UNIVERSIDADE FEDERAL DO RIO DE JANEIRO
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Nicolas Dhoye

Dynamics of decentralization in the urban utilities ecosystem

RIO DE JANEIRO
2018

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Master Dissertation presented of the Master in Business Administration (MBA), Coppead Institute of Administration of the Universidade Federal do Rio de Janeiro, part of the necessary requisites for the title of Master in Business Administration.

Supervisor: Antonio Roberto Ramos Nogueira, D.Sc. (COPPEAD/UFRJ).

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ABSTRACT

Photovoltaics, Energy efficiency, smart cities, grey water reuse… The search for sustainability has led in the last decades to create technologies that are able today to break the industrial paradigm of our urban utilities. Whether we think of energy networks, water distribution and treatment, or telecommunications, the systems widely used in the developed world are inherited from the industrial revolution: centralized, rigid and inefficient.

Aging systems requiring maintenance, population redistribution, or search for sustainability and efficiency today pose the question of reviewing our utility networks and decentralized models show many advantages to address the present issues.

Who are the relevant stakeholders of this transformation? What are the relationships between them? What drivers and dynamics are urging them to change... or to try and maintain the status quo?

Through a systematic literature review method, this dissertation shows the growth of relevance of the subject along the last decades and the difference in maturity between different sectors of utilities. We identify the most relevant actors and the new emerging ones as well as the relationships and forces that bind them together.

A framework for decentralization of utilities emerges from the literature review and shows promising new fields of research and business opportunities.

Keywords: Energy, Water, Decentralization, Urban Utilities, Policy, Sustainability, Renewable Energy, Grid

RESUMO

Painéis fotovoltaicos, eficiência energética, redes inteligentes, reciclagem de agua... a busca por sustentabilidade levou a criar novas tecnologias nas últimas décadas que podem hoje questionar o paradigma das nossas redes de serviços públicos. Que falamos de redes de energia, de distribuição e tratamento de agua ou de telecomunicação, os sistemas usados no mundo desenvolvido são herdados da revolução industrial: centralizados, rígidos e ineficientes.

Sistemas envelhecendo necessitando manutenção, redistribuição de população, ou busca de sustentabilidade e eficiência colocam o conceito das nossas redes na pauta. Modelos decentralizados mostram muitas vantagens para resolver os problemas que vemos aparecendo.

Quem são os atores relevantes dessa transformação? Quais são as relações entre eles? Quais dinâmicas estão impulsionando eles em mudar... ou manter tudo igual?

Através de uma revisão de literatura sistemática, essa dissertação mostra o crescimento da relevância do assunto nas últimas décadas e a diferença de maturidade para descentralização entre os diferentes serviços públicos. Identificamos os atores mais relevantes nessa transição e os atores emergentes junto com as forças ligando eles.

Um framework para descentralização de redes emergi da revista de literatura e mostra potencial para área nova de pesquisa e oportunidades de negócios.

Palavras chaves: Energia, Agua, Descentralização, Serviços públicos urbanos, Politica, Sustentabilidade, Energia renovável, Rede

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1 INTRODUCTION

1.1 BACKGROUND

Photovoltaics, Energy efficiency, smart cities, grey water reuse… The search for sustainability has led in the last decades to create technologies that are able today to break the industrial paradigm of our urban utilities. Whether we think of energy networks, water distribution and treatment, or telecommunications, the systems widely used in the developed world are inherited from the industrial revolution: centralized, rigid and inefficient.

The industrial model of deployment of huge urban utility networks shaped the development of cities around the world over the last two centuries and often imposed itself as the unique way to provide essential urban services – Water, energy, waste treatment… This model is today challenged in developed as well as developing countries for its intrinsic limits and through the emergence of credible decentralized solutions.

In the nineteenth century, urban growth linked to the industrial revolution made the public management of water and energy distribution a necessity. At that time was born an industrial model to produce and distribute urban utilities: production – water treatment, electricity and gas generation – is made in high scale plants to irrigate the biggest possible territory and then benefit from economies of scale and reduce equipment costs. Most of the time the management of this public service is made through private concessions. The companies running those services first invested at the city level, then at regional or even national scale, installing ever-bigger plants and wider distribution networks.

This technical organization model is not only an essential infrastructure to the occidental cities, it is the occidental city. This industrial model first lead to much better public hygiene and helped eradicate cholera and diphtheria epidemics that used to devastate the nineteenth century cities. It also brought security to the supply – steady and of quality – and comfort – no more going to the well – that were previously deemed impossible. The industrial model finally enabled the emergence of electro-domestics thus reducing the weight of the household chores in everyday life.

This organizational model of urban utilities production and distribution imposed itself as obvious in the cities worldwide. Cities are not only a concentration of dense habitat, politic, administrative and economic functions; they are also a form of taking care of energy and water issues.

Connected and dependent of the utilities networks we forget though the miracle of their technical organization and continuous operation. They are so integrated in our everyday lives that we today have difficulties in adopting eco-responsible behaviors to reduce the negative externalities of those networks. Utilities networks were conceived in an industrial perspective of constant growth and they now generate negative externalities that are barely sustainable: depletion of natural resources, pollution, global warming and spatial concentration of inconveniences. The emergence of a global preoccupation for sustainable development and growing concern for the environment highlight the limits of utilities' industrial model. (COUTARD, 2010) Even if this organization hides away the nuisances from most of the users, those who have the bad luck of living close to the production plants have to bear concentrated pollutions, noises, smells etc. for the sake of the community.

Also, the utilities networks financing and design rely on anticipating growth in consumptions (individual, demographic, and geographic) and struggle to adapt to a possible reduction in consumptions, due to the evolution of lifestyles, the efficiency of new equipment, or the demographic depletion of some urban territories. The financing of urban utilities, linked to the volumes sold (water or energy) does not cope well with the necessary drop in final consumptions. At the moment when the income generated is lowering, the infrastructure owners need to invest in network maintenance and production means refurbishment. In shrinking cities and regions, the financial resources become scarce and show the low reversibility of industrial utility networks and their difficulty to adapt to changing conditions. (FÉRÉ and SCHERRER, 2010)

In developing countries, entering in urban "modernity" would seem to require massive investment to install the production means and extensive networks to distribute the utilities benefits to the whole population. (PETITET and SCHNEIER-MADANES, 2005) In that case, the funds are lacking and the step is quite high.

Autonomous or small-scale solutions to utilities seemed endangered until a few decades ago, considered marginal and with applicability limited to remote areas. Nonetheless, the limits to industrial urban utilities and recent technological innovation allow a comeback of decentralized solutions to the spotlights.

If utilities networks through massive investment almost eradicated individual production of water, a credible alternative now exists with ultrafiltration units. In the same fashion, individual sewage water treatment only survived because of the prohibitive costs of deploying collective networks in all territories; today these individual or semi-individual treatment solutions are coming back in the name of environmental concerns. Local and decentralized production of electricity with wind turbines and photovoltaics for example are now a reality although their actual cost has limited their spread. The cost of eliminating wastes has brought back composting or semi collective biogas productions. Finally, the recent blockchain technology promises to decentralize the internet.

For emerging countries, the inability of extensive networks to respond to local needs of the population has lead to the development of local collective or individual solutions for water – pumps and ultrafiltration units – or electricity – solar panels and batteries for example. (JAGLIN, 2011)

Are these developing decentralized solutions the premises of a radical evolution of urban utilities networks and their industrial organization? In developed countries, their development could very well accelerate the drop in users' consumption and thus weaken the current organization. The logic of sustainable development certainly favor local production and consumption and question the industrial model of urban utilities. In developing countries, economic considerations might very well lead to leapfrog industrial solutions to decentralized ones. Those solutions could be competing… or complementary.

