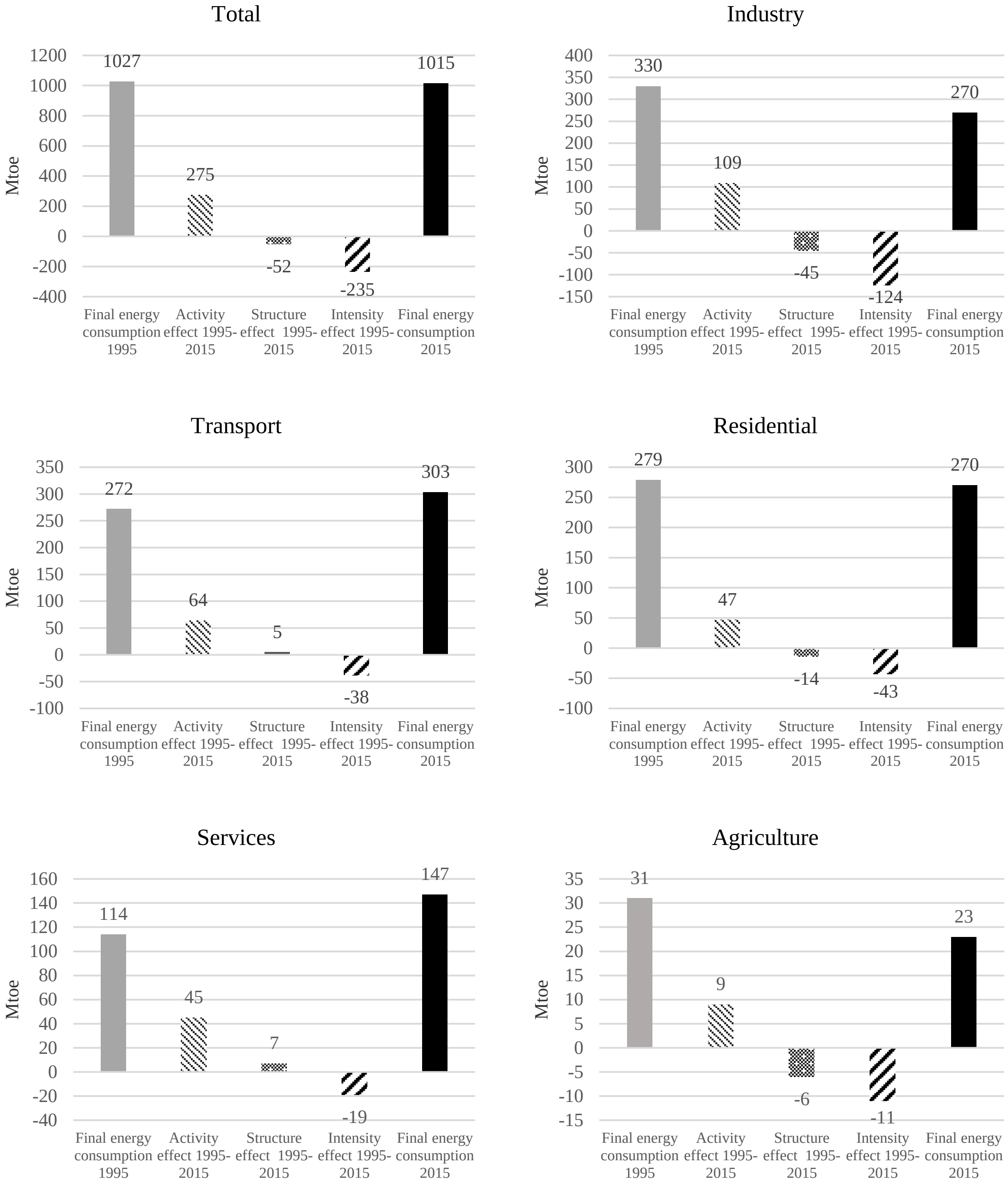
where $\overline{ECO_{2,i,t}}$ represents the average CO_2 emissions in sector *i* and year *t*, and $\overline{E_{i,t}}$ is the energy consumption in sector *i* and year *t*. Then, the yearly average CO_2 emissions coefficient in each sector $\lambda_{i,t}$ is used to estimate the total (yearly) CO_2 emissions saved as follows:

$$CO_2sav_t = \sum_{i=1}^{n} (\lambda_{i,t} * \overline{Eff_{i,t}}) \quad (11)$$

where $\overline{Eff_{i,t}}$ is the amount of energy saved due to energy efficiency improvements (each year) in sector *i*, and CO_2sav_t is the total amount of CO_2 not emitted on a yearly basis in all the sectors (*n* =5) due to energy efficiency improvements.

Results

Figures 1 illustrate the contribution of the ‘activity effect’, the ‘structure effect’, and the ‘intensity effect’ to the variation of final energy consumption by all types of end-users, and by each end-use sector in the European Union over the period 1995–2015, using the LMDI-I decomposition approach.



Figures 1. *Variation of final energy consumption in the European Union from 1995 to 2015.*

From 1995 to 2015, the EU final energy consumption decreased by 12 Mtoe, corresponding to a decrease of 1.2%. The decomposition results show that the increase of 275 Mtoe in the final energy consumption caused by activity effects was counterbalanced by intensity (-235 Mtoe) and structural changes (-52 Mtoe). Without the energy intensity improvements that occurred between 1995 and 2015 (while the other factors remained constant), the final energy consumption in 2015 could have been 23.2% higher. The 235 Mtoe saved due to energy intensity improvements corresponds to the final energy consumption in the United Kingdom, Spain, and Austria combined in 2015.

The highest energy reductions due to energy intensity improvements were achieved during the years after the implementation of the most important pieces of legislation in the energy efficiency domain: 2007 (Directive 2006/32/EC), 2011 (Directive 2010/30/EU and Directive 2010/31/EU), and 2014 (Directive 2012/27/EU that entered into force on 4 December 2012). In addition, 62% of the total energy intensity improvements between 1995 and 2015 have been achieved during the decade 2005–2015. Although it is not possible to show a causal relation between energy intensity trends and the implemented energy efficiency policies, these results may reflect the growing influence and ambition of the EU action on national energy efficiency strategies.

Between 1995 and 2015, more than half of the final energy intensity improvements were driven by the industrial sector. A structural shift towards less intensive industrial sub-sectors and more service-based economies resulted in a decrease of 45 Mtoe. Overall, the economic activity increased the energy consumption by 109 Mtoe; however, the impact of the economic recession in 2008–2009 was captured by the negative activity effect of 12.9 Mtoe in 2009.

With regard to the transport sector (both passenger and freight transport), the final energy consumption increased by 11.4%. An increase of 64 Mtoe and 5 Mtoe attributed to activity and structural effects, respectively, was only partially offset by intensity improvements (-38 Mtoe). Overall, 63.5% of the final energy intensity improvements were driven by passenger transport, while the remaining improvements were driven by freight transport.

The final residential energy consumption decreased by 3.2% over the period 1995–2015. An increase in the number of households (17.9%) and, consequently, in the household equipment ownership resulted in an increase of 47 Mtoe (activity effect). However, energy intensity improvements and structural effects contributed to a reduction of 43 and 14 Mtoe, respectively.

Concerning the services sector, the final energy consumption increased by 29% from 1995 to 2015. The moderate positive effects of energy intensity improvements (-19 Mtoe) were counteracted by a 45 and 7 Mtoe increment due to activity and structural effects, respectively; the growth and importance of the services sector in the EU economy[1] did not lead to corresponding energy efficiency improvements. Finally, the reduction in the final energy consumption in agriculture by 25.8% was mainly driven by energy intensity improvements (-11 Mtoe) and, to a lesser extent, structural effects (-6 Mtoe), while activity effects led to an increase of 9 Mtoe.

Figure 2 illustrates (i) the actual variation of the final energy consumption in the European Union from 2005 to 2015; (ii) the hypothetical variation of the final energy consumption due to energy intensity (hereinafter referred to as 'energy efficiency') improvements alone; and (iii) the energy efficiency target for 2030 compared to the historical 2005 final energy consumption levels (-20%).

[1] From 1995 to 2015, the contribution of the services valued added to the economy increased by 3.8%.

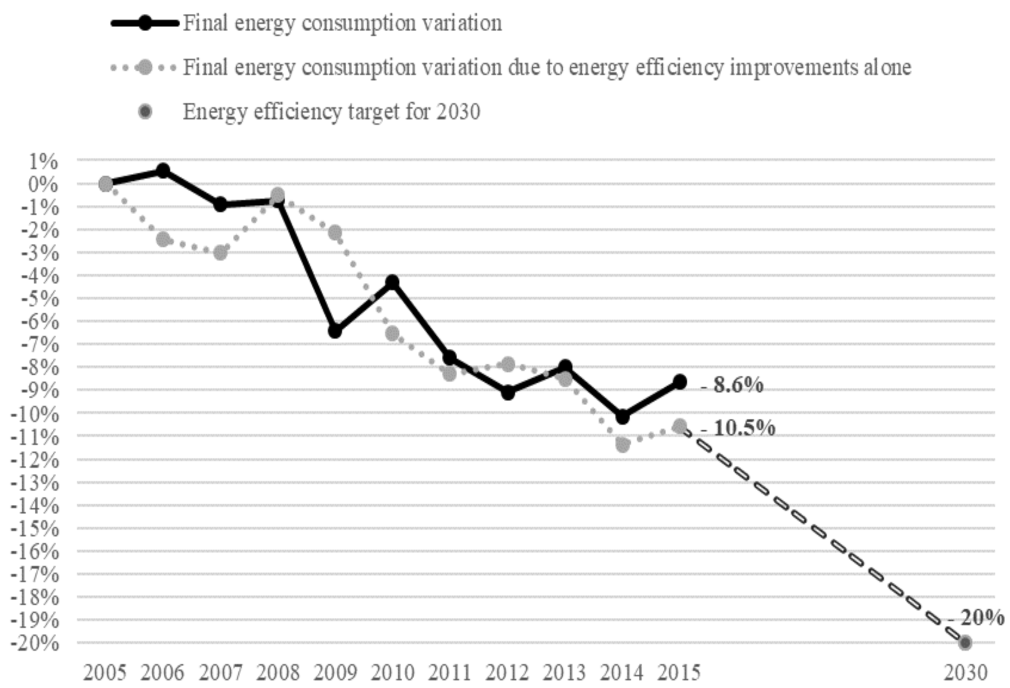


Figure 2. *Energy efficiency target for 2030 compared to energy efficiency improvements using LMDI-I (2005–2015).*

Although the 32.5% energy efficiency target for 2030 is commonly discussed in terms of the change in primary energy consumption in 2030 compared to the 2007 PRIMES baseline projections (percentage of target to be achieved), in the revised Energy Efficiency Directive (EU) 2018/2002, the European Commission, the European Parliament and the Council of the European Union translated this target into a reduction target compared to the historical 2005 energy consumption levels. This comparison facilitates the assessment of the target, improves its transparency, and makes it consistent with other climate and energy targets. This target corresponds to a 26% reduction in primary energy consumption compared to the historical 2005 primary energy consumption levels, and a 20% reduction in final energy consumption (compared to the historical 2005 final energy consumption levels). The contribution of each sector to the reduction of 20% in the final energy consumption (compared to the historical 2005 final energy consumption levels) could be as follows: a 19.9% reduction in the final energy consumption of the industrial sector compared to the 2005 levels, a 26.9% reduction in the final energy consumption of the residential sector, a 22.5% reduction in the final energy consumption of the tertiary sector, and a 12.3% reduction in the final energy consumption of the transport sector.[1]

From 2005 to 2015, the final energy consumption decreased by approximately 8.6%. However, when energy efficiency improvements are disentangled from the other factors influencing the variation of final energy consumption (activity and structural changes), the results show that the final energy consumption in 2015 would have been 10.5% lower than the consumption levels of 2005.

During 2005–2015, energy efficiency improvements alone saved 145 Mtoe and contributed to an average annual consumption reduction of 1.05%. In total, 44.2% of the energy savings were driven by the industrial sector, followed by the residential sector (27.7%), the transport sector (13.8%), the service sector (10.8%), and the agricultural sector (3.5%).

[1] These calculations are based on the methodology used by the EC (European Commission 2016) to determine the contribution of each sector to the final energy consumption reduction (compared to the historical 2005 final energy consumption levels) in different scenarios.

When the energy efficiency target for 2030 is assessed as the variation in final energy consumption due to energy efficiency improvements alone (and not other factors, such as economic activity, population, and economic structure, i.e., the EU means of assessment), the results indicate that 52.5% of the target for 2030 has already been achieved in 2015. Continuing this line of inquiry at the sectoral level, the energy saved due to energy efficiency improvements in industry from 2005 to 2015 achieved 98.5% of the target for 2030, whereas 51.3% of the target was achieved in the transport sector, 50.6% of the target was achieved in the residential sector, and 48.3% of the target was achieved in the service sector. In addition, at a constant annual contribution of energy efficiency to the reduction in final energy consumption of 1.05%, the remaining gap towards 2030 could be closed by the end of 2024.

Figure 3 illustrates (i) the actual energy dependence level (%) of the EU from 1995 to 2015; (ii) the notional variation of energy dependence per year in the absence of energy efficiency improvements; and (iii) the notional energy dependence level in 2015 without energy efficiency improvements that occurred between 1995 to 2015.

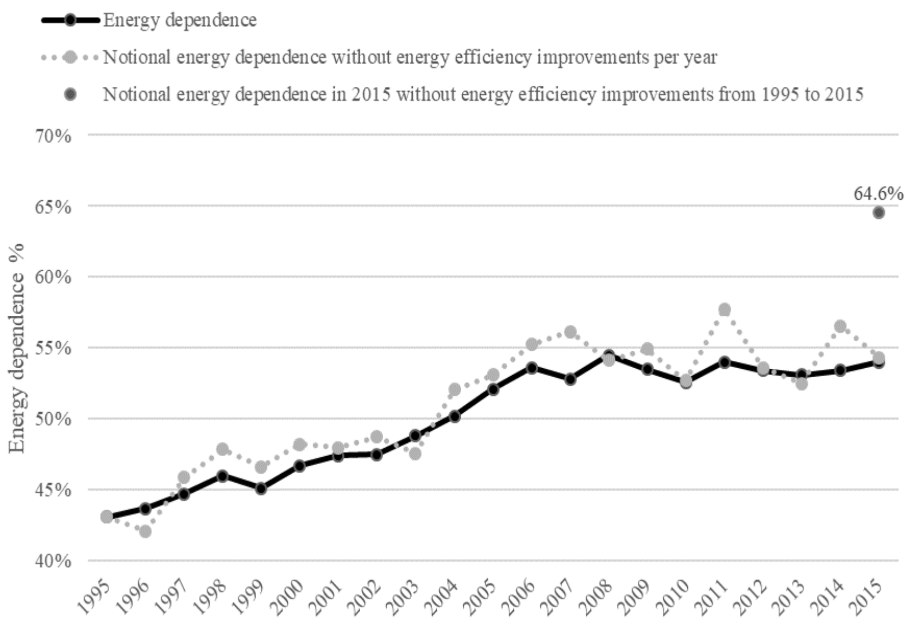


Figure 3. *Energy security benefits due to energy efficiency improvements (1995–2015).*

In 2015, the EU imported 54% of the energy it consumed; such energy import dependency increased by 25.3% over the period 1995–2015. Without the energy efficiency improvements that occurred between 1995 and 2015, the EU energy dependence on imports in 2015 could have hypothetically been 64.6%, corresponding to an increase of 12.6% in the actual levels of energy dependence – *ceteris paribus*. In total, energy efficiency contributed to saving 361 Mtoe of gross inland energy and reduced the energy dependency at an average rate of approximately 1% per year. The gross inland energy saved due to energy efficiency improvements between 1995 and 2015 corresponds to the energy imported from Russia and Norway, which are among the principal suppliers of the EU energy imports, and 22.1% of the total gross inland energy consumption in 2015.

Figure 4 depicts (i) the EU's total CO_2 emissions ($MtCO_2$) from 1995 to 2015; (ii) the notional variation of total CO_2 emissions per year in the absence of energy efficiency improvements; and (iii) the notional amount of CO_2 emissions in 2015 without energy efficiency improvements that occurred between 1995 and 2015.

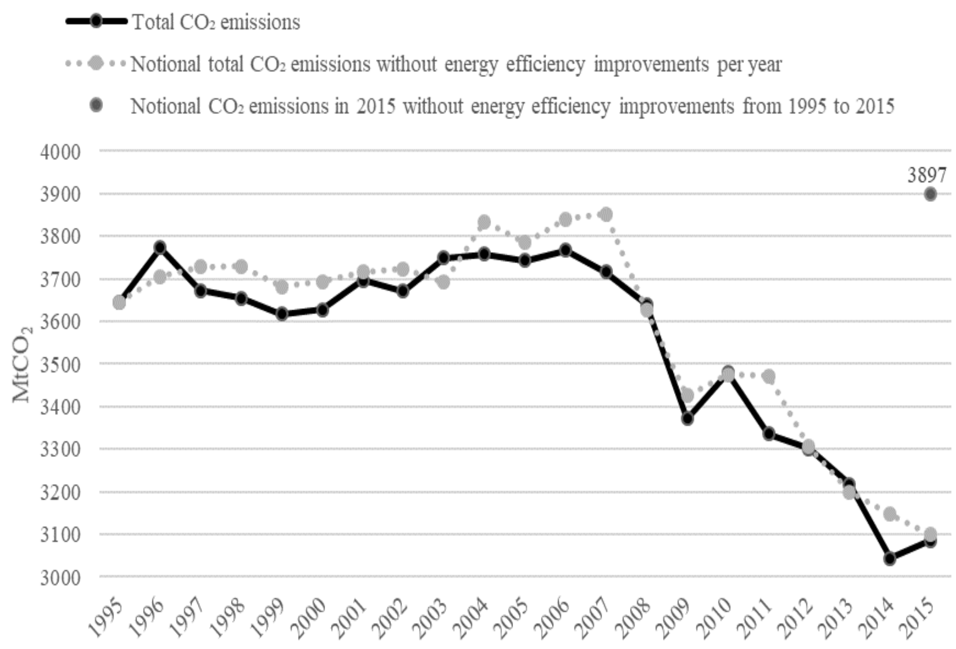


Figure 4. *CO_2 emissions reduction due to energy efficiency improvements (1995–2015).*

The CO_2 emissions resulting from the EU's energy consumption from 1995 to 2015 decreased by 15.4%. From 1995 to 2015, energy efficiency contributed to a reduction of 811 $MtCO_2$, corresponding to the total CO_2 emissions in Germany, Greece, and Finland combined in 2015. Without energy efficiency improvements improvements that occurred between 1995 and 2015, the CO_2 emissions in 2015 could have been 26.3% higher (*ceteris paribus*). The key role of energy efficiency in reducing CO_2 and other greenhouse gas emissions (GHGs) becomes more visible when the results are assessed against the EU climate targets. By 2030, the EU aims to cut its total greenhouse gas emissions (GHGs) by 40% compared to 1990 levels. In absolute terms, to achieve this goal, the total GHGs in 2030 should be 3429,82 $MtCO_2e$, corresponding to a reduction of 2286,54 $MtCO_2e$ compared to the GHGs of 1990 (5716,36 $MtCO_2e$). In addition, the roadmap for moving to a competitive low carbon economy in 2050 suggests that, by 2050, the EU should cut its GHGs to (at least) 80% below 1990 levels; in absolute terms, this corresponds to a reduction of 4573,088 $MtCO_2e$ compared to 1990 levels. Thus, the reduction of 811 $MtCO_2$ as a result of the energy efficiency improvements that occurred from 1995 to 2015 contributed to achieving 35.5% of the climate target established for 2030 and 17.7% of the climate target established for 2050.

Discussion and Conclusions

On December 11, 2018, the European Parliament and the Council set a binding 32.5% energy efficiency target for 2030 (Directive (EU) 2018/2002). The achievement of this target will determine the success of EU Member States' actions and policy measures to improve energy efficiency and contribute to reducing energy dependence and CO_2 emissions. However, the energy efficiency target is based on a hypothetical percentage of future primary energy use based on an outdated projection that does not account for the different factors influencing the variation in energy consumption and the recent evolution of EU policies.

This study identifies and quantifies the factors influencing the variation in final energy consumption in the EU from 1995 to 2015 by a employing decomposition analysis (LMDI-I) and using disaggregated data. Specifically, the decomposition analysis shows the extent to which the reduction in the EU final energy consumption was driven by energy efficiency improvements, which would otherwise be masked by changes in economic activity and structure. In addition, to track progress towards the 32.5% energy efficiency target, the estimated energy efficiency improvements from 2005 to 2015 are compared to the 2005 historical final energy consumption levels. Finally, to account for economy-wide benefits, the calculated amount of energy savings due to energy efficiency improvements is translated into a reduction in energy dependence and CO_2 emissions..

The results show that from 1995 to 2015, an increase of 275 Mtoe in final energy consumption caused by activity effects has been offset by structural changes (-52 Mtoe), and especially energy efficiency improvements (-235 Mtoe). At the sectoral level, 52.8% of the energy savings due to energy efficiency improvements came from industry, 18.3% from residential, 16.2% from transport, 8% from services, and 4.7% from agriculture.

Without the energy efficiency improvements that occurred during 1995–2015, the final energy consumption in 2015 would have been 23.2% higher. The results indicate that the energy savings driven by energy efficiency improvements alone between 2005 and 2015 contributed to achieving 52.5% of the target established for 2030. From this perspective, the 32.5% energy efficiency target appears to be significantly behind that achievable by the EU.

The need for a higher target becomes even more crucial when the benefits of energy efficiency are measured in terms of the security of supply and emission reductions. Hypothetically, the primary energy saved (361 Mtoe) due to energy efficiency improvements from 1995 to 2015 would have allowed the EU not to rely on imports from Russia and Norway in 2015. In addition, energy efficiency improvements from 1995 to 2015 lowered CO_2 emissions in 2015 by 26.3%, and contributed to achieve 35.5% of the climate target set for 2030.

Therefore, the overall level of the target and its evaluation could influence the level of ambition of energy efficiency policies at the national level and the achievement of energy security and climate change goals. The findings in this study highlight the significant contribution of energy efficiency to reducing energy consumption and the importance of redefining the energy efficiency target in a more consistent way by reconsidering the level to be achieved and evaluating progress accordingly.

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Energy Efficiency as an engine for development in countries characterized by energy poverty

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Abstract

Energy drives everything, from knowledge to economic development, to life itself. But access to energy is a sensitive issue, function of many factors, among which history and geography play a fundamental role. Among all the continents of the world, Africa is probably experiencing the most paradoxical situation: despite the abundance of energy resources (both fossil and renewable ones) on the continent, more than half of the African population does not have access to electricity. The situation is even worse in the Sub-Saharan region, where the percentage is 65% on average (WEO, 2016). Moreover, sometimes the energy available is wasted in severely obsolete appliances, and inefficient infrastructures and processes. The two levers on which to operate to face energy poverty of Africa are therefore the production from renewable sources and the promotion of energy efficiency. This process can trigger a virtuous circle with several positive repercussions, firstly the creation of local jobs and the blossom of a community-based and self-sufficient economy. The same applies to other worldwide areas where energy poverty and development are strictly linked and affect people wellbeing.

In this work, we do a review of practical initiatives, projects and studies that deal with this challenge, and try to investigate future scenarios.

Introduction and Background

In the framework of the UN's Sustainable Development Goals, energy plays a key role. One of the goals, number 7, is explicitly dedicated to it: "Ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, n.d.). Furthermore, energy access is expected to contribute to many other aspects of the SDGs, from ending poverty to ensuring high standard health, quality education and economic development. SDGs are supposed to be met by 2030, but today's statistics are not so bright. According to the International Energy Agency's "World Energy Outlook 2017" (IEA, 2017), 1.18 billion people (16% of the worldwide population) still lack access to electricity, and 2.74 billion (40% of the global population) rely on traditional cooking methods. It is estimated that 80% of energy poor people live in rural areas, which makes it more difficult to reach them through the central, state grid. Focusing on Sub-Saharan Africa, (Dagnachew, Anteneh G. Lucas, Hof, & Van Vuuren, 2018) claims that "based on relationships between electricity access on the one hand and GDP per capita, population density, and urbanization rate on the other, model projections show that following historical trends about 515 million people will still lack access to electricity in 2030". Another alarming figure is that almost four million people die every year from indoor air pollution due to the use of traditional cooking fuels and stoves, and this is also a problem of energy efficiency (for further details, please check (Bond et al., 2013)).

This work is based on two main hypotheses:

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- HP1) Reducing the gaps in development between countries is the preliminary and necessary condition to get to universal, effective mechanisms to face climate change and aim for a reduction of resource consumption.
- HP2) Energy efficiency is an engine for development, and development is in turn an engine for energy efficiency and environmental protection.

Material and Methods

In this paper we analyze some of the most important studies concerning the relationship between energy efficiency, energy access, job creation, economic and social development. The review does not claim to be exhaustive, but to offer a point of view on the variables involved in the issue of energy efficiency for energy poor countries. This means that we highlight the main drivers, the levers on which to operate, and the possible outcomes of the process.

Results

The first work analyzed is not related to a developing country, being instead realized in the United States, by the American Council for an Energy-Efficient Economy (ACEEE). It tries to answer the question: "How does energy efficiency create jobs?" (ACEEE, 2011). In argumenting the answer, it claims that three main types of jobs are created:

- Direct: Workers hired for implementation of the desired efficiency measures
- Indirect: Materials purchased from other companies thus creating new jobs
- Induced: Direct and indirect workers spending their salaries in the local economy, thus creating induced jobs

In the case study, two scenarios are considered, both based on an investment worth $15Million on the first year: Option 1 brings Energy efficiency improvements, while Option 2 is Business as usual. Net jobs created in Option 1 would be 45 more than Option 2 at the end of the first year, and 420 on the long term (considering a time span of 20 years). The study concludes that diverting investments from "business as usual" spending patterns to high labor intensity construction and manufacturing industries would support more jobs. To the same conclusions, through different data, also comes another US-based study, by Wei in 2010 (Wei, Patadia, & Kammen, 2010).

Now, of course it's not easy to reassess the impact of EE investment from mature economies to developing countries, but it's intuitive to recognise that the same amount of money would have much bigger impact on generating jobs, improving energy access and performances.

One example that adapts a US-based model and scales it to Africa is the one developed by Cantore et al. (Cantore, Nussbaumer, Wei, & Kammen, 2017). The study applies scenario analysis to evaluate the employment potential of an uptake in RE and EE in Africa. It first develops a reference scenario (or baseline scenario) with which to compare alternative future scenarios, and then it estimates the potential direct and indirect job impact of very high increases in RE in Africa energy savings and the conversion of the electricity supply mix to renewable energy generates employment compared to the reference scenario. The scenarios are based on the World Energy Outlook 2012 (IEA, 2012). The most 'pessimistic' is called 'Current Policies', and implies basically no efforts in EE and RE from current trends, that is 25% of RE and 1311 TWh of electricity demand; the intermediate one is 'New Policies', assuming 30% share of renewables and 1224 of electricity demand in 2030 in Africa. As third, the most 'optimistic' '450_PPM' (taking the name from the 450 ppm of CO_2, considered to be the maximum level of carbon dioxide in atmosphere to stay within the +2 °C threshold), assumes that by 2030 the share of RE will be 42%, and demand be 1106 TWh.

It also concludes that the costs per additional job created tend to decrease with increasing levels of both EE adoption and RE shares.

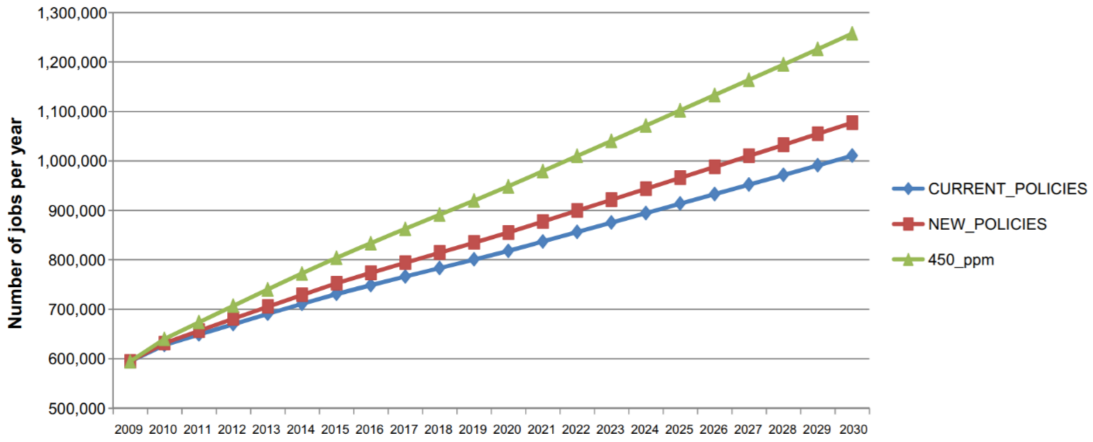

Figure 1. *Jobs in different scenarios (jobs/year vertical axis, year horizontal axis). Source: (Cantore et al., 2017)*

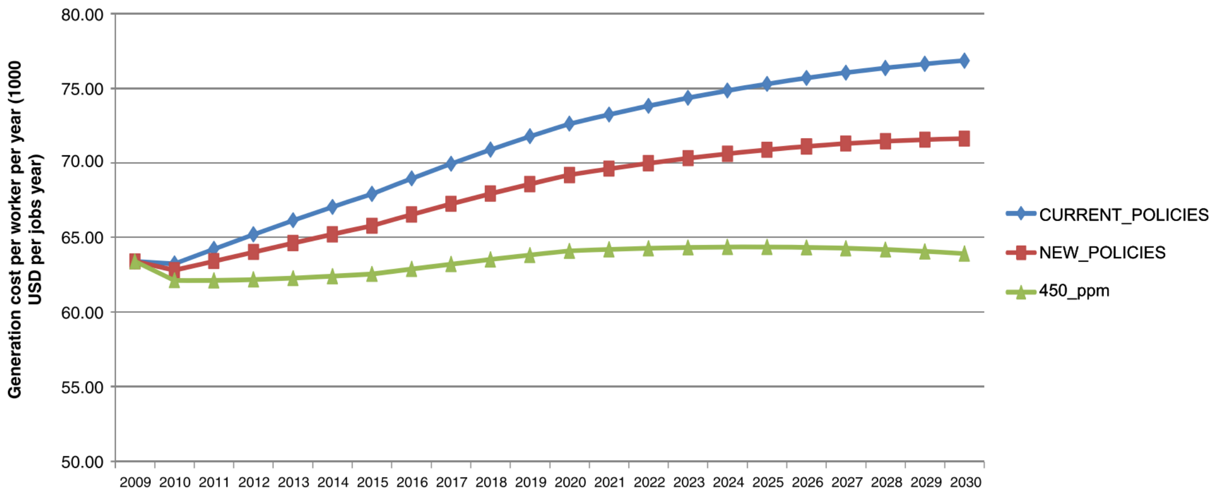

Figure 2. *Generation cost per worker. Source: (Cantore et al., 2017)*

Table 1. *Share of jobs across sources of energy. Source: (Cantore et al., 2017).*

Table 3. Share of jobs across sources of energy.

2020	CURRENT_POLICIES	NEW_POLICIES	450_ppm
Energy efficiency net of induced jobs	0.00	4.98	9.59
Induced jobs	0.00	2.13	4.11
Renewable energy	36.93	36.52	42.18
Fossil fuels	60.78	53.35	40.50
Nuclear	2.30	3.02	3.63
	100	100	100
2030	**CURRENT_POLICIES**	**NEW_POLICIES**	**450_ppm**
Energy efficiency net of induced jobs	0.00	6.61	12.08
Induced jobs	0.00	2.83	5.18
Renewable energy	43.16	43.82	51.99
Fossil fuels	54.50	43.09	26.21
Nuclear	2.34	3.49	4.54

As it can be seen above in Figures 1 and 2, and in Table 1, the conclusions of the analysis are that "a transition towards low carbon power generation in Africa would lead to additional jobs, but with a potential trade-off in terms of electricity generation costs", because energy savings do not always compensate for a higher cost of RE.. Energy savings do not always compensate for a higher cost of RE." From a societal perspective, a higher penetration of RE and EE generate a social dividend in terms of additional employment together with lower costs of generation per additional employee. To sum up, "the results of this paper reveal that if RE become a competition for fossil fuels and if at the same time technologies for EE start becoming less expensive, there is a potential that the greening of the economy favourably impacts all three pillars of sustainable development simultaneously."

The last study reviewed is the one by Mills (Mills, 2016). It takes in consideration the amount of jobs potentially created from the sale of solar-LED lighting, in places that are still not reached by the national electric grid. The major findings of the study are summed up in the following text and figure 3: "A market transformation from inefficient and polluting fuel-based lighting to solar-LED systems is well underway across the developing world, but the extent of net job creation has not previously been defined. The current employment associated with fuel-based lighting represents approximately 150,000 jobs. New jobs will accompany the replacement technologies. A survey of major solar-LED lighting companies finds that 38 such jobs are created for each 10,000 people living off-grid for whom stand-alone solar-LED lights are suitable. Applying this metric, the number of new jobs already created from the current uptake of solar-LED lighting has matched that of fuel-based lighting and foreshadows the potential creation of 2 million new jobs to fully serve the 112 million households globally that currently lack electricity access, are unlikely to be connected to the major grid, micro-grids, or are able to afford more extensive solar systems."

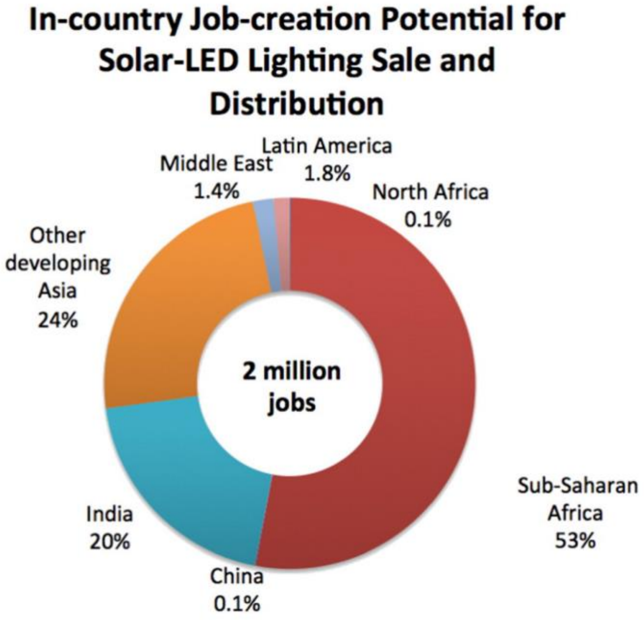

Figure 3. *Jobs by region, apportioning the unelectrified population to households at the rate of 4.4 people per household for the year 2013. Source (Mills, 2016).*

Discussion and Conclusions

In conclusion, all the studies analysed highlight the central role that energy efficiency and energy access. Main barriers to these processes seem to be, from a global perspective: a general lack or insufficiency of funding from international institutions; sometimes, the lack of business models that prove to be sustainable in the long run, thus really fitting and supporting the community in its development; the unfortunate fact that too often the climate change agenda is considered by the western countries and public opinion to be more important – sometimes also opposed to – energy poverty in developing countries.

The path to meet the Sustainable Development Goals in 2030 is still hard and steep, so deep changes in the policy making need to be done as soon as possible. Here we briefly summarise some key suggestions for policy:

- Recognise the right to energy, and the need to reduce the gap in wealth and consumption between and within continents and countries.
- Foster political stability in local governments.
- Introduce efficient, effective and equitable subsidies that consider and meet the different needs (for example that include greater allowance of greenhouse gas emissions to provide energy access for the poor).
- Design new mechanisms to fight climate change, mechanisms to be regularly assessed against their real impact also in the addressing of energy poverty.
- Establish an adequate and effective implementing international agency (for example, at UN level), with high-degree of operating autonomy (particularly from possible political pressure) and accountability in the targets to reach.
- In rural and off-grid electrification, forecast adequate expansion plans, which consider the actual needs and possibilities of communities, ensure financial viability and economic impact: premature rural electrification may miss the objective of contributing to sustainable community development (Alloisio et al., 2017).
- Push for right and adequate energy tariff policy, considering customers' realistic ability to pay.
- Foster blended finance through Public Private Partnership.

All these measures might help tackling energy poverty. This goal is fundamental to reducing poverty, creating jobs, decreasing energy and resource intensity of the economies around the world (ie, reducing deforestation, fuelwood consumption, land degradation, and finally deploying global mechanism applicable to all, thus making them finally useful (Cap & Trade, carbon tax, etc.).

Acknowledgements

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Energy Efficiency as a Driver of CO_2 Emissions in the EU

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Introduction and Background

Energy efficiency has been a very common and always actual policy objective since the 1970s. At a first glance, energy efficiency seems very handy to offer a win-win situation: improving energy efficiency decreases energy use and thus also energy costs, and at the same time, negative impacts related to energy use such as carbon dioxide (CO_2) and other emissions in the air decrease. Thus, improving energy efficiency is considered as an important means to reach climate policy targets as well as other policy goals related to energy use, directly or indirectly.

Energy efficiency, however, is a relative concept, and far from being without problems. This is one of the reasons to its popularity in political discussions. The win-win solution mentioned above assumes decreasing energy consumption, but actually per unit of production only. The Jevons paradox (see e.g. Polimeni et al 2009) implies that improvements gained by increasing energy efficiency are wasted in additional energy consumption, either by increasing the amount of units, or elsewhere. This kind of argumentation is included also in the Advanced Sustainability (ASA) approach as a “gross rebound effect” (Kaivo-oja et al 2001a; 2001b).

Energy consumption is a result of three basic drivers as identified widely in many decomposition studies (e.g. Kaivo-oja & Luukkanen 2004): activity effect, intensity effect and structural effect (cf. Kasanen 1990). What is usually meant with energy efficiency, deals directly with only one of these drivers, i.e. the intensity effect. Thus, the intensity effect is on the focus in this article.

In the next chapter, the analysis framework based on the Advanced Sustainability (ASA) approach (see Kaivo-oja et al 2001a; 2001b; Vehmas et al 2003; Vehmas 2009) developed in Finland Futures Research Centre (FFRC) will be presented and described. The chapter on results presents first trends of the drivers of CO_2 emissions the EU-28 Member States. Then results from incremental decomposition analysis of CO_2 emissions will be presented for the EU-28 aggregate, and China. Finally, conclusions will be drawn, as well as policy recommendations.

Material and Methods

The IPAT identity emerged out of the Ehrlich & Holdren/Commoner debate in the early 1970s about the driving forces of global environmental impacts (York et al 2003). The IPAT identity identifies the major drivers of environmental impact (I) at the global level: the amount of population (P), the affluence of that population (A), and level of technology (T). Waggoner and Ausubel (1992) added a new term, consumption (C) in the identity and called the result as an ImPACT identity. Kaya (1990) applied the idea of IPAT identity to the drivers of carbon dioxide (CO_2) emissions. His formulation has been called as the Kaya identity:

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \quad (1)$$

The drivers of CO_2 emissions include the following:

- Driver CO_2/TPES (carbon dioxide emissions from fuel combustion divided by total primary energy supply) describes the carbon intensity of the mix of primary energy sources. The carbon content of different primary energies varies a lot, and the differences are significant also between different fossil fuels. Chkayan the energy mix towards low-carbon or carbon-free energy sources decreases CO_2 emissions.
- Driver TPES/FEC (total primary energy supply divided by final energy consumption) represents the efficiency of the energy transformation system. This efficiency changes when changes in the transformation process take place, e.g. when fuel use is replaced with electricity. If electricity is produced in condensing power plants, the transformation process becomes more inefficient because in condensing power plants only 35-40 % of the fuel's energy content is transformed into electricity, the rest is waste heat. Thus, a drop in the efficiency of the energy transformation process increases the need of primary energy (TPES). If CHP is used, the overall efficiency change is smaller, because the heat is not wasted but used for heating purposes either in industrial processes or as district heat (which is common e.g. in Finland).
- Driver FEC/GDP (final energy consumption divided by gross domestic product) describes energy intensity of the economy, which is an inverse of energy efficiency at national level, i.e. GDP productivity of energy use. Changes in this driver are due to changes in the structure of the economy, such as change from energy intensive to lighter industrial branches and services or vice versa.
- Driver GDP/POP (gross domestic product divided by number of population), GDP per capita, describes affluence of the population referred to in the original IPAT identity.
- Driver POP (number of population) was considered as the most important driver in the original IPAT identity, which focused on global environmental issues. In industrial countries, it is less significant, but defends its position in the driver identification.

In this paper, a chained two-factor Sun-Shapley decomposition analysis will be used to divide the observed change in CO_2 emissions into the effects of contributing factors identified in the Kya identity (equation 1). The idea of chained decomposition analysis is that the results of the first wo-factor decomposition can be taken as a starting point for further decomposition (Figure 1). The order of entrance of new factors in the chain is determined by the theory, or assumptions, behind factor identification.

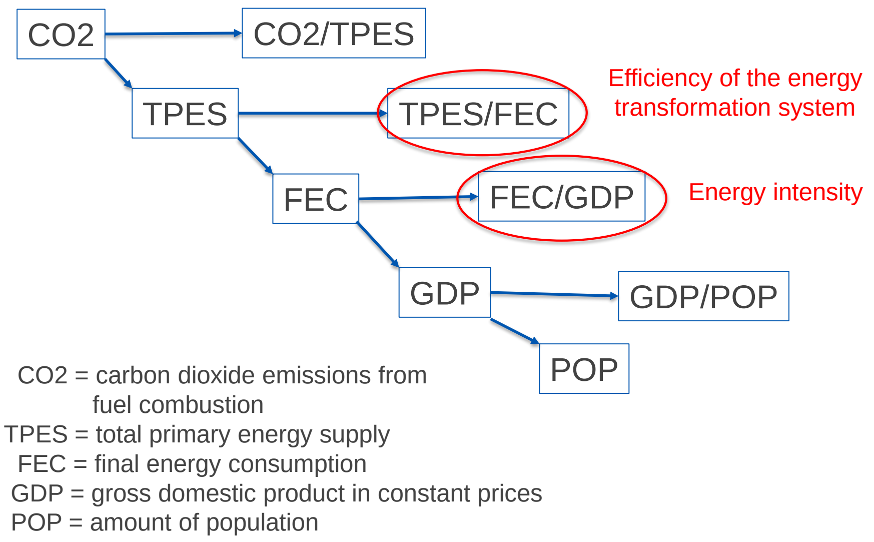

Figure 1. *The idea of chained two-factor decomposition.*

In this paper, the decomposition analysis will be made for annual changes in CO_2 emissions by using a moving base year, this is the hard core of "incremental" decomposition analysis". Longer time periods can be analysed based on the incremental results, simply by summing up the driver-specific results for getting values for preferred longer time periods. The applied decomposition technique is based on the Sun-Shapley method (Ang 2004), which has been used also in the acknowledged EUFORIE project. Detailed methodology and the equations for calculating the effects is available in Vehmas et al (2017; 2018).

Results

In the following, first the cumulative change in CO_2 emissions from the year 1990 onwards is presented for the EU-28 Member States (Figure 2). The Member States are sorted from the largest to the smallest based on the 2015 cumulative CO_2 emission value.

Figure 2 shows that there are at least three basic groups of EU-28 Member States in terms of the trend of CO_2 emissions:

1. Member States with a first decreasing and then stabilising trend (typically East European Member States)
2. Member States with a first increasing and then decreasing trend (typically Mediterranean Member States), and
3. Member States with first a stable and then decreasing trend (EU as a whole and typically the large Member States).

However, not all EU Member States fall clearly in these groups. Some EU Member States, such as Finland, have much more variation in the cumulative CO_2 emissions after the year 1990. Reflection of the financial crisis in 2008-2009 is visible in the cumulative CO_2 emissions. Figures 3−7 show indexed trends (1990 = 100) of drivers identified in the Kaya identity (equation 1), i.e. CO_2/TPES, TPES/FEC, FEC/GDP, GDP/POP and POP, respectively, for the EU-28 and the Member States.