Who are the relevant stakeholders of this transformation? What are the relationships between them? What drivers and dynamics are urging them to change... or to try and maintain the status quo? Preliminary Literature review showed that the specific reasons for decentralization of urban utilities have not been studied in relevant literature. However, the literature is abundant around the technologies involved in this decentralization, their impact on the market and on sustainability. This thesis will discuss the relevance of the topic, the possible reasons for a shift in the current paradigm and its possible implications for the involved stakeholders.

1.2 OBJECTIVES OF THE STUDY

The aim of this dissertation is to get a common understanding of the paradigm shift happening in the utilities sector. We use a systematic literature review to organize the huge amount of data produces along the last 10 years on the topic and try to get a view of the big picture. We propose the following goals:

- Define and clarify the terms and subject of decentralization in utilities
- Contextualize the initiatives of decentralized utilities in urban construction and renovation
- Observe the growing relevance of the subject in the scientific literature
- Find in relevant literature who the actors of this phenomenon are and how they are related to each other
- Find the evidence of the dynamic forces at play for decentralization or centralization of urban utilities
- Conclude on practical implications for businesses interested in this growing sector of decentralized solutions.
- Conclude on theoretical implications and gaps that should lead to further research on the subject.

1.3 RELEVANCE

We have seen that urban utilities are much correlated with the construction of the modern urban environment and with the urban way of life. Nowadays, more than half of the world global population lives in cities and this proportion is forecasted to reach 66% of the world population by 2050. (as can be seen in Figure 1; United Nations, Department of Economic and Social Affairs, Population Division, 2014). Continuing population growth and urbanization are projected to add 2.5 billion people to the world’s urban population by 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa. Today one in 8 urban dweller lives in one of the 28 mega cities that have more than 10 million inhabitants, but by 2030, the world is projected to have 41 mega-cities with more than 10 million inhabitants. Several decades ago most of the world’s largest urban agglomerations were found in the more developed regions, but today’s large cities are concentrated in the global South. At the same time some cities have experienced population decline in recent years, most of these located in the low-fertility countries of Asia and Europe where the overall population is stagnant or declining.

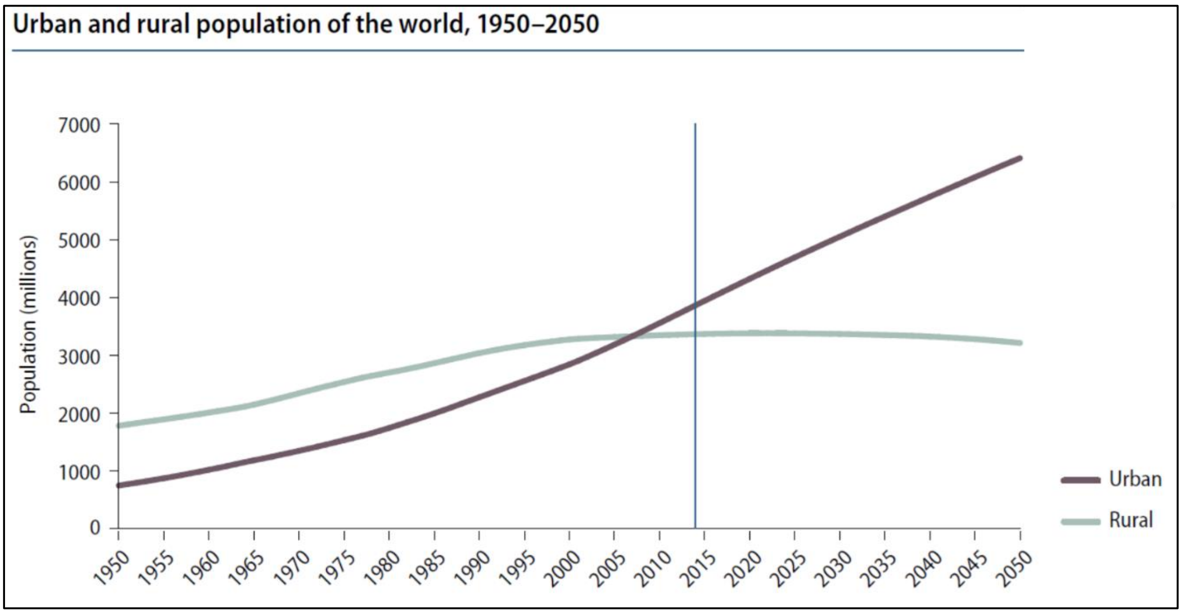

Figure 1: Urban and Rural population of the world, 1950-2050 (Source: United Nations)

The demographic scenario shows an expected increase of the demand for energy and water in cities for the decades to come. At the same time, there is a need for renovation of aging infrastructure in developed countries, and a need for deployment of new infrastructures in rapidly developing countries with an expected demand almost doubling by 2050 in those countries in cities. As the world continues to urbanize, the already existing sustainable development challenges will exacerbate, especially were the pace of urbanization is the fastest.

Coincidentally, decentralized and environmental friendly solutions have become widely available and their growth over the last decade has been astonishing, especially in the energy sector. Worldwide growth of photovoltaics has averaged 40% per year from 2000 to 2013 and the scenario is only accelerating. In 2010, the International Energy Agency predicted that global solar PV capacity could reach 3,000 GW or 11% of projected global electricity generation by 2050. Four years later, in 2014, the same agency projected that, under its "high renewables" scenario, solar power could supply as much as 27% of global electricity generation by 2050. (IEA, 2014) Wind power is not far beyond with an annual growth of the installed capacity over 10% in the last few years (GWEC, 2016). On the water part, the form of decentralized harvesting and treatment of water varies a lot from one country to the other, but for example, rainwater harvesting has made a strong comeback with sustainable construction methods and certifications over the last decades.

1.4 DELIMITATION

This research will specifically focus on energy distribution and water distribution and treatment utilities. Depending on the studied countries, water is not always as decentralized as energy can be, but in most developed countries, it is treated at a regional scale. We will also give a look at telecommunication utilities although the decentralization of telecommunication is not as developed nor studied yet as are water and energy.

Telecommunication is by essence the connection of humans over distance and as such, its decentralization does not have the same meaning as for water and energy. Achieving an off-grid state and complete autonomy for telecommunication does not make much sense so this end of the spectrum does not quite compare to traditional urban utilities. Nevertheless, we will look into telecommunication at the fringes of our study to see if the same kind of dynamics can apply to this utility as well.

For water and Energy, we are interested in any organizational model or technology that aims to produce and consume locally, thus shifting the traditional point of view of industrial urban utilities towards de-scaling and diffuse production. We will look into autonomous solutions as well as mini-grid solutions or neighborhood solutions and their roots and implications in terms of organization.

1.5 ORGANIZATION OF THE WORK

The last few sections have indicated the context of the study and relevance to indicate why this topic should be addressed and clarify why it is important to further be explored.

Chapter 2 will give some contextualization to the subject and define the concepts and technologies that we will be dealing with. In Chapter 3 we will review the method adopted to research the subject: to extract the relevant data from the abundant literature existing around these topics, we adopt a systematic literature review approach. In chapter 4 we will see how the relevant literature was selected and narrowed down. After selecting the relevant literature, in chapter 5 we extract from it the relationships between actors appearing in the literature in order to build a map of the relevant stakeholders and their interactions. At the same time, we will extract from the literature the already identified drivers leading to the installation and use of decentralized utilities. Chapter 6 will conclude the research and further theoretical and managerial implications of the findings.

2 CONTEXT OF THE RESEARCH QUESTION

2.1 NEGATIVE EXTERNALITIES OF URBAN UTILITIES

Urban Utilities have brought function, comfort, safety and progress to the modern cities but it hasn't been without any cost. Many negative externalities have come along with urban utilities. At first they might have been seen as minor compared to the great benefits urban utilities brought but the scale of our modern cities have made these externalities unsustainable on the long run and now bring us to question the choices we made during the industrial revolution.

Some externalities are quite local such as noise or local smoke or pollution but some externalities have now attained global proportions, such as Climate change, Energy resource depletion or water pollution for instance.

2.1.1 Climate Change

There is no question in any serious scientific venue today that climate change is caused by human's greenhouse gases emissions. In Figure 2 can be observed the repartition of those emissions by sector, activity and type of gas.

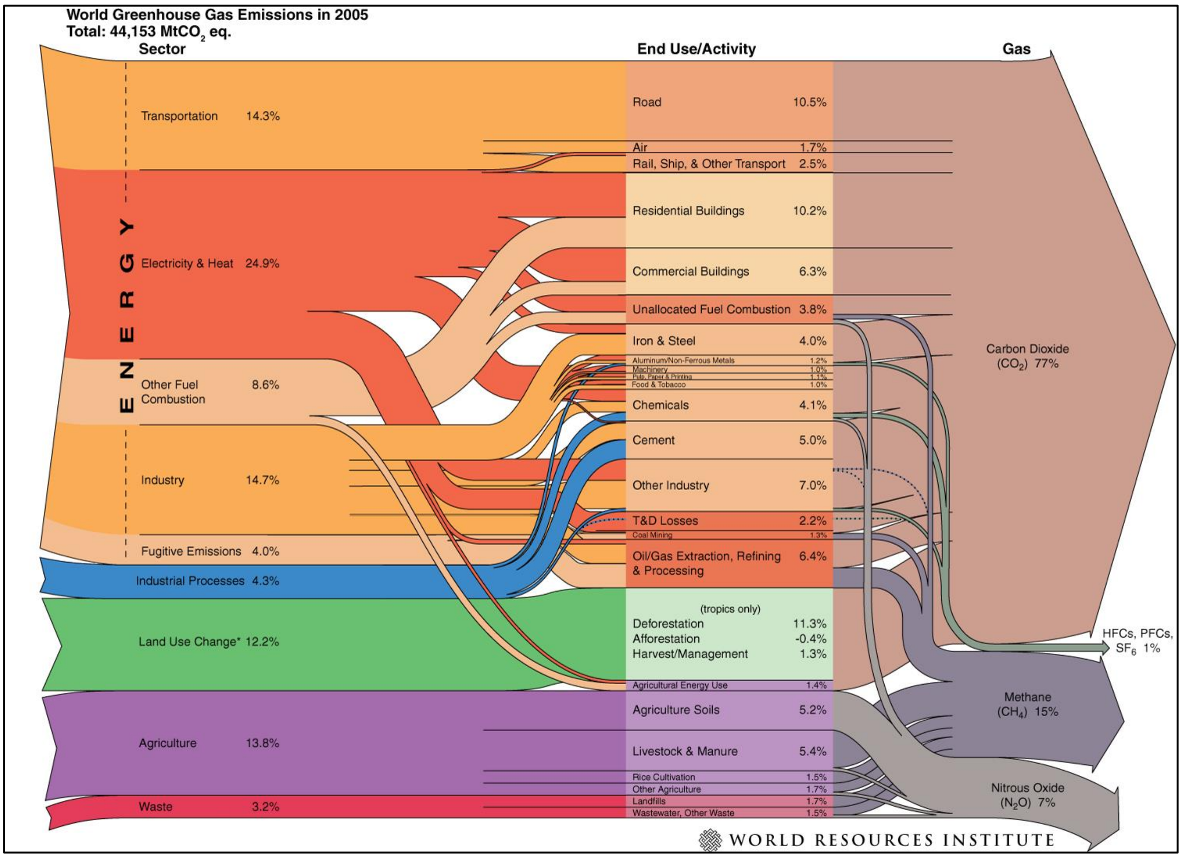

Figure 2: Anthropogenic greenhouse gases repartition per sector, activity, and type of gas (source: World Resource Institute)

The relevance of Urban utilities in greenhouse gases emissions is undeniable as the production of Electricity and heat account for almost 25% of all emissions and other fuel combustions for 8,6%. Looking at the activities, Buildings account for 16,5% and industries for 24,4%. There is no doubt that these are very relevant impacts directly linked to urban utilities and traditional electricity and heat productions through burning of fossil fuels. To reduce these impacts, our urban energy consumption models have to be revised, rethought and improved. Literature calls for at least a four-fold reduction of our emissions to tackle the global warming problem. Along with this issue comes the fossil fuel depletion problem.

2.1.2 Energy consumptions

Consuming fossil fuel does not only pollute the air and cause climate change, it also depletes reserves that, as their name infer, are fossil and therefore finite by nature. Earth seems so big that at humanity's level we will not ever be able to deplete them. Our energy consumption has today attained such a scale that this is in fact completely wrong. Figure 3 shows the peak oil depletion scenarios from environmental activists such as Exxonmobil, BP, Statoil and Total…

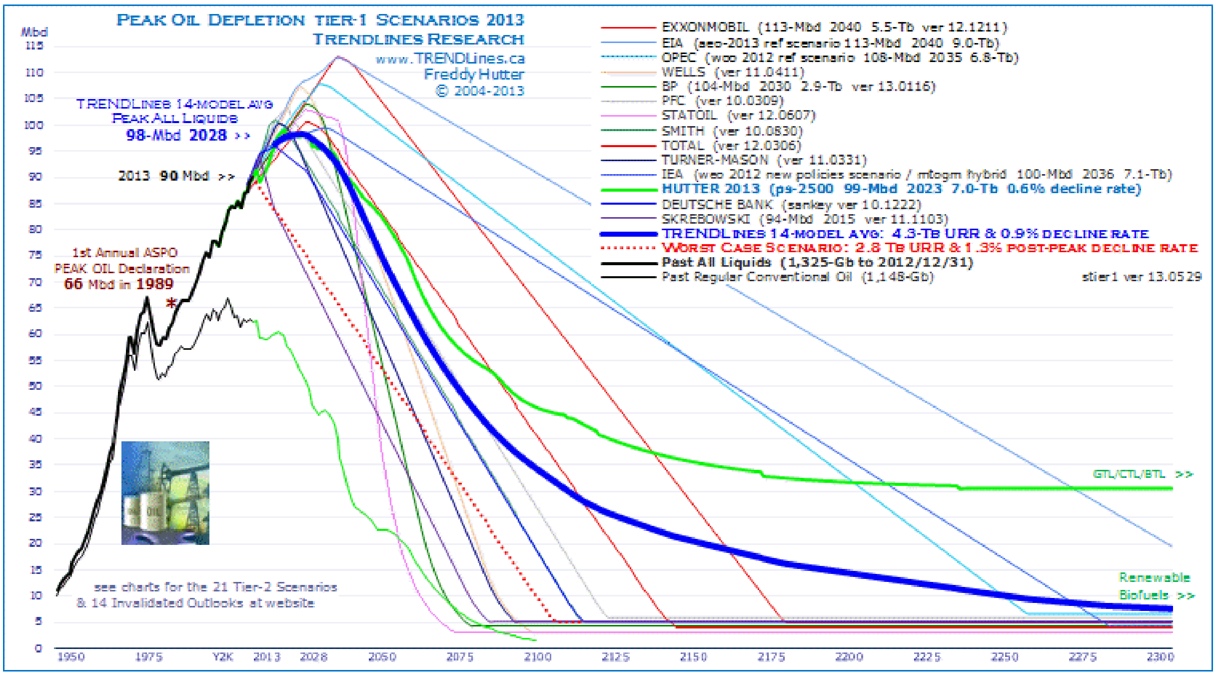

Figure 3: Peak oil depletion scenarios (source: www.trendlines.ca)

It is interesting to note that for conventional oil, the production peak was already attained around the year 2000 and the production is now declining steadily. Accounting for all types of oil, the most optimistic scenarios think that we will only attain the peak oil around 2040 when the most pessimistic ones think we already went through it. The average between those scenarios shows a peak oil around 2025.