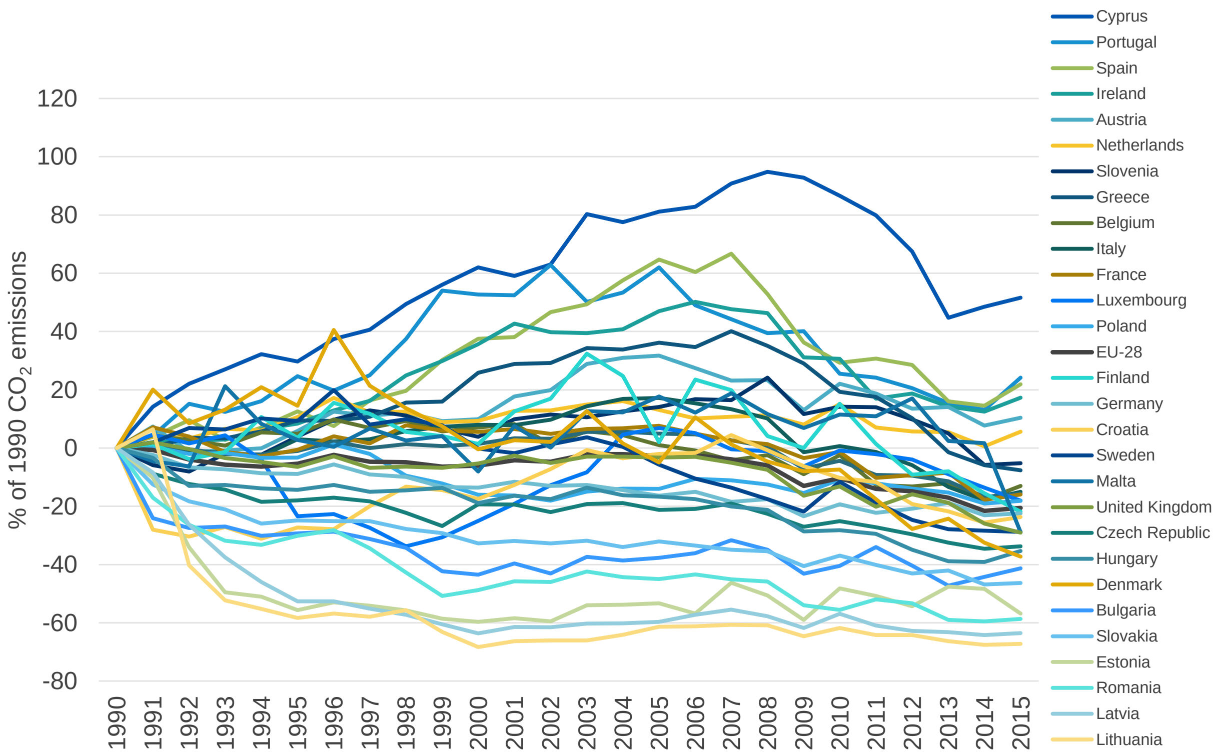

***Figure 2**.Cumulative change in CO_2 emission trends in the EU-28 Member States as a percentage from their 1990 absolute values, 1990 = 0.*

Figure 3 shows the trend of carbon intensity of the primary energy mix (CO_2/TPES). Cyprus is the only Member State where the 2015 index value of carbon intensity is larger than in 1990. CO_2 intensity has a decreasing long-term trend in all other EU Member States, although in many Member States there are many short-term exceptions.

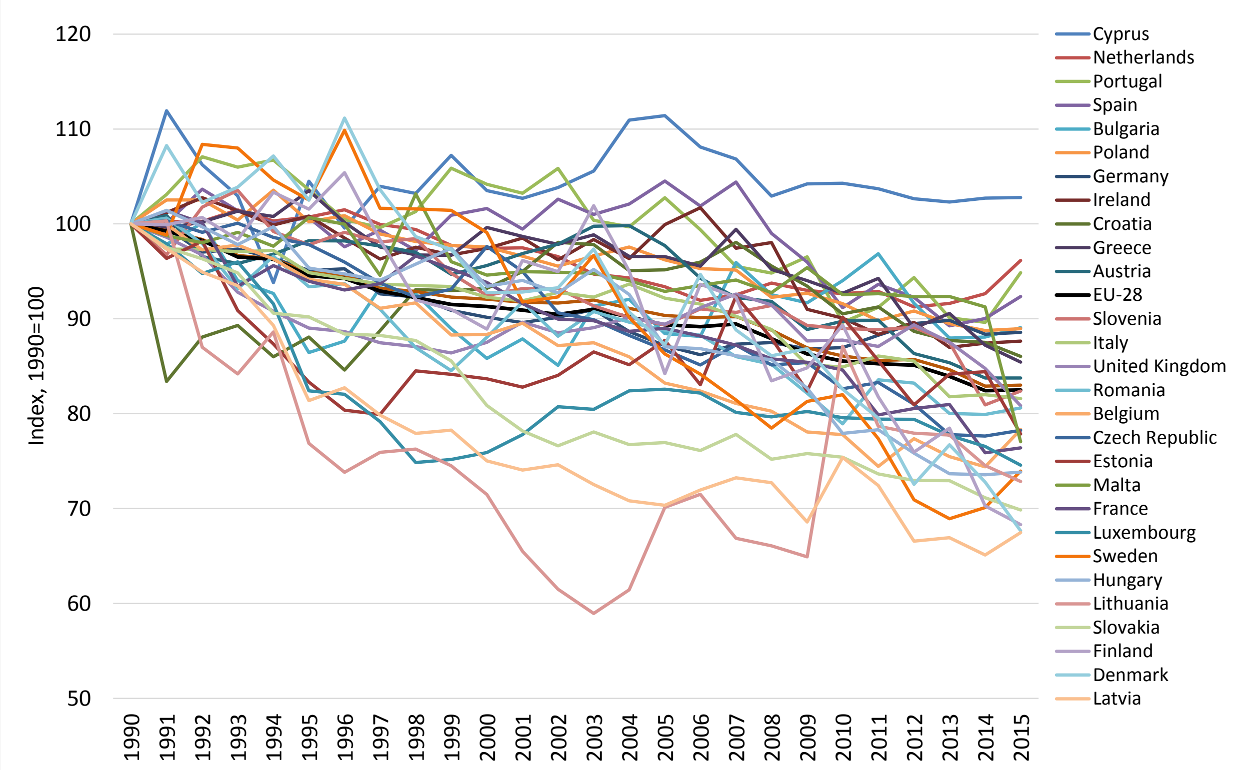

Figure 3.*Trend of carbon intensity of total primary energy supply (CO2/TPES) in the EU-28 Member States as index, 1990 = 100.*

Figure 4 shows how the ratio between total primary energy supply and final energy consumption has changed between the years 1990 and 2015 in the EU-28 and its Member States. The trend of Malta is exceptional from the quite “stable” trends after 1995 in most of the EU Member States.

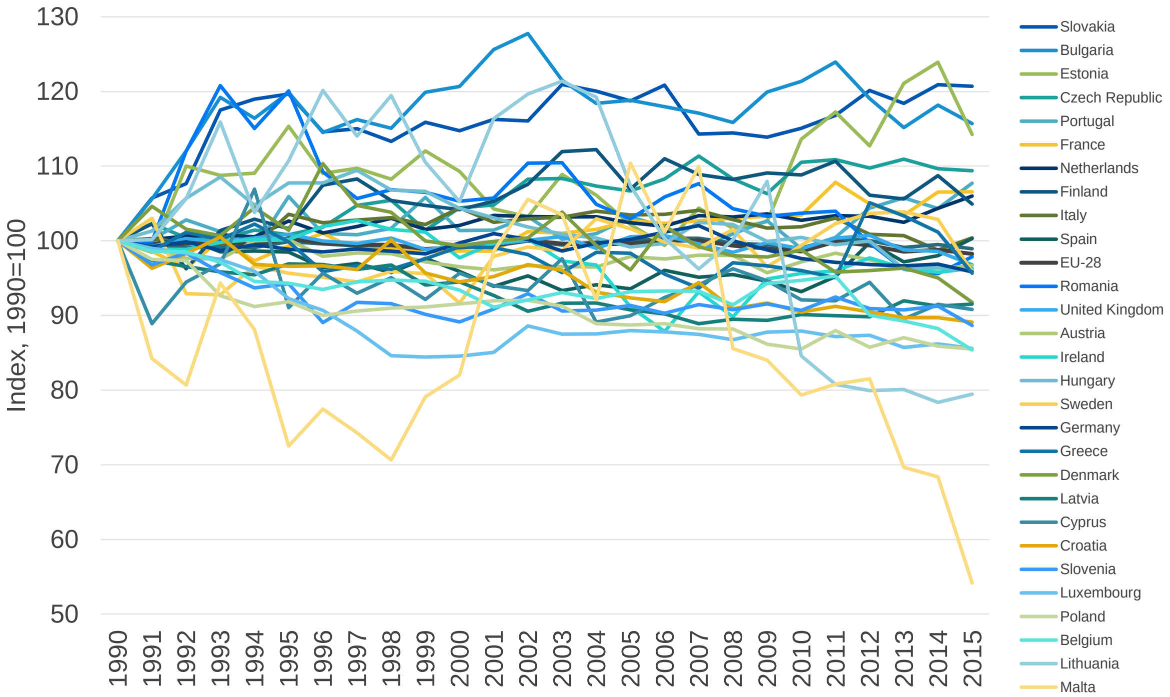

Figure 4.*Trend of ratio between primary and final energy consumption (TPES/FEC) in the EU-28 Member States as index, 1990 = 100.*

Figure 5 shows the generally nice decreasing trend of energy intensity (FEC/GDP) in the EU-28 and the Member States. There are a few short-term exceptions in some Member States, but the 2015 index value is smaller than the 1990 value in all EU Member States.

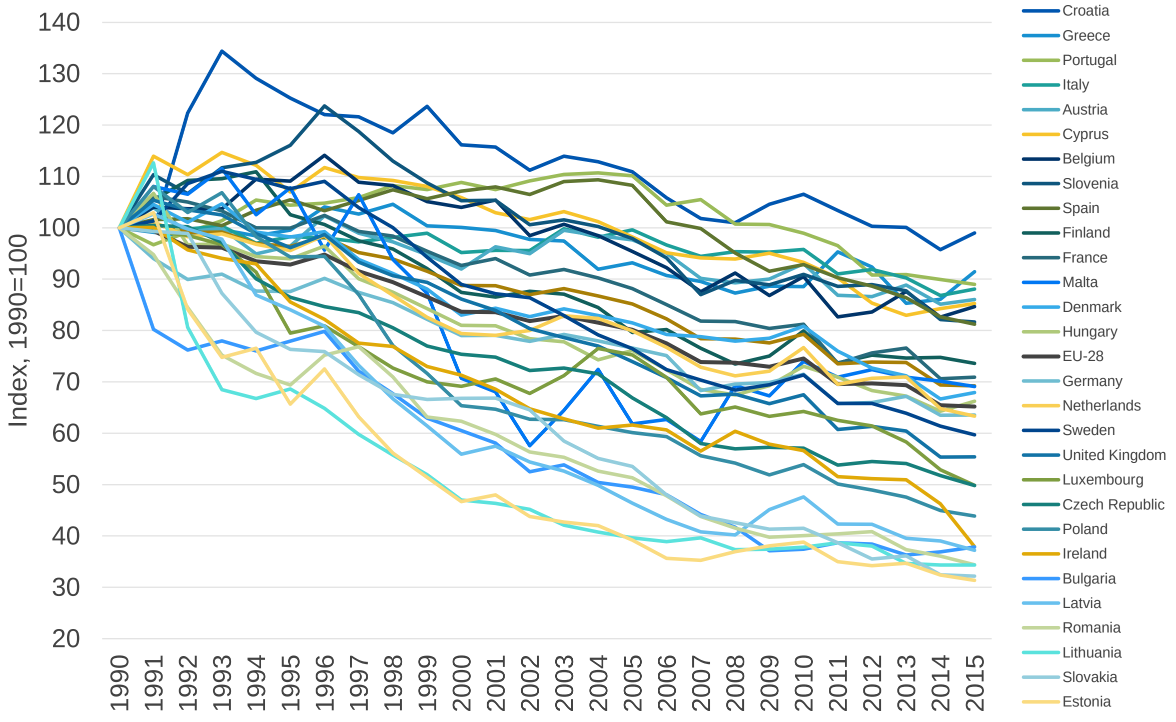

Figure 5.*Trend of energy intensity (FEC/GDP) in the EU-28 Member States as index, 1990 = 100.*

Figure 6 presents the trend of GDP per capita in the EU-28 and the Member States. The financial crisis in 2008-2009 caused a clear decline in all Member States except Poland. The East European Member States had also a decline in the early 1990s.

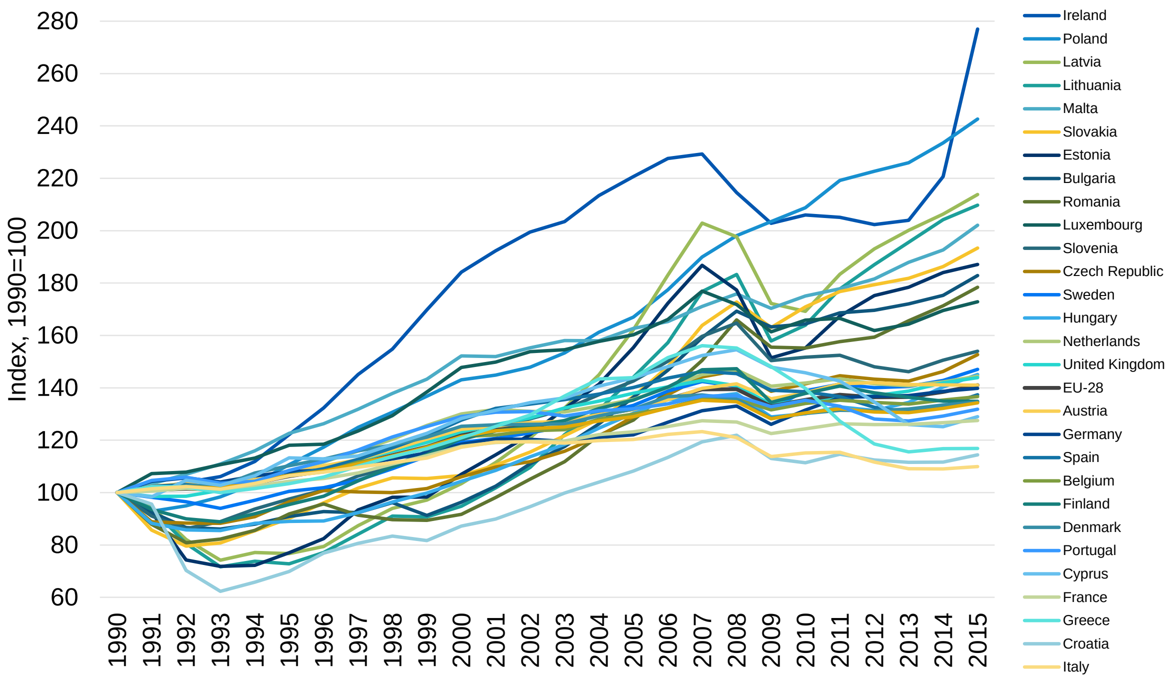

Figure 6.*Trend of GDP per capita in the EU-28 Member States as index, 1990=100.*

Finally, the trend of population is presented in Figure 7. A vast majority of the EU Member States have a slightly increasing trend. Most East European and Baltic Member States have a decreasing trend. A more serious problem than decreasing population in the EU is the structure of the population; people are getting older. This, however, is not a big issue when the decomposition analysis of CO_2 emissions is considered.

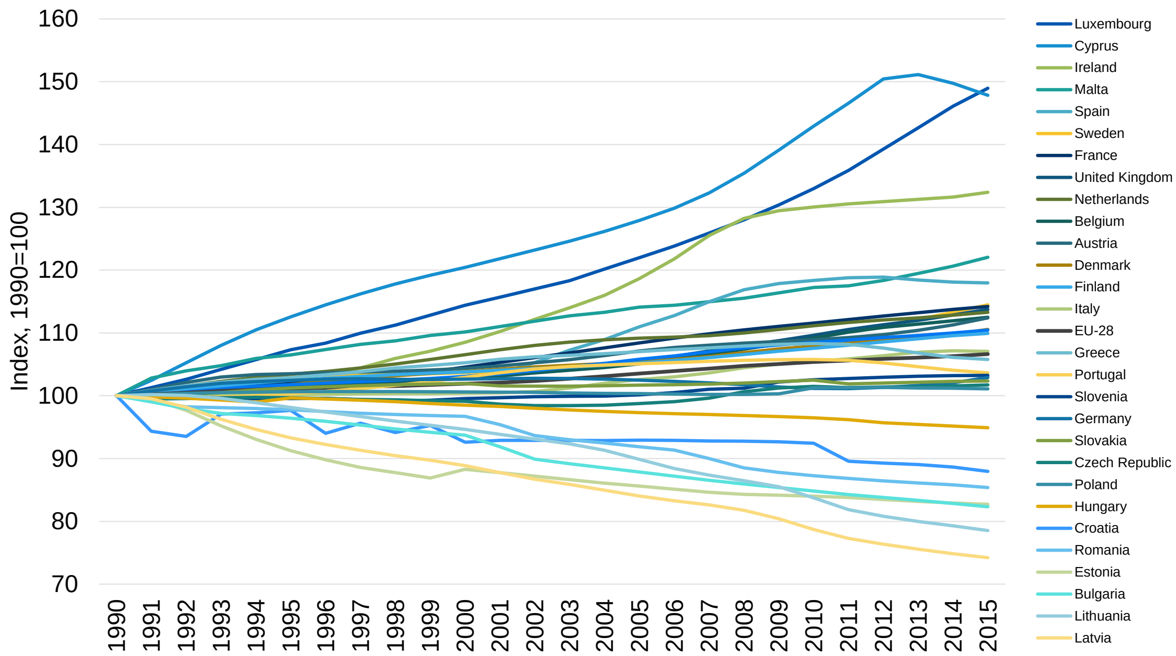

Figure 7. *Trend of population in the EU-28 Member States as index, 1990=100.*

In Figures 8−13, results from the chained incremental two-factor Sun-Shapley decomposition analysis of carbon dioxide (CO_2) emissions for the EU-28 aggregate (Figure 8), Finland (Figure 9), Italy (Figure 10), Germany (Figure 11), Spain (Figure 12) and also for China (Figure 13). All results are presented in million tonnes of CO_2 in Figures 8−13. Some of the drivers have a decreasing and some an increasing effect and the sum of all effects equals to the observed change in CO_2 emissions each year in Figures 8-13.

In the EU-28 aggregate, during the period 1990−2015, there are altogether 25 annual changes in CO_2 emissions, 8 increases and 17 decreases. Decrease in CO_2 emissions can be the most often explained by a decreasing effect of energy intensity and in some cases by a decreasing effect of carbon intensity of the primary energy mix. The financial crisis had a clear reflection to the CO_2 emissions, caused by a decreasing effect of in GDP per capita in 2008-2009. Increase in CO_2 emissions has usually been a result from an occasional increasing effect of energy intensity (FEC/GDP). Change in population (POP) and the TPES/FEC ratio have had only minor effects to the European CO_2 emissions, mostly increasing and decreasing ones, respectively. (Figure 8.)

In Finland, there were 10 annual increases and 15 decreases in CO_2 emissions during the studied period 1990-2015. Large variation in annual changes in CO_2 emissions is typical for Finland. Availability of hydro power, the amount of imported electricity, and the use of coal-fired condensing power plants vary a lot between different years. This can be seen in the remarkable effect of carbon intensity of the primary energy mix to CO_2 emissions. Economic growth, i.e. the effect of GDP per capita has not contributed much to CO_2 emissions in Finland after the financial crisis 2008−2009. The decrease in the most recent years is mainly due to a decreasing effect of carbon intensity of the primary energy mix, and the TPES/FEC ratio. (Figure 9.)

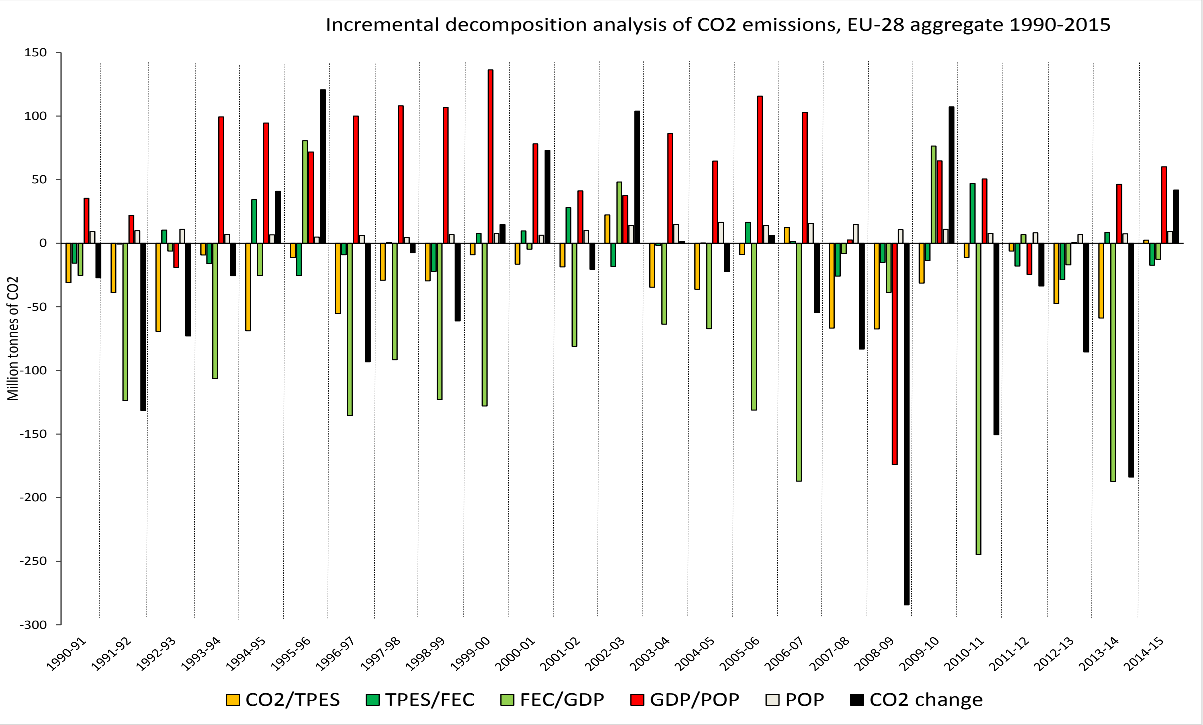

***Figure 8**. Incremental CO_2 decomposition results for the EU-28 aggregate, 1990−2015.*

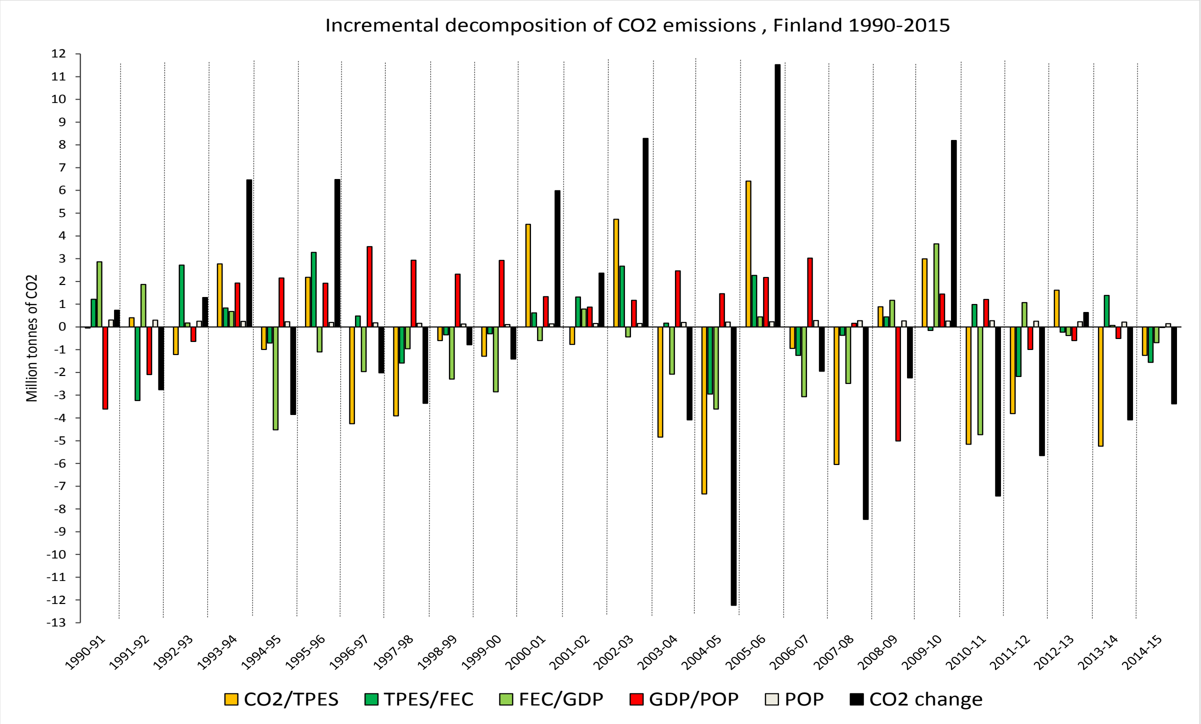

***Figure 9**. Incremental CO_2 decomposition results for Finland, 1990−2015.*

In Italy, there have been 11 annual increases and 14 decreases in CO_2 emissions in the period 1990−2015 (Figure 10). The decreases have mostly been in the recent years, and the decreasing effect of GDP per capita boosted by the financial crisis in 2008−2009 has had large effects to CO_2 emissions in Italy. Effect of the carbon intensity of primary energy mix (CO_2/TPES) has also been quite often a decreasing one. Energy intensity and the TPES/FEC ratio have both had a decreasing effect to CO_2 emissions every now and then in Italy.

In Germany during the period 1990−2015, there have been altogether 9 annual increases and 16 decreases in CO_2 emissions (Figure 11). Energy intensity had a mostly decreasing effect in the 1990s and early 2000s, but in the recent years, energy intensity has had only a few but large decreasing effects (2006−2007, 2010−2011 and 2013−2104). Carbon intensity of the primary energy mix (CO_2/TPES) has had mostly decreasing effects, for example during the periods 1996−2001 and 2003−2006. Effect of the TPES/FEC ratio has either decreased, or increased CO_2 emissions. In the 2000s, there have been several periods, when it has been the only one driver with a decreasing effect (2011−2013, 2014−2015.

In Spain, the number of annual increases in CO_2 emissions is 16 and the number of decreases is 9 during the period 1990−2015 (Figure 12). After the financial crisis in 2008−2009, CO_2 emissions have mainly decreased in Spain. Like in Italy, recovery from the financial crisis has taken more time from the Spanish economy than in the EU on average. In Spain, GDP per capita has had an increasing effect to CO_2 emissions from the year 2013 onwards. Energy intensity (FEC/GDP) has had a decreasing effect from the year 2010 onwards. Carbon intensity of the primary energy mix (CO_2/TPES) has had a significant decreasing effect quite often after the year 2005.

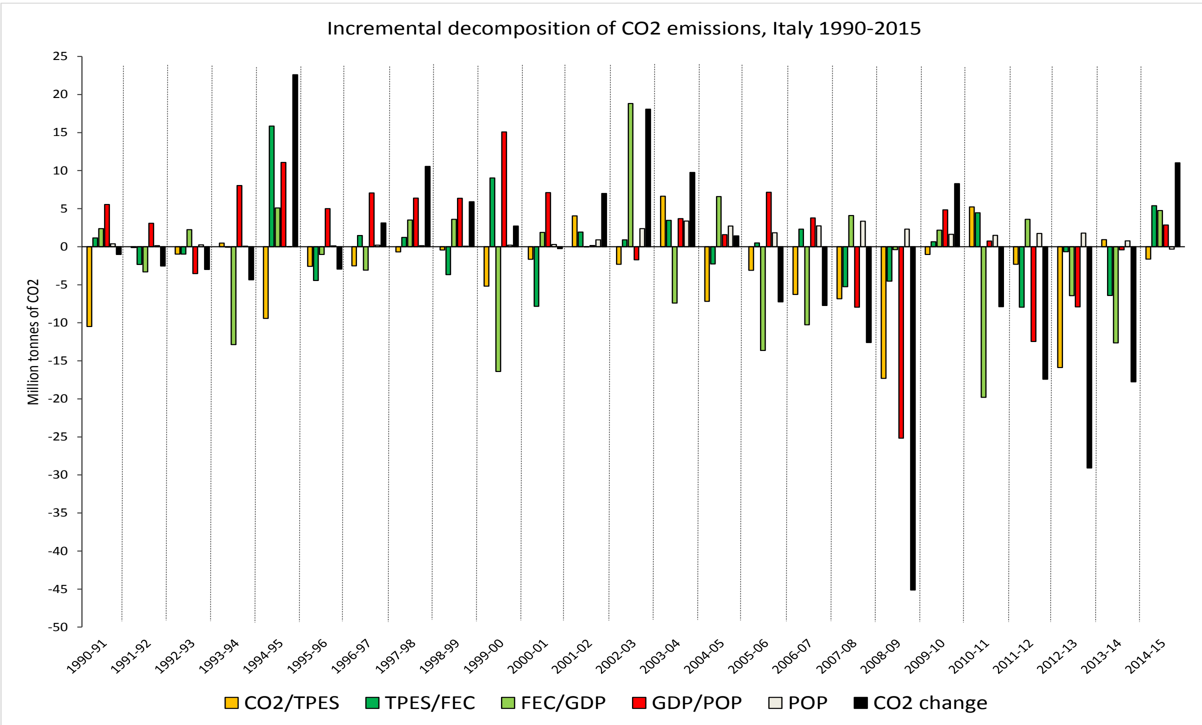

Figure 10. *Incremental CO_2 decomposition results for Italy, 1990−2015.*

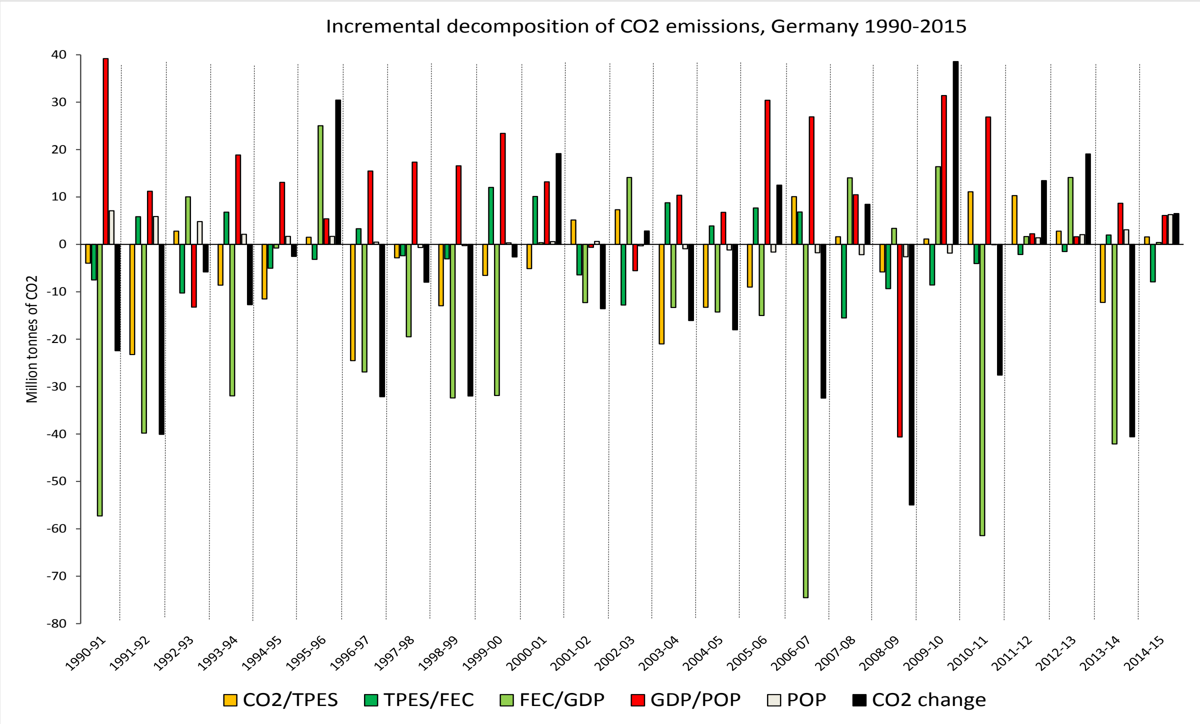

Figure 11. *Incremental CO_2 decomposition results for Germany, 1990−2015.*

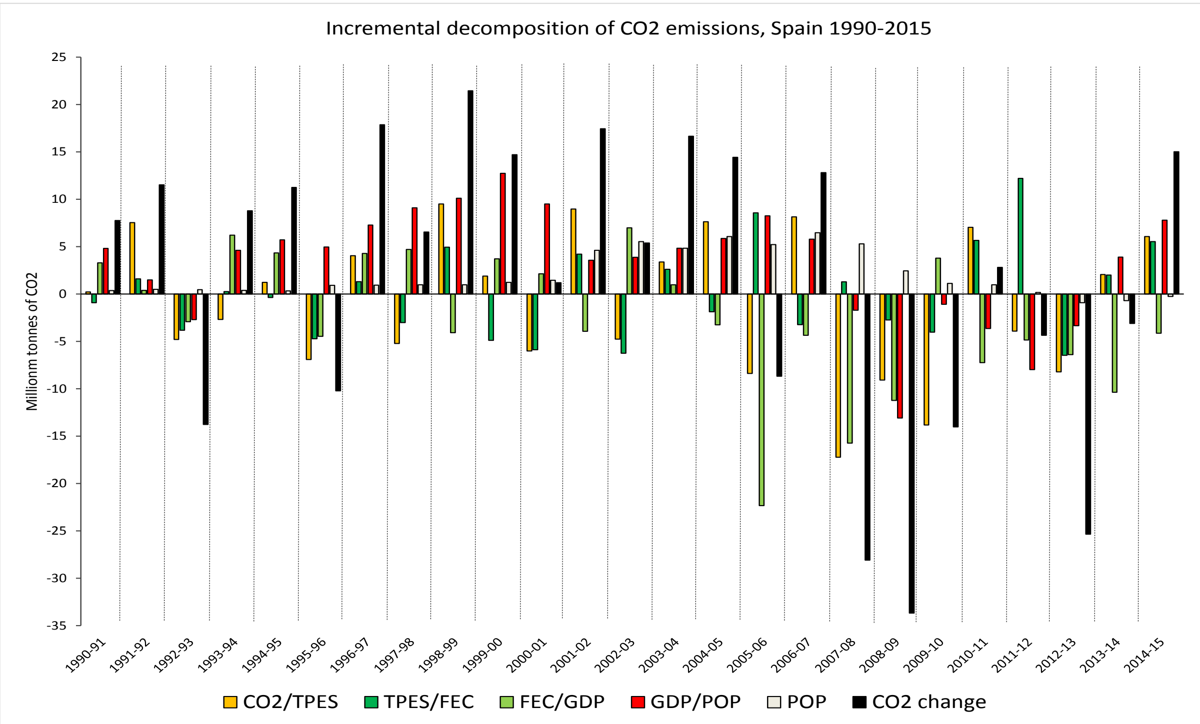

Figure 12. *Incremental CO_2 decomposition results for Spain, 1990−2015.*

In China, there are 23 annual increases and only 2 decreases in CO_2 emissions during the period 1990−2015. The economic growth has continued in China, and its contribution to the growth of CO_2 emissions has increased especially in the 2000s. Energy intensity's contribution in decreasing emissions has increased, and together with an improved TPES/FEC ratio and decreasing carbon intensity of the energy mix, it has been able to limit the growth of CO_2 emissions in the most recent years in China.

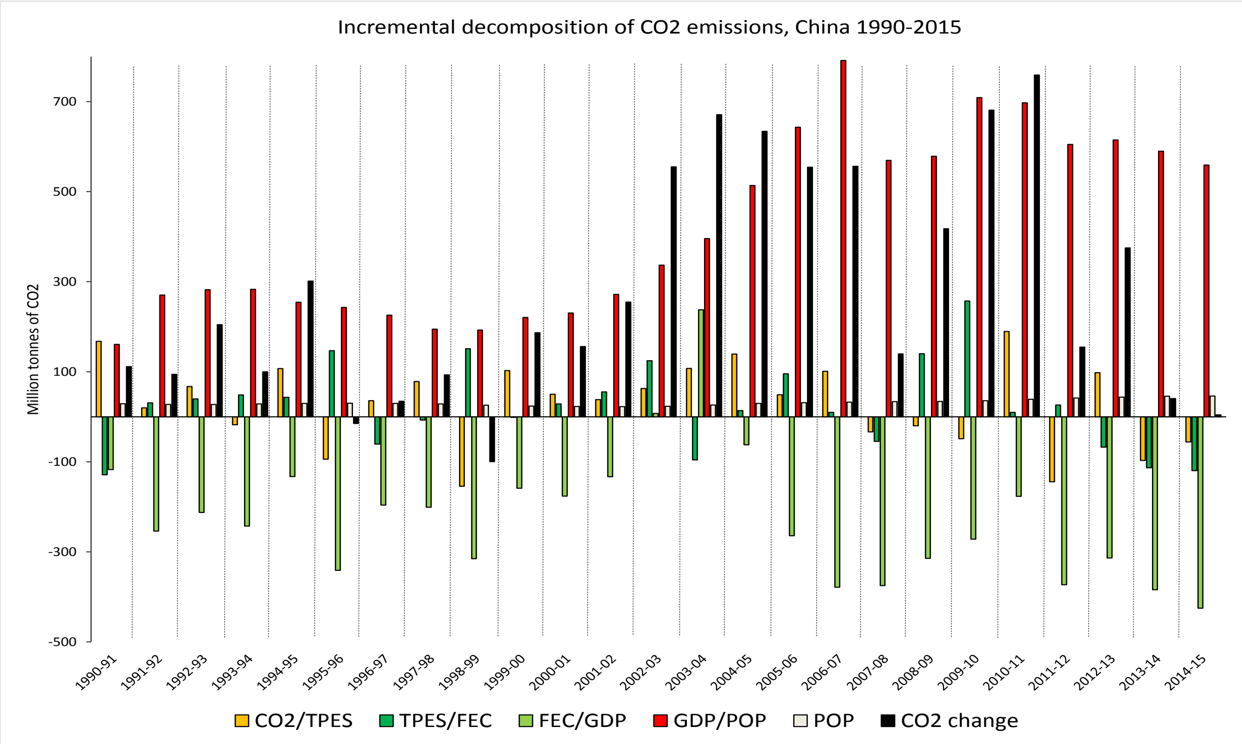

Figure 13. *Incremental CO_2 decomposition results for China, 1990−2015.*

Discussion and Conclusions

In this article, an incremental two-factor Sun-Shapley decomposition method has been introduced, and it has been applied to the analysis of carbon dioxide (CO_2) emissions in the EU and China. Usually decomposition analysis is made for a change between two selected time moments, and the LMDI decomposition method dominates (Ang 2015). In principle, any decomposition method can be applied to incremental analysis, but the method introduced in this article has some advantages: It provides a perfect decomposition, and can handle also zero Values. Annual results from the incremental analysis can be summed up in order to analyse any period within the studied range of years, 1990−2015 in this article. Annual changes may reveal interesting changes, which are not visible when a change between only two distant years are looked at. One good example is the financial crisis in Europe in 2008−2009, which is visible in the analysis of EU-28 aggregate as well as individual EU Member States.

The financial crisis caused a decrease of GDP, and thus the driver GDP per capita had a decreasing effect to CO_2 emissions overall the EU, Poland was the only exception to this. Since the other drivers (carbon intensity of the primary energy mix, the ratio between primary and end use energy, energy intensity of the economy, and population had much smaller increasing or decreasing effects, the total CO_2 emissions decreased significantly in the EU.

Generally speaking, energy intensity has the most important decreasing effect to CO_2 emissions in the EU and China. Carbon intensity of the primary energy mix is another important driver of CO_2 emissions with a decreasing effect; this driver seems to be more significant in the EU than in China. Effect of the TPES/FEC ratio, which is a proxy indicator of the efficiency of the entire energy transformation system, varies a lot. GDP per capita and population have usually an increasing effect to CO_2 emissions in the EU. In China, economic growth is so fast that the increasing effect of GDP per capita is much larger than the decreasing effect of energy intensity and other drivers.

Acknowledgements

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A Flexible Sustainability Performance Indicator for Companies

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Abstract

Energy and material consumption of a company depend on two major things: the amount of production, and the efficiency of the company's production process. These are main drivers of environmental impacts too. The purpose of this paper is to develop indicators describing the performance in energy and material consumption as well as in environmental impacts at the company level. Within a basic two-factor decomposition, two indicators describing the effect of changing activity and intensity to energy and material consumption, as well as to environmental impacts are identified and refined. These indicators can be applied to all industrial and other economic systems at different levels. Flexibility in the usage of indicators is a key issue for their wide applicability. Examples of these indicators are then calculated for selected case companies by using their publicly available data.

Introduction and Background

In general systems perspective, efficiency refers to a relationship between input and output of a defined system. Change of efficiency over time brings out an idea of eco-efficiency (e.g. Huppes & Ishikawa 2005): "getting more with less environmental impact", which explains the fact that improving efficiency has been a common goal in energy and environmental policies for a long time. Using less raw materials and energy for a certain task with less environmental impacts decreases material and energy consumption, total environmental impacts and all related costs.

In (industrial) companies, energy and raw materials are inputs of the production system. Usually efficiency refers to a relationship between the energy or material input to the system and the output, i.e. production of the system. Sometimes the output-input ratio is called as productivity. In the calculations presented in this paper, intensity, an inverse of the ratio defining efficiency is used. When input decreases and output remains the same, intensity decreases and efficiency increases. In large systems, energy and material input usually consists of many different types of energy and materials. Calculating intensity or efficiency of a large system requires consideration of all inputs and outputs to the system, if the goal is to squeeze intensity or efficiency into one figure. Here aggregation may be needed. Regarding the output (production) aggregation makes the use of monetary units attractive if the physical units cannot be easily aggregated.

Three types of intensities are in focus in this paper: energy intensity, material intensity, and environmental intensity. The following intensities are dealt with in the empirical part:

- Energy intensity of material use: energy use/material use (input/input)
- Energy intensity of production: energy use/production (input/output)
- Material intensity of production: material use/production (input/output)
- Environmental intensity of energy use: environmental impact/energy use (output/input)
- Environmental intensity of material use: environmental impact/material use (output/input)
- Environmental intensity of production: environmental impact/production (output/output).

Material and Methods

The criterion for sustainability applied in this paper is simply that the value of the explained variable V (e.g. energy consumption, material consumption, or environmental impact) does not increase over time, i.e. $\Delta V \leq 0$ ($V_t - V_0 \leq 0$). In a two-factor decomposition change in the explained variable (ΔV) is explained by two variables, activity (X) and intensity (Y=V/X). The change is a sum of the activity effect (X_{eff}) and the intensity effect (Y_{eff}). Change in the explained variable is a sum of these effects. The effects can be calculated by any available decomposition technique. In this paper, a two-factor Sun-Shapley decomposition (Sun 1996; 1998; Ang 2004; Albrecht et al 2002) has been used, where the joint effect (Figure 1) is distributed equally to both effects[1]. The Sun-Shapley equations for calculating the effects X_{eff} and Y_{eff} are the following (Vehmas & Ameziane 2017; Vehmas 2009):

$$X_{eff} = [(V/X)_0 + (1-\lambda)\Delta(V/X)_{t0}]\Delta X_{t0} \quad (1)$$

$$Y_{eff} = (X_0 + \lambda X_{t0})\Delta(V/X)_{t0} \quad (2)$$

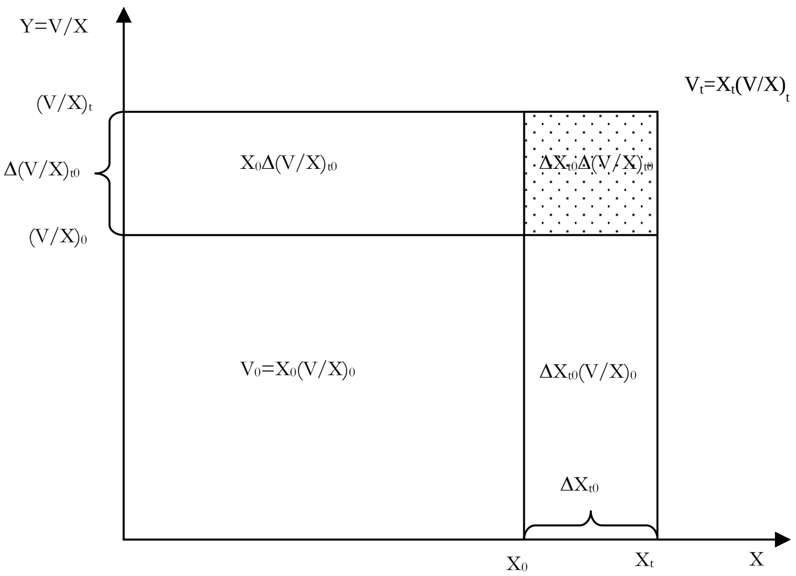

Figure 1.*Two-factor Sun-Shapley decomposition: separate effects and joint effect of changes in activity X and intensity V/X to the change in variable V (modified from Sun 1996, 48).*

The sustainability performance indicators will be defined from the relationship between activity and intensity effects (Vehmas 2018). Sustainable growth (SG) describes how much the activity X can change from the original value X_0 with a new, changed intensity $(V/X)_t$ until the limit of the sustainability criterion ($\Delta V \leq 0$) will be met. The SG can be calculated in the following way (Vehmas 2018; see also Ilvonen 2004):

[1] This is done by selecting λ=0.5 in both equations (1) and (2). By selecting λ=0, the whole joint effect would be distributed to X_{eff}. By selecting λ=1, the whole joint effect would be distributed to Y_{eff}.

$$SG = -(Y_{eff}/X_{eff}) \times 100\ \% \quad (3)$$

The SG is defined in percentage (%) of the observed change in activity (ΔX). The SG can be smaller (0 < SG < 100 %) or larger (SG > 100 %) than the observed activity change (100 %), and it can get even a negative value (SG < 0 %). Interpretation of the result depends on the directions of change in the explained variable V and the explaining variables X and Y (V/X).