Other fossil fuels such as coal or natural gas have bigger reserves and might last longer but they also carry their lot of environmental externalities and will be depleted at some point.

Finally, fossil fuels are often extracted remotely from their consumption points and thus imply international trades with countries that might not be friendly forever. Numerous wars have already been conducted for energy access and with the rise in prices that is forecastable along with rarefaction of fuels, they might get more and more frequent in the future. Thus getting rid of fossil fuel dependence is also a great geopolitical stake for most developed countries.

As seen in subchapter 2.1.1, about a third of fossil fuels consumptions go into urban electricity and heat productions, thus making them a very relevant actor into energy transition, whatever the reason invoked behind it

2.1.3 Water consumption and treatment

There are various global problem to water consumption around the world. Our urban water distribution networks make the consumption of clean, safe ad affordable water so natural that we struggle to see the problem water might be in a near future.

The notion that water is plentiful is false and misleading. Although earth is covered 70% by water, only 2,5% of all water is fresh water and not all of it is accessible to mankind. The UNU-INWEH (United Nation University Institute for Water Environment and Health, 2017) estimates that there will be a 40% gap between water demand and water availability by 2030 on the current trend. By 2050, water demand is expected to grow by 130% for household use around the world and by then over 40% of the world population might live in severely water stressed river basins. As availability decreases, the competition for the resource will increase and with it the prices for what seems now like a commodity to us. Climate change is worsening the situation through more frequent draughts and evolving climate. The cost of water scarcity is estimated to cost half a trillion dollar a year, about 1% of global GDP.

The water supply issue is not only about available quantity, it is also about quality of available water. Although progress has been made in water treatment for supply, it’s estimated that 1,8 billion people around the world consume contaminated drinking water for lack of adequate treatment. Unsafe water, poor sanitation and hygiene cause approximately 3.5 million deaths worldwide each year and is estimated to cost around $ 260 billions each year, mainly in healthcare costs.

Although the industrial take on water sanitation has improved the situation, the infrastructure is still lacking and the existing infrastructure is in dire need of maintenance. Over 80% of wastewater in the world goes to the environment without any appropriate treatment and where the infrastructure exists, its lack of maintenance make it leak an estimated 30% of distributed water.

All these issues are related to urban water systems or the lack of it and water treatment decentralization is one of the possible answers to those issues.

2.2 INITIATIVES TOWARDS BETTERMENT

Although the global picture seems bleak, numerous initiatives have risen to try and solve the present issues from the united nations to random citizens of the world

2.2.1 UN guidelines

On September 25th 2015, the UN adopted a set of goals to end poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the following 15 years. For what concerns urban utilities, the most relevant goals are:

- *Goal 6: Clean Water and Sanitation*: "Ensure availability and sustainable management of water and sanitation for all." The goals about water revolve around supplying safe and affordable drinking water and halving the amount of untreated wastewater sent back to the environment. Reuse and recycling of greywater should be increased and the efficiency of water use should increase substantially – meaning for urban utilities that water distribution networks' leaks should be treated.
- *Goal 7: Affordable and clean Energy*: "Ensure access to affordable, reliable, sustainable and modern energy for all". That means countries have to pursue granting access to affordable, reliable and modern energy services while increasing substantially the share of renewable energy in the global energy mix. The energy efficiency of consuming equipment is to improve twice as fast as it is today and countries should expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.

- *Goal 11: Sustainable cities and communities*: “Make cities inclusive, safe, resilient and sustainable”. The most relevant targets for urban utilities are about By 2030, reducing the adverse environmental impact of cities, and implement integrated policies towards resource efficiency, mitigation and adaptation to climate change
- *Goal 13: Climate Action:* “Take urgent action to combat climate change and its impacts”. That means mostly integrating climate change measures into national policies, strategies and planning

Those guidelines mean that countries should implement political agendas to favor the transformation and meet those goals by 2030. Urban utilities network’s externalities are therefore in the crosshair for countries to meet their goals.

However, this set of goals is not binding bay any measure and countries are free to implement them or just ignore them with no other penalty than peer shaming.

2.2.2 Urban and building certifications as guidelines and precursors

More local initiatives have flourished around the globe to try to treat urban externalities in general and energy and water consumptions in particular. A rather successful and widespread approach is the implementation of sustainability certification for buildings and neighborhoods.

The first one to be established was the BREEAM method in the United Kingdom in 1990. Followed the French version of the approach, HQE (standing for Haute Qualité Environnementale – High Environmental Quality) and the United States’version, LEED (Leadership in Energetic and Environmental Design).

These approaches to assessing, rating and certifying the environmental efficiency of buildings spread around the globe and most developed countries now have their own certification as can be seen in Figure 4: Map of the main Building Environmental Certifications around the world (source:). Even when a local certification does not exist, international ones can be applied to guide the design and guaranty the performances of the certified buildings.

All those certifications revolve around the same goals: responsible construction sites, energy and water efficient design, and improved levels of comfort and hygiene. Even if they began certification systems at the building level, most rating systems now include neighborhood design guides, evaluation systems and certifications.

Figure 4: Map of the main Building Environmental Certifications around the world (source:)

The latest trends in sustainability certifications for buildings are to aim for energetic and water autonomy, or at least a net zero impact. This means that those buildings or neighborhoods produce more energy and collect and treat more water than they consume over a year – even if they may exchange the exceeding production with the grid and buy back when needed along the year.

This trend advocates for decentralized production to limit the impacts of cities on the environment. They made a great success in cities around the word and certified office buildings sell higher and meet more demand in the world's capitals than their traditional counterparts meet.

2.2.3 Spontaneous initiatives

Outside of institutionalized approaches, numerous spontaneous approaches have appeared around the globe to try to solve the externalities of our cities. We can cite installation of solar panels on houses' roofs, for instance in California, Switzerland or Germany; Installation of wind turbines coupled to diesel engines to power remote areas and islands; micro-solar grids like the Brooklyn Microgrid producing solar power and distributing it in the neighborhood with blockchain enabled accountability; installation of smart grids in Europe to be able to exchange renewable energy between producers and consumers at will; installation of decentralized water treatment plants in ecovillages… Even telecommunications have their lot of decentralized initiatives providing free Wi-Fi to by-passers.

The examples of local production of energy and water treatment do not lack providing us infinite case studies for successes and failures of decentralized urban utilities infrastructures.

Figure 5: Challenger, Head Office of Bouygues Construction - this building produces over half of its energy and recycles 100% of its water on site

3 METHOD

With extensive literature around the subject of decentralization in utilities over the last decade but no common thread outlined, we use a systematic literature review to organize the data and get the big picture.