Sustainable intensity (SI) describes what the intensity effect should be in order to allow the observed change in activity (ΔX) without threatening the sustainability criterion (ΔV ≤ 0). This intensity is calculated in the following way (Vehmas 2018; see also Ilvonen 2004):

$$SI = -(X_{eff}/Y_{eff}) \times (V_0/V_t) \quad (4)$$

The SI is defined as a coefficient – the observed intensity effect multiplied by the SI coefficient gives the intensity needed to meet the sustainability criterion (ΔV ≤ 0). The SI can be smaller (0 < SI < 1) or larger (SI > 1) than the observed intensity effect, and it can also get a negative value (SI < 0). In a similar way as in the case of the SG, interpretation of the result depends on the direction of change in the explained variable V and the explaining variables X and Y (V/X).

There are six different cases (B1−B6) possible regarding the performance of a system in the two-factor decomposition framework (Figure 2). Intensity Y = V/X decreases in cases B1–B3, and increases in cases B4-B6. Performance in cases B2, B3 and B6 is towards sustainable, and in cases B1, B4 and B5 away from sustainable. Keeping this in mind, in cases B2, B3 and B6 the performance indicators SG and SI "allow" an increase in activity and intensity, because the performance already fulfils the relative sustainability criterion, and thus the system "can afford" to change away from sustainable until the limit set by the criterion will be met. In cases B1, B4 and B5 the indicators SG and SI "require" a change of activity or/and intensity effects, because the performance has been away from sustainable.

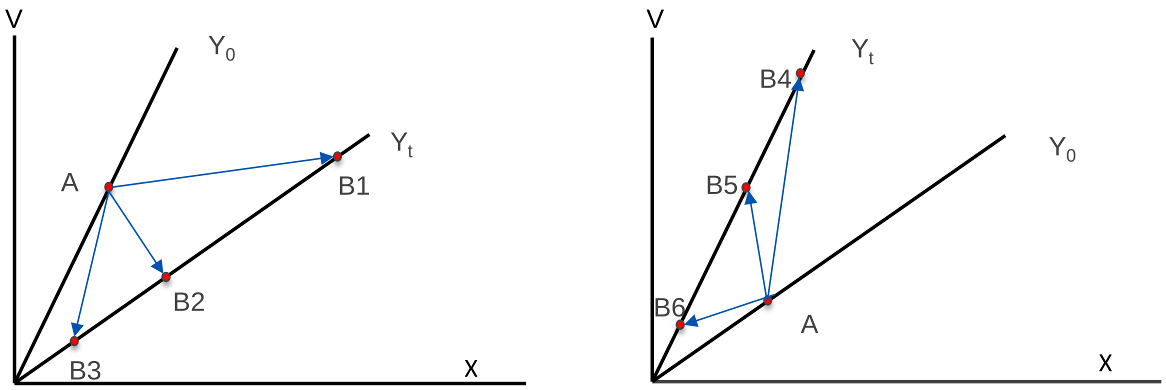

Figure 2. *Six possible cases (B1–B6) of performance in the two-factor decomposition framework. In the left figure, intensity decreases ($Y_0 > Y_t$) and in the right figure, intensity increases ($Y_0 < Y_t$). (Vehmas 2018.)*

Table 1 summarizes all quantitative information of the six cases of performance identified in Figure 2, and gives the ranges for the performance indicator SG and SI values in each of the cases. It is worth noting that the ranges are similar for cases B1 (away from sustainability) and B6 (towards sustainability), B2 (towards sustainability) and B5 (away from sustainability), and B3 (towards sustainability) and B4 (away from sustainability). Identification of the case is thus of absolute importance before drawing any conclusions based on the SG and SI values.

__Table 1.__ Characteristics of the six possible cases of performance in the two-factor decomposition framework. (Vehmas 2018.)

	A-B1	A-B2	A-B3	A-B4	A-B5	A-B6
V explained	$V_0 < V_t$	$V_0 > V_t$	$V_0 > V_t$	$V_0 < V_t$	$V_0 < V_t$	$V_0 > V_t$
Activity X	$X_0 < X_t$	$X_0 < X_t$	$X_0 > X_t$	$X_0 < X_t$	$X_0 > X_t$	$X_0 > X_t$
Intensity Y=V/X	$Y_0 > Y_t$	$Y_0 > Y_t$	$Y_0 > Y_t$	$Y_0 < Y_t$	$Y_0 < Y_t$	$Y_0 < Y_t$
Intensity effect	decreasing	decreasing	decreasing	increasing	increasing	increasing
Activity effect	increasing	increasing	decreasing	increasing	decreasing	decreasing
Size of effects	$\|X_{eff}\|>\|Y_{eff}\|$	$\|X_{eff}\|<\|Y_{eff}\|$	-	-	$\|X_{eff}\|<\|Y_{eff}\|$	$\|X_{eff}\|>\|Y_{eff}\|$
SG (%)	0< SG <100	SG > 100	SG < 0	SG < 0	SG > 100	0< SG < 100
SI (coeff.)	SI > 1	0 < SI < 1	SI < 0	SI < 0	0 < SI < 1	SI > 1
Performance	Away from sustainable	Towards sustainable	Towards sustainable	Away from sustainable	Away from sustainable	Towards sustainable
Corrective action 1	Intensity decrease	(Activity increase)	(Activity increase)	Intensity decrease	Intensity decrease	(Intensity increase)
Corrective action 2	Activity decrease	(Intensity increase)	(Intensity increase)	Activity decrease	Activity decrease	(Activity increase)

Example calculations of the performance indicators SG and SI are made in this paper for four case companies which have energy as a significant product (energy companies) or factor of production (industrial companies) by using their publicly available data. The case companies include Stora Enso (Finnish-based forest company producing paper and cardboard products, market pulp and mechanical wood products), ENEL (Italian energy company), RWE (German energy company), and Celsa Barcelona (Catalan steel company producing different metal products).

The data used in the empirical examples includes indicators of production, energy use, raw material use, and environmental impacts of the case companies for a period from the year 2010 onwards (Table 2).

Table 2. *Case companies and the data used in the examples (Tables 3−16). Data is taken from the companies' public environmental reports (Stora Enso, ENEL, Celsa Barcelona) or public data management tool (RWE).*

	Stora Enso	ENEL	RWE	Celsa Barcelona
Production	Paper and cardboard 2010−2016	Electricity from coal, oil and gas, renewables 2010−2015	Electricity from lignite, hard coal, oil & gas 2010−2016	Metal products 2010−2015
Energy	Total fuel use 2010−2016	-	-	Total energy use 2010−2015
Raw material	Wood 2010−2016	Coal, oil and gas, renewables 2010−2015	Lignite, hard coal, oil & gas 2010−2016	Scrap and steel alloys 2010−2015
Environmental impact	CO_2 emissions 2010−2016	CO_2 emissions 2010−2015	CO_2 emissions 2010−2015	CO_2 emissions 2010−2015
Data source	Stora Enso Sustainability Reports 2010−2016	ENEL Environmental and Sustainability reports 2010−2015	RWE Key Performance Tool available at rwe-kennzahlen-tool.de	Celsa Barcelona Environmental Report 2015 (in Spanish)

Results

Tables 3−16 show the results of the case company examples: Stora Enso (Tables 3−5), ENEL (Tables 6−9), RWE (Tables 10−13) and Celsa Barcelona (Tables 14−16). Each Table includes incremental (annual with moving base year) and cumulative (fixed base year 2010) analyses. The two first rows in each Table 3-16 shows the intensity effect (Y_{eff}) and the activity effect (X_{eff}), both in percentage of the base year absolute value. The third row shows their sum which equals to the observed change in the explained variable (ΔV, the corresponding variable is mentioned in the heading of each Table 3−16) in percentage of the base year value. The fourth and fifth rows show the indicator values of SG (in percentage) and SI (coefficient). The last row of each Table shows the case (B1−B6), where the performance falls in each of the analyses. Only the cumulative analysis with a fixed base year 2010 is taken into account in interpretation of the results below.

Table 3. *Sustainability performance indicators for Stora Enso's energy consumption, incremental and cumulative analysis 2010-2015. V=total fuel use, X=paper and cardboard production (pulp and wood products not included).*

V=total fuel use	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	2.31	-1.09	6.31	5.33	-0.01	5.96	2.31	1.21	7.43	12.70	12.47	18.46
X_{eff}	-4.03	-0.60	-5.27	-6.12	-3.72	-3.57	-4.03	-4.58	-9.79	-15.83	-19.22	-22.98
Total (ΔV)	-1.71	-1.69	1.04	-0.78	-3.73	2.39	-1.71	-3.37	-2.36	-3.13	-6.75	-4.52
SG percentage	57	-183	120	87	-0.3	167	57	26	76	80	65	80
SI coefficient	1.77	-0.56	0.83	1.16	-343.48	0.59	1.77	3.92	1.35	1.29	1.65	1.30
Case	B6	B3	B5	B6	B3	B5	B6	B6	B6	B6	B6	B6

__Table 4.__ Sustainability performance indicators for Stora Enso's material consumption, incremental and cumulative analysis 2010−2016. V=wood use, X=paper and cardboard production (pulp and wood products not included).

V=wood use	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	2.91	-0.54	4.36	1.06	5.66	2.62	2.91	2.36	6.67	7.56	13.10	15.63
X_{eff}	-4.04	-0.60	-5.22	-5.98	-3.83	-3.51	-4.04	-4.61	-9.76	-15.42	-19.28	-22.65
Total (ΔV)	-1.12	-1.14	-0.86	-4.93	1.83	-0.90	-1.12	-2.25	-3.09	-7.87	-6.18	-7.02
SG percentage	72	-90	83	18	148	74	72	51	68	49	68	69
SI coefficient	1.40	-1.13	1.21	5.95	0.66	1.36	1.40	2.00	1.51	2.22	1.57	1.56
Case	B6	B3	B6	B6	B5	B6	B6	B6	B6	B6	B6	B6

__Table 5.__ Sustainability performance indicators for Stora Enso's environmental impacts, incremental and cumulative analysis 2010−2015. V=direct CO_2 emissions, X=total fuel use.

CO_2 emissions	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	-15.20	-1.20	2.80	-2.65	-6.75	-0.73	-15.20	-16.09	-13.87	-16.07	-21.34	-22.13
X_{eff}	-1.58	-1.68	1.06	-0.77	-3.60	2.38	-1.58	-3.10	-2.20	-2.87	-6.00	-4.01
Total (ΔV)	-16.79	-2.88	3.86	-3.43	-10.36	1.65	-16.79	-19.18	-16.07	-18.94	-27.34	-26.14
SG percentage	-961	-72	-264	-343	-187	31	-961	-519	-631	-559	-356	-552
SI coefficient	-0.13	-1.43	-0.36	-0.30	-0.60	3.21	-0.13	-0.24	-0.19	-0.22	-0.39	-0.25
Case	B3	B3	B4	B3	B3	B1	B3	B3	B3	B3	B3	B3

Stora Enso's energy, material and environmental performance is characterized by a decrease in activity: the activity effect is negative in all the analysed cumulative periods (Tables 3−5). Regarding energy (Table 3) and material use (Table 4), change in the intensity has increased energy and material use. All the analysed periods fall in case B6, which means that the energy and material performance is towards sustainability, but not in a good way: change in activity has decreased energy and material consumption more than the change energy and material intensities have increased them. SG percentage values between 0 and 100% tell that decrease in activity has been too large; a smaller one had met the sustainability criterion. SI coefficient values over 1 tell the same thing in other words: the sustainability criterion would have been fulfilled even with a larger increase in energy and material intensity.

On the other hand, Stora Enso's environmental performance in terms of CO_2 emissions falls in case B3. This means that both change in CO_2 intensity of fuel use and change in use of fuels have decreased CO_2 emissions. This indicates that Stora Enso's energy mix has changed towards less carbon intensive fuels, which is good from the sustainability point of view. Stora Enso's overall performance during the years 2010−2016 is, however, strongly characterized by decreasing activity.

__Table 6__. Sustainability performance indicators SG and SI for ENEL's primary energy use, incremental and cumulative analysis, 2010-2015. V=use of coal, X=electricity production from coal.

Coal use	2010-11	2011-12	2012-13	2013-14	2014-15	2010-11	2010-12	2010-13	2010-14	2010-15
Y_{eff}	-4.2	1.2	1.4	0.6	0.5	-4.2	-3.2	-1.4	-0.7	-0.2
X_{eff}	17.4	6.6	-11.6	1.0	4.5	17.4	25.1	11.0	12.1	17.2
Total (ΔV)	13.2	7.7	-10.1	1.6	5.0	13.2	22.0	9.6	11.4	16.9
SG percentage	24	-18	12	-67	-11	24	13	13	6	1
SI coefficient	3.65	-5.30	9.03	-1.48	-8.81	3.65	6.53	7.15	14.63	58.99
Case	B1	B4	B6	B4	B4	B1	B1	B1	B1	B1

Table 7. *Sustainability performance indicators SG and SI for ENEL's primary energy use, incremental and cumulative analysis, 2010−2015. V=use of oil and gas, X=electricity production from oil and gas.*

Oil and gas use	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2010-11**	**2010-12**	**2010-13**	**2010-14**	**2010-15**
Y_{eff}	-0.8	1.4	-0.6	-5.6	7.8	-0.8	0.6	-0.024	-5.2	1.4
X_{eff}	2.3	-8.7	-11.9	-2.5	3.4	2.3	-6.6	-17.7	-19.2	-17.3
Total (ΔV)	1.4	-7.3	-12.5	-8.1	11.2	1.4	-6.0	-17.7	-24.4	-15.9
SG percentage	37	16	-5	-229	-232	37	9	-0.137	-27	8
SI coefficient	2.64	6.64	-22.22	-0.47	-0.39	2.64	11.50	-888.70	-4.92	14.79
Case	B1	B6	B3	B3	B4	B1	B6	B3	B3	B6

Table 8. *Sustainability performance indicators SG and SI for ENEL's primary energy use, incremental and cumulative analysis, 2010−2015. V=use of renewables, X=electricity production from renewables.*

Renewables use	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2010-11**	**2010-12**	**2010-13**	**2010-14**	**2010-15**
Y_{eff}	14.02	-3.16	-9.88	-42.08	6.80	14.02	10.65	0.67	-41.44	-36.13
X_{eff}	-11.05	0.96	8.72	3.15	-6.11	-11.05	-9.94	-1.13	2.22	-2.68
Total (ΔV)	2.97	-2.20	-1.15	-38.94	0.68	2.97	0.71	-0.46	-39.22	-38.80
SG percentage	127	329	113	1338	111	127	107	60	1864	-1350
SI coefficient	0.77	0.31	0.89	0.12	0.89	0.77	0.93	1.68	0.09	-0.12
Case	B5	B2	B2	B2	B5	B5	B5	B6	B2	B3

Table 9. *Sustainability performance indicators SG and SI for ENEL's environmental impacts, incremental and cumulative analysis, 2010−2015. V=CO_2 emissions, X=total fuel use.*

CO_2 emissions	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2010-11**	**2010-12**	**2010-13**	**2010-14**	**2010-15**
Y_{eff}	-24.70	2.22	-0.10	5.59	-2.36	-24.70	-22.83	-21.68	-16.01	-18.70
X_{eff}	30.83	1.26	-9.48	-5.65	5.85	30.83	32.64	20.96	15.23	21.38
Total (ΔV)	6.12	3.47	-9.59	-0.06	3.49	6.12	9.81	-0.71	-0.78	2.69
SG percentage	80	-176	-1	99	40	80	70	103	105	87
SI coefficient	1.18	-0.55	-100.03	1.01	2.39	1.18	1.30	0.97	0.96	1.11
Case	B1	B4	B3	B6	B1	B1	B1	B2	B2	B1

Primary energy sources have been considered as raw materials in energy companies, which produce energy carriers such as electricity. ENEL's performance has been analysed in terms of use of coal (Table 6), oil and gas (Table 7), and renewables (Table 8). The performance depends on the studied primary energy source. Coal consumption seems to depend more on change in activity (produced electricity) than change in intensity (Table 6). The change of intensity has slightly decreased coal use in the power plants during the studied period. However, coal use has increased during the studied period. SG percentages are very low in the cumulative analysis, and the performance in case B1 is away from sustainability. In the case of oil and gas, performance falls into cases B3 and B6 in most of the analysed periods because their use has decreased (Table 7). The intensity effect's role is not very significant. SG percentages remain low (in cases B6) or negative (B3), and SI coefficients are large or negative, correspondingly. The use of renewables is treated in this analysis in a similar way than fossil fuels. Performance in the use of renewables changes from case B5 to cases B6, B2 and B3 towards sustainability, because the intensity effect has decreased their use significantly in two most recent periods and caused e.g. a high SG percentage and low SI coefficient in 2010−2014 (case B2; Table 8).

Table 9 reveals that ENEL's performance in CO_2 emissions is in the edge of fulfilling the sustainability criteria. Performance varies between cases B1 and B2, and sometimes intensity effect decreases CO_2 emissions more than activity effect increases them. This obviously depends on changes in the energy mix. SG percentages are relatively close to 100 and SI coefficients relatively close to the value 1 (Table 9).

Table 10. *Sustainability performance indicators SG and SI for RWE's primary energy use, incremental and cumulative analysis, 2010-2016. V=use of lignite, X=electricity production from lignite.*

Lignite use	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	4.38	9.18	0.24	-5.02	0.78	-4.50	4.38	13.92	13.89	8.60	9.48	4.60
X_{eff}	0.59	-3.07	-4.41	3.78	1.00	0.18	0.59	-2.54	-7.15	-3.18	-2.18	-1.95
Total (ΔV)	4.97	6.11	-4.17	-1.24	1.78	-4.33	4.97	11.38	6.74	5.41	7.29	2.65
SG percentage	-738	299	5	133	-78	2539	-738	549	194	270	434	236
SI coefficient	-0.13	0.32	19.05	0.76	-1.26	0.04	-0.13	0.16	0.48	0.35	0.21	0.41
Case	B4	B5	B6	B2	B4	B2	B4	B5	B5	B5	B5	B5

Table 11. *Sustainability performance indicators SG and SI for RWE's primary energy use, incremental and cumulative analysis, 2010-2016. V=use of hard coal, X=electricity production from hard coal.*

Use of hard coal	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	-13.16	28.46	-14.28	-7.39	-4.08	-4.65	-13.16	10.20	-6.08	-13.64	-18.94	-23.25
X_{eff}	-3.36	14.25	1.14	7.39	18.36	-3.44	-3.36	8.93	9.56	17.12	37.20	31.94
Total (ΔV)	-16.52	42.71	-13.14	0.00	14.29	-8.09	-16.52	19.13	3.48	3.48	18.26	8.70
SG percentage	-392	-200	1253	100	22	-135	-392	-114	64	80	51	73
SI coefficient	-0.31	-0.35	0.09	1.00	3.94	-0.81	-0.31	-0.74	1.52	1.21	1.66	1.26
Case	B3	B4	B2	B1	B1	B3	B3	B4	B1	B1	B1	B1

Table 12. *Sustainability performance indicators SG and SI for RWE's primary energy use, incremental and cumulative analysis, 2010−2016. V=use of oil and gas, X=electricity production from oil and natural gas.*

Use of oil and gas	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2010-11	2010-12	2010-13	2010-14	2010-15	2010-16
Y_{eff}	-10.17	2.78	-6.75	3.43	10.79	24.98	-10.17	-7.37	-13.73	-10.41	-0.44	23.22
X_{eff}	2.30	-5.22	5.50	-4.70	-8.23	-1.23	2.30	-2.74	2.50	-1.95	-9.67	-11.99
Total (ΔV)	-7.87	-2.44	-1.25	-1.27	2.56	23.75	-7.87	-10.11	-11.24	-12.36	-10.11	11.24
SG percentage	441	53	123	73	131	2031	441	-269	550	-533	-5	194
SI coefficient	0.25	1.92	0.83	1.39	0.74	0.04	0.25	-0.41	0.20	-0.21	-24.19	0.46
Case	B2	B6	B2	B6	B5	B5	B2	B3	B2	B3	B3	B5

Table 13. *Sustainability performance indicators SG and SI for RWE's environmental impacts, incremental and cumulative analysis, 2010−2015. V=total CO_2 emissions, X=total primary energy use.*

Total energy use	2010-11	2011-12	2012-13	2013-14	2014-15	2010-11	2010-12	2010-13	2010-14	2010-15
Y_{eff}	-0.97	2.02	-1.61	1.74	-0.64	-0.97	1.07	-0.47	1.16	0.57
X_{eff}	-1.65	-9.86	-0.27	-1.25	3.25	-1.65	-11.32	-11.47	-12.67	-9.77
Total (ΔV)	-2.62	-7.84	-1.88	0.50	2.61	-2.62	-10.25	-11.94	-11.50	-9.19
SG percentage	-58	21	-607	140	20	-58	9	-4	9	6
SI coefficient	-1.76	5.29	-0.17	0.71	4.94	-1.76	11.80	-27.61	12.29	18.73
Case	B3	B6	B3	B5	B1	B3	B6	B3	B6	B6

RWE's performance in lignite use is bad in cumulative analysis. Acticity effect slightly decreases lignite use, but intensity effect increases it more and the use of lignite increases as a result (Table 10). Performance thus falls in case B5. Large SG value means that decreasing effect of change in activity should be much larger than the oberved ones. The use of hard coal has also increased due to increased activity (electricity production from lignite), but intensity effect has decreased it and performance falls in case B1 in the recent cumulative periods (Table 11). RWE's performance in the use of oil and gas has fallen mostly in case B3 towards sustainability, but in the most recent cumulative period, the intensity effect increased oil and gas use significantly and performance fell in case B5 (Table 12).

RWE's performance in CO_2 emissions has fallen in cases B3 or B6 in all cumulative periods (Table 13). Decrease is mostly caused by the activity effect. SG percentages are small and SI coefficients high (case B6) which means that the decrease in activity has been too large in relation to the sustaimnability criterion. High SI coefficient tells that the observed increase in intensity could have been even larger, and the sustainability criterion could still be met.

Table 14. *Sustainability performance indicators SG and SI for Celsa Barcelona's energy consumption, incremental and cumulative analysis, 2010−2015. V=total energy use (gas and electricity), X=total production of metal products.*

Total energy use	2010-11	2011-12	2012-13	2013-14	2014-15	2010-11	2010-12	2010-13	2010-14	2010-15
Y_{eff}	-0.97	2.02	-1.61	1.74	-0.64	-0.97	1.07	-0.47	1.16	0.57
X_{eff}	-1.65	-9.86	-0.27	-1.25	3.25	-1.65	-11.32	-11.47	-12.67	-9.77
Total (ΔV)	-2.62	-7.84	-1.88	0.50	2.61	-2.62	-10.25	-11.94	-11.50	-9.19
SG percentage	-58	21	-607	140	20	-58	9	-4	9	6
SI coefficient	-1.76	5.29	-0.17	0.71	4.94	-1.76	11.80	-27.61	12.29	18.73
Case	B3	B6	B3	B5	B1	B3	B6	B3	B6	B6

Table 15. *Sustainability performance indicators SG and SI for Celsa Barcelona's use of raw materials, incremental and cumulative analysis, 2010−2015. V=use of scrap and steel alloys, X=total production of metal products.*

Use of scrap and steel alloys	2010-11	2011-12	2012-13	2013-14	2014-15	2010-11	2010-12	2010-13	2010-14	2010-15
Y_{eff}	-0.43	1.45	0.63	3.47	-4.28	-0.43	1.02	1.62	4.94	0.80
X_{eff}	-1.66	-9.83	-0.27	-1.26	3.19	-1.66	-11.32	-11.60	-12.92	-9.78
Total (ΔV)	-2.09	-8.38	0.36	2.22	-1.08	-2.09	-10.30	-9.97	-7.98	-8.98
SG percentage	-26	15	234	276	134	-26	9	14	38	8
SI coefficient	-3.92	7.39	0.43	0.35	0.75	-3.92	12.32	7.95	2.84	13.38
Case	B3	B6	B5	B5	B2	B3	B6	B6	B6	B6

Table 16. *Sustainability performance indicators SG and SI for Celsa Barcelona's environmental impacts, incremental and cumulative analysis, 2010−2015. V=CO_2 emissions, X= total energy use.*

CO_2 emissions	2010-11	2011-12	2012-13	2013-14	2014-15	2010-11	2010-12	2010-13	2010-14	2010-15
Y_{eff}	-1.63	-1.72	-3.27	-1.01	2.78	-1.63	-3.24	-6.21	-7.11	-4.78
X_{eff}	-2.60	-7.77	-1.85	0.49	2.64	-2.60	-10.08	-11.54	-11.07	-8.96
Total (ΔV)	-4.23	-9.49	-5.12	-0.51	5.43	-4.23	-13.32	-17.76	-18.18	-13.74
SG percentage	-63	-22	-177	204	-105	-63	-32	-54	-64	-53
SI coefficient	-1.67	-4.98	-0.59	0.49	-0.90	-1.67	-3.59	-2.26	-1.90	-2.17
Case	B3	B3	B3	B2	B4	B3	B3	B3	B3	B3

Tables 14−16 show Celsa Barcelona's energy, material and environmental performance in the period 2010−2015. All analyses fall in either case B3 or B6, both representing performance towards sustainability. Performance of Celsa Barcelona resembles performance of Stora Enso analysed above: decrease in activity characterizes the performance, measured by either production of metal products, or by energy use, and decreasing activity explains decreasing energy and material use as well as decreasing CO_2 emissions. Intensity change seems to explain more decrease in CO_2 emissions than decrease in energy or material use of Celsa Barcelona. SG percentages are low in all cumulative analyses and negative for environmental performance (Table 16). SI coefficients are high, and positive in case B6 and negative in case B3.

Discussion and Conclusions

This paper introduces two new sustainability performance indicators; sustainable growth (SG) and sustainable intensity (SI). They are applicable at any level of economic activity, and the variables to be included in the analysis can be chosen by the user, and a causal relationship between them is assumed such as: production explains energy use, production explains material use, production explains environmental impact, energy use explains environmental impact, or material use explains environmental impact. The explainer describes activity, and the explained divided by the explainer describes intensity. The new indicators SG and SI have an advantage compared to specific energy and material consumption and specific emissions: they take into account, so they consider "Jevons paradox" too.

The crucial point is availability of data describing production, energy use, material use and environmental impact of a productive system in the same level, as in all attempts to develop new (sustainability) indicators. The indicators SG and SI have also their challenges; they are not stand-alone indicators: similar results can be get in different situations, and their interpretation depends on the situation, i.e. the direction and size of changes in the variables included in the analysis.

The empirical analysis covered the years from 2010 to the most recent year with available data in the published company reports and other public data sources. The analysed companies include Stora Enso (Finnish forest company), ENEL (Italian energy company), RWE (German energy company), and Celsa Barcelona (Catalan metal product company). A typical observation is that the European companies' economic activity has not increased very much when measured in physical amount of production. Quite often, the activity effect has decreased energy use, material use and environmental impact. Another typical observation is that the intensity effect does not play a major role in decreasing energy use, material use, and environmental impact.

This study brought out improvement possibilities to company reporting, especially regarding their performance from the sustainability point of view. Time series data on environmental impacts, the use of different primary energy sources and energy carriers, the use of major raw materials, and the amount of production would give a good starting point to the analysis of the company's sustainability performance. Even more beneficial could be if the data would be available for different production sites, processes and for individual products.

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Capacity Building for Renewable Energy Foresight in Cuban Electric Sector

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Abstract

Nowadays, the renewable energies have emerged like an important energy source in the entire world. They have a quick growth and diverse factors triggered it, particularly in the electric sector. The Electric Union (Unión Eléctrica de Cuba) has the challenge to change Cuban energy matrix with the introduction of renewable energy, by the acquisition of technologies to satisfy the electric power demand with efficiency, effectiveness and an environmental perspective. This paper aims to propose a training strategy designed to increase the absorptive capacity of technology (ACAP) to optimize and enrich the new technologies concerning to renewable energy development in Cuban electric sector. The starting point is the current level of ACAP, at different levels of organization, in order to build, operate and maintain new electrical power plants, based on renewable energy sources. The paper presents the main proposed strategies and actions to improve the ACAP level.

Introduction and Background

The human and economic developments have required the consumption of large amounts of energy. The fossil fuel (coal, oil and natural gas) have been the most used. They are really advantageous but they present some disadvantages too. They are non-renewable resources and highly polluting fossil fuels. They produce CO_2 and hydrocarbons that are responsible for the current urban pollution and climate change (Grafström, J. 2017). However, these fuels create a great economic dependence from abroad. Many countries do not possess their own production, therefore, they should buy them at high prices to producing regions.

The deployment of renewable energy sources (RES) has become one of the main aspects of the sustainable development, although the main motivations differ between developed and developing countries. Cuba is not an exception. The Cuban Electric Union (Unión Eléctrica de Cuba) has the challenge to change Cuban energy matrix with the introduction of renewable energies, by the acquisition of technologies. The purpose is to satisfy the electric power demand with efficiency, effectiveness and environmental perspective. Then, the Cuban Electric Union requires acquiring new technologies. Consequently, this organization will have to work on internal drivers in order to assimilate these technologies by a capacity building process.

Vallejo, B. & When, U. (2016) have developed the concept of "capacity development". This process contributes individually, organizationally, institutionally, and in the society to increase their abilities to: perform core functions, solve problems, define and achieve objectives; and understand and deal with their development needs, in a broad context and in a systematic approach, different to enhancing and strengthening existing capacities (Vallejo, B. & When, U., 2016, p. 2).

The United Nations in 2015 decided "to establish the Paris Committee on Capacity-building whose aim will be to address gaps and needs, both current and emerging, in implementing capacity-building in developing country". This agreement addressed to enhance the government capacity-building efforts, including the coherence and coordination between entrepreneurial strategies in capacity-building activities, by FCCC/CP/2015/L.9/Rev.1 – Adoption of the Paris Agreement (UN. 2015). This research has been developed in accordance with the concept of capacity building established by United Nations.

The process of technology transfer is critical to deploy new technologies into organizations. The effective assimilation of technology depends on the absorptive capacity. Absorptive Capacity (ACAP) have been defined as "the ability of a firm to recognize the value of new external information (knowledge), acquire it, assimilate it, and apply it to commercial ends" (Cohen & Lenvinthal, 1990, p.128). In the same direction, Sun & Anderson (2008) defined ACAP as "a kind of organizational learning from external sources" (Sun & Anderson, 2008, p.141). This capacity emerges from the linkages–connections of the knowledge entangled at the organizational activities and the individual skills of the people who constitute these organizations. Due to the structural inherent complexity and the associated multidimensionality of the learning process during technology transfer process, many authors recommend the process/capabilities perspective as a broader approach (Lane et al, 2006; Volberda et al, 2009).

In the literature we found many models to evaluate ACAP: Cohen & Levinthal (1990); Van den Bosch, Volberda and Boer (1999); Zahra & George (2002); Lane, Koka and Pathak (2006); Jansen, Van den Bosch and Volberda (2005); Jones, Arnold, Chivatras and Sardana (2008); Vega-Jurado, Gutiérrez-Gracia and Fernández de Lucio (2008) and Volverda, Foss and Lyles (2009). However, we emphasized the applications such as Kim (1998), Szulanski (1996), Filgueiras (2013) and De Paula Guedes et al. (2016).

The essence of the innovation process resides in the capacity of an organization to establish mechanisms of social interaction, and in the integration of the knowledge allowing to recombine its resources and to absorb external knowledge to deploy them into the innovative organizational activity (Filgueiras & Castro, 2012; Clausen, T.H., 2013; De Paula Guedes et al. 2016). Technological transfer is a way to innovate from external sources of knowledge. One of the approaches is that organisations need to have a proper infrastructure and its organizational processes need to be regulated in a way to enable and support knowledge processes (Dávila, G. A., Andreeva, T. and Varvakis, G., 2017, p. 19). The other approach is that the level of organizational performance depends on the path followed in its evolution, its culture, its base of knowledge (Clausen, T.H., 2013).

Hence, the level of organizational performance depends on the path followed in its evolution, its culture, its base of knowledge, its strategic attitude[1], the conditions of the environment, but the organizational design too. All these factors influence the organizational learning and subsequently the level of ACAP. This is the basis for the capacity to innovate (Filgueiras & Castro, 2012; Recalde, M.Y., Bouille, D. H. and Girardin, L. O., 2015; van der Heiden, P., Pohl Ch., Bin Mansor, Sh. and van Genderen, J., 2015; De Paula Guedes et al. 2016; Dávila, G. A., Andreeva, T. and Varvakis, G., 2017, p. 19).

De Paula Guedes et al (2016) developed a model taking into account the same principles of the model developed by Filgueiras (2013). Methodologically speaking, it is possible to put into practice De Paula Guedes model and afterwards to conduct the survey to evaluate the ACAP and applying the procedure to create and develop ACAP generated by Filgueiras (2013), this procedure can be used considering the features included at the model of De Paula Guedes et al (2016). The Figure 1 represents the model

This research has been developed to build absorptive capacity for renewable energy foresight in Cuban Electric Sector, in order to implement the Cuban Policy for Development of Renewable Energy. The decisive factor that justifies and guides this research is the increasing assimilation of RES technology in the power generation in Cuba.

[1] It is recognized that a group of enabling conditions for the development of the RES, among them: institutional and organizational capability, capability building program for people, groups and organization

The study pursues to increase the ACAP by a formation and training strategic design. This capability will contribute to optimize and enrich the new technologies concerning to the renewable energies development. The starting point is the actual level of ACAP at different levels of organization, in order to build, operate and maintain new electrical power plants, based on RES in Cuba. At the same time, would be created a base of forecast for renewable energies at the Cuban electric sector.

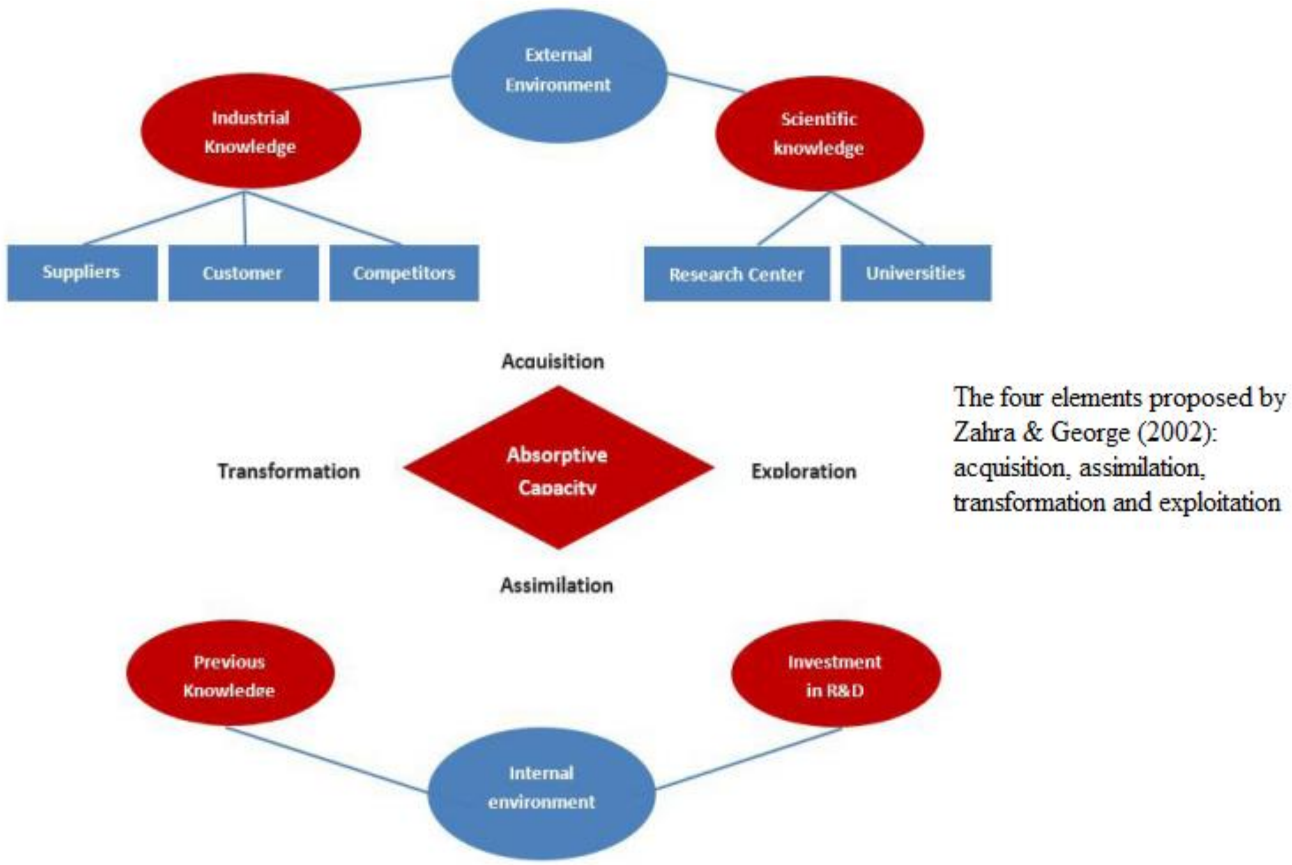

Figure 1.*The model of ACAP by De Paula Guedes et al (2016).*

The practical contribution of this work lies in the contextualization under Cuban conditions of the model developed by De Paula Guedes et al (2016) to evaluate the ACAP and the application of the procedure developed by Filgueiras (2013) Capacity Building for Renewable Energy Foresight in Cuban Electric Sector.

Material and Methods

A quantitative descriptive survey was used as a research strategy for accomplishing the assessment of ACAP of the Cuban electric enterprises, with the application of a diagnostic tool adapted to the reality of those companies based on the De Paula Guedes et al (2016) survey to evaluate the ACAP entailed to the Cuban conditions, in Table 1. The questionnaire was structured in two parts, the first being the identification of the surveyed organizations and the second consisting of 26 questions, divided into four groups, using primarily the four elements proposed by Zahra & George (2002), as shown in Figure 1: acquisition, assimilation, transformation and exploitation. We used the Likert five-point scale (1 = lowest level and 5 = highest level).

This research performed with 10 electric enterprises distributed through the Cuban Island; four sugar cane producers, with development of RES projected, four enterprises, which produce the different components of RES power plants and six organizations that take part in the construction and assembly of these generation plants with RES. The research only addresses those organizations, assessing their ability to absorb technology for the participating of the deployment of RES nationwide, therefore justifying the choice for that target population.

According to the Cuban Electric Union (UNE), there are 16 enterprises in the sector of distributed power generation in the whole country, and the enterprise of the Island of Youth. Moreover, seven sugar cane producers, with development of RES projected in the next 10 years. The enterprises, which produce the different components of RES power plants at this moment, are five. The research focused mainly on electric power producers, but to absorb technology it is necessary to consider all actors with a role-play in this process. The questionnaires sent to all 36 organizations to obtain the greatest possible amount of respondents. A part of them, 24 organizations, responded the survey with a confidence level of 95% and 5% of accuracy for the group studied. This research used statistical techniques for processing and analyzing data, culminating in the creation of a ranking that places the type of organizations according to their level of ACAP.

Table 1. *Survey to evaluate the ACAP level entailed to the Cuban conditions, based on the De Paula Guedes et al (2016) survey to evaluate the ACAP.*

Elements	Questions
Explore 1	The organization values the attitudes of people who promote change, whatever their hierarchical position.
Explore 2	The organization collaborates systematically with different institutions in projects for innovation or improvement of products & services, their commercialization, processes, and management systems
Explore 3	The organization systematically searches for important information on aspects related to the field of activity in which it operates
Explore 4	The workers, technicians and specialists have the appropriate qualification to work in projects of improvement or innovation of products & services, their commercialization, processes, and management systems
Explore 5	The organization makes significant investments in research and development activities
Explore 6	Systematic exchange is promoted with technology providers, with similar organizations in other countries and with clients to improve and innovate the products & services, their commercialization, processes, and management systems
Assimilate 1	The organization often uses knowledge or technologies developed by other organizations (suppliers, universities, research centers, consulting firms)
Acquire 2	Workers master the technologies they use and receive training and systematic courses with technology providers
Acquire 3	The managers and specialists of the organization have the appropriate knowledge to perform their functions
Acquire 4	In the organization, workers, technicians and specialists are encouraged to participate in scientific or academic events (conferences, seminars, courses, workshops)
Acquire 5	The organization systematically uses multidisciplinary work teams from different organizational units to solve technological and organizational problems
Acquire 6	The organization promotes integration and knowledge sharing among its different organizational units
Assimilate 1	The organization systematically promotes the exchange of experience and knowledge among its different organizational units
Assimilate 2	Information moves between hierarchical levels with ease and agility within the organization.

Assimilate 3	The organization systematically practices the rotation of functions and tasks among its workers
Assimilate 4	Formation and training is promoted in order to achieve quality improvement and efficiency in production processes
Assimilate 5	In the investment processes, the organization uses the knowledge and experience accumulated by its technology suppliers, hiring technical assistance during the assimilation process.
Assimilate 6	There is a spontaneous and informal cooperation among workers at all levels.
Transform 1	The organization uses the knowledge and experience accumulated by the personnel for the development of organizational technological strategy (new technologies, systems and methods of work, and processes)
Transform 2	The organization is capable to incorporate technological knowledge into new developments that contribute to improving performance (R&D results, publications, patents)
Transform 3	The organization has a structure to manage science, technology and innovation activities, with established objectives, allocates resources and control over them.
Transform 4	The organization responds skillfully to changes in the field of activity in which it operates using new knowledge.
Transform 5	There are clear procedures or rules to develop innovation and it disseminated throughout whole organization.
Transform 6	The organization is projected to innovate in advance to changes in the environment

The methodology to determine strategies is the general procedure proposed by Filgueiras (2013) until the third phase in this stage for UNE, conformed by four phases:

Phase I: Setting. To determine premises
Phase II: Diagnosis of the ACAP level. To determine the limiting components
Phase III: Process to improve the existing ACAP. The objective of this phase is to establish the strategies and actions to solve inadequacies. This process has into account the integration of knowledge provided by University-Industry interaction and foreign supplier of technology. These entities are considered the main external sources of knowledge. The output of this process is the implementation of strategies and the concerning actions plan to improve the level of ACAP.
Phase IV: Monitoring and Management of the ACAP process. To establish and deploy the management system over the effectiveness of the process to improve ACAP.

Results

Some factors were limiting the ACAP in Cuban electrical enterprise are:

Exploration dimension:

- The organization sometimes searches for important information on aspects related to the field of activity in which it operates.
- The workers, technicians and specialists have a poor qualification to work in projects of improvement or innovation of processes and management systems related to RES.
- The organization has promoted a poor exchange with technology providers, or with similar organizations in other countries to improve and innovate the products & services, their commercialization, processes, and management systems.

Acquisition dimension:

- The managers and specialists of the organization don´t have the appropriate knowledge to perform their functions, related to RES.

- The organization doesn`t use multidisciplinary work teams from different organizational units to solve technological and organizational problems.

Assimilation dimension:

- The organization doesn´t promote the exchange of experience and knowledge among its different organizational units.
- The organization doesn´t practice the rotation of functions and tasks among its workers.

Transformation dimension:

- The organization doesn´t use systematically the knowledge and experience accumulated by the personnel for the development of organizational technological strategy (new technologies, systems and methods of work, and processes).
- The organization doesn´t have implemented clear procedures or rules to develop innovation and it disseminated throughout whole organization.

The factors were limiting the ACAP in the other organizations:

Exploration dimension:

- The organization sometimes searches for important information on aspects related to the field of activity in which it operates.
- The workers, technicians and specialists have a poor qualification to work in projects of improvement or innovation of processes and management systems related to RES.

Acquisition dimension:

- The managers and specialists of the organization don´t have the appropriate knowledge to perform their functions, related to RES.
- The organization doesn`t use multidisciplinary work teams from different organizational units to solve technological and organizational problems.

Assimilation dimension:

- The organization doesn´t have a structure to manage science, technology and innovation activities, with established objectives, allocates resources and control them.
- The formation and training promoted sometimes in order to achieve quality improvement and efficiency in production processes.

Transformation dimension:

- The organization doesn´t use the knowledge and experience accumulated by the personnel for the development of organizational technological strategy.
- The organization is not capable to incorporate technological knowledge into new developments that contribute to improving performance
- The organization does not respond skillfully to changes in the field of activity in which it operates using new knowledge.

The median values obtained with the survey for each item have shown in the Figure 2.

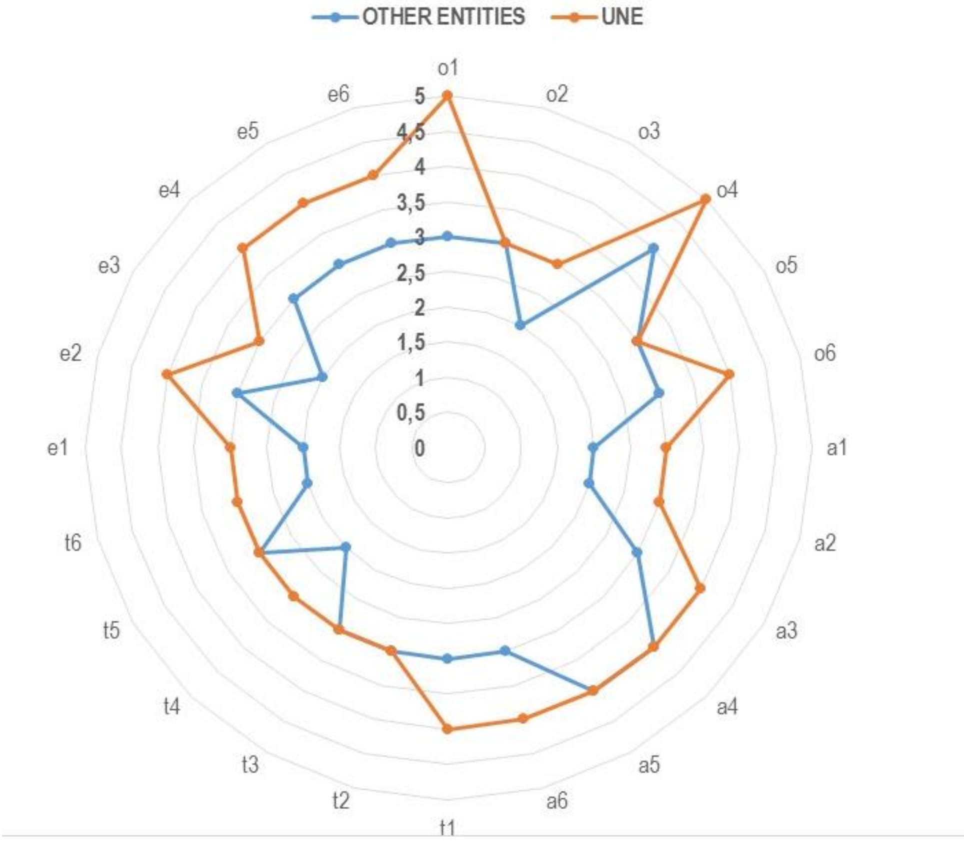

Figure 2. *The graphic with median values obtained by the Survey to evaluate the ACAP level entailed to the Cuban conditions at the UNE and other entities involved in the development of the RES in Cuba.*

Discussion and Conclusions

The diagnosis results of the existing level of ACAP confirmed it is not adequate to face the accelerated assimilation of renewable energy in all organization. Both the UNE and the rest of the organizations involved in the development of the RES have a low performance in the exploration, acquisition, assimilation and transformation of knowledge to achieve success in the technology transfer processes. The analysis to determine the internal consistency of the survey by Apha of Cronbach obtained value = 0,9191 demonstrating a very strong consistency.

The research demonstrated a need to develop strategies to increase the basis of knowledge, having into account that the managers, specialists, technicians and workers don´t have the appropriate qualification to work in projects of improvement or innovation of processes and management systems related to RES. But according to Roxas et al. (2014) "an organisation with knowledge management capabilities tends to be more innovative and has better performance" (Roxas et al., 2014, p. 444). These organizations did have not developed mechanisms to integrate external knowledge, and they have not even developed mechanisms for the integration of knowledge internally.

The UNE is implementing the general procedure proposed by Filgueiras (2013) until the third phase. This phase comprises the process to improve the existing ACAP.

Three levels have been structured for the personnel of the Electric Union: workers, chief in each power plant, and national and regional managers. Moreover, an interdisciplinary approach in three stages: Levelling: to be executed in the enterprise of UNE to incorporate people in the enterprise, and to reinforce basic knowledge. Basic: to execute at the National Centre of International Certification to general preparation about RES for personnel contracted. Specialization: it is a specific training for each technology, and it will be executed at the National Training Centre for RES and where the personnel will work, culminating with the certification by the adviser of the specific technology.

The ACAP level and her limiting components are determined. The path and the culture to develop new technology is adequate. Managers at different levels of organization have a narrow view of innovation, combined with an incorrect organizational design, though. All these aspects are limiting the internal knowledge integration. Lack of attention to the interaction with external sources of knowledge is limiting the integration of knowledge from the external sources, at the same time. Consequently, a poor organizational learning emerged and the level of ACAP required to assimilate new technologies is low.

The main strategies and actions to improve the ACAP level proposed, will permit to that 100% of personnel in the level of workers should finish their specialization in a period not more than 4 years and planned re-certification for each person annually. This result contributes to create the basis of knowledge required to develop the process of technological transfer.

Summarizing, capacity building for renewable energy in the Cuban electrical sector is still a big challenge to be faced.

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Cuban Electricity Sector Development. Challenges of Increased Intermittent Renewable Production.

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Abstract

The article deals with scenarios for future Cuban electricity demand and supply. The scenarios are constructed with CubaLinda model for different future options for renewable and fossil energy production. The scenarios are constructed up to 2040 with different amounts of solar and wind production. The scenarios are calculated to provide hourly balance for supply-demand. The model constructs scenarios for hourly demand in different sectors in the economy (households, industry, services and agriculture). The CubaLinda model calculates the required ramping rates for the residual load production based on data of hourly wind speed and solar radiation and the related wind and solar production with the installed capacity. The presented scenario results illustrate differences based on different economic growth rates, different power plant construction rates and changes in the Cuban energy matrix.

Introduction and Background

Cuban energy system has gone through several periods of change and in the future new challenges in the development of the system can be seen. The introduction of larger amount of intermittent electricity production by wind and solar power can create challenges for controlling the supply demand balance in the electricity grid. The electricity demand in different sectors of economy is varying every hour of the day and the electricity production should be able to follow these changes in order to maintain constant frequency and voltage level in the grid (Del Pino et al 2016, 1−4).

The article looks for different future alternative development paths by constructing scenarios for future development. The scenarios are constructed for electricity demand and supply using CubaLinda model. This article analyzes the paths of future development of the Cuban electrical system emphasized in two main scenarios, baseline scenario (BAU) and renewable scenario (REN). The CubaLinda model constructs scenarios for hourly demand in different sectors in the economy (households, industry, services and agriculture) for weekdays and weekends taking into account the monthly variations in electricity demand and different economic growth rates. Part of the demand can be supplied by the wind and solar power, but the residual load (demand minus production of intermittent sources) has to be covered with fossil power production and biomass based production.

The CubaLinda model calculates the required ramping rates for the residual load production based on data of hourly wind speed and solar radiation and the related wind and solar production with the installed capacity. In this paper we present and illustrate the results of the analysis of both scenarios.

Material and Methods

Long-range INtegrated Development Analysis (LINDA) model is an accounting framework type of model which is based on decomposition of the drivers of energy demand into meaningful components (Vazquez et al 2015, 638–645): (i) the energy use and; (ii) CO_2 emissions. For more details of LINDA model see (Luukkanen et al 2015, 866-881). A general simplified structure of the Linda model is presented in Fig. 1.

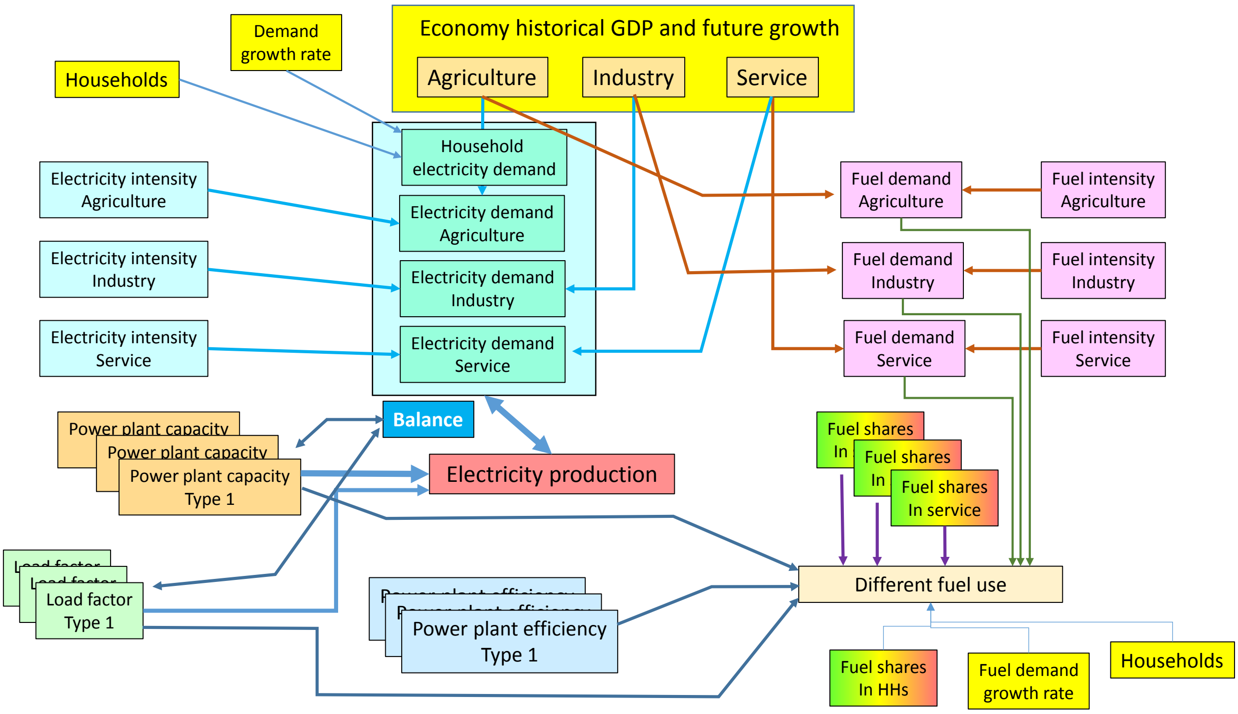


***Figure 1**. Basic simplified structure of the Linda model.*

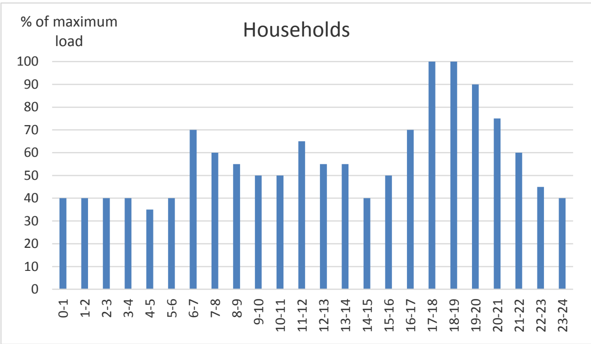
As you shown in Fig. 1 the economy in the LINDA model is divided in different sectors; agriculture, industry and services. The energy use is divided in different Fuels and Electricity. The user can construct different economic scenarios by choosing different economic growth rates for different sectors of economy. Different economic structures will affect the energy demand since the energy intensities are different in different economic sectors.

By changing the energy intensities in the scenarios the user can have an impact on the final energy demand. The energy intensity of a sector can decrease due to introduction of a more efficient technology or shift to less energy intensive products or structure.

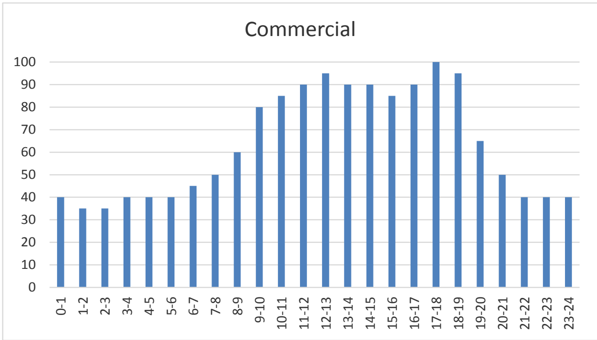
A-Load curves

The CubaLinda model uses load curves for different sectors of economy to analyse the future electricity demand. The model user gives the future hourly load curve for different sectors of the economy. The load curves are given for weekdays and weekends as well as for the different months of the year. They are also given for all the future years of the scenario.

Fig. 2 shows the given load curves for household sector, commercial and industry sector in January on weekdays.



a)



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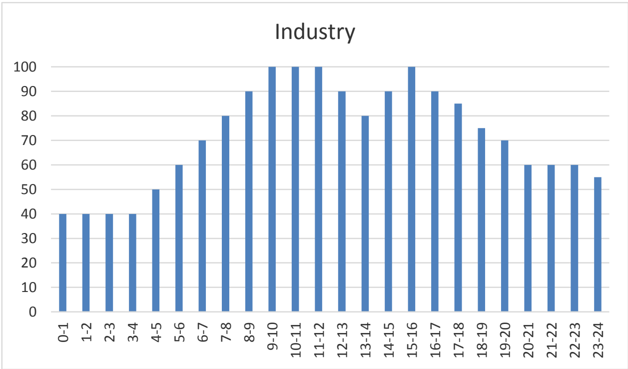


c)

Figure 2. *Load curves for a weekday in January in the basic scenario.*

The data for the analysis is taken from the International Energy Agency (IEA) World Energy Statistics (IEA 2017), Cuban statistical sources (ONE 2018), and UN sources (UN 2017). The data for future development is partly based on expert opinions.

B- Electricity production

The electricity production by the intermittent renewable energy sources, solar and wind, are calculated in the CubaLinda model based on hourly data on wind speed and solar radiation. For the calculation of hydro power production the rainfall data for different months is used. The monthly rainfall data is filtered to estimate the delay in the availability of water for hydro power production. In addition, biomass bagasse is assumed to be used mainly in the months from October to March for electricity production in the sugar factories. The Cuban government plans to introduce wood based power production in the future.

The hourly daily change in solar radiation is shown in Fig. 3 and wind speed variations in Fig.4.

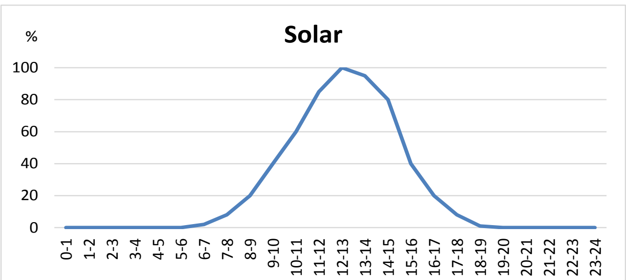


Figure 3. *Hourly solar radiation curve for one day.*

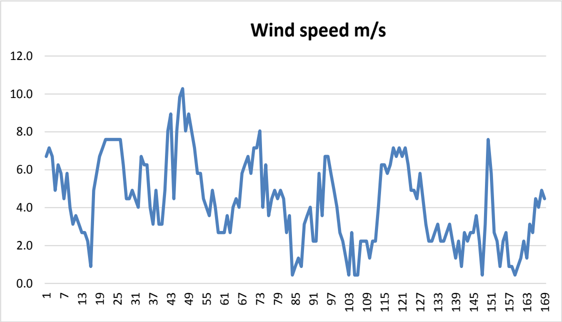
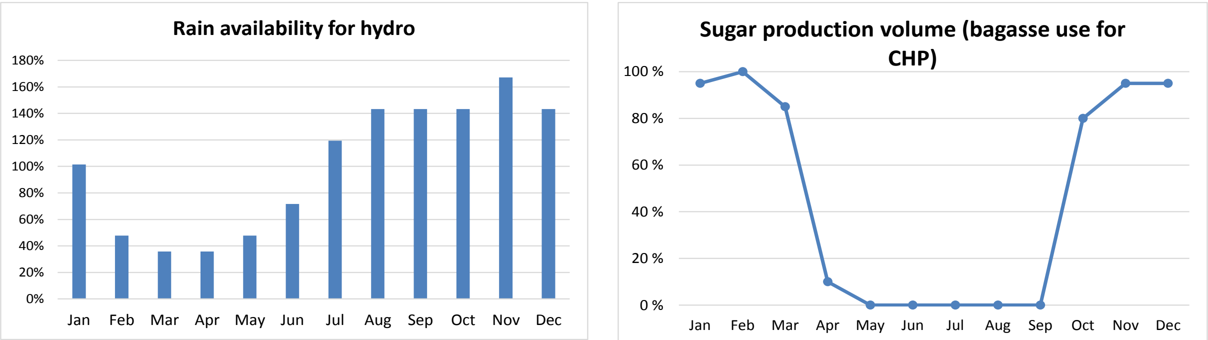


Figure 4. *Hourly wind speed measurement for one week in “Jardines del Rey” (10 m height).*

Fig. 5 shows the rainfall for hydro and variation in bagasse availability for one year.



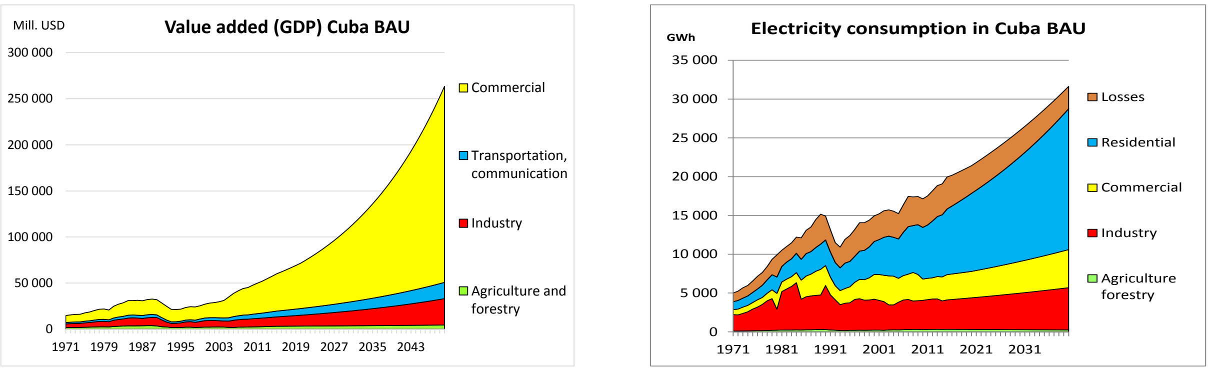
a) b)

Figure 5. *Rainfall for hydro and variation in bagasse availability in the year.*

The demand and supply have to be in balance every hour of the year in the electrical system. With CubaLinda model the user can calculate the electricity demand for every hour of the year and the model matches the supply to this. Other important aspect, the residual load, is calculated as the hourly demand minus the hourly production by the intermittent renewable energy sources, wind and solar. The production of residual load has to be carried out with power plants that can be controlled such as fossil fuel condensing power plants or hydro power plants.

Results

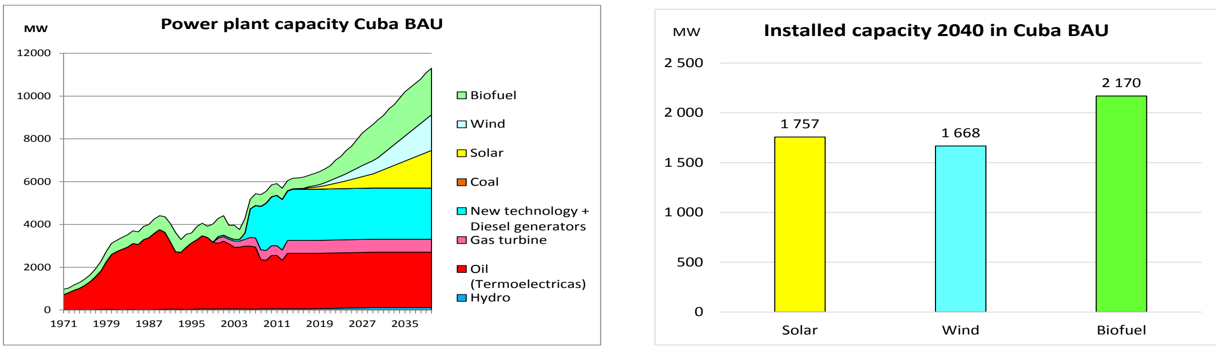
A baseline scenario for Cuban economic development up to 2050 and electricity consumption in different sectors are presented in Fig. 6.



a) b)

Figure 6. *Economic development and Electricity consumption in different sectors of economy in Cuba.*

For the electricity production scenarios the model user has to define how much new power plant capacity will be constructed and whether old capacity will be decommissioned. This paper analyzed two scenarios; Fig. 7 shows a scenario for future power plant capacity. In this scenario the old power plants still remain, but their use is reduced in the model because new power plant capacity for renewable wind, solar and biofuel were added.



a) b)

Figure 7. *Installed power plant capacity in Cuba in the basic scenario.*

For this scenario electricity production with different types of power plants are presented in Fig. 8.

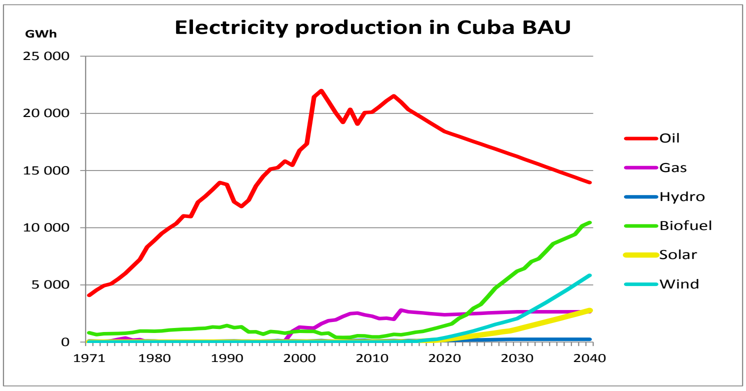


Figure 8. *Electricity production with different energy sources based on hourly calculation.*

Fig. 9 shows the electricity production in one day in 2040 in the basic scenario. In this case we can observe that the production from wind power, solar power and biomass power exceeds the demand between 14 and 15 hours indicating need for electricity storage.

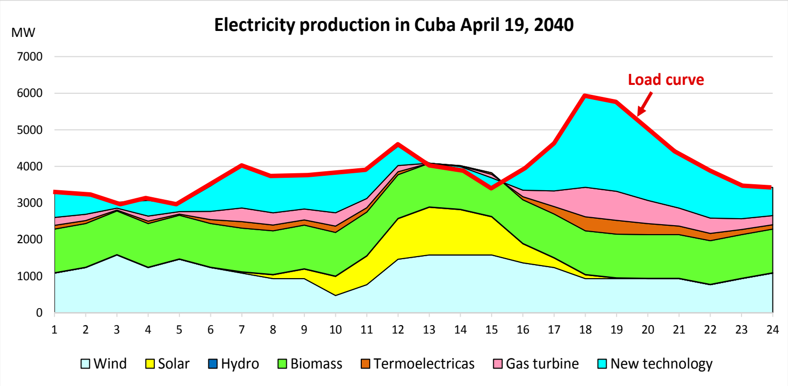


Figure 9. *Electricity production by different power plants in one day in April in 2040 in the BAU.*

The CubaLinda model calculates the required ramping rate for the residual load production. The ramping rate is calculated for required 1 to 6 hour maximum (increase) and minimum (decrease) changes in power production as well as average increase and degrease of power production. The Fig. 10 shows the ramping rate envelope in the baseline scenario.

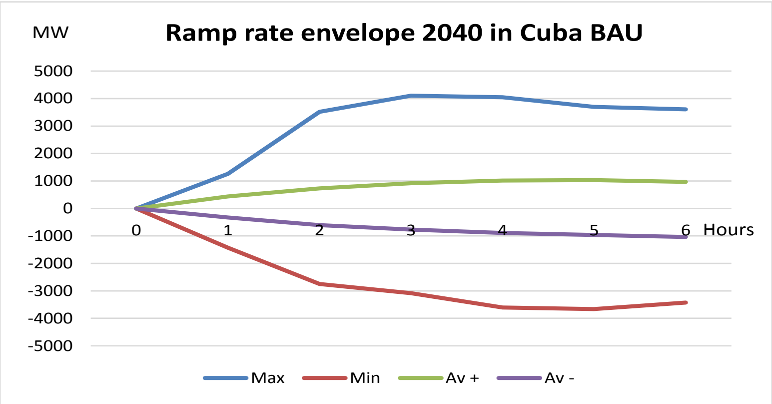


Figure 10. *Ramp rate envelope in Cuba in 2040.*

The ramping rate figure illustrates that there can be maximum increase in power demand of more than 1000 MW within one hour and about 3500 MW within two hours. Such fast changes require considerable controllability from the fossil based power plants.

In the REN scenario (Renewables scenario) the old fossil based power plants still remain (as reserve) but their use is reduced. Besides there will be considerably more investments in the wind and solar production capacity. The Fig. 11 shows installed capacity for solar, wind and biofuel in 2040 in REN scenario.

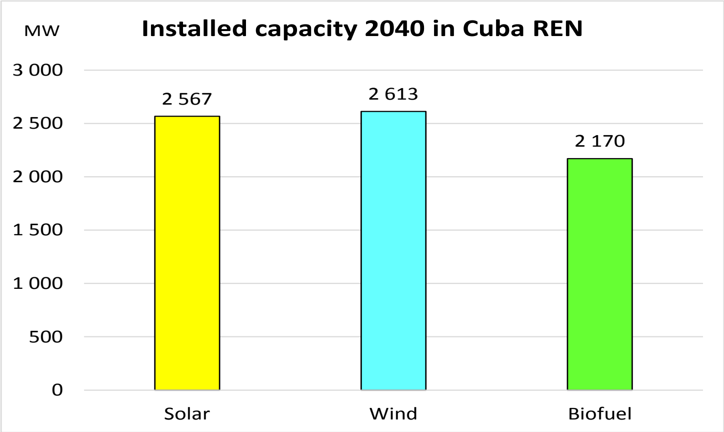


Figure 11. *Installed solar, wind and biomass based electricity production capacity in Cuba in 2040 in the REN scenario.*

Electricity production with different types of power plants in the REN scenario is shown in Fig.12.

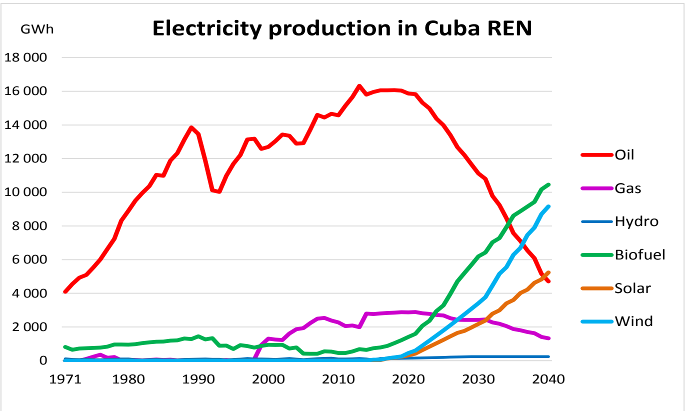


Figure 12. *Electricity production with different energy sources in Cuba in 2040.*

In the REN scenario there is considerable overproduction during the afternoon hours caused by large solar and wind production during some days. This illustrates the need for storage capacity in order to shift the production peak to the consumption peak at 18−20 o'clock in the evening. Electricity production for one day in April in 2040 in the REN scenario is shown in Fig. 13.

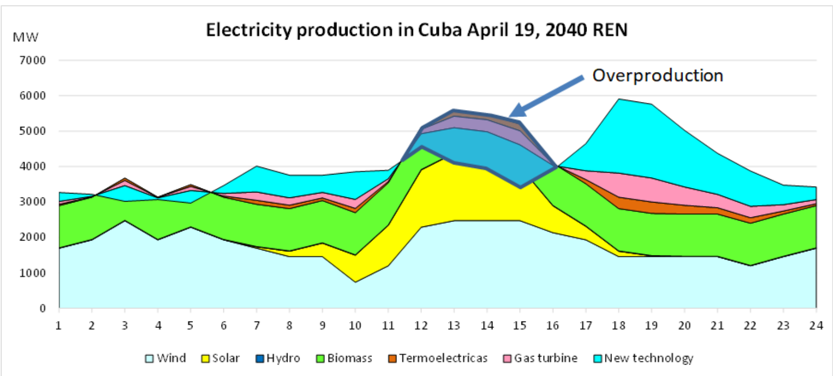


Figure 13. *Electricity production by different power plants in one day in April in 2040 in the REN scenario.*

The required ramp rates in the REN scenario are illustrated in Fig. 14.

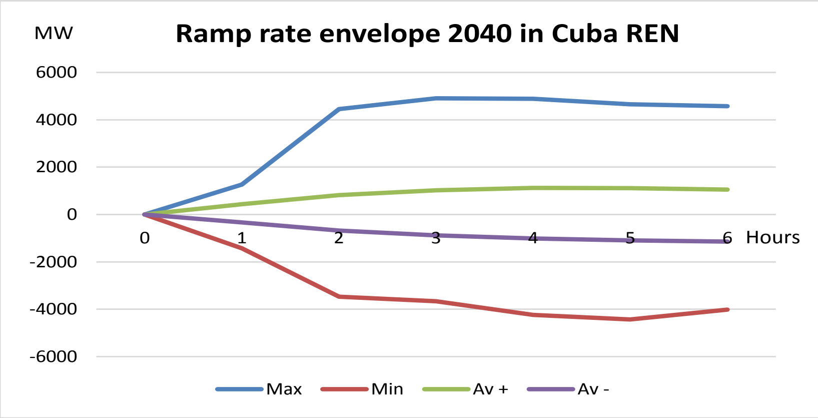


Figure 14. *Ramp rate envelope in Cuba in 2040 in the REN scenario.*

With such large wind and solar capacity the maximum ramp rates become very large. The maximum increase of residual power production within two hours is about 4500 MW, which constitutes considerable challenges for the power plant control systems.

Discussion and Conclusions

Increase in the use of renewable energy production provides several advantages. They are essential in reducing greenhouse gas emissions. At the moment the Cuban electricity production system is to a large extent based on fossil energy use with large CO_2 emissions. Shift to renewable energy sources like wind, solar and biomass reduces the overall CO_2 emissions, but also other harmful emissions like SO_x and particle emissions. This is important for the local air quality.

Increase of renewable energy production also decreases the reliance on fossil fuel import. Increase in the security of supply is important as well as the possibilities of reducing the production costs of electricity. The trend of decreasing costs of wind and solar production is an important driver in the shift towards renewable production.

There are, however, also challenges in the shift towards renewable energy production. The problems related to balancing the supply and demand in every second will be increased with the increased amount of intermittent wind and solar production. The fast changes in wind speed and solar radiation require fast ramping rates in the residual load production. The possibilities of fossil based steam power plants to follow fast changes is limited. Special attention has to be paid on these challenges and possibilities to follow the fast changes with gas turbine of pumped hydro production has to be analysed.

Large share of wind and solar production requires the use of energy storage to balance the supply and demand in an economic way. There exist several technological alternatives for energy storage, some of them are still in the development face. Batteries are one solution, but they are still considerably expensive and the storage capacity is not very large. Pumped hydro is one option for Cuba as well as power to gas or compressed air storage. The cost efficiency of different storage options needs close scrutiny and evaluation of future development paths for the whole electricity system.

Important question related to the increase of renewable energy production is the required investments. Even though the investment costs of wind and solar production are going down the renewal of the whole electricity production system of Cuba is very expensive and possibilities of to use different funding sources have to be analysed.

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Off-Grid Power Quality and Its Effects on Commonly Used Appliances: A Case Study of Nepal

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Abstract

A significant share of Nepal's rural population live without access to electricity, many in places where grid extension is not possible. Even where power is available, many decide not to get connected due to the unreliable supply. This study establishes the status quo of the power quality in existing rural off-grid systems in Nepal, and and estimates its effect on commonly used household appliances. The results may be used in designing more robust power systems for the rural scenario.

The voltage and frequency of the studied AC off-grid systems are found to deviate substantially from government norms. The waveform has less harmonic distortion than in the reference on-grid locations. Out of the tested appliances, switched-mode power supplies and LED loads show high resilience to voltage fluctuations, whilst resistive loads are the most affected. Changes in frequency has little effect on any type of appliance tested. As the first level of household electrification often only provides lighting and tv, power quality does not become an issue as long as LED-bulbs and LED-based tv sets are used. For further appliances, an effective power management system is essential to provide reliable power supply.

Key words: rural electrification, power quality, off-grid power systems, Nepal

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Introduction

Energy in Nepal

Nepal ranks very low in terms of per-capita power consumption and the Human Development Index [1]. The majority (over 80 per cent) of its population reside in rural areas, and an estimated 20 to 40 percent live without access to any modern energy services [2], [3], [4]. With effectively no oil, natural gas nor coal reserves, Nepal has to rely on substantial exports of both fossil fuels and energy [5]. To meet their energy demand, households use traditional biomass such as dung cakes or firewood, leading to health issues and high CO_2 emissions.

Currently, over one third of Nepal's electricity supply is imported from India, and the reach of the national grid is very limited. Due to their challenging geography, providing connections in rural regions is strenuous and expensive, and despite the substantial hydropower potential in Nepal, the resource has remained largely underutilised [5]. The chronic shortage of electricity leads to power-quality issues and frequent outages in the existing decentralised grids.

Harnessing more of the hydro potential could greatly improve the energy shortage and provide access to those still out of reach of the national grid. Small hydro off-grid systems offer flexibility and lower distribution losses than centralized large-scale power plants. However, their low power capacity makes them more susceptible to power quality issues. It is thus necessary to determine the minimum power quality requirements for such systems and design an adequate power management scheme if needed. Further, studying the existing power quality might provide answers as to why, in places, achieving energy access has not lead to expected positive change in socio-economic aspects [6].

Power Quality

In the context of this study, power quality is taken as the measure of the reliability of a given power supply. Any deviations from constant operating setpoints may be considered a sign of worsened power quality. In the context of hydropower, microgrids with AC bus are widely in use, and thus only AC power is considered in this report. Further, as individual Nepalese households using off-grid systems often have access to only one phase, the power balance of three-phase systems is not considered. To measure power quality, three indicators, namely RMS voltage, frequency and sinewave form, are used. Figure 1 shows these three measured indicators. For further reference, the power quality norms of Nepal give 230 V RMS and 50 Hz as the nominal values for voltage and frequency, respectively. Deviations up to 5 percent for the former, and 2.5 per cent for the latter are allowed [7].

Two locations in rural Nepal with off-grid hydro power are chosen as measurement sites, and the results are compared with two reference on-grid locations. The local power quality conditions are subsequently reproduced in a laboratory environment and the short-term effects of power fluctuations tested on commonly used appliances.

In the following chapters, first the methodology of the power quality measurements and the experiments on appliances is described in Chapter II, and subsequently the results for the same are presented in Chapter III. Finally, Chapter IV discusses the findings and possible future work, and additionally addresses some shortcomings of the study.

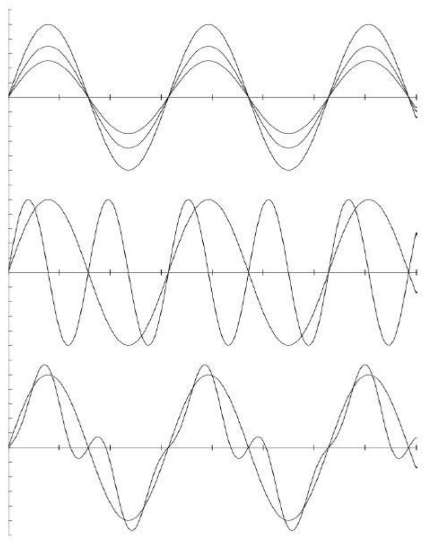

Figure 1. *Disturbances in wave amplitude, frequency and sinewave form.*

Method

The aim of this study is firstly the measurement of power quality in existing off-grid power systems in rural Nepal, and secondly the determinations of the impact of such conditions on commonly used electrical appliances. To this end, measurements are conducted in two locations in the Manang Valley in Nepal, and the obtained data is then compared to two referene on-grid locations. Subsequently, the measured conditions are replicated in the laboratory to test their effect on chosen household appliances.

The off-grid locations are the city of Chame, and a private boarding school (Lophelling Boarding School, LBS) near the city of Humbde. Both locations are shown in Fig. 2. LBS, among various villages in the region, is supplied by the Sabje Power Station with the maximum capacity of 80 kW. Chame is the only village powered by the Chame Power Station of 45 kW.

As for the on-grid locations, the quarter Maxvorstadt in Munich, Germany, and that of Thamel in Kathmandu are chosen to provide both a local and international reference. Thamel may also be seen in Figure 2.

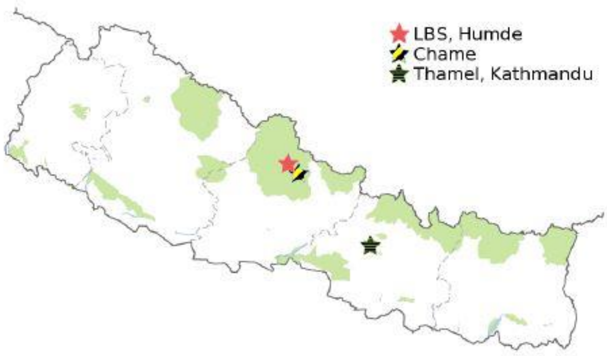

Figure 2. *Location of the Lophelling Boarding School (LBS), Chame and Thamel, Kathmandu on the map. Own illustration, map data from Google [9].*

Power Quality Measurements

To measure the three power quality indicators chosen, standard multimeters and a hand-held oscilloscope are used. Further, a low-cost self-made datalogger capable of measuring RMS voltage and frequency is used, mainly to show that similar measurements can be conducted with a more accessible budget for rural scenarios. The simple datalogger is controlled by an Arduino Uno microcontroller, and powered by the source it is measuring, or alternatively an external battery. The total cost of the datalogger is under 50€[1].

Both the multimeter and the self-made datalogger are set to provide measurements at a 10-second interval. The oscilloscope has a sampling rate of 100 million samples per second and its measurements are given in one-second snippets at 10-second intervals. The measurements are conducted over the period of, at minimum, one week at each location.

Experiments on Commonly Used Appliances

Based on an extensive survey of rural households in Nepal [8], the most widely used electrical appliances are lightbulbs (LED's, incandescent bulbs and CFL's), mobile phones and television sets. Further, rice cookers and electric kettles form a clear trend for future energy need of rural Nepal, and are thus included in the power quality experiment.

To ensure realistic testing conditions, all appliances are bought in Nepal, mainly at the Kathmandu market. Further, care is taken to acquire equipment of the same brands and power rating that are typically in use in rural households.

To test mobile phones, two types of typical mobile charger are chosen; one is an original from a large multinational brand, and the other a cheap local brand likely to be bought as replacement in case of a malfunction of the former. Instead of charging mobile phones, battery banks are used to simulate mobile charging.

[1] The open-source code used for the datalogger may be found on https://github.com/mathibot/Datalogger

The tested appliances may be set into different categories based on their characteristics. From the consumer point-of-view, the decisive characteristic is the impedance of the appliance as it affects the power factor. Using this criterion, the following categories are defined:

1) Resistive Loads
- Incandescent Lightbulb
- Rice Cooker
- Electric Kettle

2) Switched-Mode Power Supplies
- Mobile Charger
- Television Power Supply

3) Other Lighting Loads
- CFL Lightbulb2
- LED Lightbulb3

In order to ensure statistical significance in the experiments, a number of identical appliances are studied. In the case of lightbulbs, three bulbs of each brand and type are tested. Also in case of the mobile chargers, three units of both types are tested. For charging, three identical battery banks are used.

Only one electric kettle is tested, but in the case of televisions, two different types are considered; an old CRT tv and a modern LED tv. Two rice cookers of different power ratings (300W and 700W) are studied.

1) Testing Setup: The testing of appliances is carried out by changing voltage and frequency independently. Thus, when altering the voltage level, the frequency is kept constant and vice versa. In both cases, an isolation transformer is used to keep the voltage at the desired level. Figure 3 shows a block diagramme of the test bench.

When altering the frequency, a frequency inverter is utilised. However, the output of the inverter is a square wave, and thus an unrealistic input for the tested appliances. For this reason, the inverter is connected to a synchronous motor that then drives an asynchronous generator. The generator provides a nearly sinusoidal output that is used to power the tested loads.

Results

Power Quality

The on-site measurements show that the off-grid power quality is very low compared to that of the on-grid reference locations. Substantial deviations in voltage and frequency are recorded in both directions, with a strong tendency to be lower than their nominal value. [1] [2]

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[1] CFL bulbs actually contain some power-electronics circuitry and a filter capacitor that makes it appear a capacitive load in the circuit.

[2] LED's show a constant voltage drop across a line but their behaviour with changing voltage is higly nonlinear and therefore they belong to their own category.

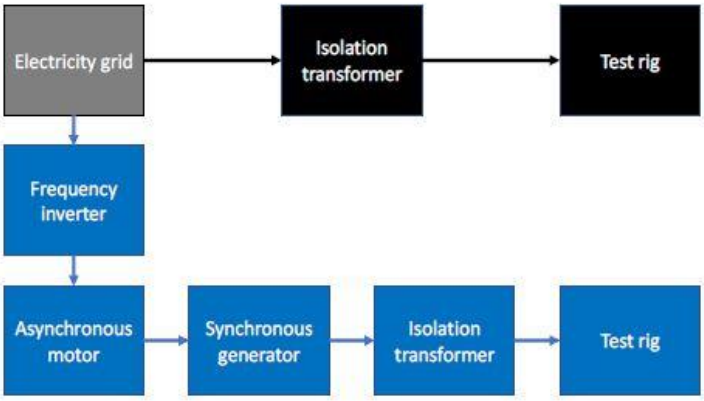

Figure 3. *Block diagramme of isolated voltage (black) and frequency (blue) experiment setup. The electricity grid (grey) provides the needed power in both experiments.*

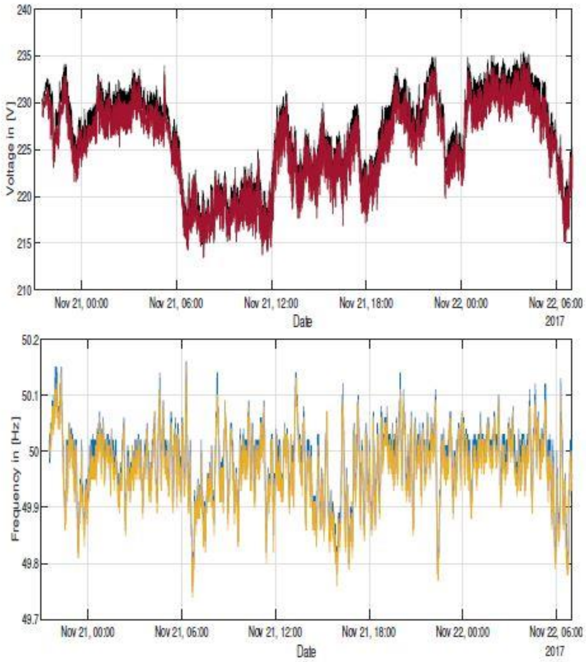

Figure 4. *Voltage and frequency measured with the self-made datalogger (black and blue) and a commercial multimeter (red and yellow).*

1) Validation of Self-Made Datalogger: The self-made lowcost datalogger introduced in section II-A is validated by comparing its measurements with those obtained with a high-tech multimeter. The comparison is visible in Figure 4. As the devices show essentially the same accuracy in both measurements, the low-cost datalogger is proven a viable alternative to expensive commercial measurement equipment. Thus, the rest of the measurements shown in this chapter are, where applicable, conducted with the self-made datalogger.

2) Voltage and Frequency: Figures 5 and 6 show the results for voltage and frequency in the on-grid reference sites (Munich and Kathmandu). Clearly, the power quality in Munich is very good. The voltage behaves in a stable manner, staying within 12 V of the nominal value over the whole measurement period. Further, no interruptions in power supply are detected. The frequency looks extremely stable around the nominal frequency of 50 Hz. It fluctuates within a mere 0.30 Hz interval along the course of the recording. For the most part, the frequency stays within 0.05 Hz of the nominal frequency, which is a clear indicator of good power quality. Compared to Munich, the results from Kathmandu show more instability within the grid, although the voltage is held in the desired range to a certain extent. Apart from five short power outages over the course of the measurement, the voltage stays in the 200 V to 250 V interval. Similarly, the frequency stays around the nominal value of 50 Hz for most of the time. Still, even short power outages may lead to problems where constant power supply in essential.