We then identify in the literature the ecosystem in which decentralization is happening, its actors and relationships, and the internal dynamic forces leading to decentralization.

3.1 EXPLORATORY AND SYSTEMATIC LITERATURE REVIEWS

Traditional literature reviews are usually critical and not purely descriptive. They do not try to encompass every approach to a problem but rather the literature deemed relevant by the writer of a publication. (Jesson et al., 2011) they are a personal selection of materials that the writer believes relevant.

Traditional literature review can serve different purpose such as:

- *critical review* – comparing different approaches by critically examining them
- *conceptual review* – synthesizing an area of conceptual knowledge
- *state-of-the-art review* – to get the most recent research on one topic
- *expert review* – written by a recognized expert
- *scoping review* – to get a broad sense of the available research on a subject for a future research project and be able to point out the gaps and refine the research question

This traditional approach is by essence biased with the author's choices and point of view, but it has the advantage to be able to bring forward literature that would not pass the screening process in a systematic review.

On the contrary to the traditional approach to literature review, the aim of a systematic review is to embrace all the relevant literature and screen through a systematic process which are the articles that will enter the review. It is very usefull to help identify and clarify research gaps and where no further research is necessary for the time being. It is a more neutral and un-biased process for being standardized than its traditional counterpart. The process in place in such a systematic review needs to be well described and transparent to the reader.

Jesson et al. point out the key phases of a systematic literature review:

Table 1 Key Phases of a systematic review (Jesson et al.. 2011)

Phase 1: Mapping the field through a scoping review	What do we know and what are the knowledge gaps? How much relevant material is available? Prepare the review plan. This includes the method and the protocol for the systematic review. Define the question or questions, compile key words. Set up the inclusion and exclusion criteria. Design the data extraction pro-forma or data sheet.
Phase 2: Comprehensive search	Access the electronic databases and search using your key words. Search and document the search results. Check whether the hits are relevant or are you coming up with too many hits. If so, do you need to refine the search and revise the key words? Do you need to revise the inclusion and exclusion criteria? Do you need to change the research question being addressed? Document the results/numbers in a table. Screen the title, the abstract and, if relevant, print or obtain the paper.
Phase 3: Quality assessment	Read the full paper and apply the quality assessment, using the 'hierarchy of research'. Decide whether papers are IN or OUT of your review. Document the reasons for excluding papers and compile a numerical table of the process.
Phase 4: Data extraction	Write down the relevant data on to your pre-designed extraction sheet. This can be handwritten or in an electronic format.
Phase 5: Synthesis	Synthesize the data from each individual article into one. Shows what we know now and what we still need to know. Is a meta-analysis or a mathematical synthesis feasible?
Phase 6: Write up	Write up a balanced, impartial and comprehensive report, using a systematic review format, presenting the process reports which will enable another researcher to replicate your review. Disseminate to inform practice.

Part of the 4th phase, data extraction, will be done to create an ecosystem analysis of the topic of decentralization in urban utilities. We will go more in detail about this method in the 3.2 subchapter.

How the systematic review method was put in practice will be the object of chapter 4.

3.2 ECOSYSTEM ANALYSIS

The concept of a business ecosystem has emerged in the work of James F. Moore (1993) in the Harvard Business Review article, titled "Predators and Prey: A New Ecology of Competition". It grasps the interactions and common destiny of co-dependent actors in business and advocates for taking into account these interactions for developing one’s business strategy. Moore defined "business ecosystem" as:

> An economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles.

Business ecosystems can be modelled through ecosystem analysis, then showing the intensity of dependency among the interconnected actors. It helps detecting the essential relationships as well as the threats and opportunities for the survival of one organization or actor (Iansiti & Levien, 2004; Adner, 2006). It is especially relevant in innovation strategy as new products and services cannot exist outside of an ecosystem with co-dependent infrastructures and services. For example for decentralization of electric production, a grid connected solar plant cannot work without:

- its supply chain (suppliers, installers…) but also,
- a home owner to provide the rooftop area,
- an electricity retail company to buy and sell the solar produced energy,
- a maintenance company to monitor the installation and take preventive and corrective measures when the production is not aligned with its forecast,
- a financing agent to pay for the installation
- a smart grid operator to orchestrate monitoring and energy exchanges between producers and consumers
- eventually some public institution to subsidize the installation
- …

An ecosystem analysis thus grants us a good perspective of the systemic interactions between all involved actors and their possible evolution. Social network analysis tools were applied including the Gephi software in order to identify key nodes and clusters, and built the ecosystem.

4 PROCESS AND SELECTION OF RELEVANT LITERATURE

4.1 MAPPING THE FIELD THROUGH A SCOPING REVIEW

The first step in studying the decentralization of urban utilities was to search scientific databases for relevant research already conducted on the subject. This first search showed that although the technologies and their installation have been researched broadly in the last decades, there is no relevant existing research responding close or far to our research question: what aspects lead to centralization or decentralization of utilities networks?

To get a broad view of the phenomenon, we began the research with a simple scoping review to get the most relevant key-words for the systematic search. After trying different scientific databases (Pro-quest, EBSCO, Google scholar…), we settled on the use of Scopus for its broad spectrum and search capabilities through the use of keywords.

The search was limited to the relevant scientific domains to avoid irrelevant results: Sociology, Business, Decision Science, Economy, and Multiple fields. Specifically, we avoided engineering fields that would return many technical results not much relevant to a Business research.

The first search was simply about *Utilities* and *Decentralization* with the following query:

> TITLE-ABS-KEY (utilities AND decentralization) AND (EXCLUDE (SUBJAREA , "ENVI") OR EXCLUDE (SUBJAREA , "MEDI")) AND (EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "EART")) AND (LIMIT-TO (DOCTYPE , "ar"))

We found a total of 83 articles for that search. After reading them, only 24 articles did in fact talk about our subject and were relevant to our research. These articles amounted a total of 203 unique key words.

However, none of these keywords or articles were related to the decentralization of telecommunication utilities. We then did a second search about *Decentralization* and *Telecommunication* to gather more keywords to include that theme into our research. The query was the following:

> TITLE-ABS-KEY (telecommunication AND decentralization) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "ECON"))

We found 63 new articles with this query but after reading them, only 6 proved relevant to our research. Nonetheless, they provided 143 keywords to our research.

After gathering all he keywords we found with these searches, we only selected the keywords that were repeating for more than one article to get only the most relevant ones. 77 unique key word made it to the final list.

4.2 COMPREHENSIVE SEARCH

The first query with the 77 key words returned tens of thousands of articles and a quick scope through them showed that most of them had nothing to do with the subject of our research. We decided to classify the key words in order to get a more focused result. The key words went into 3 categories: “Technology oriented” (such as Renewable energy, Water treatment, or Peer-to peer network…), “Organization Oriented” (such as decentralization, rural electrification, or public policy…) and “Generic or Irrelevant” (such as Quality control, or carbon emissions)

Table 2 Final Keywords list

Technology oriented	**Organization Oriented**	**Generic or Irrelevant**
Electric utilities	Electricity demands	Developing countries
Renewable energy	electricity supply	Game theory
Electricity generation	Emission control	Monte Carlo
Photovoltaic	Energy management	cost-benefit analysis
renewable resource	energy market	Least cost
Drinking water	Regional planning	Optimal pricing
Solar energy	Energy systems	Levelized cost
Water supply	Open access	efficiency measurement
AC optimal power flow	public service	learning
biomass power	Power market	Project management
Decentralised energy generation	decentralization	Carbon dioxide
Decentralized energy system	Energy policy	Pathways
Electric generators	Rural electrification	Attacks
Electric power systems	rural area	Best available
Electricity	Energy model	technologies
Grid	Energy planning	carbon emission
Hydropower	Regional disparity	Quality control
Mini grid	Decentralized control	Security
Off-grid	Decentralized networks	

Security constrained optimal power flow Power generation Water management Solar power Building energy management system (BEMS) alternative energy Distributed computer systems Distributed generation Greywater reuse Peer to peer network Point-of-use/point- of-entry (POU/POE) water quality telecommunication water treatment Wireless telecommunication systems	Distributed resource allocation Public policy Distributed systems energy efficiency governance approach Low impact development Reputation systems	

The Generic and irrelevant key words were obviously left out and our research focused into crossings of the technology and organization aspects. However, some combinations of key words are pretty trivial and out of our scope, for example “Grid” + “Energy Policy”… To avoid such trivial results, we decided to create a two stage query: either decentralization related technology key words with organization key words, or technology related key words with decentralization related organization key words. A diagram of this query is shown in Figure 6

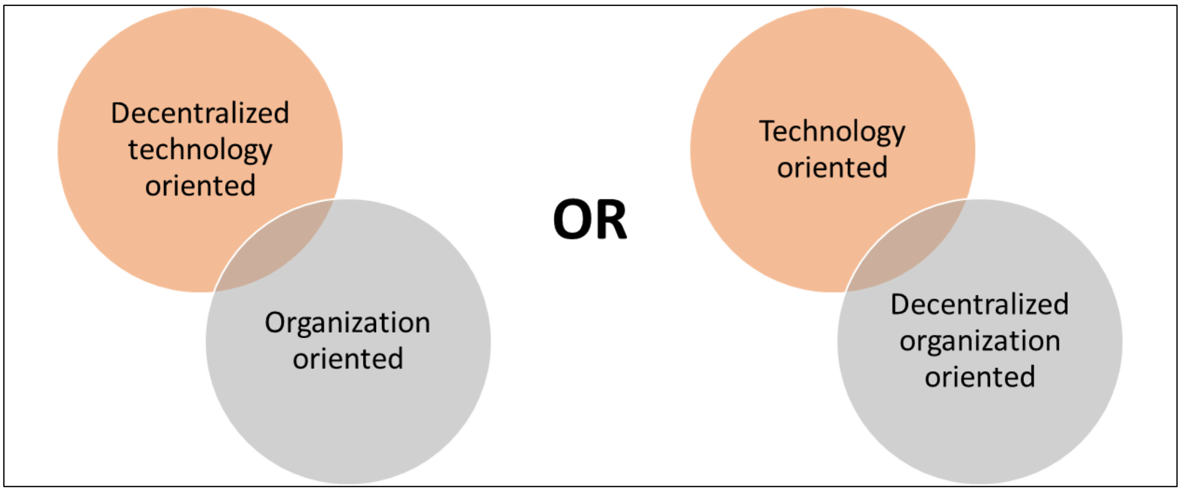

Figure 6: decentralization oriented crossing diagram to avoid trivial results

The final query with these parameters fine tuned was the following:

KEY ((("Decentralized energy generation" OR "Decentralized energy system" OR "Mini grid" OR "Off-grid" OR "alternative energy" OR "Distributed computer systems" OR "Distributed generation" OR "Greywater reuse" OR "Peer to peer network" OR "Point-of-use/point- of-entry (POU/POE)") AND ("Electricity demands" OR "electricity supply" OR "Emission control" OR "Energy management" OR "energy market" OR "Regional planning" OR "Energy systems" OR "Open access" OR "public service" OR "Power market" OR "decentralization" OR "Energy policy" OR "Rural electrification" OR "rural area" OR "Energy model" OR "Energy planning" OR "Regional disparity" OR "Decentralized control" OR "Decentralized networks" OR "Distributed resource allocation" OR "Public policy" OR "Distributed systems" OR "energy efficiency" OR "governance approach" OR "Low impact development" OR "Reputation systems")) OR (("Electric utilities" OR "Renewable energy" OR "Electricity generation" OR "Photovoltaic" OR "renewable resource" OR "Drinking water" OR "Solar energy" OR "Water supply" OR "AC optimal power flow" OR "biomass power" OR "Decentralised energy generation" OR "Decentralized energy system" OR "Electric generators" OR "Electric power systems" OR "Electricity" OR "Grid" OR "Hydropower" OR "Mini grid" OR "Off-grid" OR "Security constrained optimal power flow" OR "Power generation" OR "Water management" OR "Solar power" OR "Building energy management system (BEMS)" OR "alternative energy" OR "Distributed computer systems" OR "Distributed generation" OR "Greywater reuse" OR "Peer to peer network" OR "Point-of-use/point- of-entry (POU/POE)" OR "water quality" OR "telecommunication" OR "water treatment" OR "Wireless telecommunication systems") AND ("Open access" OR "decentralization" OR "Rural electrification" OR "Decentralized control" OR "Decentralized networks" OR "Distributed resource allocation" OR "Distributed systems" OR "Reputation systems"))) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "MULT"))

This query gave us the final list of 1.203 published articles used in this study.

4.3 QUALITY ASSESSMENT

To filter from the 1.203 article list the relevant ones to be included in this research, a two step process was adopted:

- First, a filter was applied using the number of citation of each articles to get the most cited ones. This is a proxy of how relevant the article is in the literature.
- Secondly, the remaining articles were read and articles off topic were discarded

The average citation number for our list of articles was 10,5 citation per article. The citation filter had to be customized to take into account the age of the article. To avoid outdated literature, we filtered out articles over 10 years old with less than 100 citations. For the rest of them, we used a 20 citation threshold. This limited the list to 130 articles to be included in the study. However, looking into the dates of the selected articles, we observed that no articles from the last two years were included in the final list. The 2016 and 2017 articles probably have not been around enough to get cited to their true potential and a final tweak had to be given to our filter to account for this effect: the citation threshold for 2016 was lowered to 2 citations and no limit was applied for 2017. This added to our list 42 articles from 2016 and 22 articles from 2017.

All those articles were read in order to detect off topic articles. This fine screening process eliminated 34 articles thus leaving us with our final list of 160 relevant articles.

4.4 DATA EXTRACTION

Three kinds of data extraction were performed on the articles from the systematic literature research:

- Bibliometric analysis of the complete list in order to observe the growth of the relevance of the subject.
- Ecosystem analysis on the filtered 160 article list
- Systematic identification of dynamic forces documented in the filtered article list

In order to perform the bibliometric analysis, the entire metadata of all articles was downloaded from Scopus and worked through in an excel table.

To be able to perform the ecosystem analysis, while reading the relevant articles we identified each relation between actors described in the articles and compiled them into an Excel file to be able to build the complete ecosystem surrounding utilities and their decentralization. Each relationship s directional and is registered as “Actor 1” acts through “Relationship” towards “Actor2”. All those interactions are compiled and tagged with the corresponding article before being processed through the Gephi software.

The dynamic forces identified in each article were noted along the reading and tagged with the corresponding article to be compiled later in the research process.

5 ANALYSIS OF LITERATURE

5.1 BIBLIOMETRIC ANALYSIS

The bibliometric analysis of our research results can give a lot of insights about the relevance of the subject of decentralization in utilities.

As can be seen in the Figure 7, the number of articles on topic has grown exponentially in the last decade. There were almost no article published on the subject until the middle of the nineties when the frequency of publication begun to rise. However, the subject really began to rise around 2007-2008 alongside with the sustainable development issues. Coincidentally, 2007 is the year the climate change issues began to find a strong echo in the general public and to be widely discussed in public policies. In the last 5 years, the number of yearly on topic articles rose above one hundred thus confirming the global relevance of the theme of decentralization in utilities.