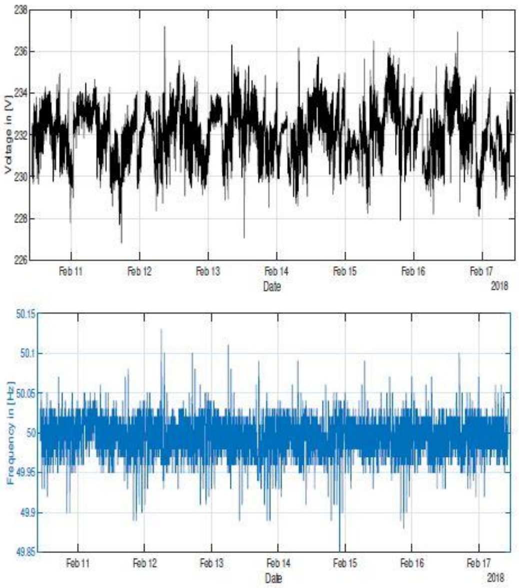

Figure 5. *Voltage and frequency fluctuations in the German national grid in Munich, over a period of one week.*

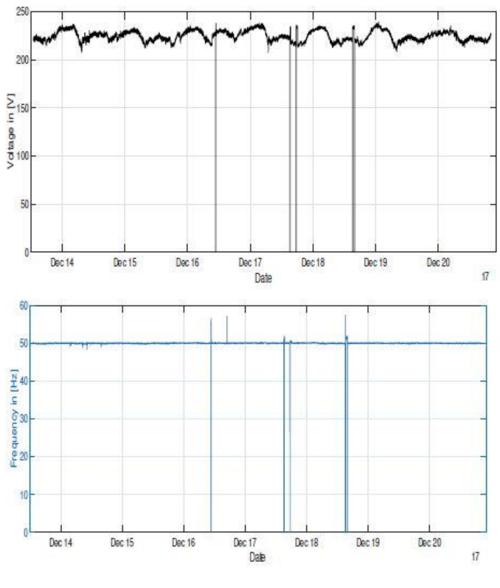

Figure 6. *Voltage and frequency fluctuations in the off-grid power system of Chame over a period of one week.*

Figures 7 and 8 display the voltage and frequency measurements from Chame and the Lophelling Boarding School, respectively. Substantial grid instability is seen at both locations with frequent and sustained power outages. These interruptions of the power supply are almost a daily occurence and last from a few minutes to several hours. In the case of LBS, the last interruption takes over 24 hours.

In both off-grid scenarios, voltage and frequency deviate wildly from the nominal values. Deviations to lower values are far more frequent than peaks, even though the latter also occur. In Chame, the voltage ranges from 80 to about 240 Volts, and the frequency is anywhere between 25 to 70 Hz, neglecting the power outages. At LBS, voltages as low as 50 Volts are measured, accompanied by a frequency ranging from 30 to 70 Hz.

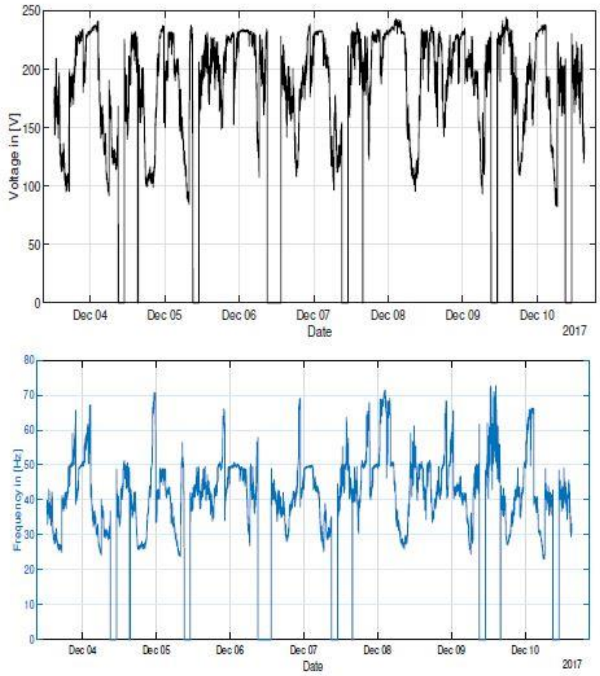

Figure 7. *Voltage and frequency fluctuations in the off-grid power system of Chame over a period of one week.*

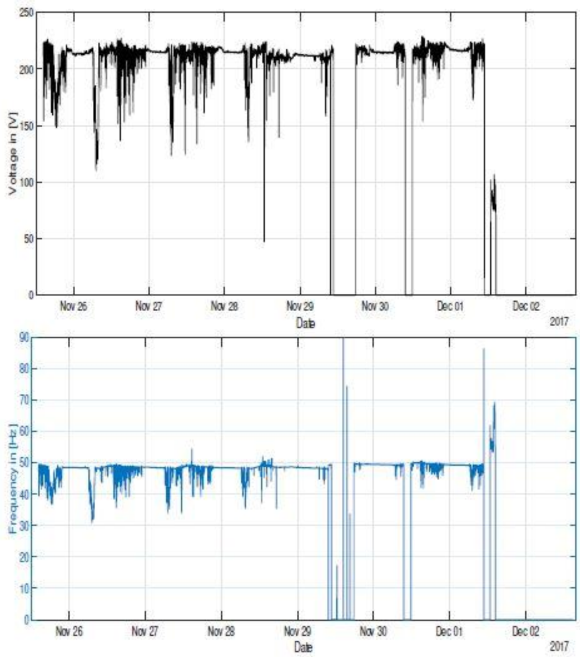

Figure 8. *Voltage and frequency fluctuations in the off-grid power system of LBS over a period of one week.*

3) Sinewave Form: Despite the substantial deviations in voltage and frequency, the off-grid locations show an almost ideal sinewave form. Interestingly enough, by far the worst sinewave is seen in Munich, most likely due to the high number of power electronic components connected to the German main grid. Figure 9 displays the results. In Munich, the voltage signal is not as smooth as the ideal sinewave and it shows oscillations of higher harmonic order within the fundamental.

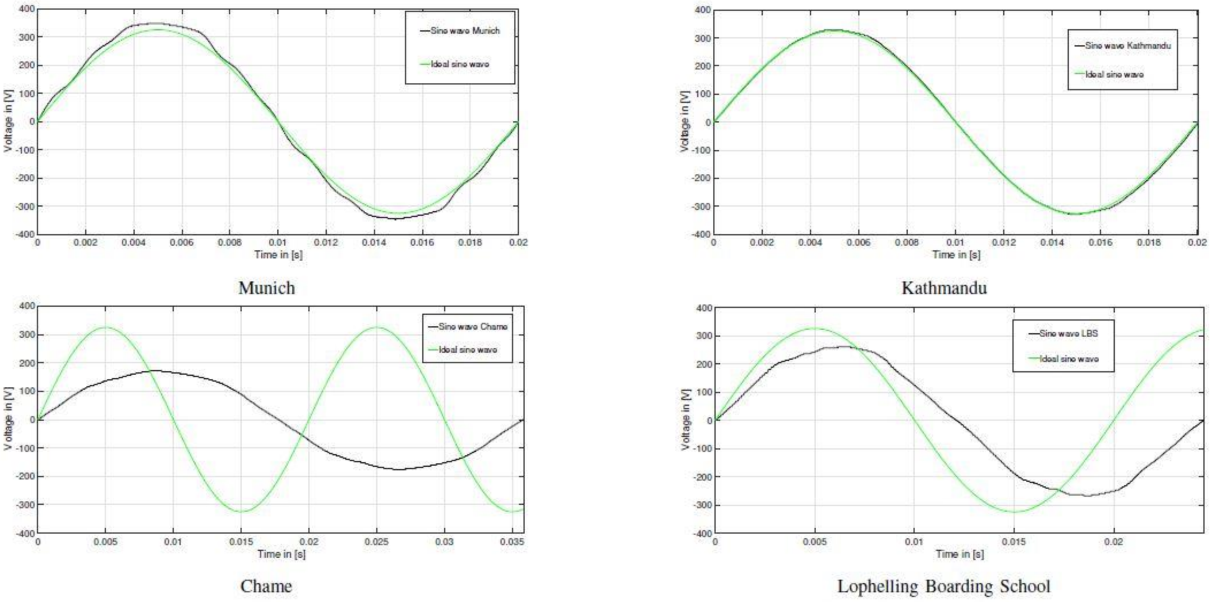

Figure 9. *Sinewave form at all measurement locations compared to the reference wave of 50Hz.*

Experiments on Appliances

In this part of the study, experiments with deviations between 50 and 110 per cent of the nominal voltage are conducted in 5-per cent steps for most of the appliances. If the tested unit stops working at a certain voltage, further voltage deviations in that specific direction are not to be performed as the appliance presumably either does not have enough power to function, or has failed. Selected loads will be exposed to more extreme levels of deviation.

Frequency deviations are tested from 42.5 Hz up to 65 Hz. As the supply voltage generated by the synchronous generator reduces with decreasing frequency and the isolation transformer has a limit for boosting up the voltage, the setup for frequency deviation does not allow for more extreme deviations in the negative direction. Seeing that the sinewave form is almost ideal in the off-grid systems visited, no tests with varying levels of distorsion are conducted.

Both quantities are studied independently, keeping one constant whilst varying the other. Depending on the tested appliance, various input and output quantities are measured. Input power, power factor and THD[1] are determined for all devices, and appliance-specific quantities include illuminance for lighting sources, time taken to boil water for the electric kettle and rice cookers, and output voltage and power for the power supplies (mobile charger and tv).

The illuminance is measured by placing a given lightbulb inside a box (approximately 25cmx15cmx15cm) with a sensor pointed straight at the light source. Hence the illuminance values presented in the following chapter are not directly comparable with universal lighting recommendations for rooms.

[1] Total harmonic distorsion

1) Resistive Loads: Due to the similar characteristics of all resistive loads, only results for the incandescent lightbulb and one type of cooking device (300W rice cooker) are displayed. Unsurprisingly, in the case of resistive load, the power factor stays constant at 1, as there are no inductive or capacitive components in the circuit. Similarly, the THD of the current is minimal at 1.3 per cent, and originating from the German main grid itself, rather than the tested appliance.

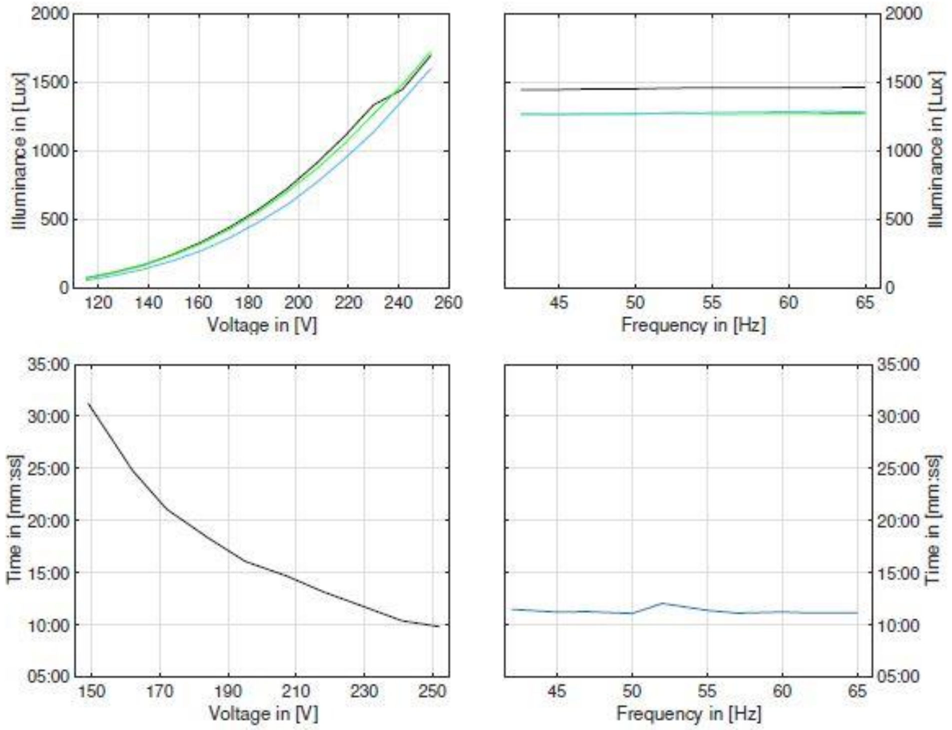

***Figure 10**. Above: Illuminance of incandescent bulbs. Below: Time for water to boil in rice cooker.*

As seen in Figure 10, the illuminance of incandescent bulbs drops in a linear fashion with decreasing voltage, resulting in direct decline of comfort from the point of view of the consumer. Flickering lights are irritating and may cause headaches and problems in concentration. The three lines seen in the image correspond to three different bulbs of the same brand.

The lower image in Figure 10 shows how the time needed to boil water with a rice cooker is also linearly dependent of the grid voltage. The 300 W rice cooker experiments are conducted with 500 ml of water and started at the exact same temperature of 27 centigrades for every voltage/frequency level.

With the nominal RMS voltage of 230 V, the time to boil is about 12 minutes, but rises to over 30 minutes when the voltage drops to 150 V. Clearly this could affect the acceptance of electric clean cooking methods in rural households. If cooking with electricity takes longer than with traditional biomass, people will be less eager to adopt the former.

The frequency of the grid has no influence on either the illuminance of resistive lighting or the boiling time of water with resisitive cooking equipment.

2) Switched-Mode Power Supplies: In this category, two types of tv sets (CRT and LED) and two types of mobile charger are tested. Due to the similarity of the results for the tv's, only those of the LED tv are shown in Figure 11. For both tv's, their input power increases slightly with increasing grid voltage, and the power factor decreases. The output power of the tv's power supply is constant irrespective of voltage and frequency. The THD of the input current also increases with higher voltage, from 133 to 156 per cent for 104 and 253 Volts, respectively, for the LED tv. For varying frequency, no such systematic change is detected.

In the central image of Figure 11, the power output of a local brand of mobile charger is displayed. All three units failed to maintain a constant power output with decreasing voltage, and simlarly to the tested tv's, both the input power and THD grow with rising voltage level. The power factor tends to decrease when the voltage increases, ranging from 0.34 to 0.48.

The high-end mobile charger of a multinational brand is capable of providing constant power output despite the changes in voltage or frequency. The THD and power factor are affected in the same manner as before. Again, frequency does not seem to affect the output power at all.

3) Other Lighting Loads: In this section, LED and CFL lightbulbs are tested. Looking at Figure 12, it is clear that the LED bulbs effectively provide constant illumination irrespective of the grid voltage. The illuminance vaires minimally compared to the incandescent bulbs shown at the top of Figure 10 and the CFL lights. From the point of view of lighting, frequency again seems unproblematic. For LED lights, a slight decrease in power factor is detected with increasing voltage. At the same time, the THD value rises. Input power, however, stays more or less constant, ranging from 4.5 to 4.6 W.

The CFL lightbulb shows different behaviour. As with incandescent bulbs, the illuminance drops linearly with decreasing voltage. The input power falls from 14.0 W at 253 V to 6.8 W at 115 V, and the input current stays constant at 0.09 A. Just as before, the power factor decreases with increasing voltage and the THD rises.

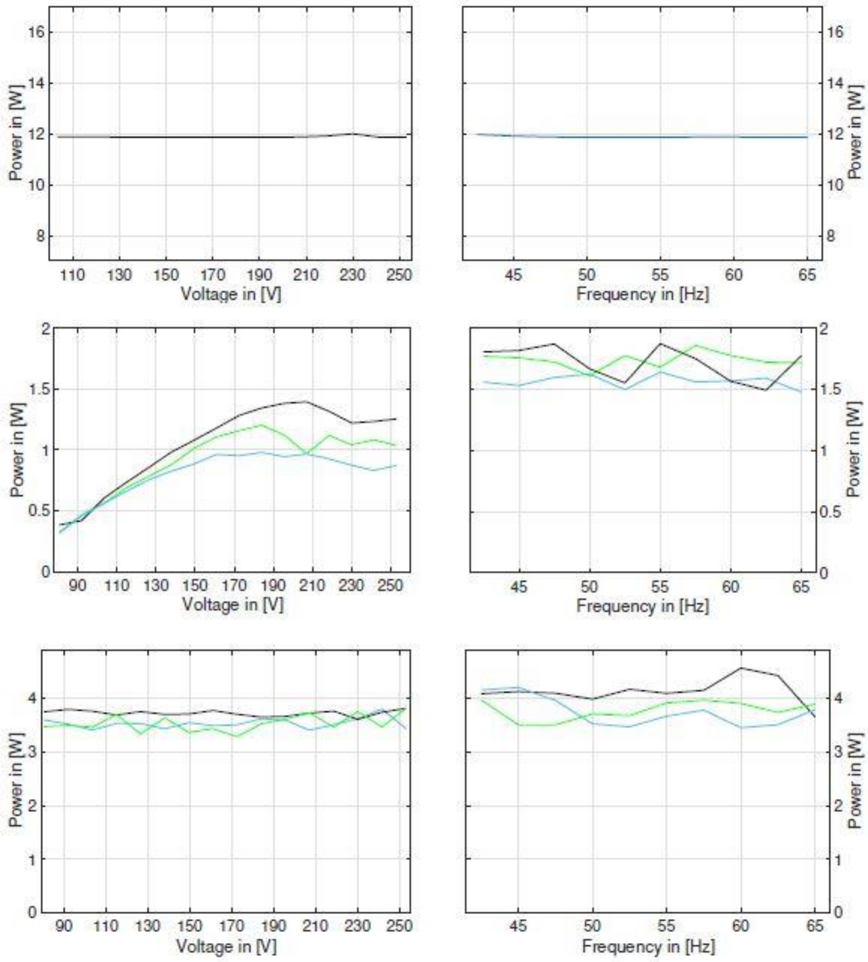

Figure 11. *Above: Output power of power supply of LED tv. Centre: Output power of local brand of mobile charger. Below: Output power of high-end mobile charger.*

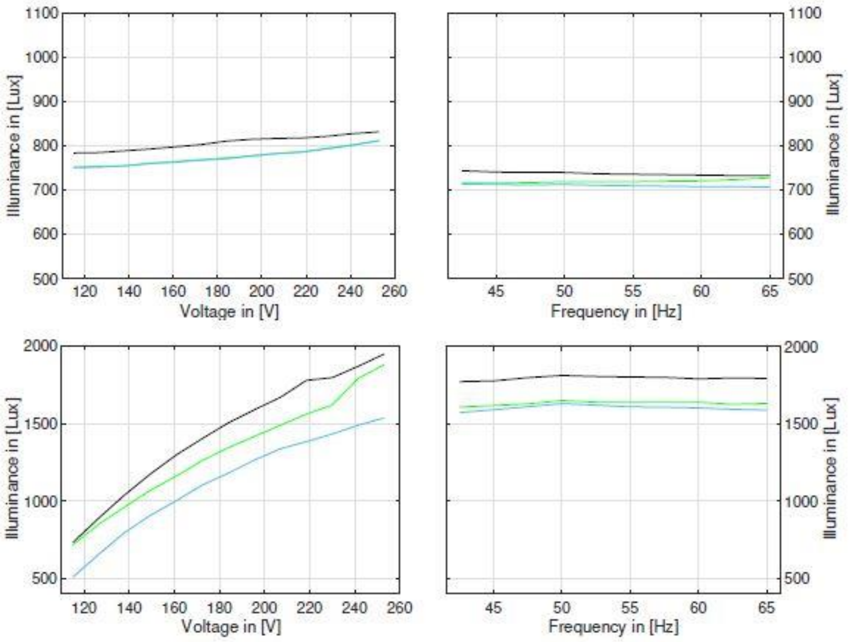

Figure 12. *Above: Illuminance of LED bulbs. Below: Illuminance of CFL bulbs as before, the power factor decreases with increasing voltage and the THD rises.*

Discussion

Power quality is important especially from the consumer point of view as the lack of it may dissuade people in low income groups from adopting connections. Continuing to use traditional fuels is detrimental to health and insufficient to boost the local economy. The lack of access to modern energy services is one of the major obstacles to socio-economic development [10].

This study shows that the status quo of power quality in the existing off-grid installations in Nepal is dreadful. The frequent power outages alone are enough to discourage locals from opting for electricity services but the effect of fluctuating voltage and frequency on household appliances may cause a further disincentive to pay for energy.

The experiments conducted on common electrical appliances show clearly that frequency does not affect the functionality of the most frequently used devices. The fluctuating voltage, however, causes resistive appliances such as incandescent bulbs and cooking devices to underperform, decreasing consumer comfort and taking time from other activities. Without improving the reliability of the power supply, this type of appliances cannot be adequately used.

Switching-mode power supplies and LED-based appliances show little deterioration in their functionality even with varying voltage level. Thus they are a very good option in existing off-grid installations with no sophisticated control system in place. Further, communities receiving electricity for the first time usually underline the importance of having access to lighting and television [8]. In such scenarios, if cost is a major concern, a microgrid could be constructed even without an efficient control system as long as only LED-based lightbulbs and tv sets are used. The added advantage of such an approach is that LED loads need a fraction of the power used by more conventional appliances. Incandescent lightbulbs, for example, reach ratings up to 100 W whereas LED bulbs are usually in the range of 3 to 9 W. Similarly, the LED tv tested as part of this study only draws around 12 W compared to the 35 W needed by the CRT tv. Adopting LED appliances, consumers could significantly decrease their power consumption, or alternatively connect far more loads than before.

On the other hand, it is evident that power outages are always undesirable and even the most rudimentry power management systems should aim to eliminate them to improve end-user satisfaction. Additionally, as soon as the need of a rural household grows, power quality will become an issue beyond power disruptions only. Especially if cooking devices are acquired, an intelligent control system becomes more and more important.

The results presented in this report are by no means an all-encompassing take on the subject of power quality, and further research is needed to investigate the relationship between supply reliability and household adoption, as well as the effects of bad power quality on electrical appliances. The major shortcomings of this particular study are the following:

Firstly, the experiments only consider voltage and frequency fluctuations independent of each other. However, in practice, these phenomena occur simultaneously. What is more, here the tested appliances are powered by the national grid, without any limitations. In practical off-grid systems, the voltage and frequency oscillations are accompanied by a drop in available power. Including these characteristics in the test setup would lead to more realistic testing conditions.

Secondly, No long-term effects of power quality are studied within the scope of this research. Such knowledge would be essential before designing off-grid power systems with no or little voltage and frequency control.

Further research into the topic of power quality is vital in order to design robust, low-cost control solutions for off-grid power systems for rural electrification. Consumer satisfaction should be the central design requirement to guarantee the sustainability of such projects.

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University – Industry interaction: Cuban Study Case at the Electric Sector

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Abstract

Internationally there is an extensive literature on university-industry linkage, and its impact on the innovative performance. The empiric evidence obtained through diverse regions of the planet suggests the multiplicity in the channels of interaction through which the knowledge is transferred.

In the Cuban economy, the studies about this linkage have received little attention. This paper focuses on the experiences of linking the electric sector. The objective is to analyse the nature of collaboration between one Research Centre (CIPEL) and Electrical Union (Unión Eléctrica). This research has been directed to reveal: Which are the major mechanisms in the interaction between CIPEL and the Electrical Union? Which are the similarities and differences with the same mechanisms reported by Latin American countries? The results revealed that the interaction channels differ from their importance and frequency according to the actors' perception of both sides and that some similarities and differences exist between the Latin American countries.

Introduction and Background

The interaction or linkage between Universities and Industry in the productive sector has become, in modern times, an important strategic need for economic and technological development, including the cultural field, for any country, with increasingly importance and impact on developing countries. One of the point of view around this interaction is the role that universities should play in assisting industry in capacity building.

The creation of collaborative spaces, where University and Industry can get mutual benefits, is one of the ways that should express their interrelationship. Mainly is expected that the University supplies results related to their substantive processes (formation and training of professionals, the development of applied research, extension and a set of technical services). In turn, the Industry demands professionals, invested in research and offer compensation for extension work and services provided by the Universities. All this would contribute to generate and improve products and processes, with scientific and technological knowledge.

The empirical evidence obtained through different regions of the planet suggests the multiplicity in the channels of interaction through which knowledge is transferred (Albuquerque, E. et al, 2015; Arza, V. et al, 2015); in particular, the transfer of knowledge between universities and research centres with companies in the productive sector (Arza, V. et al, 2015).

Some authors consider the opening of science, patents, human resources, research and R & D projects sets, as well as work networks as the most important channels (Cohen, W., Nelson, R. & Walsh, J. P., 2002). Other authors consider the creation of new physical facilities, the development of consultancies, contractual relations, training, meetings and Scientific conferences as the base to promote linking processes between universities and companies (D'Este P. & Perkmann M., 2011).

Dutrénit et al (2010) suggest classifying the interaction channels in four (4) groups: (1) traditional, from academia to industry based on the conventional roles of academia, teaching and research. (2) Services, from academia to industry, through a contractual relationship (consulting, testing, training). (3) Commercial, from academia to industry, through the products made by the academy with commercial value (patents, technology licensing, incubators of knowledge). (4) Bidirectional, knowledge flows in both directions, expressed through the development of joint R & D projects, participation in networks, etc.

A close link between these sectors allows obtaining benefits to both actors, such as:

- Exchange of knowledge, theories and applications, increase of contacts between them and acquisition of new perspectives for the application of the knowledge generated by the academy in industry and the productive sector (Arza, V. et al, 2015);
- increased productivity and innovation with positive impacts on productive development (Rosenberg, N. & Nelson, R.,1994);
- increase in absorption capacity in the business sector (industry), to explore external knowledge (universities and research centres), supporting the exploitation of this knowledge with financing (Filgueiras, M.L. et al, 2016).

As a result of a study conducted in four Latin American countries (Argentina, Brazil, Costa Rica and Mexico), a country from Africa (Nigeria) and three from Asia (India, Korea and Malaysia), some elements of interest were extracted (Arza, V. et al, 2015):

- It was confirmed that channels such as the training of human resources, the creation of new facilities, the consultancy, joint research, research contracts, training, technical meetings and conferences, are more important forms of interaction than patents;
- the actors of the knowledge transfer process have different perceptions about the importance of the different channels;
- commercial channels have negative effects on the intellectual benefits for researchers and do not they have positive effects on the profits obtained by the companies.

In Cuba, the link between the university and the business sector (U-I) has been little studied. Literature has focused on case studies, mostly on the contribution of universities to local development, with few jobs on the productive sector; which also suggests that the U-I linkage in low-medium intensity sectors technology has not reached adequate levels (Lage, A., 2015; Morales, M. & Herrera, Y., 2015). But, from some experiences developed in recent years, it is possible to identify a set of barriers to which the U-I link has been confronted, which must be overcome in order to achieve a greater contribution to socio-economic development (Nuñez, J., 2013; Núñez, J & Montalvo L. F., 2015).

The present work focuses on the experiences of linkage in the electricity sector. The objective is to analyse the nature of collaboration between one Research Centre (the CIPEL) and Electrical Union, which represents Cuban electric industry. This research has been directed by the following questions: What are the main mechanisms that act on the link between the CIPEL and the Electrical Connection? What are the similarities and differences with the mechanisms reported on this interaction in Latin American countries? Do is possible to draw lessons that can contribute to the formulation of the policy and socio-economic development of the country, with the results of the work?

University-Industry interactions could contribute to strengthen the external and internal interaction into an intensive learning process, helping to create and develop absorptive capacity (ACAP) along the innovative technology transfer processes at the productive base organizations. Cuban electric sector is working in this address to introduce RES technologies (Filgueiras, 2016). De Paula Guedes et al (2016) developed a model to evaluate ACAP which consider the four dimension established by Zahra & George (2002): exploration, acquisition, assimilation and transformation, in figure 1. To show the results of this work we have assumed this model and the survey to apply it.

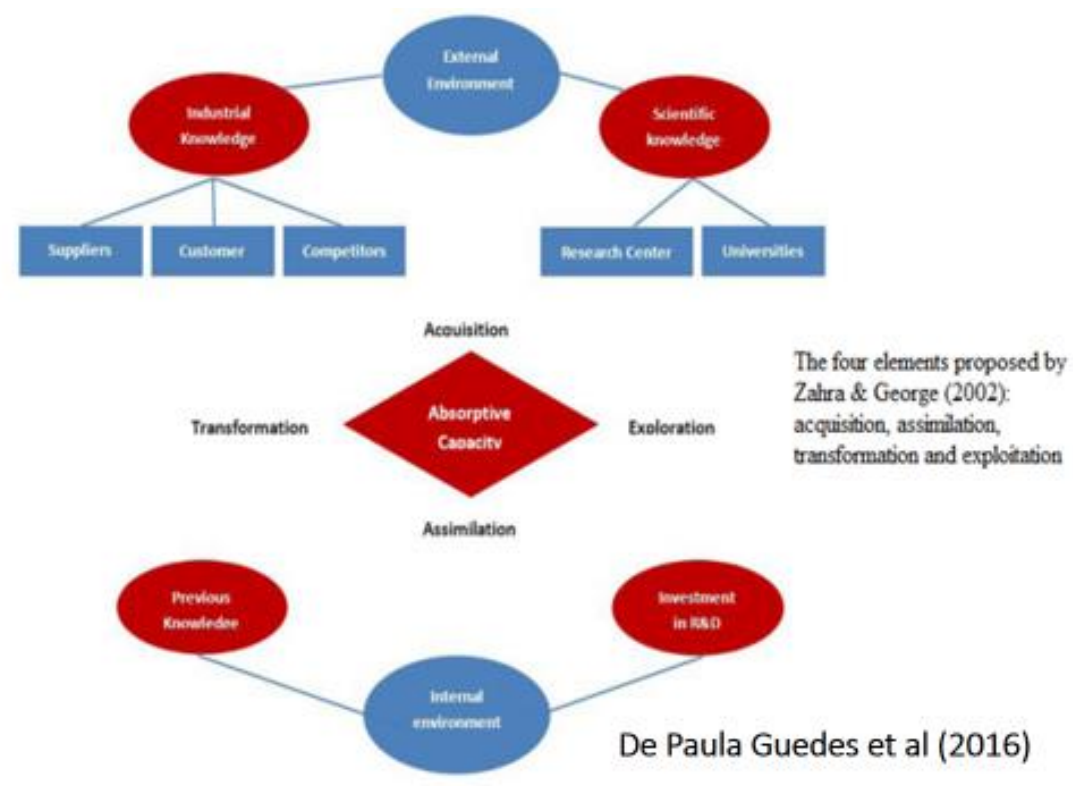

Figure 1.*The model of ACAP by De Paula Guedes et al (2016).*

Material and Methods

The methodology is based on two surveys of 23 managers and specialists of the Cuban electric sector and 15 professors/researchers from the University. They have been characterized by a high link with the electric sector, providing solutions to the problems that arise there for more than 20 years of working together. The first survey explores the perception of both actors on the channels of interactions, which can be grouped into the four channels suggested by Dutrénit et al (2010), which are compared with the perception about the same channels that has been found from Latin American countries.

The questionnaire covers a group of 22 identified ways to transfer knowledge between universities and businesses which can then be grouped into the proposal given by Dutrénit et al (2010), following the proposal of the mentioned authors, but incorporate adaptations to the Cuban case, and to the electric sector in particular:

- In the traditional channel, was incorporated "students working in job training", and differentiated between" university graduates as employees "at the masters and specialties, with respect to doctorate level;
- in the commercial, was incorporated "university by products (as sources of knowledge);
- in the service sector, "personal contact of the membership of non-governmental organizations of Cuban professionals such as the National Association of Economists of Cuba (ANEC), the National Union of Construction Engineers of Cuba (UNAICC), the National Association of Innovators and Rationalisers (ANIR), among others";
- in the bidirectional ,"collective projects in the context of the structure of the National Program of Science and Technology (PNCT)".

The changes introduced in all the channels maintain the essence of the same, that is, the motivation and directionality of the flows of knowledge. The analysis of the survey was carried out with descriptive statistics, in two parts. The first part consisted of identifying the importance and frequency of each of the modes of transferring U-I knowledge, analysing separately the perception of the academy (CIPEL) and the company (UNE). The second part consisted of comparing different modes of ties identified in Cuba, with experiences in other Latin American countries. This analysis allows identify the similarities and differences regarding U-I linkage modes in different environments.

The case study focuses on the nature of the linkage between Research Centre representing the Cuban Higher Education and Electrical Union representing the Cuban electric companies, and the evolution of the electrical sector and university facing the necessary challenges of Cuban development. The information obtained for the case study was ordered chronologically. The identification of the roles played was emphasized by CIPEL and UNE over time. This information also was analysed contextually, and it was observed how changes in the environment contributed to strengthen the interaction of these two agents over time.

We apply a second survey to know which is the level of absorptive capacity (ACAP) for both actors, related to the introduction of renewable energy technologies in Cuba: professors/researchers from the University (15) and twelve (20) managers and specialists of the Cuban electric sector who have to achieve the accelerated increase of renewable energies in the Cuban power system. The survey has been adapted based on the De Paula Guedes et al (2016) survey to evaluate the ACAP entailed to the Cuban conditions.

Results

A study about the evolution of industry and academy in the Cuban electricity sector shows that the features influencing the evolution of interaction between CIPEL–UNE have path dependence, due to its contingency and self-reinforcement nature. The University – Industry relationship, for this case, had specific initial conditions that were followed by a series of contingent events (external and internal) whose influence on the path enhancing the initial conditions and creating a virtuous cycle that favoured successful results (Filgueiras, M.L. Vilaragut, M. Castro, M & Díaz, R., 2017).

The Centre of Electrical Research and Testing (CIPEL) was officially created on December 17, 1987 with the merger of specialists from the two research centres that existed at that time addressed the issues of the electricity sector: one belonging to the Ministry of Higher Education (MES) and another belonging to the old Ministry of the Electrical Industry. CIPEL is the governing centre of the Electrical Engineering career within the MES. This centre has among its facilities the only laboratory of high voltage tests in the country that allows the evaluation of dielectric characteristics for any equipment and components, used in the National Electric System (SEN).

Since its foundation, CIPEL has responded to the different problems raised in the energy sector, in different agencies of the Cuban State, entities and companies in the productive and service sectors of the country. This response has been recognized in different ways by the organizations and institutions to which the results have been linked (Castro, M. & Vilaragut, M., 2012).

The scientific activity in the centre has boost the improvement and reconfiguration of the organizational structure. In recent years, the centre has adopted a structure by projects, with two research groups that serve the three fundamental lines of work: Distributed Generation, High Voltage and Industrial Applications. This work by projects has promote the increase of students linking to research, and it allows us to respond the requests from the productive sector and services, which mainly coming from the UNE and its companies. As a result, almost 97% of the diploma works are articulated with these projects. However, this experience of university-industry interaction has been little studied and the knowledge by the researchers and professors of CIPEL about the most successful channels is still limited.

The graphical results obtained on importance of knowledge transfer between institutions and frequency should be realized are showed in Figures 2–3.

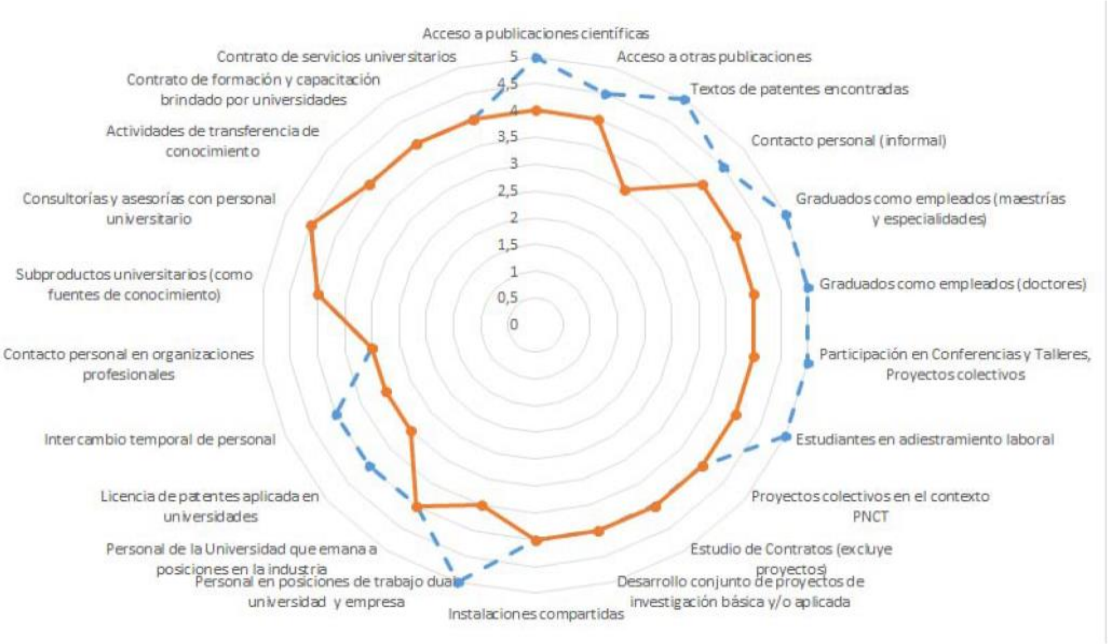

Figure 2. *Radar Diagram with the perception about the importance by type of mechanism of interaction University – Industry, according the survey applied. Source: self elaboration.*

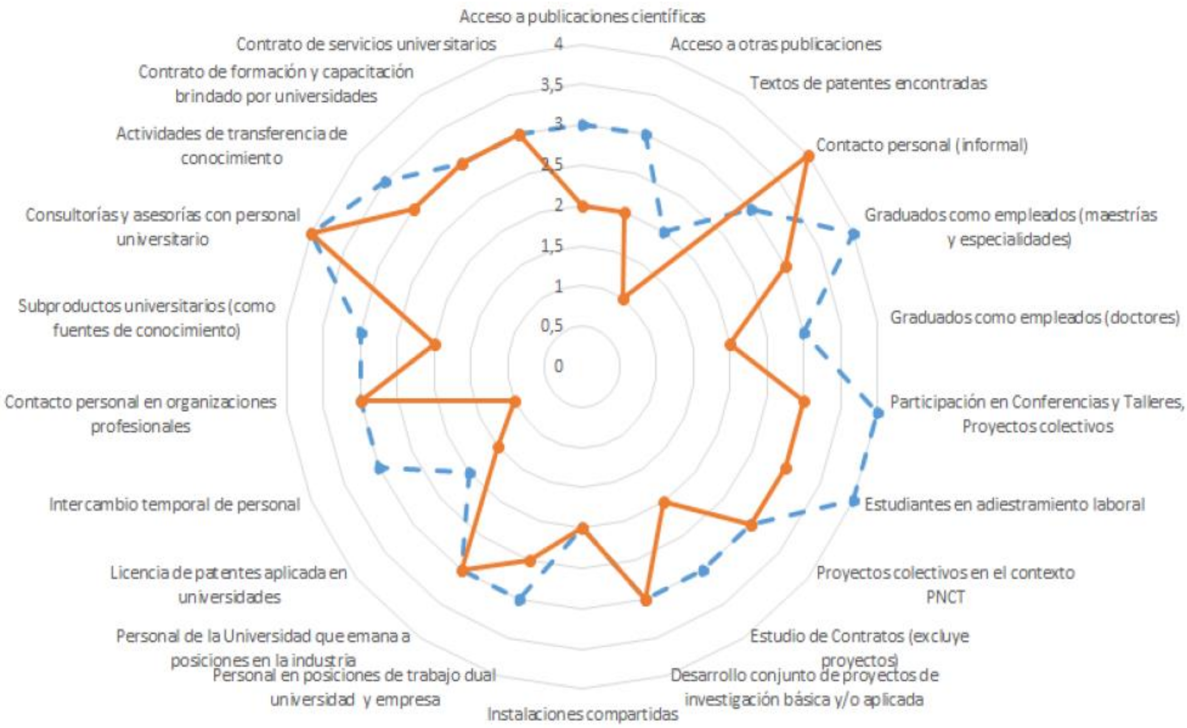

Figure 3. *Radar Diagram with the perception about the frecuency by type of mechanism of interaction University – Industry, according the survey applied. Source: self elaboration.*

Table 1. *Comparison of vision in academic sector on importance about links channels between University and Industry in the Cuban electricity sector with other four Latin-American countries. Source: Castro et al. (2017)*

Interaction manner	Channel	Cuba		Argentina*		Brasil*		Costa Rica*		México*	
R&D joint projects	Bidirectional	80,00	2	36,2	4	70,60	5	62,30	4	61,00	1
Contratcs		69,70	5	37,1	5	74,80	2	36,70	7	55,30	3
Patents	Comercial	65,00	6	10,1	12	42,90	11	8,10	15	30,60	11
Consulting and advisory	Services	75,00	3	78,7	1	52,10	9	49,00	6	50,10	4
Temporal staff interchange		63,89	7	12,4	11	53,10	8	-	-	-	-
Contact staff (informal)		61,54	8	44,9	2	66,00	6	82,60	1	57,70	2
Conferences and workshops	Traditional	70,83	4	43,8	3	74,30	3	73,10	3	48,60	6
College graduates as employees		83,33	1	29,2	7	58,30	7	26,70	10	34,30	9
Publication		50,00	9	24,7	8	74,90	1	74,5	2	30,1	12

Table 2. *Comparison of vision in industry sector on importance about links channels between University and Industry in the Cuban electricity sector with other four Latin-American countries. Source: Castro et al. (2017)*

Interaction manner	Channel	Cuba		Argentina*		Brasil*		Costa Rica*		México*	
R&D joint projects	Bidirectional	52,78	5	25,50	6	68,10	2	26,60	9	46,50	4
Contratcs		43,78	7	23,50	7	54,60	6	29,00	5	37,80	8
Patents	Comercial	35,86	9	15,00	10	33,10	10	16,90	12	33,50	10
Consulting and advisory	Services	55,41	3	26,60	5	52,10	7	29,00	6	40,30	7
Temporal staff interchange		38,99	8	10,20	12	32,80	12	24,20	11,00	25,20	12
Contact staff (informal)		57,14	2	51,00	1	61,30	4	57,30	1	41,90	6
Conferences and workshops	Traditional	54,39	4	45,90	3	61,00	5	50,80	2	48,90	2
College graduates as employees		59,61	1	26,90	4	62,90	3	41,10	4	48,90	3
Publication		48,05	6	47,30	2	69,60	1	41,10	3	45,30	5

The second survey was applied to know which is the level of absorptive capacity (ACAP) for both actors, related to the introduction of renewable energy technologies in Cuba showed that University has the higher level and the Cuban Electric sector could take benefit of this, as is showed in figure 4.

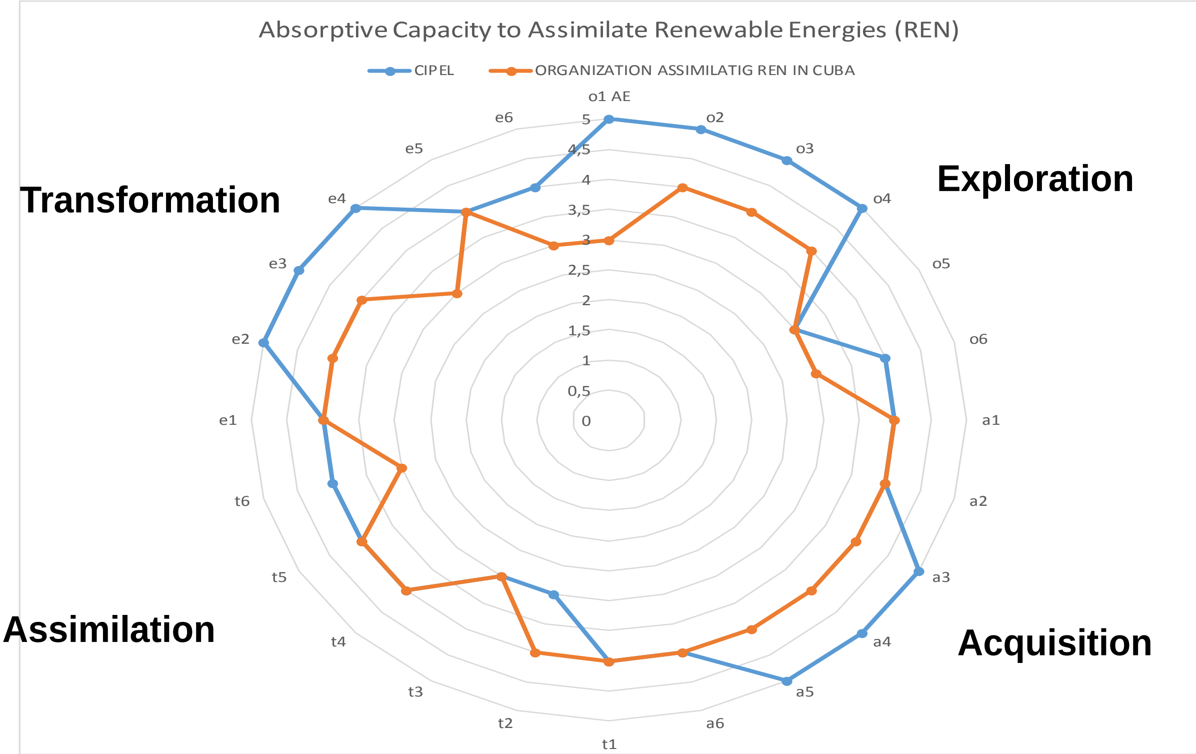

Figure 4. *Radar Diagram with the the result of the survey to evaluate the level of ACAP in organization assimilating REN in Cuba and in the CIPEL at University. Source: self elaboration.*

Discussion and Conclusions

It is possible to observe similar trends at academics and managers from UNE, demonstrated a similarity with the perception between managers of Cuban electric sector and the academics about the channels used and the importance of the knowledge transferred, at the figure 1. The value of the correlation coefficient r between both actors 0.98%. The managers consider about the frequency in that the interaction occurs, is still a low interaction and academics consider it is enough (Castro et al, 2017).

In Cuban case, the main channel recognised by the academics is the graduates recruiting to industry, while the linking way through the projects of I+D among the university and industry is considered in a second place. The same as in the other four Latin American countries, the investigators spread to assign a bigger importance to any channel comparatively with the representatives of the productive sector (Castro et al, 2017).