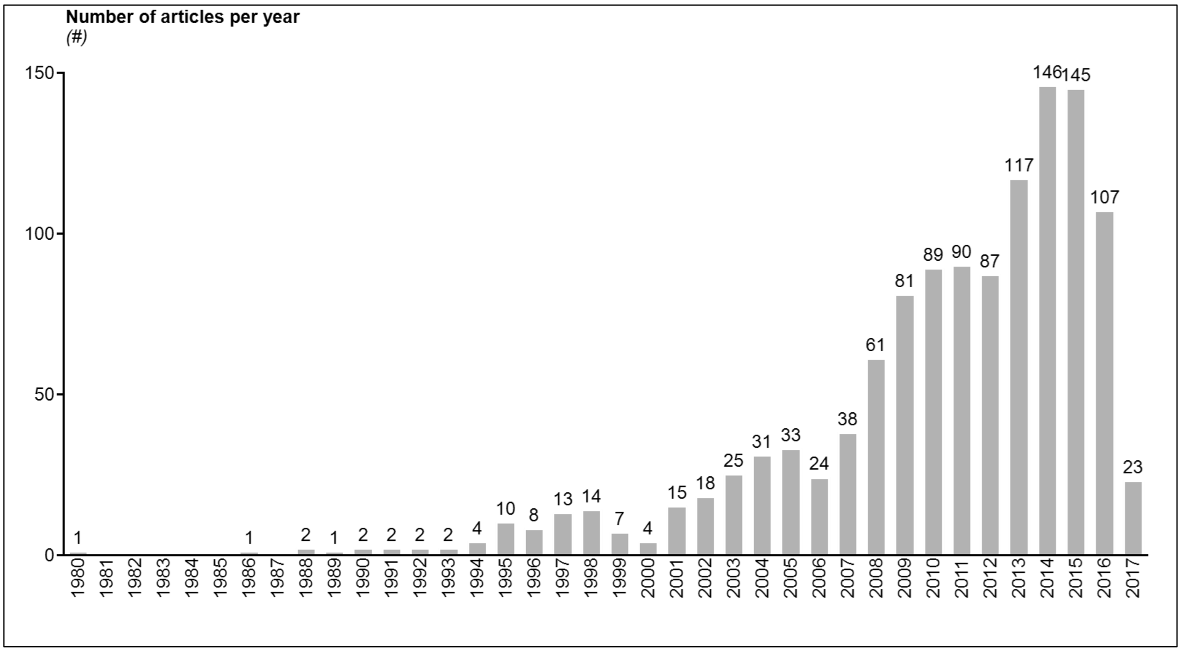

Figure 7: Evolution of the number of articles through the years

To confirm that the selected articles show the diversity and evolution of the topic throughout the years, we compared the profile of articles in the complete list to the profile of articles in the filtered one. This can be seen in the Figure 8 where the red articles appear in red compared to the complete list in dark grey. In our fine selection, all the relevant years are represented with their most cited articles and the less relevant years are represented with a smaller selection. The vast majority of the articles are under 10 years old thus guarantying an updated and relevant point of view for the study. What is presented here is of course the end result of the study but this bibliometric study has been key to fine tuning the quality assessment criteria of the systematic literature research in order to guaranty the representativeness of the final articles sample used in the study.

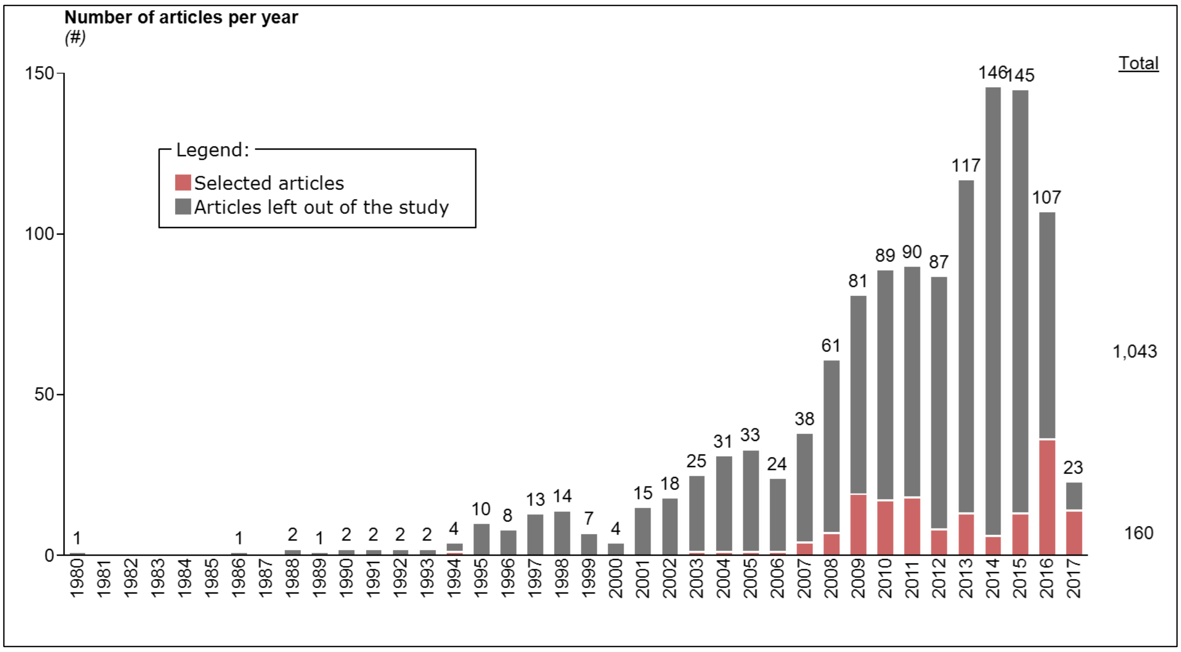

Figure 8: Repartition of selected articles

After Reading the articles in the filtered list, they were tagged by general theme between General papers, Energy related ones, Water related ones, and telecom related ones. The evolution of the representation of those themes is displayed in the Figure 9.

We can observe that the Energy theme is largely dominating the selection of articles even though the selection process was unbiased towards a specific theme. This could be explained by the huge pressure at international level to install and use renewable energies, and mostly solar panels. For instance, the European Union set in 2007 the goal of having by 2020 20% of renewable energy production in Europe. They started financing great research programs to be able to attain these goals and incentivized companies and research institutes to look into the matter. The interest in the Energy theme has been very relevant in developed countries with the rise of petroleum prices, and with it the risk of dependence towards third countries. Finally, the accords signed in Kyoto in 1997 and renewed in Paris in 2015 also give a good incentive for every country to pursue the energy theme and research how to install renewables.

The Water theme is less represented in our article list but it is present from the beginning to the end. The technological solutions linked to decentralization for water systems are less evident and less mature than the energy decentralized solutions and that might explain a part of it. Also, a lot of the water related articles are linked to less developed countries' issues with water and they probably get less funded to research the problem. Most developed countries have solved a great part of their water issues through the installation of extensive water networks and treatment plants and they don't "feel" the water problems the same as African countries can "feel" them. This issue seems to be a lot more regional than the energy one.

Finally, the telecom theme is the least represented and it seems to concentrate in the last 3 years mostly. This is no surprise as the decentralization of telecommunication is only an emerging subject.