In Cuba, as in the four countries, researchers trend to assign higher importance to any channel than firms. Bekkers and Bodas-Freitas (2008) also found this result for other region. As it was found by Dutrénit and Arza (2010), the agreements across countries in the case of researchers are slightly weak (Table 1). In Brazil and in Costa Rica, researchers trend to prefer traditional channels (especially publications and conferences), while in Argentinean researchers prefer the service channel (consultancy) and in Mexico joint R&D. But, in all the countries, join R&D or contract research appear within the most important. In Cuban case the contractual college graduates by industries is the most important channel for academics, while R&D joins projects between University and Industry is the second.

Cohen et al. (2002) and D'Este and Fontana (2007) reported a relative importance of informal interactions through conferences or other type of informal information exchange. This result was also found for the four Latin-Americans countries analysed. However, in the case of Cuba, formality is more important for the researchers.

In relations with the importance for interactions and channels, at the industry sector, Cuban industry sector have more positive perception than other countries at similar level obtained in Brazil as it showed in Table 2. For this sector, the channel of college graduates as employees is the most important too, while in second place informal personal contact is considered. This last channel is important for Argentine and Costa Rica too; however the patents are low relevant channels for Latin-America and the lowest relevant in the Cuban case for industry. To contract Universities to develop researching for industry is has not been consider important for this last sector as it is showing.

These similarities and differences, in the Cuban case at electricity sector, could indicate that the relationship between the university and academic research with UNE is different. These results have high matching criteria from relationship experiences maintained for more than 40 years, and where the relationship grounded between the current CIPEL and national and regional companies of UNE has been one of the key elements.

The results of ACAP level evaluation for both actors, showed that University is best prepared to absorb this technologies in exploration, acquisition and transformation dimensions, but is at the same level in assimilation. This is natural because to assimilate you need to acquire, and this depends of the others sectors.

Otherwise, the linkage developed by the CIPEL with Cuban electric sector could contribute to strengthen the external and internal interaction helping to develop ACAP along the innovative technology transfer processes with the introduction of RES technologies in Cuba, as in the pass this centre help UNE in other process of technology transfer that occur before. And, all these experiences could help to the decision makers formulating the policy, in order to achieve de main objective of Cuban electrical sector: change the energy matrix by a new one with a high penetration of renewable energies.

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What Does the Future Hold? Study on the Perceptions of the Opportunities and Challenges for the Finnish Energy Sector

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Abstract

As the energy sector undergoes a major shift, the managers and decision-makers of different organizations struggle to make sense of the changing regulations, norms and disrupting market boundaries. As an explorative research, this study examines the managers' and decision-makers' perceptions of the driving forces of the energy sector change: the technical, economic and business factors that empower and facilitate the energy transition, and those that hinder or slow down such transition. The key aim of the study is to understand the challenges and opportunities in the Finnish energy sector renewal towards more sustainable development through the lens of managerial cognition. This study followed the Gioia method for analysis of interviews of 26 decision makers in business and public organizations operating in energy sector in Finland. The outcomes of the study revealed that the respondents perceive the future of the energy sector controversial representing societally divergent but centralized around a few technologies and business platforms. However, the industry boundaries of energy sector are still emerging.

Introduction

Industrial change is not an immediate event, but rather a process that may take number of years, and both emerging quickly and completely, or slowly and incompletely, and therefore difficult to recognize and envision (Wessel & Christensen, 2012). Often fast-changing industries meet rapid changes in their product and process technologies, and firms' competitiveness is limited by their ability for strategic awareness (Anderson & Tushman, 1990; Karim et al., 2016). In contrast, stable industries may provide relatively predictive business environment to operate and gain sustainable competitive advantages by continuously developing firm's competencies and operations (Brown & Eisenhardt, 1997). When operating in a rapidly developing business environment, such as the energy sector, managers' cognitive limits become important factors in organizational decision-making and development (Bogner & Barr, 2000; Nadkarni & Narayanan, 2007a).

Earlier research on managerial cognition has addressed interest in capturing and understanding managerial beliefs about the competitive industry boundaries and how they are shaped by collective actions (e.g. (Walsh, 1995; Hodgkinson, 1997; Kaplan, 2011). Individual managers and organizations do not pursue action against environmental stimuli, per se. They respond to such issues that meet their previous experience (Weick, 1979) and are advocated by internal or external meaningful stakeholders, e.g., sustainability directives set by the EU commission (Bundy et al., 2013). Managers, who are intermediaries between their organization and the complex business environment, continuously make sense of the environmental stimuli focusing on issues that are perceived as having a potential impact on the organization and their stakeholders and that resonate the goals of the organization (Martignoni et al., 2016). If beliefs of competition within an industry are equally shared among the firms, there would be no differences between firms' actions (Spender, 1989). Depending on the manager's and firm's history, they perceive and respond differently changes in the environment, for example, managers of Polaroid failed to perceive the progress of digitalization, and did not succeed to renew their strategies into evolving new business conditions (Tripsas & Gavetti, 2000). Nevertheless, if beliefs of competition vary between the managers within an industry, firms engage into different actions and might gain competitive advantage or underperform among their competitors. In this regard, the sharedness and similarities in beliefs of the competitive environment among the managers across the firms are important for understanding the development of the industry.

The energy sector is under transformation due to fast developing renewable energy technologies and digitalization and has a great influence on a broad range of firms from different industry sectors, e.g. manufacturing, construction, and chemistry offering solutions using non-renewable resources less than conventional solutions (Pernick & Wilder, 2007). The competitive boundaries are searching for their forms, the networks of the industry members are unstructured, and consequently there may not yet been developed well-established collective strategy frames among the industry members (Georgeson et al., 2014; Giudici et al., 2017). In addition, the industry has the peculiar nature by serving "public good", and requires tailored incentives and regulations to simulate the development of the industry and to become a coherent network of actors (Guidici et al., 2017). Therefore, the energy sector a fertile context for managerial cognition research, especially studies on industry change.

In our exploratory study, the aim is to examine the perceptions of the decision-makers among the energy sector actors in Finland to recognize shared beliefs of the future development of the industry. The article is organized as follows. Firstly, the study opens the nature of the managerial cognition by discussing how managers interpret the current environment and perceive the development of that particular environment from the social cognition perspective. Secondly, we outline our research method and report the analyses and results. Finally, we discuss the results, theoretical and managerial implications of this study, and suggest the future research avenues.

Theoretical Background

The cognitive approach in strategy research has its roots in Simon's (Simon, 1959) notions on the capacity of human cognition relative to the requirements of information environments in which the individuals perform. On a collective level, shared cognition refers to a system of fundamental strategic cause-effect beliefs and priorities that are embedded in an organization's routines and processes and in wider stakeholder network that shape the strategy implementation to meet the changing environmental requirements (Stubbart, 1989; Nadkarni & Narayanan, 2007b). Cognitions of managers develop in a continuous interplay of a context wherein persons such as a group, organization, or industry act and the previous experiences that guide their cognitive orientation into predetermined goals (Martignoni et al., 2016). In each business context, a large number of cognitive attributes constrains managers' interpretations, which creates cognitive diversity among members of that particular context (Mohammed et al., 2014). Managers also have different experiences, knowledge bases, motivations, and social contexts, which shape their interpretative abilities (Kaplan, 2008). Within these boundaries, managers develop subjective interpretations of their environment that affect an organization's strategic priorities and actions (Ocasio, 1997, 2011).

Despite of the individual origin of cognitions, they are always situated and influenced by other people embedded with commonly accepted values, norms, and beliefs of that particular social environment (Levine et al., 1993). Social cognitive view in strategy assumes that the firms in an industry interact with each other, and during that interaction firms' members perform creating collective beliefs about a particular industry development, boundaries and related competition (Porac et al., 1989). These collective beliefs then shape the character of the industry by giving frames for the firms' actions (Nadkarni & Narayanan, 2007a; Cattani et al., 2017). Nadkarni and Narayanan (2007a) claim that central to the collectively constructed cognition is that the basic understanding about the competitive environment and firms' roles they are holding in are available and shared across the industry members. Besides the commonly shared beliefs about the boundaries of the competitive environment, the collectively constructed cognition includes differentiating 'peripheral' knowledge that managers and firms strive for and develop to gain competitive advantage over their competitors that in turn, creates heterogeneity in firms' actions and promotes industry changes (Huff, 1982; Nadkarni & Narayanan, 2007a). Because collective strategy frames develop over a long period of time around a core set of beliefs shared across the industry, incumbent firms are those that have been learning from each other's actions and potentially share more common beliefs of the environment, show more unity in their strategies, and carry out more collective actions compared to new venture firms (Kiss & Barr, 2015). Nadkarni and Narayanan (2007b) found that changes in the incumbent firms' strategy frames led changes in collective behaviour across the firms in that particular industry, which in turn, generated changes in industry level assumptions and network activities perpetuating the industry transition. They further suggested that the firms facing changes construct and experiment enacting assumptions of the environment through which the firms search for new ideas and strive to shape the environment for their needs beyond the existing industry boundaries. Kaplan (2008) found similar effects when studying the firms' responses to the fiber-optic revolution in communication industry.

Thus, organizations interacting within the same industry begin to share the beliefs on how the industry operates leading managers to cognitive convergence at the industry level and finally similarities in their future actions (Bogner & Barr, 2000). Such shared belief structures are cognitive templates that reflect how managers conceptualize the environment and how they categorize the strategic issues within it (Daft & Weick, 1984). Over time, shared cognitions store the strategic repeatable behavioral patterns of the organization that channel managers' attention to the issues that are relevant to the strategy and goals of the organization (von Krogh et al., 2000). Despite the relatively intensive research, there is still a need for studies on differences in organizational cognitive structures and their role in managers' interpretation and organization behaviour (Gavetti & Warglien, 2015) providing an opportunity to increase our understanding of managerial cognition and organizations' strategic outcomes.

Research Design

The emergence of new environmental friendly technologies and digitalization have been involving a transformation of organizations strategies, emergence of new actors, and disruption of existing competitive boundaries promoting the development of the energy sector (Davies, 2013; Heiskanen et al., 2018). In addition, the industry has the peculiar nature by serving "public good", and therefore requires tailored incentives and regulations to stimulate the development of the industry and to become a coherent network of actors (Giudici et al., 2017). The altered competitive boundaries are searching for their forms, rules and norms are developing, the networks of the industry members are evolving (Georgeson et al., 2014; Giudici et al., 2017). As a whole, the tightening international regulation to minimize effects of climate change and national-level political decisions as well as grassroots level movements towards sustainable societies (Kemp & Rotmans, 2009; van der Schoor & Scholtens, 2016; Korjonen-Kuusipuro et al., 2017) have been stressing the role of sustainability issues in firms' strategies and have gained increasing attention among both practitioners and scholars during recent years (Epstein, 2014; Martin et al., 2016).

Thus, our study focused on the energy sector in Finland as one of the most advanced countries in the field within the EU (Commission, 2016; Sworder et al., 2017). During the study, the Government of Finland was developing "National renewable energy and climate strategy 2030" and launched a series of strategic projects in clean solutions triggering firms and other actors to channel their operations towards sustainable businesses. As an indication, the environmental goods and services sector output in 2017 achieved 6% of total GDP in Finland (Statistics Finland, December 2017). Especially, the energy sector is adapting these strategies and is under continuous change driven by the fast technological and business development (Farfan & Breyer, 2017; Ritala et al., 2017), and thereby provides a good opportunity to examine differences in managerial cognition (Bogner & Barr, 2000; Nadkarni & Narayanan, 2007b).

Data collection and analysis

Data collection. For our exploratory study, the initial sample of the interviewees was selected from different business sectors within the energy sector to investigate the similarities and differences in managers' perceptions across the sector. As the overall aim was recognize the driving forces of the operative environment and the triggers behind the collective cognitions of the energy sector, 26 semi-structured interviews were conducted allowing open-ended probes to gain the experts' insights to energy sector change. The interviewees included a variety of experts: 6 leading energy-sector-related academics, 2 research institute representatives, 5 policy makers, 10 company representatives, 2 industry association representatives and 1 representative of a non-governmental organization. Researchers conducted the interviews during 2017. During the data collection, the researchers recorded the interviews and made notes. As the aim was to understand a phenomenon, the changing energy sector, the interviewees were encourage to express their own interpretation of the change. Each interview provided from 30 to 60 minutes recorded data. The interviews were then transcribedby the third party.

Categorical analysis of the data. The study followed the approach developed by Gioia et al. (2012) to perform the categorical analysis of the interviews (Fig. 1). For our interview data, we used the text analytics techniques for the text extraction and coding of the textual content with the help of the NVivo12 program. Firstly, a researcher read all the transcriptions of the interviews investigating how the interviewees perceived the change in their environment. In the transcript data, researchers claimed the phrases describing the change drivers and grouped them into five categories: 1) energy technology and digitalization, 2) economic, 3) societal, and 4) threats and opportunities emerging for Finnish energy sectors actors, and finally 5) the envisioned future states of the energy sector in Finland.

In the first-order analysis, the researchers interpreted the recognized phrases by searching the similarities and differences among the phrases, and distilled them giving phrasal descriptors, *the first-order concepts*. The phrasal descriptors were then grouped by merging overlapping phrases into the categories. This phase generated 197 first-order concepts derived from the interviews: technology drivers 17, economic drivers 33, societal drivers 31, threats 51, opportunities 35, envisioned future states of the energy sector 20. At this phase, the categorized phrases were also labelled according to interviewees' backgrounds into the industry, expert, and authority groups for further analysis. Based on the first-order concepts, the concepts were analyzed further to capture the interviewee categories at the higher-level abstraction subsuming the first-order concepts or referring the existing literature that enabled to describe the abstractions as *larger second-order themes* to understand the ongoing change. Finally, the second order abstraction, themes, were further distilled *to aggregate dimensions* for finding the phenomenon under consideration, i.e. energy sector change due to technology development (see Appendix A).

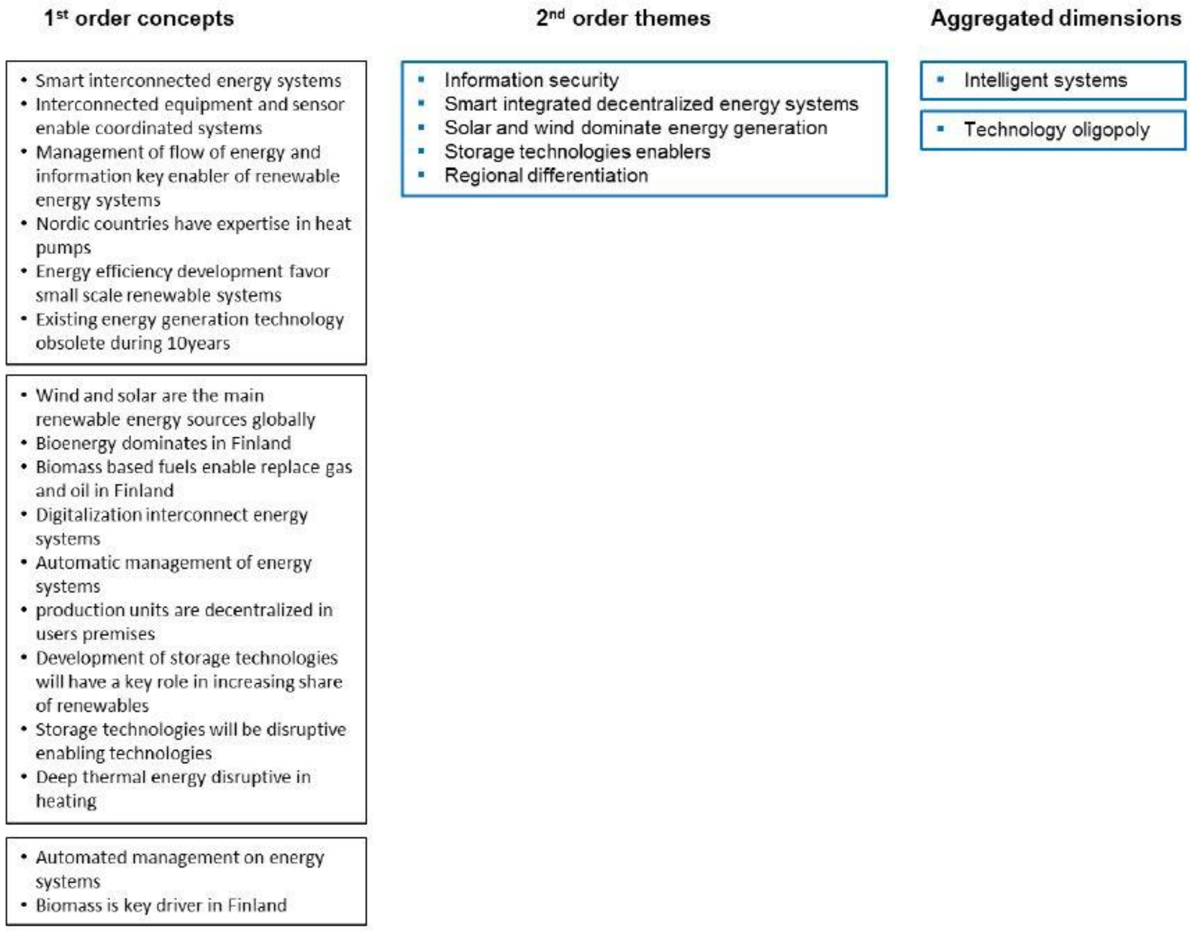

Figure 1. *Data structure of the technology drivers and categorical analysis (see Gioia et al. 2012).*

Following the approach described above, the data was analyzed to understand the ongoing phenomenon of energy sector change through the interviewees' interpretation of the change created in interaction among the energy sector actors (Nadkarni & Narayanan, 2007; Cattani et al. 2017). The data provided patterns on managers' interpretations over the technological, societal and economic drivers, threats, opportunities, and the envisioned future states of the energy sector in Finland. In addition, the study included quotes from the interviewees to show the character of the themes.

Findings

The focus of the study was on interpretation of issues regarding the change in energy sector. Taking the social cognition approach to analyze data allowed to assume that energy sector actors create collective beliefs on industry boundaries, e.g. norms and rules, values, roles of members. This approach has it roots in social construction of industry (Berger & Luckman, 1967). Based this, we interpreted the data capturing perceptions of the interviewees'. The interviewees were asked to describe energy sector change asking open-ended questions, e.g. how do you see the situation with regard to the renewal of the Finnish energy sector? What are the trends, what are the new opportunities, and then, are there some significant risks? Also, they were asked to discuss about disruptive technologies, the role of authorities and other actors in the renewal of the energy sector, and who are the other forerunners?

Generally, the experts provided relatively wide array of perspectives compared with industry and governmental representatives. For example, in the data, we claimed 50 expert references, 32 industry representative references and only 30 authority references to threats. The same were able to notice with opportunities. As digitalization considered one of the most potential business areas, a leading expert in

Finland described clearly "*in smart (parts), smart power or smart energy systems, that's definitely an area where we have a lot of knowledge.*" Authorities had often more complex approach to opportunities, e.g. components. "*It's not the turbines (but it may be) components and, (in the) service supply chains, (may) (--). And then biofuels, there is the whole technological development of, using different raw materials, developing, new types of biofuels, and, then in the forestry industry sector, because they, what they do is, renewable.*" When interviewees were discussing the threats, the key challenge was the public awareness of the need for change towards sustainable behavior and readiness of big players to replace old technologies with new less fossil resources consuming technologies. An expert addressed attention to dominating actors saying that "*But as long as the, power of the larger, market players are always preferred, they can always, in a way influence that the entrance, the new entrance to the markets, they have very bad chances*." The same interviewee explained about the challenge of lack of awareness: "*But the point is, at least that, (from) [0:04:39] my point of view for the last 20, 30 years there was no discussion [about options for nuclear in Finland]. So it's so difficult to change your mindset. If you have the completely wrong mindset, then it takes, so long to get it [renewable technologies]*."

An interesting finding is that the technology drivers had notable less references (55) compared with societal (84) and economic factors (91). The technology considered to be dominated by the wind and solar energy and digital applications as an inherent feature in all technological as well as business solutions. An interviewee from the leading energy company in the Europe expressed the role of digitalization as ubiquitous *"smart meters to energy meters on the district heating for example, where, we can read the consumption over time. And of course we can build algorithms with outside temperature and indoor temperature connected to the consumption of energy as such. And this kind of data, once we install, meters in the way that we had two-way communications, so that we can actually also steer the meter and we can then, the whole district heating system for example starts to really operate, the way that we've been operating power plants for many many years."* This represented the general perception of the role of digitalization in energy sector across the interviewees.

Perceptions of the future development generated fewer references among the interviewees and had quite similar expectations of the future. Experts and industry perceived the future more complex than authorities did. Authorities assumed that the energy generation will be based on renewables and the EU climate targets will be achieved. The role of consumers considered to increase in the future as an interviewee mentioned *"there's a (new) proposal by the Commission the so-called clean energy package in which, they are introducing, so-called local energy communities which would be, a new thing in Finland as well because that would mean that we would have, customer groups with (the prosumers)"*. Experts and industry representatives found more diversity in future development, especially how the business will be organized and the roles of actor segments develop in the future. However, experts stressed more the role of consumers compared to industry representatives, for example *"you would like to see energy resources being shared, so that the energy would never leave the neighbourhood. It would stay in the neighbourhood, and you wouldn't need the huge cable to the neighbourhood, because the neighbourhood would only need the February energy, and they could maybe have storage within that community."*

In figure 2, the ongoing change in energy sector based on the categorical analysis of the data is described to understand the phenomenon. The themes presented in the figure are 2nd-order aggregated dimensions. These higher-level abstractions enable to find the collective beliefs of the future shared among the energy sector actors (Bogner & Barr, 2000). As shown in Figure 2, the envisioned future is determined by the global stakeholders, trends, and drivers. However, the interviewees still saw some role for the role of Finnish actors defining the development path into the envisioned future of energy sector in Finland during the next ten years. For example, how the industry is utilizing new technologies, and how the regulation can accelerate the transition to renewable energy solutions.

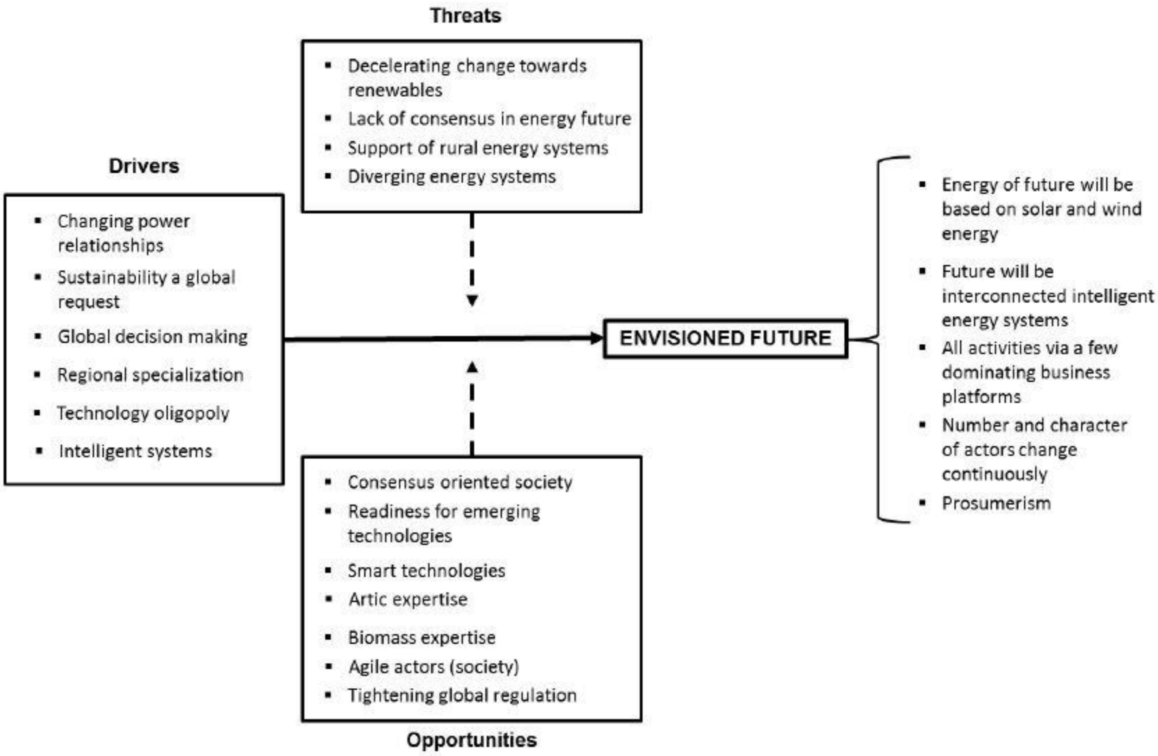

Figure 2. *Description of the ongoing change of the energy sector in Finland based on the aggregated dimensions of the 2nd-order themes (see Gioia et al., 2012).*

In sum, the findings of this study provide knowledge on the driving forces of the future developments of the Finnish energy sector. The findings show, how the energy sector ecosystems (are likely to) develop in Finland, as different actors become more inter-dependent or find emerging business opportunities together across different fields such as traditional energy as well as other industries such as ICT. Furthermore, the study presented the future challenges and opportunities for the energy sector organizations in terms of energy technology, business and policy decisions. The study shows how managers share their perceptions creating collective beliefs of the change.

Discussion and Conclusions

As the energy sector transition accelerates, not only challenges but also new opportunities emerge due to digitalization and fast developing energy technology. The changes have a larger impact, and those open up opportunities for new actors that can enter from various other industries and even disrupt the current businesses. Important for energy sector actors is how the challenges and opportunities in sustainable development and energy transition are perceived and translated into actions. Understanding the challenges and opportunities in sustainable development and energy in transition have implications for both incumbent firms and potential new actors.

In this study, we have been tackling one of the fundamental questions in recent management and managerial cognition research – how the actors collectively share their beliefs of the competitive environment, and consequently shape the development of the industry (Narayanan, 2011; Kaplan, 2011; Gavetti & Warglien, 2015; Bromiley & Rau, 2016; Hodgkinson, 2017). Especially, our study contributes to the social cognition literature by examining the future oriented beliefs embedded in the collective belief structures (Porac et al., 1989; Nadkarni & Narayanan, 2007; Cattani et al., 2017). In addition, the study provides new insights into the understanding of the development of the energy sector driven by the energy efficient technologies embedded with digital solutions and the requirements for more sustainable business (Pernick & Wilder, 2007; Hahn et al., 2015; Schaeffer, 2015; Cumming et al., 2016; Ritala et al., 2017; Heiskanen et al., 2018).

By taking the social cognition view based on the social constructivism, this study investigated the energy sector actors' interpretations of ongoing change in the field. This enabled to recognize the shared beliefs of the future with regard to the key technology areas, and in turn envision the industry development. Following the earlier qualitative studies, this study utilized the Gioia approach (see e.g. Gioia et al., 2012) for categorical analysis of the data. Firstly, the interviews were analyzed to find the phrases expressing the respondents' perceptions on phenomenon under scrutiny. These phrases were merged and distilled towards higher-level abstract themes and finally into aggregated dimensions. The step-by-step merge-distil process enabled to explain the phenomenon of the energy sector change in Finland.

The findings show that interviewees have similarities in their beliefs of the future across the energy sector. However, there exist differences between the interviewees depending on their personal social networks and functional backgrounds. The interviewees shared several key beliefs of the change. The global decision are the most influential drivers considering the future development of Finnish energy sector. Digitalization and fast developing energy technology together with the regulation and public awareness on sustainability created the local (Finland) limits how the Finnish actors are able to utilize the opportunities and avoid the threats offered by global development.

This study provides also practical and policy contribution in showing that technology driven industry change is rarely based on a single driver rather it seems that industry change occurs as a complex interconnected phenomenon of global trends and actors. This knowledge provides important guidelines for firms and other organizations in considering allocation their scarce resources, e.g. R&D resources to avoid first mover disadvantages (Lieberman & Montgomery, 1988) that might realize under systemic technology transition contexts such as energy sector.

We also acknowledge methodological limitations that are inherent for qualitative studies. First, our sample is limited into a single industry sector and a country. Second, the data set should be larger to provide more generalizable finding, as currently we are able to provide only indicative evidence. All in all, our results provide promising results explaining the ongoing change in energy sector driven by new technologies. This study also provided interesting research avenues for future studies, for example, the data collection could be repeated and analyze the evolution of the collective cognitions in another point in time.

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Appendix. *The second order themes and aggregated dimensions interpreted from the data.*

DRIVERS

2nd order themes

- International decision making shapes energy sector development
- Finnish public sector has a weak role driving transition
- Global attitudes towards sustainability

- Strong decision-making role of consumers
- New entrants globally
- Big actors are searching for new business opportunities
- Big firms resist energy transformation
- Growth of renewable energy sector accelerates
- Regions differentiate by their natural strengths of resources
- Biomass central for Finland

- Information security
- Smart integrated decentralized energy systems
- Solar and wind dominate energy generation
- Storage technologies enablers
- Regional differentiation by their natural strengths

Aggregated dimensions

- Changing power relationships
- Sustainability a global request
- Global decision making
- Regional specialization
- Technology oligopoly
- Intelligent systems

ENVISIONED FUTURE

2nd order themes

- Future energy generation is optimized mix of renewables
- Future energy will be interconnected intelligent renewable energy systems
- Future will be interconnected smart energy systems
- Industrial internet will be reality in a long run
- Energy Future will be based on solar and wind energy

- Energy communities
- Energy sector will become diversified with numerous different actors
- Energy business will concentrate around a few platforms in Finland
- Local distributed energy systems will enable local energy generation for local needs

- Biomass based renewables the most important for Finland
- Consumers become influential actors in energy sector
- Circular economy is coming within next 5-7 years
- Individual level CO emission market

Aggregated dimensions

- Energy of future will be based on solar and wind energy
- Future will be interconnected intelligent energy systems
- All activities via a few dominating business platforms
- Number and character of actors change continuously
- Prosumerism

OPPORTUNITIES

2nd order themes

- Stable society in Finland
- Radical changes in mindset of all actors in Finland

- Biomass based technology an opportunity to Finland
- Intelligent energy components
- Control and management of energy systems
- Distributed local energy systems in Finland
- Batteries and cars provide minor technology/business opportunities for Finland
- Energy solutions for Northern conditions

- New business models based on social media
- New entrants from "intelligent industries"
- Finland offers business for SMEs operating within the biomass based energy
- Fast growing global renewable energy market to expand firms' business
- Rising taxes for fossil energy sources accelerates transition in Finland

Aggregated dimensions

- Consensus oriented society
- Readiness for emerging technologies
- Smart technologies
- Artic expertise
- Biomass expertise
- Agile actors (society)
- Tightening global regulation

THREATS

2nd order themes

- Finland stay out of global development
- EU regulation establishes obstacles to actors
- Different political decision across the countries hinder development of renewable energy markets
- An exceptional global crisis may hinder energy transformation

- Dramatic changes in behavior of all actors needed to reach zero level in co2 by 2050
- Mindset changes slowly towards renewables
- The existing corporative system secures big actors' interests
- Lack of collaboration between Finnish actors
- Lack of risk taking entrepreneurs

- Disruptive effect of urbanization for the business of the rural energy utilities
- The current biomass strategy of Finland

- Delayed transition in technologies to renewables
- Cyber security
- Management of stability of grids
- Lack of interoperability of energy systems
- Lack of IT expertise in the energy industry

Aggregated dimensions

- Decelerating change towards renewables
- Lack of consensus in energy future
- Support of rural energy systems
- Diverging energy systems

How Advanced Power Electronics Can Accelerate the Diffusion of Energy Storage?

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Abstract

This paper focuses on an innovative advanced power electronics device (PED) with integrated storage management capabilities that is being developed within the Horizon 2020 project RESOLVD. To start with, the technology behind the devices is described together with its key functionalities. The paper proceeds by referring to key stakeholders that may benefit from the solution and explains the motivations and implementation possibilities for various stakeholder groups. Based upon well composed narratives, the stakeholders are classified according to two different sets of mapping dimensions: Power-Interest-Attitude and Power-Urgency-Legitimacy. The performed stakeholder analysis suggests that the PED can, besides its primer use by distribution system operators, be attractive for various low-voltage grid users. The versatile operation and design of the PED make it a key technology for the modernization and decarbonization of the low-voltage distribution grids and a profitable business environment for the RESOLVD solution is envisioned.

Introduction and Background

With an increasing number of distributed renewable energy sources installed at various ends of the low-voltage grid challenges arise with respect to ensuring security and quality of supply. Combining local renewable generation with local energy storage capacities can mitigate those challenges. Yet, an increasing market for storage with dropping costs of the various storage solutions can be demanding, as batteries with different schedules of charging and discharging must be managed simultaneously. However, technological innovation can well respond to that issue.

Within the H2020 Project RESOLVD (2017–2020) an innovative advanced power electronics device (PED) with integrated storage management capabilities is being developed. The device will be capable of optimizing on the co-joint charging and discharging schedules of different storage technologies. In this way the device will allow for significantly improved grid-to-storage interactions and will contribute for better control and flexibility utilization in the low-voltage grid, based on flattening the demand curve at the substation level, loss reduction, improved voltage control and supply quality.

More specifically, the new PED embraces a variety of new technology – a modular power conversion system operated by an innovative intelligent local energy manager to cater for communications and for implementation of the overall device control logic. These new technologies will be supported by a decision support toolkit, a distributed software platform and a wide area monitoring system to comprise an overall solution that successfully supports the low-voltage grid.

The advanced PED is to facilitate interactions with legacy systems which makes it suitable for integration at various low-voltage grid levels. Thus, a diverse set of new business models can be envisioned to provide for an optimal utilization of energy storage capacities located at the premises of various stakeholders.

Material and Methods

As previously introduced, the PED to be produced in RESOLVD embraces a variety of new technologies including a modular power conversion system managed by an intelligent local energy manager (ILEM hereinafter) to cater for the communications and of the implementation of the overall device control logic. These new technologies will be integrated into an innovative distributed software platform and a wide area monitoring system managing the low-voltage grid. A basic understanding of the technology is an important prerequisite for evaluating the stakeholders' capability of taking it in use and for making references to relevant use cases.

The basic features of the novel PED are graphically depicted in Figure 1. As shown, the device is equipped with a heterogeneous grouping of battery types, composed by high performance lithium-ion battery packs and low-cost lead-acid ones. Thus, the system becomes a hybrid energy storage device. To exploit the main benefits of such hybridization, each battery pack is connected to a separate module of a power electronics-based power conversion system. The modularity of power electronics provides the device with high reliability and design flexibility.

At the time of receiving a power demand from the distributed software platform, the ILEM distributes it among the different battery packs according to their capabilities and state. Such action is performed by an innovative optimization algorithm inside ILEM named as power sharing algorithm. The power sharing algorithm takes into account the specificities of the batteries such as efficiency, energy storage and power capacities, cyclability, admissible charging and discharging rates, among others. Thus, it ensures the proper management of the heterogeneous grouping of the battery packs, exploiting in this way the main performance of each one. As a result, and in response to a step-profiled power demand from the distributed software platform, for instance, the ILEM (through its embedded power sharing algorithm) may determine to rapidly discharge lithium-ion packs, taking advantage of the remarkable admissible current rates and low degradation of this technology. After such a rapid response, the power sharing algorithm may slowly and progressively activate the lead-acid packs to provide a sustained power injection in time, minimizing their degradation.

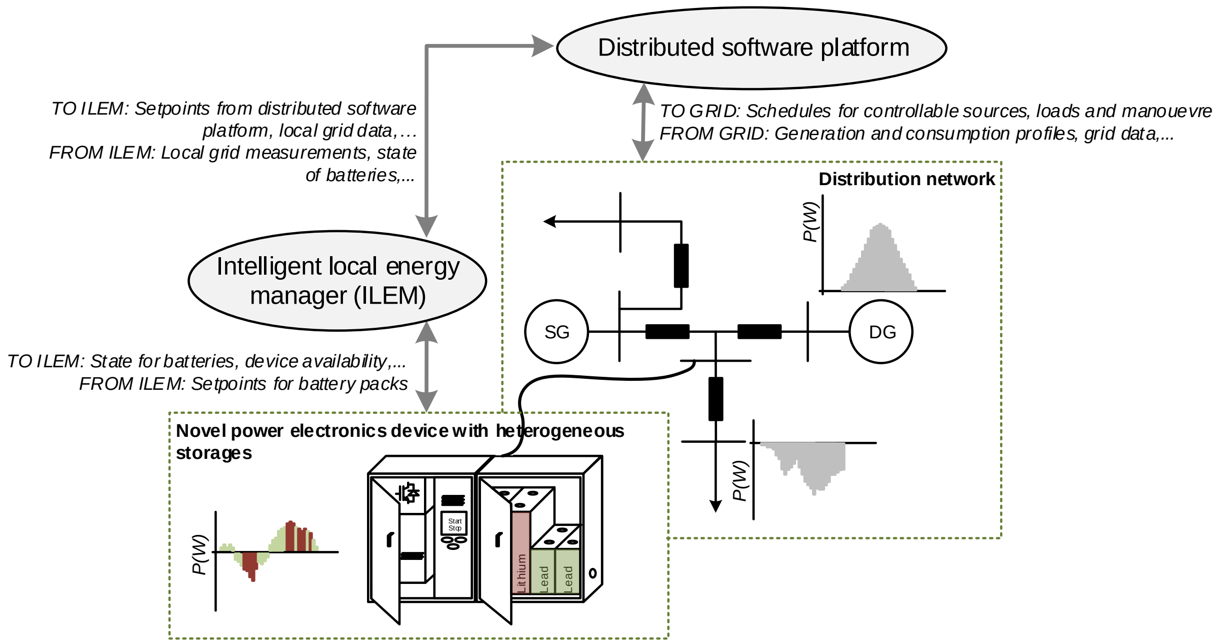

Figure 1. *The novel PED with heterogenous storage and its interaction with the management of the network.*

The exploitation of the benefits of hybrid storages is one of the main technological challenges tackled in the RESOLVD project with respect to the design of the PED. Such innovative approach aims to answer the need of developing energy storage solutions for electrical networks with reduced cost and enhanced performance.

Apart from the hybridization aspect, other characteristics make the PED an advanced solution beyond the state-of-the-art. Those refer to the novel modular architecture of the power conversion system itself, and to the other management algorithms embedded into the ILEM. The ILEM provides the PED with high connectivity towards other agents of the network so as to provide services to the grid. These are based on exogenous control signals and remote measurements in either grid connected or isolated mode. The relevance of the ILEM is connoted while in grid isolated mode. In this situation, the PED is operated as a voltage source for the consumers connected nearby. The electrical stability and power quality of such a microgrid and the security of supply to consumers solely depend on the PED. In the same manner, the transition from grid-connected to isolated mode and vice versa, and the provision of anti-islanding protection to the associated neighborhood are services managed by the ILEM, thus providing added value to the PED. While in grid-connected mode, the ILEM may manage the energy storage capability of the PED so as to maximize the hosting capacity of distributed renewable generation for the connected neighborhood.

Having described the RESOLVD technology's concept, it is important to discuss the possibilities for market pick-up of the solution, given the specific stakeholder environment. Supporting market uptake of innovation and developing effective business models involves engaging affected stakeholders. Possible values which can be created by an innovation are key to understand the innovation's impact on stakeholders. RESOLVD's novel PED provides value to grid operators but could also be attractive to various other stakeholders. Identifying values for additional stakeholders would further boost market uptake of the solution.

To explore possible values, narrative building technique is used. Narrative building is qualitative method where storylines are developed to understand perspectives of various stakeholders. This work uses narratives to identify possible values for different types of stakeholders. A broad range of stakeholders from different market domains which could be affected by the innovation are selected. For each of the selected stakeholders a brief storyline is created on how the RESOLVD innovations can affect the stakeholders' businesses. These storylines form the narratives of different stakeholders and provide insight to their pain points and how these could be relieved using the PED, thereby revealing possible values for the stakeholders.

For the stakeholder analysis two maps are chosen, namely Power-Interest-Attitude map and Power-Urgency-Legitimacy map. Based upon the narratives, attributes like interests, attitude and urgency can be gauged and subsequent mapping can be done. Detailed explanation of the stakeholder mapping is out of scope of the current work and readers are referred to RESOLVD Deliverable D6.2.

Once values are identified using narratives, it is possible to create business models which define how value is created, delivered and captured (Osterwalder and Pigneur, 2010). Value identification through narratives is the first step towards building new business models for PED. This is crucial for the success of the innovation and an important ongoing task within the RESOLVD project.

Results

Value identification through narratives

Table 1 provides narratives for few of the stakeholders identified. Readers who are interested in the exhaustive list of stakeholders are referred to RESOLVD Deliverable D6.2. Along with the narratives, the envisioned business motivation of each stakeholder is shown. The values for each stakeholder are revealed through the narratives. It should be noted that services from distributed software platform are required for scheduling the PED. These services can be requested to the DSO which owns the software platform or the software can be owned by other stakeholders (e.g, SaaS or license). As it can be observed, the benefits for some stakeholders are not direct (e.g., for battery suppliers, for whom success of the power electronics device would mean more market demand for battery solutions). Such stakeholders do not directly benefit from the innovation but have complimentary benefits associated with its success. Thus, such stakeholders are prime candidates for being strategic partners in developing business for power electronics device. Some stakeholders would also feel threatened by the innovation as it would be competing with their products/solutions. Thus, through narratives it is also possible to identify the friction arising.

Table 1. *Stakeholder narratives and motivation.*

Stakeholders	Motivation	Narratives
DSO	• Better grid management • Improved reliability • Delaying upgrade investments • Flexibility services possible	DSO have multiple challenges while managing the grid, especially under growing distributed generation. PED can provide multiple values to DSO: • Prevent congestion and over/under voltage issues • Voltage control through local reactive power injection • Improve power quality and reduce losses • Power management capabilities in intentional and controlled-island mode
Balance responsible parties (BRP), Balance service providers (BSP)	• Minimize imbalances	BRP have financial obligation to maintain production/consumption as committed in the market. BRP have contracts with the TSO for this obligation. In occurrence of imbalances, fines are levied or BRP take services from balance service providers at a cost. Flexibility facilitated through the PED could be used to reduce the imbalances at transmission levels when several PEDs are managed collaboratively.
Local energy producers	• Improved integration of renewable energy - increased profitability	PED can help in storing excess generation. PED can also allow effective grid connection of local energy producers in rural areas. PED together with distributed software platform and wide area monitoring system offers opportunity to plan resources in an efficient manner, improve profits by bidding in the market more accurately and a higher level of local energy integration using load scheduling.
Energy communities	• Increased consumption from local energy resources • Improved grid reliability • Economic benefits from flexibility • Possibly lower electricity price/grid tariff	PED can enable local energy communities to better manage their resources, both generation and demand. Efficient management could also lead to reduced electricity tariffs. Such technologies provide information on when to activate flexibility using both storage and load scheduling. PED will enable energy communities to provide flexibility services to the DSO. Providing these flexibility services from PED will lower the payback period on the battery investment.

Parking lot owners (or EV charging station owners)	• Lower peaks resulting in lower connection charges • Lower energy costs • Reduce lead time to start operation	By investing in PED these stakeholders can reduce peaks and thus reduce connection charges (or use the same connection to charge more EVs). PED coupled with smart charging, using software applications, can reduce electricity bills. Most likely, actual management of charging will be outsourced to charge point operators as charging management is not the parking lot owners' core business. Charging station owners also face challenge of long waiting period for the grid to reinforce (or grid connection) before they could start operations. PED could thus reduce the lead time to start operation and provide early revenue generation opportunity for charging station owners.
Charge point operators (CPO, responsible for smart charging)	• Use of flexibility to reduce costs • Reduce lead time to start operation	CPO can either invest in PED to manage their customers' loads more economically or manage PED owned by their customers. Smart charging with PED could minimize electricity bills for charge point operators' customers. Critical events can be avoided and when such events occur PED could provide back-up and ability to operate in isolated mode. PED would enable charge point operators with competitive edge over their competitors. Depending upon ownership of the PED, the CPO could be customers or strategic partners.
Prosumers	• Higher integration of self-generated electricity • Possibly lower electricity price/grid tariff	The PED can be an attractive innovation for larger prosumers. The narrative replicates the one of energy communities.
Industries/ commercial buildings	• Higher integration of self-generated electricity • Efficient energy management of facilities - reduced electricity costs • Green profiling	Dependent on the size but the narrative is similar to the one for energy communities.
Battery manufacturers/ suppliers	• Increase in battery sales	The PED will be a market facilitator for different batteries to realize their potential in the future smart grid. The ILEM, which is a top-layer management of the PED, could be used in other hybrid battery systems. Apart from this, the PED could be a solution for integrating second life batteries coming from the electromobility or stationary fields. More services from batteries means more revenues, thus making batteries a good investment case and further increasing market demand. Battery manufacturers can benefit by making their battery management system (BMS) open/compatible to the ILEM. Battery suppliers could package various batteries under the PED and provide better solutions to their customers.

Energy service companies (ESCOs)	• Increased customer interest for investment in local storage/local generation	PED with storage could allow ESCOs to provide flexibility services and increase the quality of services they offer. By providing flexibility the payback period of investments can be reduced (like investments in storage or rooftop PV). Direct benefit exists only when the ESCO decides to venture in providing flexibility services. Otherwise, benefits are indirect and the ESCOs would most likely partner with other relevant stakeholders for providing services to the DSO.

Stakeholder mapping based upon narratives

By assessing attributes like interest, attitude and urgency through narratives, the two maps (Power-Interest-Attitude & Power-Urgency-Legitimacy) are created and a stakeholder analysis is performed. The two stakeholder maps are shown in Figure 2 and Figure 3.

Our analysis suggests that the PED with storage management capabilities can, besides its primer use by distribution system operators, be attractive for various low-voltage grid users. Among the most eminent ones are considered energy communities owning storage of various types, neighborhood/block managers, industrial facilities and commercial buildings of larger-scale. In addition, there are indirect beneficiaries of the innovation which would become promoters of the innovation and strategic partners for delivering the expected value. The narratives indicate a profitable business environment for the RESOLVD solution. However, possibilities for high degree of customization are needed and the overall applicability of the solution will depend on the market developments within the energy storage field.

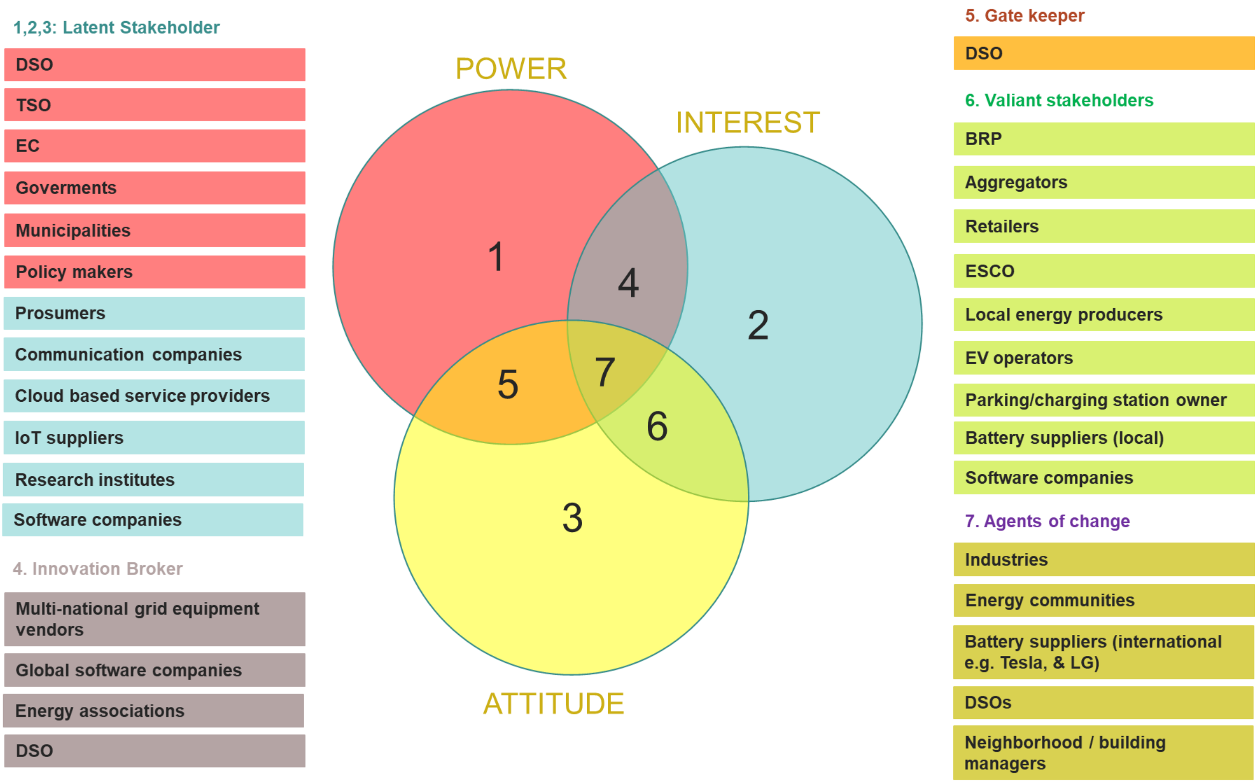

Figure 2. *Power-Interest-Attitude map of stakeholders based upon the narratives. Interest and attitude attributes are assessed through the narratives developed. Source: RESOLVD Deliverable D6.1.*

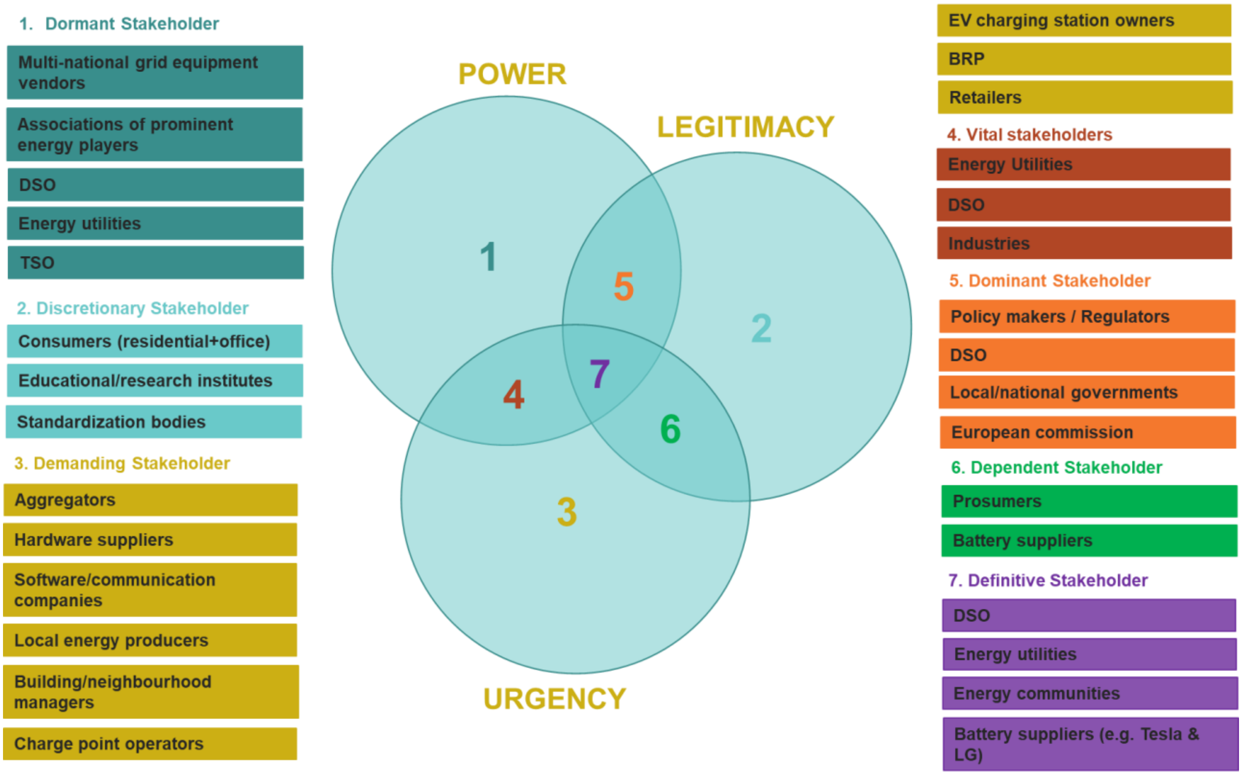

Figure 3. *Power-Urgency-Legitimacy map of stakeholder. The attribute of urgency is determined from the narratives. Source: RESOLVD Deliverable D6.2.*

Our analysis suggests that the PED with storage management capabilities can, besides its primer use by distribution system operators, be attractive for various low-voltage grid users. Among the most eminent ones are considered energy communities owning storage of various types, neighborhood/block managers, industrial facilities and commercial buildings of larger-scale. In addition, there are indirect beneficiaries of the innovation which would become promoters of the innovation and strategic partners for delivering the expected value. The narratives indicate a profitable business environment for the RESOLVD solution. However, possibilities for high degree of customization are needed and the overall applicability of the solution will depend on the market developments within the energy storage field.

Stakeholder mapping, derived from narratives, helped in selecting appropriate methods to engage different types of stakeholders based upon their salience. The stakeholder engagement strategies are out of the scope of this work and are described in RESOLVD Deliverable D6.2.

Discussion and Conclusions

This paper described the functionality of an advanced power electronics device to be developed in the RESOLVD project that will significantly improve grid-to-storage interactions, potentially resulting in flattening the demand curve at the substation level, loss reduction, improved voltage control and supply quality. Our research showed that the technology solution proves to be attractive for a variety of stakeholders who possess storage technology of various types and may serve as an excellent instrument for solving low-voltage grid challenges by helping DSO to operate the grid. Importantly, the device can contribute to solving the pending challenges of the low-voltage grid caused by distributed generation.

It could be the case that the stakeholders do not see the direct values as investigated through the narrative development technique. Thus, an important next step is to engage stakeholders and make them aware of the potential that the PED can provide to them. Initiatives for stakeholder engagement would further reinforce identified values and eliminate values which are weak or not attractive. The process of stakeholder engagement could also reveal new values.

The stakeholder attributes which have been identified using qualitative method of narratives need to be validated. For validating the stakeholder mapping presented in this paper a stakeholder innovation group (SIG) has been established in the project. SIG contains crucial stakeholders as members from whom feedback will be taken to complete the analysis.

Considering the possibilities discussed in this paper, we recognize the vast potential of the RESOLVD PED and are grateful for being given the opportunity to work on this interesting topic within the RESOLVD project funded by the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement No 773715.

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RESOLVD Deliverable D6.1. Stakeholders, actors and role [online]. Available at: https://resolvd.eu/documents/ (Will be available to download once accepted by the EC).

Peer-to-Peer Principles in Radical Renewable Energy Visions – New Risks and Opportunities of an Electrified Circular Economy

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Abstract

Discussing renewable energy technologies in the context of cultural transformation highlights the role of culture as a game changer. Too often only economic, technological and political dimensions are taken to be key drivers of change. This research focuses on the different modes and implications of peer-to-peer activities, as a means of organizing social interaction, which are assumed to have an increasingly important role in an energy transition to a renewable energy system, and the development of a circular economy as ingredients for a desirable future society. A futures workshop was organised as a special conference session, in connection with the Millennium Project, to explore possible interactions of these three elements. The results of the workshop have been analysed, resulting in a discussion of the potential impacts, benefits, and downsides of different manifestations of such a nexus. The results indicate that synergetic advantages can be demonstrated, although a few notable caveats remain. Furthermore, envisioning means of integrating a peer-to-peer ethos with circular economy practices warrants further attention.

Introduction

In the 1970s, it was assumed that the automatization of routine tasks would lead to emancipation, increasing leisure time and reducing working hours. This promise has gone largely unfulfilled. Today, peer-to-peer logics can increasingly be observed in the cultural sector, encompassing the self-organisation of non-hierarchical activities as a way to pursue value-based aspirations to freedom, equality, and human rights. Peer-to-peer principles are changing society as they become more embedded in ICTs and other technology (Fattah 2002), and even aspire to transform the dominant material order. Peer-to-peer principles may also converge with the drive for widespread utilisation of renewable energy (Ruotsalainen et al. 2017). There are major pressures to make energy systems emissions-free. Some socio-technical imaginaries of future societies envision novel ways in which to better adhere to ecological limits and the climate targets of the COP21 Paris Agreement[1]. Furthermore, there are increasing calls to ensure a healthier balance with natural ecosystems through the formation of a circular economy (Ghisellini et al. 2016; Korhonen et al. 2018; Wijkman & Skånberg 2016).

Emerging socio-technological configurations have a constantly-evolving reciprocal relationship with new socio-technical imaginaries (Jasanoff 2014) of what a future society might look like. More autonomous, empowered and interconnected citizens will be less constrained by hierarchies, while being supported by numerous novel technologies that are expected to be adopted. The convergence of these principles and technologies could nurture and expedite the creation of a culture and economy focused on

[1] Already Malaska (2010) called for novel types of growth that are increasingly immaterial, services-based, and aim for the intelligent use of resources. He coined the term "neo-growth" to describe this approach. In analogy, the term "neo-carbon" was launched in the Neo-Carbon Energy (2014–2017) project to introduce new uses for carbon as raw material (Neo-Carbon Energy 2017).

self-actualization (Glenn 2018)[1]. In such an economy, people can cope even without traditional employment if they have access to meaningful activities. Up until this point, there has been limited study of the systemic changes that might result from such a transformation, and in particular their social aspects (Miller et al. 2015). If these kinds of futures are realized, what kind of a world would be created? What kinds of cultural and socio-technological configurations might emerge to influence and possibly even serve humankind?

The vision of a peer-to-peer based, renewable energy powered, circular economy could in principle be technologically realizable in the forthcoming decades, if decisive action is taken to support it. The aim of this paper is to study how peer-to-peer principles would contribute to attaining such a future, anticipating various positive and negative impacts, including new opportunities and risks, of such a future. While presently shrouded in some ambiguity, the nexus of peer-to-peer principles, renewable energy, and circular economy merits further exploration. Previous studies have not examined in detail how peer-to-peer principles, which are constantly gaining strength, could be harnessed to support the realisation of such a vision, and what other impacts might arise as a result. These themes are discussed in this paper using the results of a futures workshop in which these issues were tackled. The examination of the ideas produced by the futures workshop is made more rigorous by employing a systemic view, which scrutinizes the influence of peer-to-peer principles on the transition towards a renewable energy society and circular economy.

Theoretical framework

A systems-oriented view requires the exploration of the dynamics and interrelations of different aspects of society. In general, societies develop in cycles as they advance through stages, creating processes of structural transformation that are both deep and long[2]. An ideal model of societal dynamics, described by Lemma and Malaska (1989) and presented in Fig. 1, divides society into three semi-autonomous sectors, each of which follows its own set of principles[3]: a particular logic and order, and a set of values and goals that the logics uphold (see also: Wilenius 2018, 23–26). The sectors are prone to change over time. Changes in the activities, dynamics and logic of one sector have the potential to influence other sectors as well.

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[1] According to Glenn (2018), artificial intelligence (AI), robotics, synthetic biology, computational science, cloud & big data, Internet of Things, augmented reality, nanotechnology, semantic web, quantum computing, tele-presence & holographic communications, intelligence augmentation, collective intelligence, blockchain, 3D/4D printing materials and biology, drones and other driverless vehicles, conscious-technology will greatly improve energy efficiencies and what is thought to be possible for the future of civilization.

[2] Development from an agricultural society to an industrial society, and subsequently to its advanced stages: an information or service society. In the digital economy and knowledge society, the role of data is particularly important.

[3] “The cultural sector draws on freedom to produce ideas, values, art and science for society. The political and social sector, based on equality aims to maintain the rule of law; and an economic sector, based on solidarity aims to establish the material framework for society and to create prosperity.” (Wilenius 2018, 23-26)

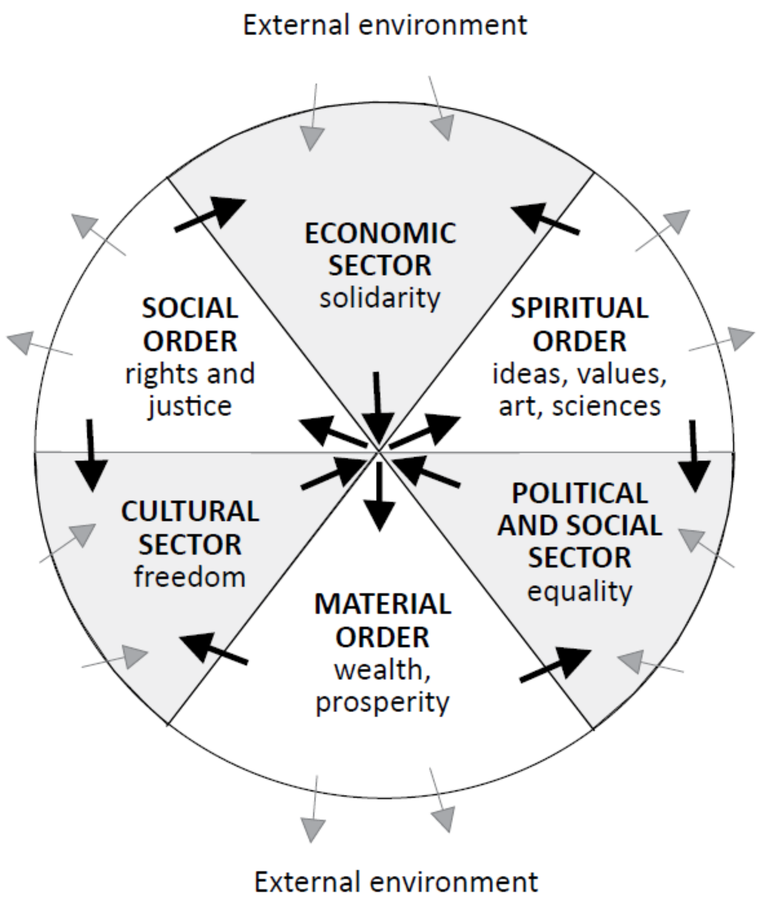

Figure 1. *Model of the open, threefold society with its interacting sectors and orders (Lemma & Malaska 1989, 300).*

The material order, as a basis of wealth and prosperity, includes technological and energy systems. The external environment of the bio-physical world enfolds all of the model's sectors and orders. This model is used as a conceptual tool for analysing and interpreting the workshop results. The concepts of peer-to-peer logics, a renewable energy transition, and the circular economy three key drivers of systemic change, are examined more closely in the following sections.

Peer-to-peer activities

Castells (1996) was already conscious of increasingly networked ways of organising societal interactions. He paid special attention to networked global labor and talent, a newly thriving phenomena made possible by the technological infrastructure of the information economy. Today, peer-to-peer networking extends beyond the labor sphere. Peer-to-peer logics are those through which citizens co-operate with each other in non-hierarchical ways, based on informal social relations. Citizens who depend less on hierarchies can become more autonomous, empowered and interconnected in the future, if society encourages open source and peer-to-peer based activities. The peer-to-peer principle as a socio-cultural and mode of thinking is originally drawn from the peer-to-peer production model. In his Peer-to-Peer Manifesto, Bauwens (2007b) anticipated the emergence of a peer-to-peer civilization and form of political economy. He defines peer-to-peer as a new threefold human dynamic: as a third mode of production, third mode of governance, and third mode of property (Bauwens 2005). He sees peer-to-peer theory as the overall emancipatory system of our new age (2007a). However, peer-to-peer does not necessarily describe all behaviour that takes place within distributed networks. It refers only to those processes that aim to foster "the most widespread participation by equipotential participants" (Bauwens 2005).

Peer-to-peer logics are also inherently linked with sustainability and limits-to-growth thinking. Moreover, the approach poses a radical challenge to our current world system, which is characterized by a counterproductive logic of social organization. Bauwens (2007b) claims that the current system is based on two false concepts: the false concept of abundance in a finite material world, as has been the message of the Club of Rome since its Limits to Growth report in 1972; and the false concept of scarcity in an infinite immaterial world, as explored in *No Limits to Learning,* a report by Botkin et al. (1979), also to the Club of Rome.[1] Consequently, Bauwens (ibid.) argues for the overturning of these principles in favour of their opposites as the number one priority for creating a more sustainable civilization. The physical economy should recognize natural resources as finite, while free and creative co-operation could be liberated and thus become limitless through reform of copyright and other intellectual property restrictions.

A peer-to-peer production mode differs from both for-profit production and public production by state-owned enterprises. A peer-to-peer product does not embody exchange value for a market, but use-value for a community of users (Bauwens 2005). Accordingly, community orientation is what makes peer-to-peer a strong socio-cultural driver. Benkler (2017) sees peer-to-peer production as "the most theoretically radical organizational innovation that has emerged from Internet-mediated social practice". As a consequence, the practices of companies will have to be rethought in order to aim at "co-operative continuity", which involves internalizing considerations of how best to address motivational diversity and maintain social integrity. It is the knowledge-production features of peer production that make diverse motivations and successful collaboration essential concerns in this area (ibid.).

There are several phenomena observable in the context of the emerging societal changes and new paradigms that are closely related to, but not synonymous with, peer-to-peer practices. Prosumerism enables consumers to become producers – though they may not necessarily be producing primarily for their peers. The sharing economy has given rise to appealing platforms through which to share products and services, empowering people to break out of top-down hierarchies, though it focuses exclusively on the sharing mode. Peer-to-peer is also very often conflated with crowdsourcing. While the tasks involved in the latter are narrow and pre-determined by the task designer (Benkler 2017), in the former mode they are volunteer-based, informal and open.

Peer-to-peer thinking is a fundamentally social-cultural phenomenon, even though it becomes visible in concrete economic production processes. According to our claim, its core value can be seen in how it contributes to the formation of personally chosen communities of meaning. Peer-to-peer principles enable people to "govern themselves while engaging in the pursuit of their best interests and passions" (Good 2007). However, the peer-to-peer approach is not automatically a desired element of the futures to be. The benefits or risks of its manifestations and outcomes are in the eye of the evaluator. For those that wield power within hierarchies, decentralised peer-to-peer emancipation may seem like anarchy. For others, peer-to-peer itself may become polarising or, paradoxically, elitist, as discussed later in the section describing the results of the workshop. The wealth generated by peer-to-peer activities will also not automatically be evenly distributed. Therefore, in a peer-to-peer society, citizens will be able to act as equal energy prosumers only if they have motivation, skills and access to suitable platforms and related enabling technologies.

[1] This is the first Report to the Club of Rome written by authors from socialist and Third World countries as well as from the West.

Energy transition for a renewable energy system

Decarbonising the global energy system, while remaining cost-effective and reliable, is an immense challenge. In order to meet this challenge, the future of the energy sector can be guided by the principles of electrification, decentralisation, and digitalization (WEF 2018)[1].

Electrification is a strategy to mitigate carbon emissions from fossil fuel combustion. Consequently, a growing number of energy-use sectors are being electrified. Electricity is already used for light and power. Electric mobility is shaping the mobility sector, co-evolving with battery technology. Electrification of the energy system is leading to the emergence of novel principles of energy production and consumption, implying the potential for it to be a basis of larger-scale transformations.

Increasingly decentralised energy systems enable growing energy generation from renewable energy sources. Self-production enables citizens and companies to produce their own energy, as well as trade their surplus energy with each other, becoming energy prosumers. This would represent a fundamental shift in the logic of the energy system, thereby bringing “power to the people” in more ways than one (van der Schoor & Scholtens 2015). In a renewable energy system, solar and wind energy become the basis of energy production, with their intermittency counterbalanced by energy storage and digital technologies. Electricity generated from renewables can be transformed into multiple end products, including synthetic chemicals, gases, and liquids[2].

Peer-to-peer logic is embedded in information and communications technologies and the process of digitalization. In the field of energy, digital platforms can match supply and demand, integrate renewable energy with mobile payments, use more omnipresent data for optimisation, and facilitate experiments in trading energy between peers using blockchain. An even more ambitious vision is one of an entirely electrified, intelligent energy system, or “internet of energy” that comprehensively integrates renewable energy, electricity and ICTs (Metcalfe 2009; see also Rifkin 2011, 2014).

Circular economy

A circular economy would represent a reconfiguration of the currently dominant economic model, which is predicated on continuous open-ended growth and driven by increasing throughput of largely non-renewable resources. Korhonen et al. (2018) have referred to this linear system as the “extract-produce-use-dump” model of material and energy flows. A circular economy would aim to make more efficient and ecologically sensitive use of resources in order to better balance the requirements of the economy, society, and the carrying capacities of the environment. Ultimately, the goal of its advocates is the decoupling of economic activity from its environmentally deleterious effects, including excessive use of virgin materials, reliance on toxic compounds, and release of damaging pollutants into the biosphere (Ghisellini et al 2016). Through the explicit recognition of a waste hierarchy that places reuse, refurbishment, and repair above recycling for raw materials, and which holds waste combustion for energy as preferable only to landfill disposal, Korhonen et al. (2018) propose that a circular economy aims to preserve the highest possible material value across the value chain and life cycle of products for as long as possible, while using as little energy as it can. Powering production and consumption processes exclusively with renewable energy would bring us significantly closer to this goal (EMAF 2012).

Circular economy can be seen as a way to simultaneously pursue three interrelated goals of sustainable development: improving environmental quality, increasing economic prosperity, and achieving greater social equity. However, Kirchherr et al. (2017) have pointed to the conspicuous absence of such

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[1] One low-carbon energy vision is a vision of a neo-carbon society, which assumes that all future energy could be produced with the aid of renewable energy based electricity to mitigate for future emissions (Breyer et al. 2017).
[2] In a neo-carbon energy system, electricity from renewables is used, and converted with so-called power-to-X technologies into synthetic end products in line with the principle of carbon capture and utilization. This is a new relation to carbon – not solely as an emission of CO_2, but as raw material for other processes (Neo-Carbon Energy 2018).

a holistic view in most circular economy definitions. Economic prosperity is most commonly at the forefront, followed by environmental quality, while social equity is addressed much more rarely. Sauvé et al (2016) critique the view that the development of a circular economy would automatically result in social benefits, emphasizing that these will not materialize absent the explicit formulation of normative social goals in connection with circular initiatives. To be a true vehicle for sustainable development, a circular economy needs to work toward establishing the most socially desirable resource cycles, going beyond consideration of their technical efficiency alone (Anderson 2007).

Korhonen et al. (2018) caution that entropy precludes the perfectly efficient use and re-use of materials and energy, making a truly circular economy an unrealizable ideal. In addition, they warn that a circular economy will not necessary lead to more sustainable resource and energy use if the overall physical footprint of the economy is not taken into consideration, since a circular economy will not be exempt from rebound effects.

Collaborative consumption that reduces the need for individual ownership of goods by focusing on other ways to provide equivalent functionality might be one way in which a circular economy could be furthered (Sauvé et al 2016). Ghisellini et al. (2016) suggest that although many business models of the "sharing economy" are based on renting, alternative social practices such as gifting, lending, or bartering might become more prevalent in a peer-to-peer society. A potential limitation is that collaborative consumption is most effective when participants are located in areas such as large cities in which these schemes are common and the necessary infrastructure, such as trusted platforms, are well developed. This poses a challenge for the adoption of these strategies in other contexts.

Actors across different segments of society have important roles to play in reconfiguring practices of collaboration and exchange in order to support the implementation of a circular economy that can achieve desirable outcomes across all three objectives of sustainable development. Current modes of production and consumption are increasingly unviable not only because of the strain they place on environmental carrying capacities, but also as a result of the social inequity they have historically fostered.

Material and Methods

Foresight work

This study build on the foresight part of the Neo-Carbon Energy project[1] where several futures research methodologies were used to study a long-term transformation into a renewable energy based energy system and society. In the horizon scanning phase of the project, emphasis was paid to the identification of emerging issues and weak signals as the first signs or symptoms of coming change (Heinonen & Hiltunen 2012; Lesca & Lesca 2014). The scenario-building process assumed that renewable sources of energy would be the main sources used in the future. In crafting transformative scenarios leading to the year 2050, peer-to-peer logics and ecological awareness were selected as the key uncertainties to explore in different future manifestations. Accordingly, they formed the axes of the scenario framework (Heinonen et al. 2017). The scenarios were then tested with other methods, including Causal Layered Analysis (CLA), pioneer analysis, futures cliniques, and futures workshops. The insights of this foresight work were used to elaborate a vision of renewable energy in a peer-to-peer society, incorporating selected key elements of a technological and social nature. A futures workshop was then organised to explore this vision more closely and to immerse participants into its various manifestations through thematic and co-creative brainstorming.

[1] The Neo-Carbon Energy Project (2014–2017) was the largest renewable energy research project conducted in Finland, studying a completely new energy system to solve renewable energy's flexible use, storage and distribution (Neo-Carbon Energy 2017).

Futures workshop

The purpose of the futures workshop (Jungk and Müllert 1987) was to address how peer-to-peer principles could underpin the vision of a renewable energy-based society producing and consuming within a circular economy. The key elements of this vision were presented to the workshop participants (Heinonen & Karjalainen 2018), after which a number of technological forces were presented from the viewpoint of a self-actualizing economy and culture (Glenn 2018). The specific question addressed by the groups was how to organise a circular economy with renewable energy and peer-to-peer principles. The group participants consisted of the conference participants[1], representing a wide range of various stakeholders from government, business and academia, and coming from various countries. Five small groups were formed randomly and moderated by workshop organisers. Each group was at liberty to choose a specific topic or perspective from which to approach the issue. The groups chose the following topics: mobility and equality; the nexus of skills-education-employment-inequality; health; new risks; and leisure.

The futures workshop adopted a lightweight structure, emphasizing the generation of novel ideas from the viewpoint of the theme provided. The groups were also asked to imagine how their topic might be affected by the widespread adoption of a prospective technology, such as artificial intelligence, big data, blockchain, the Internet of Things, 3D printing, robotized services, or nanotechnology. The lightweight structure of the workshop process was designed to encourage fast but open elaboration of ideas through creativity-based discussion (Balcom Raleigh & Heinonen 2018). Adapting the three crowns method to filter the core ideas, each group was asked to select three of their most important ideas, and then to present one of them. As a limitation to the work, the groups generally focused more on the social logic and organisatory dimensions of the unfolding peer-to-peer principles, rather than their environmental aspects. Most of the impacts discussed can be considered opportunities, although one group focused specifically on new risks as their core topic.

The results of the group work were analysed thematically (see e.g. Boyatzis 1998). The results of the five working groups were first coded inductively, and then organized into new opportunities and new risks. All in all, the groups proposed more opportunities than risks. In the analysis, six clusters of opportunities and four of risks were identified. Then, the systems model which is presented as Fig. 1, with its six interconnected sectors embedded in the external environment, was adopted as an interpretative tool for looking at the session results.

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[1] A Special Millennium Project Workshop in the FFRC Futures Conference 2018 was organised as a futures workshop. The Neo-Carbon Energy project had used the expertise of Millennium Project representatives in earlier futures cliniques as well. The results are presented in more detail in Karjalainen et al. (2018).

Results: New ideas, opportunities and risks

This section first describes the results of the five groups' work across their chosen thematic areas, and then analyses them in greater detail using a systems framework.

Group work results

The first group, having chosen mobility and equality as their focus, considered the role of 3D printing, mixed reality, synthetic biology, and artificial general intelligence (AGI). They envisioned *a personal futures simulator* as a means of simulating the ways in which mobility can increase equality, equality of autonomy, and the overall social good.

The second group explored the nexus of skills, education-to-employment, and inequalities as these areas might encounter robotization. While acknowledging that peer-to-peer principles and technologies may expedite circular economy and renewable energy, the level of control over algorithms, coding and learning that would be possible, and who would exercise it, was raised. *Peer-to-peer learning – aided by robotisation and AI or not?* was their puzzle.

The third group examined the connections between food and health, in light of the systemic pervasiveness of technologies and digitalisation. They questioned the concepts of control and the distinction between what it means to be natural or artificial, envisioning *Farewell to hospitals: decentralised, multi-technology health care*.

The fourth group focused on new risks for individual members of future societies, identifying a number of compelling competences that would be needed for individuals to make the most of a peer-to-peer environment. They envisioned an *AI-enabled empathy exchange,* a set of tools that would make such surroundings less stressful and easier to navigate.

Finally, the fifth group discussed how leisure might be organised in the envisioned society, and what tools constitute that sphere, to create a vision of *Self-actualization for leisure (and work) in virtual reality*.

Table 1. *Key results of the group work.*

Group #	**Chosen topic**	**Main discussion points and supportive ideas**	**Key idea**
Group 1	Mobility and equality	Shared consciousness space with an equality patch Mobility could be dematerialized Moment-to-moment metrics Competitive worldview shifts to seeing each other as equals How can dreams/aspirations be decoupled from privilege?	Personal futures simulator
Group 2	Skills-education-employment-inequality nexus	New systemic view emerges as a novel knowledge basis What knowledge and control in the design of algorithms? Learning becomes horizontal rather than expert-led Producers could have a recognizable face "Glocal" networks facilitated by AI Could immersive augmented reality have more impact on learning than AI?	Peer-to-peer learning – aided by robotisation and AI or not?
Group 3	Health	The relationship of food and health Concept of control What are the distinctions between natural and artificial? Decentralization of health infrastructure	Farewell to hospitals: decentralised,

		Tools for effective and safe self-diagnosis and self-treatment Shift toward communities where peers take care of each other What does it mean for something to be “natural”?	multi-technology health care
Group 4	New risks	Particular competences are needed for peer-to-peer success Continuous self-determination is psychologically demanding AI can find patterns but cannot create meaning Empathy is a necessary partner for intelligence	AI-Enabled Empathy Exchange
Group 5	Leisure	Leisure should not only be on screens Sharing Economy reduces the need for material consumption and ownership Work-life boundary may become increasingly blurred Individuals will need to strike a personal balance in how they spend time on different activities	Self-Actualization for Leisure (and Work) in Virtual Reality!

New opportunities and new risks

From the group work, six clusters of opportunities can be identified. They point to the possibility of a new peer-to-peer based order and new norms that are supported by technologies. Systemic thinking is aligned with these goals. New configurations and networks can be created to strengthen sharing economy models and produce new innovations. At the micro-level, this could result in greater equality of autonomy, or equality of life chances (Sen 1999). Thanks to technological developments and such principles, novel learning methods and simulations can also be created. These changes do not, however, mean that everything old will disappear; past practices will persist as a layer atop which future societal structures will be built.

Table 2. *New opportunities and new risks of the circular economic peer-to-peer renewable energy world.*

New opportunities	**New risks**
Technology as a true enabler: new concept of what is “natural” unleashed by p2p and technologies	Embedding bias in technology invisibly and misjudging the potentials of emerging technologies
Holistic view helps access to all sub-systems: creating new sustainable p2p structures	Inequalities in conditions of access and necessary skills
Ease of sharing and new openings: new networks, sharing economy models, new innovations	Multiple issues of ensuring privacy
From self-sufficiency to peer-sufficiency: equality of autonomy	Disruption of mental health, requiring individuals to establish a new personal balance between self and society
Opportunity for new ways of learning and mediating p2p practices: e.g. sophisticated immersive simulation tools	
Past practices: What remains valuable can be preserved	

The results also point to new risks. While the research framework emphasized the potential of technologies, many groups pointed to their corresponding dangers. Technologies could be designed in ways that accentuate rather than mitigate existing social problems. One of these issues concerns inequalities of initial conditions, access and skills, which may mean that technologies are not accessible to all. All-encompassing intelligent technological systems that build on digitalisation may undermine privacy, as already seen in concerns arising from attempts to utilise data from the health sector in novel contexts. All in all, the pervasiveness of technologies seems to be a concern, potentially becoming overwhelming and leading to new mental health issues, forcing human beings to seek a new mental balance.

Aspirations of equality and the model of an open, threefold society

The new opportunities and risks based on peer-to-peer potentials are reflections of a changing society. The proposed idea of a Super-AI "Mother Earth" that aspires to use technological means, such as artificial intelligence, embedded in all sectors of society to ensure a balance with nature conflicts with a more negative interpretation of pervasive technological penetration as possibly weakening human connections with nature. A constantly evolving relationship with the external environment is blurring and challenging what is perceived as “natural”. The circular economy itself, along with energy-intensive new technologies, could also increase overall energy use if they are not implemented with ecological limits in mind.

Fairness in the distribution of value across the economy aligns with an aspiration for solidarity in *the economic sector*, but ideas about how it can be achieved are less well-developed. The openness of access to emerging technological solutions should be enhanced; if it is not, new peer-to-peer based technologies may be no more than platforms for the rich. Data and technology make a sharing economy increasingly transparent, while the valuation of social goods could also become a component of new profit-generation models.

AI-aided real-time feedback may make it possible to fine-tune renewable energy and circular economy dynamics moment-by-moment, redefining the nature-human-technology relationships that are the foundation of *the material order*. Emerging technologies individually, as well as their potential convergences, can underpin new environmentally-conscious large socio-technical systems as older infrastructure is replaced. However, these new models may have an uneasy coexistence with costly legacy infrastructure that cannot be rebuilt instantaneously.

Technology-aided lifestyles could build more “genuine” equality at all levels of *the social and political sector*, if technology tools are designed with this purpose in mind. Present actions will need to be taken to recognize and reinvent power structures that have led to inequalities of opportunity and rebuild technologies around social goals. Open source P2P learning, and the involvement of more types of people in creating technological tools through widespread facility with coding, could make this reinvention more effective and participatory. New simulations depicting greater social goods may give us compelling and immersive means to make arguments for change. As artificial intelligence becomes more involved in decision-making, it may be more difficult to identify where agency is being exercised and by whom. In addition, we will need to take care that empathy is combined with intelligence in order to keep it from the ruthless pursuit of efficiencies at any social cost.

The potential for a peer-to-peer ethos to be a vehicle for autonomy and emancipation within *the social order* is evident, though it may be constrained by inequality of initial conditions. Decentralised and widely diffused knowledge can encourage new types of agency, but information-sharing bubbles in a “post-truth” era mean that criticality is needed among peers if misinformation is not to propagate through more horizontal modes of learning. A downside of labor-saving technologies is that jobs may disappear, with a more confusing landscape emerging in which the question of what skills are valued is harder to answer. Preventive healthcare through do-it-yourself (DIY) or e-diagnostics could have widespread benefits as certain types of formerly highly-specialized expertise become democratized or embodied in more accessible smart systems. At the same time, the pursuit of lifespans of maximum length can usher in its own higher-order consequences to contend with.

Freedom, trust, and opportunities for technology to enhance meaningfulness may lead to a positive work-leisure-self-actualization arrangement in *the cultural sector*, as more autonomous individuals are able to decide for themselves what uses of their time will be most rewarding. However, resistance is also a natural reaction to change, and people can be reluctant to relinquish social practices and materialities that have become heavily invested with meaning over time. The freedom to build support for counter-trends and engage in resistance may widen social divisions, as some choose a slower lifestyle in contrast to high-speed ways of living. While technology may lead to greater self-knowledge through pervasive data collection, its role in managing new opportunities for autonomy remains to be defined, and the balance between individual freedoms and collective goals will likely continue to the subject of ongoing contention and negotiation. If uncritical techno-optimism is allowed to flourish, technologies could just as easily be turned to other ends than freedom.

Peer-to-peer principles could even transform *the spiritual order*, as new individualized paths to meaning are opened up, and an ethos of care for ourselves, each other, and the natural world takes hold. Opening minds to sustainability may create a new consciousness of human beings' embeddedness in the environment. Encouragement to achieve bold new aspirations for society will need to triumph over despair at daunting environmental challenges for this to be possible. Ethical issues surrounding pervasive data-gathering, possible erosions of privacy, and risks of self-censorship (cf. state-led paternalism) may encourage a reconsideration of duty and responsibility as internalized logics for guiding the choices of individuals.

Table 3. *New opportunities and new risks of the circular economic peer-to-peer renewable energy world.*

Sectoral ideals	**New opportunities**	**New risks**
Relationship with the external environment	New worldview Super-AI "Mother Earth"	Blurring human-environment relationship Tech penetration weakens nature connection Energy use of circular economy, data and ICT
<u>*Economic sector:*</u> *solidarity*	Recognition of interdependence between humans and ecosystems Lowered cost of production, efficiency Valuation of empathy and common good Fair and equal distribution of value Transparent sharing economy	Access to applications and technology Costs of new tech solutions
<u>*Material order:*</u> *wealth and prosperity*	AI-aided real-time feedback for CE/RE Birth of new large socio-technical systems Nature-human-technology relationship Emerging technologies, tech convergence and transport for p2p-RE-CE Old infrastructure replaced	Unfounded techno-optimism Counter-trends and resistance widen social divisions (slow-life vs. tech-aided high-speed life)
<u>*Political and social sector:*</u> *equality*	Present actions to change power structures 'Genuine' equality Empathy combined with intelligence Open source P2P learning and coding New simulations of greater social good	AIs or humans making decisions? Both high- and low-quality information can be more easily shared Unequal access to technology

<u>Social order:</u> rights and justice	P2P as autonomy, emancipation Decentralised, diffused knowledge Preventive healthcare: DIY-/e-diagnostics	Inequality of initial conditions Loss of jobs - what skills are valued? Post-truth; information sharing bubbles Maximum lifespans
<u>Cultural sector</u>: freedom	Freedom, trust, tech for meaningfulness Managing opportunities for autonomy Greater self-knowledge Positive work-leisure-self-actualization nexus	Algorithms obscure agency Individual freedoms vs. collective goals Excessive technology fascination
<u>Spiritual order:</u> ideas, values, arts and sciences	Encouragement over despair Opening mind for sustainability New paths to meaning – values as a duty	Skepticism of emerging technologies and novel scientific contributions Ethical issues of pervasive data-gathering Erosion of privacy, self-censorship (cf. state-led paternalism)

Conclusions

This paper has outlined a vision of a renewable energy society based on peer-to-peer principles in a circular economy as a possible, and potentially desirable, future. Careful study should underpin such a bold vision, and the social aspects of such a future at the present are not yet adequately understood. To shed light on this topic, the paper first presented the results of a futures workshop on these themes, identifying new opportunities and risks among the findings. Lastly, the resonance of the results with the ideals of Lemma and Malaska's (1989) model of an open, threefold society, with its interacting sectors and orders, and the external environment, was assessed.

The paper has in particular examined the socio-cultural, organisatory, and technological aspects of the envisioned changes. Based on the results, it became clear that the social and environmental pressures currently driving large social shifts are reconfiguring the functions and organisation of tasks system-wide. It is rather interesting to notice that when the pervasiveness of technologies intertwines with peer-to-peer principles, past practices are challenged, and in the long-term, so are perceptions of what is perceived to be "natural". Novel technological and societal principles can be introduced in different ways, resulting in divergent effects, which is why their potential implications must be carefully studied in a holistic manner.

For further research, some key suggestions can be made. From a social standpoint, these novel consequences, including opportunities and risks, require closer attention. Additionally, a peer-to-peer based vision of an electrified circular economy requires more careful consideration from an environmental perspective, as it receives only limited attention in this work. This may include further studies of how the peer-to-peer logic, surge of renewable energy technologies, and electrification, align with the principles of the Fourth Industrial Revolution, with its novel types of production processes even at industrial scale.

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Appendix: Workshop instructions and group work questions

1. How to organise a circular economy with renewable energy and peer-to-peer principles? Choose the topic/angle the Group will address the question from: housing, mobility, leisure, production, security, health, equality, new risks, other?

2. Imagine what happens, if you combine one future technology to your topic? (e.g. Artificial Intelligence / Big Data / Blockchain / Internet of Things / 3D Printing / Robotized Services / Nanotechnology)

3. Discuss in groups and write down the ideas

4. Select three of your most important ideas (product, service, innovation, new way of working/acting, new risks) Share the most important idea of those three ideas of your group.

Magnetism Will Inaugurate the New Era of Humanity - Analytical Trilogy applied to the Keppe Motor Technology

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Abstract

Although not currently a mainstream view in energy research, the theory of magnetism proposes an entirely new, opposite view, according to which magnetism is an energy abundant throughout the universe and, if such a view was accepted, its possible use could lead humanity to a new era. This paper presents results of a scenario study of the use of magnetism by means of the Keppe Motor technology whose working principles are based on the science created by psychoanalyst and researcher Norberto Keppe: Analytical Trilogy.

Introduction and Background

Civilization and its science are based on postulates. Changing postulates changes civilization. According to Steven Weinberg (2007, 29–42), resolving the current problems in physics would in fact demand the emergence of radically new ideas. As well, Kragh (2011), states that basic methodological and epistemological rules of science are in need of revision and a proposed shift in epistemic standards may be of such a drastic nature that it challenges the very meaning of science as traditionally understood. Although not currently a mainstream view in energy research, the theory of magnetism proposes opposite postulates, according to which magnetism is an energy abundant throughout the universe and prior to matter. Dis-inverting Aristotelian Metaphysics has led Norberto Keppe to set a new basis for understanding energy, from which springs a revolutionary motor technology, more efficient in capturing magnetism, energy abundant in the universe. His view of electricity considers it as a partial sub product of magnetism that is captured from space (Keppe, 1996, 82–83).

The first electrical motor in history was made by Michael Faraday. He perceived the connection between electricity and magnetism, but as James Clerk Maxwell mathematized his discoveries, these ended up being considered as only one phenomenon (Forbes et Mahon, 2014). Nikola Tesla discovered the magnetic rotative field and built the induction motor using the double characteristic (attractive and repulsive) of magnetism. Based on Keppe's Dis-inverted Metaphysics, engineers Cesar Soos (Keppe Motor, 2017), Roberto Frascari and Alexandre Frascari were able to develop commercialized models of the *Keppe Motor* capable of capturing this essential magnetism in a more efficient way.

Having discovered the phenomena of inversion[1] in 1977, Keppe (1982, 26–30) was able to understand that humanity is living upside down, seeing goodness as evil, fantasy as pleasant, reality as harmful, love as dangerous, truth as aggression. And this inversion is based on an emotion, inconscientized envy, within every man and woman. Soon after, Keppe applied his discoveries in the areas of psychotherapy and psychosomatic medicine, calling his method Analytical Trilogy, as it unifies science, philosophy and theology. Keppe considers that nervousness, neurosis, psychosis and physical diseases exist due to a battle that we carry on against truth, beauty and goodness which constitute the essence of the human being (Bezerra, 2013, 18–22). In other words, everything that exists in itself is good (except when

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[1] Inversion means the process through which a person sees good in that which is evil and evil in that which is good.

we omit, deny or alter it). Therefore, there must be something wrong with the present technology if the use of energy is destroying resources and polluting the planet (Soos, 2005, 34–35). Keppe's perception culminated in understanding that: "The fundamental mistake in physics is of the equation of energy with matter", instead, matter is a sub-product of energy, and this energy can be tapped directly without destroying planet's resources (Keppe, 1996, 17–18).

The inversion leads Man to follow Aristotelian Metaphysics that is based on the concept of act and potency, or rather, that the greater would derive from the lesser. This has led science to follow the same materialistic path and, therefore, to consider energy as a result of matter. However, Keppe proposes that in fact energy is prior to matter and matter its consequence, and thus it should not be necessary to destroy matter in order to get energy that exists everywhere in space. It is based on the hypothesis that matter captures and transforms immaterial energy, called essential energy, into secondary forms of energy, namely electricity and magnetism. (Keppe, 1996, 17–18). Aristotle called this energy "ether"; Nikola Tesla named it "scalar energy" (Nováček, 2011, 376–379).

The objective of this paper is to analyze how the use of magnetism could possibly impact the futures, in case that humanity accepts the discoveries of a new science called Analytical Trilogy that is the unification of theology, philosophy and science. Keppe's paradigm inversion theory and practice turns physics on its head. According to Keppe, nuclear energy (radioactivity) or orbital energy (electromagnetism), are secondary energies. Today's science is focused on those secondary energy effects, which can be registered by electronic measuring devices. This is an example of how the inverted philosophical principles limit our understanding. A different perspective of the conventional scientific philosophy can lead to a new understanding of physics and an upgraded technology, which is able to give a practical solution to problems which are, so far, considered as intrinsic factors such as counter electromotive force, magnetic drag, hysteresis and eddy currents. (Pacheco, 2008, 10–11).

In addition to the possible futures scenario, this paper brings the official governmental studies of the energy efficiency of the *Keppe Motor* Technology and briefly transmits a few of Norberto Keppe's hypothesis that have made this magnetic technology possible alongside other innovations.

Material and Methods

This study is based on Analytical Trilogy or Integral Psychoanalysis which is the result of more than fifty years of research conducted by Keppe in the field of psycho-socio-pathology. Trilogy because it encompasses three elements: science, philosophy and theology - thus providing a broader, unified perspective to understanding the phenomenon, and analytical as it accomplishes an analytical scientific work. (Pacheco, 2014, 15–17). Perhaps it seems incompatible that hard scientific proposals could come from psychology and even philosophy, but it is precisely Keppe's work in these fields that has enabled him to elaborate his revolutionary scientific view. (Pacheco, 2008, 7).

In the present study, the official documents of The National Program of Electrical Energy Conservation (PROCEL) where *Keppe Motor* technology efficiency is compared to other technologies were studied. PROCEL is responsible for Energy Efficiency Label system in Brazil and it was created to stimulate the rational use of energy at the end user side. It informs the public of the efficiency of electrical products, that is, how much products consume electrical energy, to do certain work, in relation to other devices. It has shown to be one of the most important Brazilian instruments for the quest of energy efficiency since its foundation in 1985. (Abreu, 2016, 14–15). In the case of fans, the energy consumption of the fan that is working one hour per day during thirty days is measured and compared to the air flow produced. (INMETRO, 2018).

From the past perspective, the reasons behind the energy efficiency of the *Keppe Motor* technology were studied. What is the underlying theory? What is Keppe's thesis on inversion, applied to energetics and physics? How did he come to these conclusions? A book review on the subject has been extensive, including in particular Keppe's books *The New Physics Derived form the Dis-inverted Metaphy*sics (1996) and *Magnetonics* (2013) among other publications.

For understanding futures, scenario planning was used. Scenarios are narratives of the future, which describe plausible future paths and consider various factors. The objective of scenarios is to provoke thinking of decision makers and this way they also provide a base for strategic planning. The question asked was "What would the possible outcomes be, if Keppe's theory on magnetism, as well as resulting technologies, such as Keppe Motor, presented in this paper, and related know how, were taken up in energy research and consequently applied in society?" However, it is understood that this occurrence faces several barriers deriving from individual and societal pathology such as universal envy and theomania, inversion, alienation and inconscientization, and in particular the human will and pathology of power which will create obstacles to the acceptance of new theories and technologies as they will impact the present status quo of power. (Marques et al., 2015, 250–259).

Results

The *Keppe Motor* is an advanced, energy efficient motor technology that consumes up to 90% less energy compared to other single-phase induction motors (Moreira, 2017 and INMETRO, 2018). Whereas the state of the art electromagnetic motors are constantly fed with electricity, *Keppe Motor* switches the input current on and off collapsing the magnetic field and the high voltage peaks. This way *Keppe Motor* is able to tap essential energy in its integrality, particularly its second component. Keppe holds that the essential energy, in the case of the magnetic fields, is twofold and bidirectional, i.e., it always acts in two equal components, but in opposite and complimentary directions. (WIPO, 2009). These solutions are far ahead of similar conventional motors in energy efficiency tests. (INMETRO, 2018).

The energy efficiency of ceiling fans is the ratio of average air flow produced and electric power. The PROCEL energy efficiency labeling system categories range from A to E stating three different speed modes: high, medium and low. The compared efficiencies refer to the energy consumption of one hour a day during one month, totaling 28 manufacturers and 542 models. The energy efficiency leader of ceiling fans of 127V is the *Keppe Motor Universe Turbo*, whose energy consumption at high speed, 0.66 kWh / month, medium speed, of 0.17 kWh / month, and at low speed, 0.06 kWh / month. The air flow at high speed of 2.15 (m3 / s), medium speed 1.39 (m3 / s) and low speed 0.84 (m3 / s). (INMETRO, 2018). This efficiency is outstanding, since the second one consumes at high speed 1.00 kWh / month, medium speed 0.45 kWh / month, and low speed 0.12 kWh / month, corresponding the air flow at high speed 2.11 (m3 / s) medium speed 1.7 (m3 / s) and low speed 1.12 (m3 / s). The efficiency of the *Keppe Motor* fan at high speed is 0.098 when the second most efficient is 0.064. (INMETRO, 2018). Therefore, it is considered "the best available technology for ceiling fans". by the Brazilian Ministry of Science, Technology, Innovation and Communication (RATHMANN, 2017).

The *Keppe Motor* received patents in the U.S., China, Russia and Mexico. It won the Gold Award for Energy Efficient Motor Technology and the Grand Prize for Outstanding Innovation and Technology Product at the Hong Kong Electronics Industry Association trade show in 2015 and was selected as a finalist at the 2015–16 Global LEAP Awards in USA. In Brazil, it won the 2017 *Potência de Inovação Tecnológica* Award.

Scalar Energy discovered by Nikola Tesla is a powerful force that exists throughout the universe; the *Keppe Motor* makes better use of this energy. Working through the principle of resonance, this technology guarantees maximum efficiency for motors of any power over their entire working range. The *Keppe Motor* differentiates from both conventional AC and DC motors by its unique RC (resonant current) operating waveform. It is based on studies published, 1996, France, *The New Physics derived from the Disinverted Metaphysics* by psychoanalyst and researcher Norberto Keppe (1996). His hypothesis is: Magnetic energy that motors use is captured directly from the external environment, functioning the same way as other material, sensorial and psychic forces (power and movement, light, time and space). The author holds that the essential energy, in the case of the magnetic fields, is twofold and bidirectional, i.e., it always acts in two equal components, but in opposite and complimentary directions. Everything that exists is structurally an energetic vibration that manifests in solid, liquid, gas or energetic form. With the new science of magnetonics, it is possible to move from the partial use of energy to the total use of energy. From this point forward, a new formula substituting Einstein's $E=mc^2$, is M=RE/TS, M being matter which is a consequence of resonant energy inside time and space. (Keppe, 2013, 15–16).

INMETRO

INSTITUTO NACIONAL DE METROLOGIA, QUALIDADE E TECNOLOGIA
PROGRAMA BRASILEIRO DE ETIQUETAGEM

EFICIÊNCIA ENERGÉTICA - VENTILADORES DE TETO / 127V - Edição 01/2018
EFICIÊNCIA ENERGÉTICA - VENTILADORES DE TETO / 127V - Edição 04/2016

PROGRAMA BRASILEIRO DE ETIQUETAGEM

Fabricantes	31
Marcas	41
Modelos Etiquetados	598

		Velocidade Alta			Velocidade Média			Velocidade Baixa		
► Mais Eficiente	A	0,019	$< E_A$		0,022	$< E_M$		0,020	$< E_B$	
	B	0,017	$< E_A \le$	0,019	0,020	$< E_M \le$	0,022	0,018	$< E_B \le$	0,020
	C	0,015	$< E_A \le$	0,017	0,018	$< E_M \le$	0,020	0,016	$< E_B \le$	0,018
	D	0,014	$< E_A \le$	0,015	0,016	$< E_M \le$	0,018	0,013	$< E_B \le$	0,016
► Menos Eficiente	E		$E_A \le$	0,014		$E_M \le$	0,016		$E_B \le$	0,013

05/07/18

(*) Consumo de Energia mediante o uso do equipamento por 1 hora por dia por mês.

FABRICANTE	MARCA	LINHA	MODELO (NOME FANTASIA)	TENSÃO (V)	CONTROLE	Nº DE PÁS	MATERIAL DA PÁ	VAZÃO MÉDIA DE AR (m³/s) VELOCIDADE			EFICIÊNCIA [(m³/s)/W] VELOCIDADE			CONSUMO DE ENERGIA (kWh/mês) (*) VELOCIDADE			FAIXA DE CLASSIFICAÇÃO			SELO PROCEL
								ALTA	MÉDIA	BAIXA	ALTA	MÉDIA	BAIXA	ALTA	MÉDIA	BAIXA	ALTA	MÉDIA	BAIXA	
PLAJET MAGNETICA DISTRIBUIDORA LTDA	IC AIR	IC AIR	LIGTH	127	CAPACITIVO	2	POLICARBONATO	2,83	2,2	1,82	0,030	0,033	0,029	2,84	2,00	1,89	A	A	A	SIM
PLAJET MAGNÉTICA DISTRIBUIDORA LTDA	IC AIR	IC AIR	LED	127	CAPACITIVO	2	POLICARBONATO	3	2,29	1,65	0,031	0,032	0,029	2,89	2,12	1,69	A	A	A	SIM
PLAJET MAGNÉTICA DISTRIBUIDORA LTDA	IC AIR	IC AIR	SOLO	127	CAPACITIVO	2	POLICARBONATO	3	2,29	1,65	0,031	0,032	0,029	2,89	2,12	1,69	A	A	A	SIM
PROTON TECNOLOGIA	KEPPE MOTOR	UNIVERSE	UNIVERSE	127	3 VELOCIDADES CONTROLE REMOTO	3	PLÁSTICO	1,84	1,36	0,92	0,075	0,143	0,288	0,74	0,29	0,10	A	A	A	SIM
PROTON TECNOLOGIA	KEPPE MOTOR	UNIVERSE	UNIVERSE TURBO	127	5 VELOCIDADES CONTROLE REMOTO	3	PLÁSTICO	1,96	1,19	0,74	0,089	0,198	0,435	0,86	0,18	0,05	A	A	A	SIM
PROTON TECNOLOGIA	KEPPE MOTOR	UNIVERSE	UNIVERSE TURBO ECO	127	5 VELOCIDADES CONTROLE REMOTO	3	PLÁSTICO	2,15	1,39	0,84	0,098	0,253	0,442	0,66	0,17	0,06	A	A	A	SIM
QUALITAS	QUALITAS	TETO	Q900C 3P 127V	127	1 VELOCIDADE	3	METAL	2,3	NA	NA	0,022	NA	NA	3,09	NA	NA	A	NA	NA	SIM
QUALITAS	QUALITAS	TETO	Q900RL 3P 127V	127	CONTÍNUO	3	MADEIRA	2,03	1,66	1,09	0,020	0,024	0,027	3,00	2,10	1,19	A	A	A	SIM
QUALITAS	QUALITAS	TETO	Q900RLE 3P 127V	127	CONTÍNUO	3	MADEIRA	2,03	1,66	1,09	0,020	0,024	0,027	3,00	2,10	1,19	A	A	A	SIM
RIOPRELUSTRES	RIOPRELUSTRES	CHILD	CHILD 1054	127	3 VELOCIDADES	3	PLÁSTICO	2,15	1,72	1,36	0,018	0,018	0,016	3,65	2,81	2,61	B	D	D	
RIOPRELUSTRES	RIOPRELUSTRES	CHILD	CHILD 1055	127	3 VELOCIDADES	3	PLÁSTICO	2,15	1,72	1,36	0,018	0,018	0,016	3,65	2,81	2,61	B	D	D	
RIOPRELUSTRES	RIOPRELUSTRES	CHILD	CHILD 1056	127	3 VELOCIDADES	3	PLÁSTICO	2,15	1,72	1,36	0,018	0,018	0,016	3,65	2,81	2,61	B	D	D	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1026	127	3 VELOCIDADES	4	MADEIRA	2,24	1,74	1,35	0,018	0,019	0,015	3,67	2,81	2,61	B	C	D	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1026	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1027	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1027	127	3 VELOCIDADES	4	MADEIRA	2,24	1,74	1,35	0,018	0,019	0,015	3,67	2,81	2,61	B	C	D	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1028	127	3 VELOCIDADES	4	MADEIRA	2,24	1,74	1,35	0,018	0,019	0,015	3,67	2,81	2,61	B	C	D	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1028	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1036	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1037	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1038	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1039	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	
RIOPRELUSTRES	RIOPRELUSTRES	CLASSIC	CLASSIC 1040	127	3 VELOCIDADES	4	PLÁSTICO	1,88	1,47	1,11	0,015	0,016	0,013	3,69	2,82	2,63	D	E	E	

Figure 1. KEPPE MOTOR in PROCEL Listing showing its energy efficiency. INMETRO (2018) Author's adaptation.

Discussion and Conclusions

The *Keppe Motor* is an advanced, energy efficient motor technology that consumes up to 90% less energy compared to other single-phase induction motors. Its substantial energy gain is due to voltage peaks and magnetic field collapses, as well as considerable reduction of losses, considered intrinsic to the motors according to the mainstream science. It is named after Brazilian scientist, Norberto Keppe, whose book, *The New Physics Derived from a Dis-inverted Metaphysics* (1996), lays out a complete re-directioning of technological and scientific philosophy.

The objective of this study is to understand what the possible outcomes would be, if Keppe's theory on magnetism, as well as resulting technologies, such as *Keppe Motor* and related know how, were taken up in energy research and consequently applied in society. The conclusions relating to environment, health, life expectancy, migration, economy, politics, transportation and energy generation are the following:

1) Mitigating Green House Gases and other pollutants, as a result of using magnetic energy instead of fossil fuels. Preservation of ground, air and seas, consequently reducing pulmonary and circulatory diseases.
2) Eliminating the menace of energy crises. Abundant energy without harming environment will enable many projects, which were not economically feasible, such as desalinization of seawater or transportation of water to desert areas. Making deserts into fertile, agricultural areas and thus reducing migration movements due to harsh living conditions.
3) Gradual substitution of thermoelectric, hydroelectric and nuclear plants, avoiding the risk of catastrophes similar or worse than Chernobyl and Fukushima or other environmental hazards.
4) Economic development due to cost reduction in energy, allocating resources to benefit population, ending economic slavery in favor of independence of nations.

5) Possibility of new projects previously unfeasible, as the *Keppe Motor* is inexpensive to produce and use; it works perfectly with materials that are both lighter and less resistant to temperature. Eliminating the need for silicon-iron cores and inverters that optimize the rotation.
6) Creating an entire new market of portable products supplied with batteries or solar panels especially applicable in spacecraft and communication satellites. Helping companies to achieve new regulations such as ISO 50.001 at low cost.
7) Eliminating worldwide conflicts caused by the search for domination of fossil fuel resources: World peace. All nations to be self-sufficient because of their enrichment. Their citizens no longer controlled by international economy groups. Energy would cease being a cause for war or the source of concentration of the wealth.
8) Higher durability of motors (Longer Life Cycle) and consequent positive impact on the environment.
9) The *Keppe Motor* runs cold, an indication of its high efficiency, needing less maintenance. More silent as it works with or without brushes for any application.
10) Contributing to the dematerialization of vehicles and making them nearly 100 % ecological. Enabling heat and air conditioning systems with extremely low costs.
11) Improving the energetic environment and decreasing pollution, providing better economic conditions, curtailing class struggles, domestic and urban violence, which directly affects people's health and costs involved. Greater comfort and dignity for needy populations without a significant negative environmental impact. Not only in technology but in the area of psychosomatic medicine and mental health, the use of magnetism will increase the quality of life and life expectancy.
12) Redirecting the technological philosophy of the world and simplifying technology as many of the technological advancements have been created to correct the mistakes deriving from the materialistic interpretations.

It was also acknowledged that the greatest challenge is how to make humanity, inverted as it is, to give up this materialistic view of reality, consolidated in Einstein's theories that energy would derive from matter, and to accept new theories and forms of living, and consequently improving technologies to harness magnetism to serve humanity. The dis-inversion of physics may lead humanity to an abundant source of energy and consequent development, but this shift faces a great resistance, due to human pathology, and in particular the pathology of power and needs to be addressed in scientific, political and ecological realm.

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Developing Visionary Concepts for the Water Sector

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Abstract

This paper is based on CIRCLE research project running from September 2016 to November 2018 financed by ERDF, with the focus on the energy and nutrient recycling in the context of the water supply services. Laurea´s FuturesLab CoFi reseach team has built alternative scenarios for the water supply services in long run as well as visionary concepts for water supply service business in general. We have applied scenario working and visionary concept design to find out new solutions for the water supply/demand problems faced both at the global level in the world and at the regional level in Finland, too.

Introduction and Background

According to the international climate change panel, the consequences of the climate change are more concrete, rapid and visible in practice than ever expected (IPCC 2018). The global warming will have its expressions often in the form of the heavy storms causing floods and shortage of the clean water in the catastrophe areas. On the other hand, the draught is at the same time a big problem because of the climate change causing rapid fluctuations in the weather conditions. The lack of clean water has its explanation also from agricultural reasons, namely nutrients running from the fields to the seas, rivers and lakes.

This paper is based on CIRCLE research project (9/2016–11/2018), financed by ERDF European Regional Development Fund. Häme University of Applied Sciences acts as a coordinator and the other partners are Laurea University of Applied Sciences (UAS) with its FuturesLab CoFi, the Association for Water and Environment of Western Uusimaa (LUVY), Aalto University and Sykli Environmental School of Finland.

CIRCLE project will focus on the energy and nutrient recycling in the context of the water supply services. Laurea´s FuturesLab CoFi is responsible for the future-orientation in the CIRCLE project, building alternative scenarios for the water supply services in long run as well as building visionary concepts for water supply service business in general. The key questions in this context are as follows:

- What the world or the society needs? -to create future-oriented solutions to resource scarcity and polarization at world level
- What the water supply service branch needs? -to find knowhow-intensive education modules for export
- What the firm needs? -to exploit new opportunities and visionary concepts based on scenario alternatives
- What the individual or the consumer needs? – to get easy solutions to everyday life concerning sustainable way of living

We have applied scenario working and visionary concept design to find out new solutions at the world level but also at the regional level.

The framework of our study consists of three elements, which are scenario planning, visionary concept design and hybrid product concept model (Figure 1).

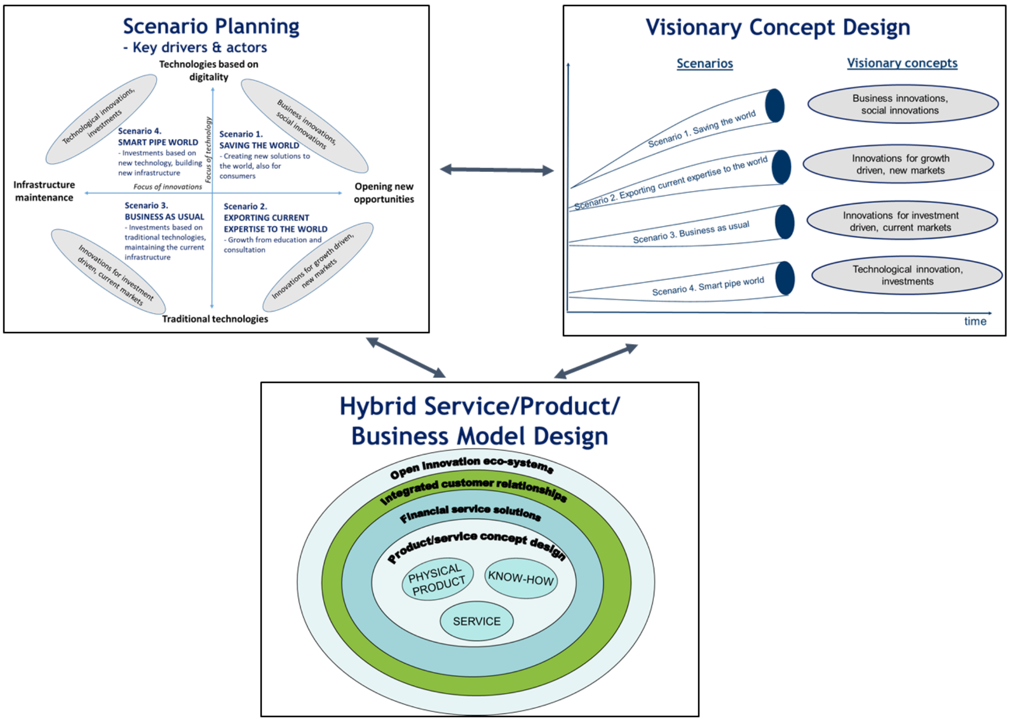

Figure 1. *The framework for the study in the context of water supply services.*

Scenario planning includes the recognition of key drivers and key actors influencing on the future in long run and visionary concept design will use alternative scenarios as a basis for service and product concept design for different needs. Finally, hybrid product concept model will deepen these concepts more precise with the help of its elements consisting of physical, service and know-how core elements but also of financial services, customer relationships and open innovation ecosystem elements which should be taken into consideration to form comprehensive solutions (Figure 2).

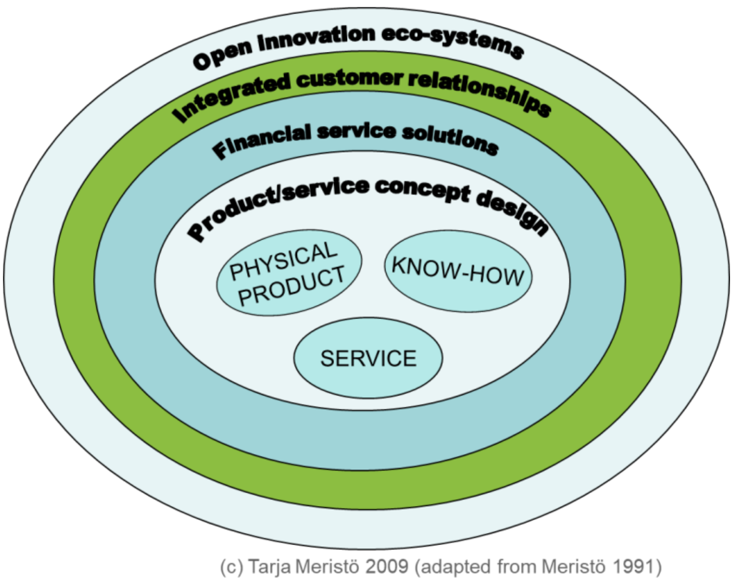

Figure 2. *The framework of hybrid product concept model.*

Preliminary visionary concepts were created first with the student group in spring 2017, results were presented in the futures research conference in Turku 2017 (Laitinen & Meristö 2018a). The completed results and visionary concepts were produced in the facilitated visionary concept design workshop in spring 2018, and this paper will focus on that process and those concepts developed there.

Material and Methods

Data collection for the study included futures workshops with ecosystem actors to produce visionary knowledge, web surveys to actors and experts to collect trends and impacts on this field and complementary interviews among key actors from water business and from water research side. The main data of this study comes from the visionary concept workshop held in March 2018 but several preparatory phases preceded it (Figure 3). The preliminary scenarios were created by the research group based on the data collection done in 2017 which included web survey, interviews and a future workshop (Meristö & Laitinen 2017, 2018b). The contents of the scenarios were supplemented by the futures table method in a workshop. The futures table results offered input to form scenario stories which were used as a basis for the visionary concept workshop.

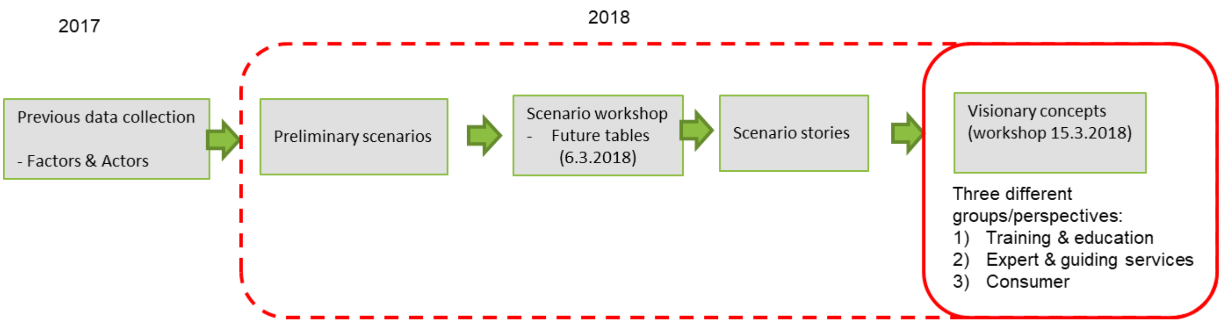

Figure 3. *The main phases of the research process.*

The goal of the visionary concept workshop was to develop new solutions (product/service/operational model) based on the scenarios. The workshop was carried out in three different groups. Two of the groups had a case organisation perspective: training & education organisation had education as a theme and expert & guiding services organisation had water management in rural areas as a theme. Additionally, the third group focused on a consumer perspective at a general level.

The main method applied in the study is scenario planning integrated to the visionary concept design. Visionary concept design starts from the future and its alternative development paths and focuses on needs and opportunities identified from alternative scenarios. Scenarios will serve as an ideation source to design visionary concepts, but also as wind tunnels to test ideas and concepts (Kokkonen et al. 2005). The method for creating visionary future product concepts consists of five main steps. The first step is the identification of change factors, which forms a basis for the second step i.e. scenario building. The third step is the identification of product needs in each scenario. The fourth step is the actual generation of future concepts based on the market need identified in each scenario. The fifth and last step of the method is the timing of R&D activities and operations. This step also includes other considerations concerning the contribution the visionary concepts might have to the company's business planning or strategy (Kokkonen et al. 2005).

The time perspective of the visionary concepts is long which has several benefits. Visionary concepts enable systematic examination of alternative future developments because future scenarios are illustrations of the operational environment in the future. It also takes into account the driving forces as well as market potential, uncertainty and challenges related to future in alternative scenarios. Moreover, visionary concepts enable product concept design and R&D for the future, over the next product generation visualizes the future as products which are corresponding to the future needs (Leppimäki et. al. 2008).

Based on the collected data we ended up to two main drivers for the Finnish water services sector: 1) Focus of innovations (infrastructure maintenance vs. opening new opportunities) and 2) Focus of technology (technologies based on digitality vs. traditional technologies).

Examining the chosen drivers against each other, we built a fourfold table which formed starting points for the scenarios (Figure 4). Solutions based on digital technology are opening new market opportunities enabling profitable business and saving the world at the same time (Scenario 1) whereas expertise based on traditional technology can focus on exporting the current know-how to all around the globe to the new markets (Scenario 2.). On the other hand, focusing on traditional technology combined and maintaining the current infrastructure leads to the business as usual development (Scenario 3). Maintaining the infrastructure by totally new solution based on digital technology is also a possible alternative (Scenario 4).

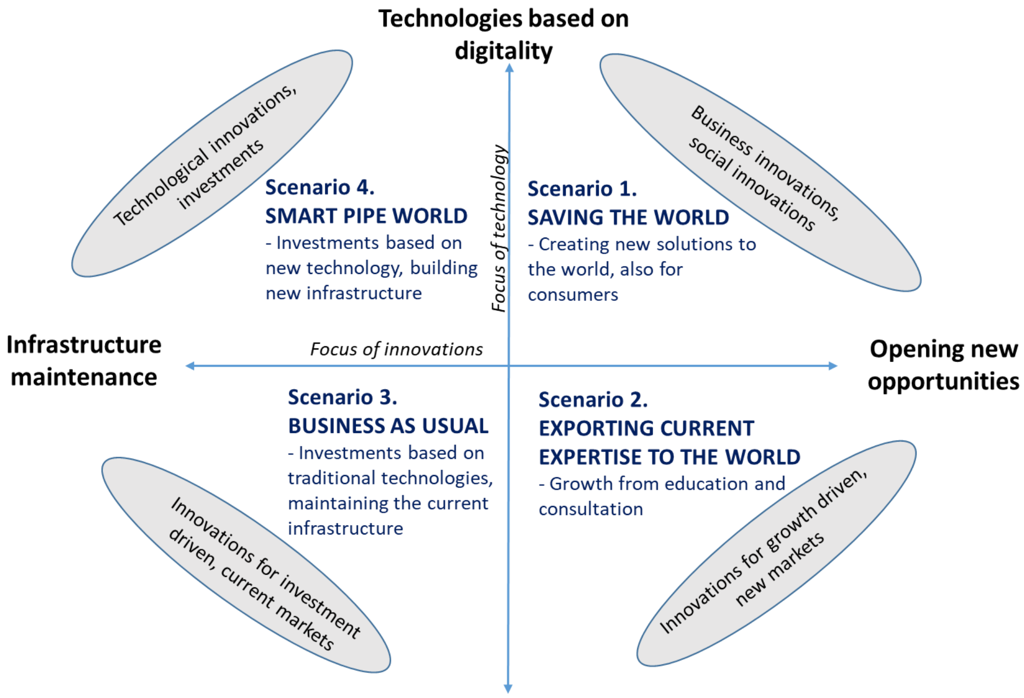

Figure 4. *Water supply service scenarios according to the key drivers in the field.*

These four scenario alternatives were deepened by using futures tables describing all the factors and actors influencing on the future in long run. Three different scenario levels were used: the World level, the level of Europe/Finland and the level of Water Branch with its Actors. Altogether 30 variables were used: eight (8) from the world level, 13 from the Europe/Finland level and nine (9) from the branch level. All these variables carry alternative values varying from three to five alternatives each. E.g. at World level *Leading countries in water management business: /Finland/USA/China/Europe/No leading countries/* or at Europe/Finland level *Integrated energy production to water purification:/New normal/Not common/Locally somewhere/Only pilots/Not at all/* and at the Water branch with its actors *Key actors: /Water treatment actors/R&D&I actors/User sector organisations /Consumers/Legislators and International agreements/.*

The driving forces for each scenario were recognized and marked to the futures tables first, the consequences according to these driving forces were estimated and finally the scenario storylines based on these marks in the futures tables were written as follows.

Scenario 1. Saving the world

In this scenario all interest groups including companies, public sector and consumers are committed to save the world and the environment. The opinions of NGOs are also taken into consideration in public discussion and decision making. The focus of the water sector solutions is on business and social innovations. The goal is to open new opportunities for the water service business sector especially by applying solutions based on the digital technology. The business is focused not only on B-to-B and B-to-P solutions but also B-to-C solutions are looked for.

The basic assumption behind the scenario is the legislation, which enables developing new business activities so that the supply of water is ensured also in the free market economy. The water services sector is investing in new technologies, abandoning conservativeness and looking for new opportunities. Water service providers form an international network of small companies which takes into consideration local circumstances but also global standards in its operational development work.

The sufficiency of water resources is ensured by new technology but also the administration and payment collecting system of the water sector is working well. The migration of people due to water resources is working as driver, which also awakens Finnish people who do not have much experience of the lack of water. Water crises are a recognized risk which is taken into account in the water sector’s development work. China is the leading country developing business in the water sector where as Europe is the leader in the social innovations regarding the water sector.

Scenario 2. Exporting current expertise to the world

The starting point for the scenario is the export of education and project management know-how based on traditional technologies to the new market. The demand for the water supply services and other water related business increases everywhere in the world. The biggest need is focusing on Africa but also in the Asian big metropolitan cities there is a demand for the top of world expertise which can be found from the Finnish and Scandinavian actors. Especially the Finnish expertise in water treatment and water supply is appreciated around the world.

The EU legislation supports the developing of the water service business and export possibilities. In Finland, private companies will also become the owners of the water utilities in addition to the municipalities. In the operational environment of the free market economy, the water supply security has been ensured with the legislation. In a competitive environment, the Finnish water expertise develops into agile and top-quality. The appreciation towards clean high-quality water has risen and even in Finland the pure water is not taken for granted anymore. Consumers are willing to pay extra for the clean water. There will not be specific fees to the water use in Finland but the financing of the infrastructure of the water supply and sewerage is taken care of through the taxation. The solutions of water supply services in Finnish sparsely populated areas are high level and standardized. There is also global demand for the Finnish water expertise regarding sparsely populated areas. The export of the water expertise is supported by the advanced sales expertise. The expertise of immigrants who have moved to Finland are utilized opening new export opportunities.

The Finnish water expertise is based on the high-quality know-how of traditional technologies but the solutions based on digitalisation and artificial intelligence support the traditional technologies. In Finland, the energy production integrated into the water treatment plants becomes more common which increases new export possibilities for its part. The expertise related to the recycling of nutrients also develops and creates new possibilities to the export. The Finnish water expertise is supported by the high-quality education which is carried out with the help of coordinated multiactor forum. The close cooperation of the water field with the bio and circulation economy also supports the development of the expertise.

Scenario 3. Business as usual / Conservative water sector

The use of traditional technologies in the water sector and the management of the repair debt of the infrastructure are the drivers for the scenario. Inadequacy of water resources cause conflicts. The specific problem in the global scale is a non-existent excrement management, likewise the non-existent handling level of waste waters. The leading countries in water supply services come from Europe, especially Netherlands. The main market is in the big towns of the world, in especially their slum areas.

In Europe, the legislation opens new opportunities but in Finland the legislation is more like restricting by nature. The awareness of the importance of clean water increases and the people are ready to pay a little extra fee for clean water also in the form of the sewage fees. The smart technology is widely applied in the field of anticipatory supervision solutions and controlling activities. The energy solutions integrated into the water purifying activities are the “new normal”. The immigration does not have big effects on the water supply and sewerage; the effects are mainly for example local arrangements related to the water supply and sewerage of refugee centres.

The Finnish water services sector is investing in a digital technology and the market is around the globe. However, the operation philosophy of companies is conservative. Local water service providers are still the key actors of the field. The education and expertise in the water field are in the recession and its supply decreases. Public-private cooperation becomes more common in the field, in other words the municipalities have the possession of water treatments plants but the services will come from the companies. The water supply services are seen to an increasing extent as a part of bio economy and circulation economy, utilizing synergic advantages. To this kind of a combination there is a global demand but it requires investments in the infrastructure even in the present market areas.

Scenario 4. Smart pipe world

The drivers for the scenario are the investments into the digital technologies and into management of the repair debts of the infrastructure. Good even global economic growth is needed so that it is possible to invest in both. A mutual understanding of the climate change agreement will be reached and at least the current level of commitment and solution-centric attitude will be continued. No country in the world is a specific leader in the development of the water supply services but all are seen as equal actors in the water supply management.

The operational activities require regional cooperation and the wide applying of public private partnership models. The EU legislation enables circulation economy solutions and the rich big towns are willing to pay for the clean water or solutions related to it. The extra finance needs are solved in the form of the new payments, e.g. drainage water payment. The demand for water service solutions in the sparsely populated areas are not seen as an interesting market potential but the urbanisation enables new business opportunities due to the changing consumer habits.

The aware actors use smart technology and the digitalisation becomes common in all the functions of the water sector. New breakthrough technologies will come to the recycling of nutrients and the whole innovation system is renewed so the water sector gets along to the new phase of development. The market is over regional limits, however, paying attention to local special characteristics and to condition differences. The whole field must attempt to radical reforms so that the advantages of the scenario can be realized. The actors of the field are big, national companies which perhaps search for synergies from bio economy and circulation economy through the mergers.

Results

The idea of the visionary concept design is illustrated below (Figure 5), where the alternative scenarios and the innovation areas for the water supply services needed in the long run are described.

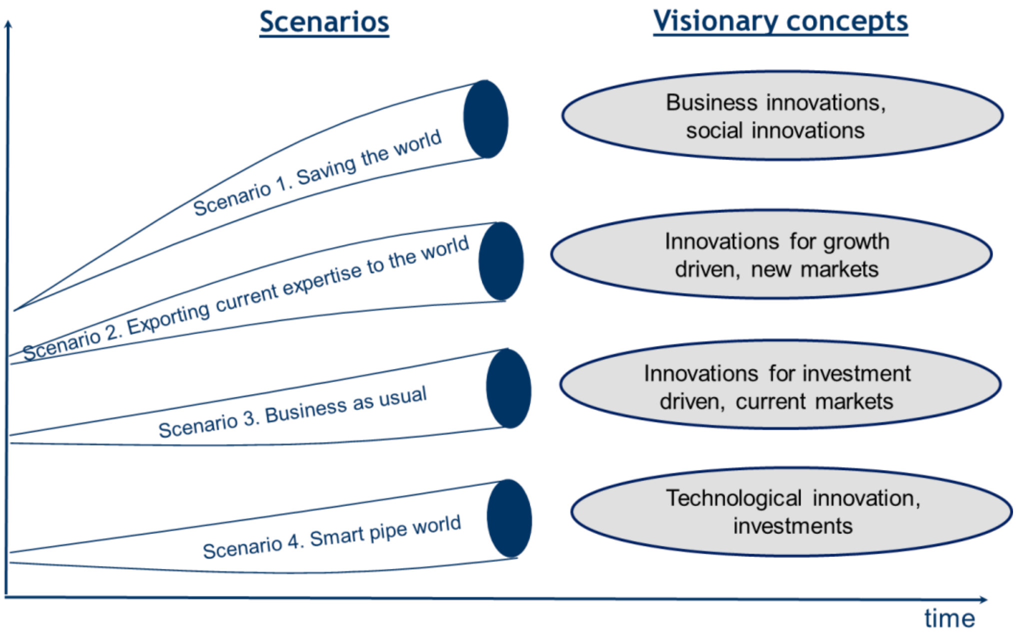

Figure 5. *Water service scenarios in long run and visionary concept innovations needed in each case.*

In the visionary concept design workshop every group firstly developed preliminary concept ideas for each scenario which are shown in Table 1. In the next phase groups chose one concept and to describe it more deeply.

As an example, we will illustrate the concept of 'Standardized water footprint' in more details, including steps towards the desired vision. The concept was developed in the group focusing on the consumer theme and it was based on the idea of the taking water footprint widely to general use in the 'Scenario 1. Saving the world'. The concept on standardized water footprint suits well for this certain scenario because it raises awareness of scarce water resources and thus saves water resources.

The concept concerns a wide group of stakeholders including consumers, companies and government. Furthermore, the concept could be copied to other countries easily. The novel features of the standardized water footprint concept include all the core elements of the hybrid product framework: consumers can make better decisions and observe his own consumer behavior (know-how element); companies can monitor their activities and thus market their products and services based on the water footprint (service element); government can allocate taxation and tariffs on consumers and companies (service/know-how element); mobile devices can bring digital, real time information to consumers e.g. via different mobile applications (physical/service/know how element). The concept fits well into to the open innovation framework because companies and research institutions are developing the system together under the guidance of authorities including EU and the national level.

Table 1. *Summary of preliminary concept ideas for different themes*

Theme / Scenario	1. Education	2. Water management in rural areas	3. Consumer
1. Saving the world	• Exporting the management and development of water supply services to developing and less developed countries • Educating water management in Central European way	• Branding of voluntary work • Committing companies to voluntary work • Pointing out unsatisfactory state of affairs	• 'No waste at all'– mindset to the common use • Denying the disposable bottles (and other disposable things), safe nondisposable bottles • Digital meters • Stopping the use of useless chemicals (e.g. when washing clothes) • Consumer driven information channel: reliable information in understandable way (ensuring reliability e.g. with block chain technology) • **Water footprint widely to the general use**
2. Exporting current expertise to the world	• Training of immigrants for water management expertise export	• Productization of water expertise to e.g. supplementary education • Productization of collecting water management data in rural areas	• 'Quality water' (standards and cerfication). • Using of social media to raise awareness of water issues
3. Business as usual	• Organizing internal education of water treatments plants in order to utilise tacit knowledge • BWSP (Building Water Safety Plan)	• Comprehensive, holistic solutions • Co-operation of wide partner network	• Own activity of consumers in sustainability issues • Preferring local products • Recycling
4. Smart pipe world	Flow efficient graduation, i.e. removing barriers between different levels of education	• Continuous measurements • Solutions utilising big data and artificial intellingence • Automatic linking of different data	• Digital solutions related to use of water • Considering water footprint in all activities (e.g. measuring own daily water footprint by mobile app) • Measuring the quality of water by cell phone scanning

Finally, the necessary steps towards to the standardized water footprint were considered (Figure 6). Implementing the concept into the real life requires a wide co-operation of different interest groups, decisions and from authorities, commitment from companies, investments in research & development and coordinating partner network. The implementation could be done in 10 years.

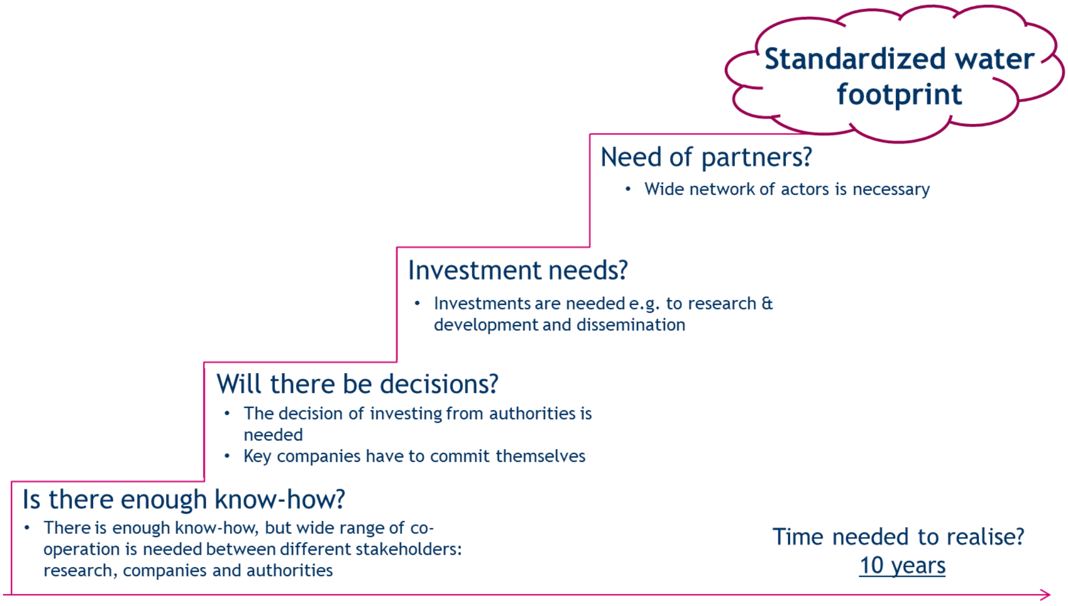

Figure 6. *Steps towards to the Standardized water footprint concept.*

Discussion and Conclusions

The climate change with its wide consequences to many areas of the everyday life is one of the key factors related to the future in all industry branches. The future challenges related to energy, nutrients and water are fundamental and relevant to many different levels including society, industry, business and consumers as well. Scarcity of clean and pure water is one of the barriers towards the sustainable well-being in the world.

In the context of water service supply and energy recycling the elements of the hybrid solutions can come from various actors: service element from the water treatment plant, know-how from the university and education and the product element from industry companies in different branches. As a hybrid solution, these aspects can be combined in a new way towards a visionary solution for the future, as we have described above an example called standardized water footprint for the scenario number 1: Saving the world.

It is important to have global perspective even if looking for and considering local or national solutions. In the global context companies will reach the full potential in the market, also in the other scenarios e.g. in the scenario 2 Exporting current expertise to the world or in the scenario 4 Smart-pipe world, where technological innovations will bring new insights to the infrastructure investments worldwide. Also, the multinational pilots and even pop-up solutions can bring new perspectives to the domestic problems even in the scenario 3 Business as usual.

Finally, in order to get out the full potential of the facilitated workshops and to create holistic future-oriented solutions, it is recommendable that the workshop participants consist of different groups presenting business, society, NGOs and individual citizens, if possible, from other cultures, too.

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