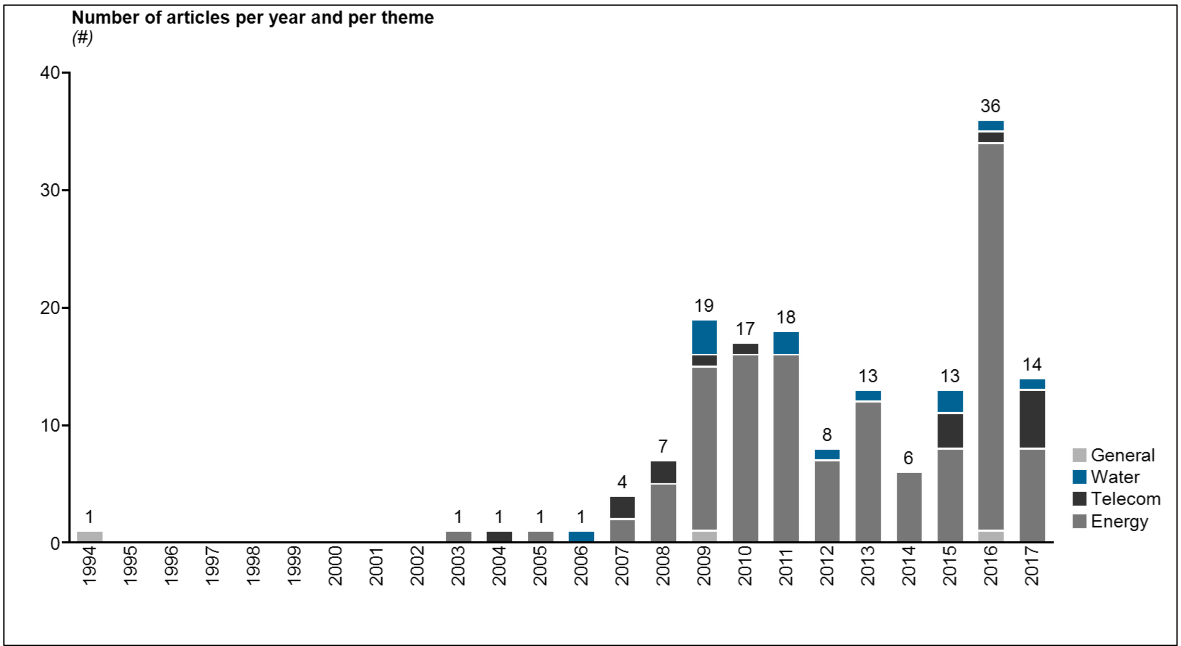

Figure 9: Repartition of selected articles by theme

Finally, we performed a keyword density analysis to get a sense of the most pressing issues in our articles sample. In the top fifty most repeating keywords, almost half are related to energy. This confirms the bias towards energy we observed in the previous theme analysis. Key words such as "alternative energy", "Solar", "Wind", or "electricity generation" seem to set the tone of the most research part of our topic.

Second to energy comes a lot of organizational subjects such as "policy", "resource management", or "governance". This shows that the issue is not likely to be solved at an individual level but rather at a collective level, be it the neighborhood, the city or the country. Government of different scales are likely to play a big role in utilities decentralization.

The Figure 10 shows the evolution of the use of the ten most recurring keywords. This graph is much correlated with our article sample, but it shows even more clearly the drastic rise in publications on topic from 2007 on.

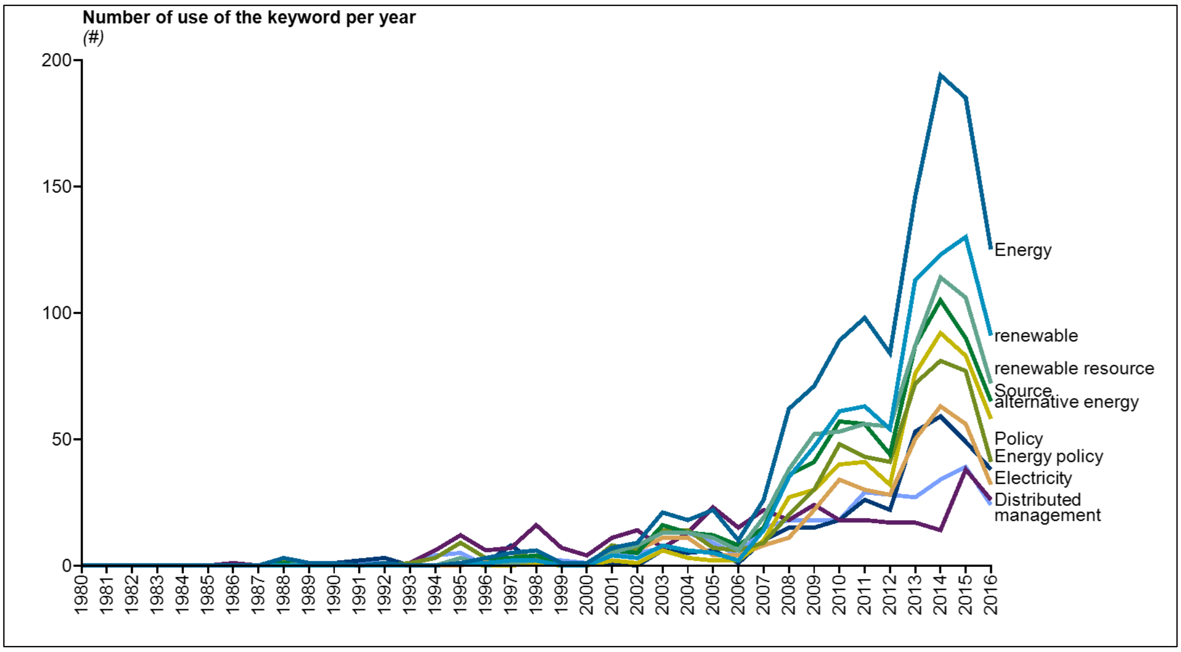

Figure 10: Repartition of most common keywords usage

The bibliometric analysis showed us:

- The steep growth of our topic over the last decade.
- The relevance of our article sample compared to the article population
- The strong prevalence of the energy topic over the water and telecom ones

The rise in publications in 2007 is probably to link to the growth of the public awareness about sustainable development in the midst of 2006 and 2007. One catalyst of this was the release of the documentary *An Inconvenient Truth* in 2006 that managed to get sustainability and global warming issues widely known to the general public. This later translated into funding for sustainability related research aiming to orient public policies on the matter.

5.2 ECOSYSTEM ANALYSIS

In the analysis of the literature sample, relationships between actors present in research were recorded to create an ecosystem map. Here are the different actors encountered, their definition and examples of articles where they appear:

- Policymaker: Either central country lawmakers or local council, policymakers influence laws applied on the economic environment and can either facilitate or make decentralization difficult. (JOHARI, 2004; PALMER, 2005; WIGINTON, 2010; KIRUBI, 2009; WILDER, 2006; MCELROY, 2009; PALIT, 2011)
- Tax administration: this actor appears for applying tax facilitations applying voluntary policies towards sustainable energy (PALMER, 2005)
- Energy Retailers: Companies selling energy to the end User (PALMER, 2005; WIGINTON, 2010; KIRUBI, 2009; SOVACOOL, 2009)
- User: User of the service, Energy or Water (JOHARI, 2004; PALMER, 2005; WIGINTON, 2010; WILDER, 2006; KETTER, 2013; WOLFE 2008)
- Renewable Energy producers: Companies producing Energy from renewable sources (PALMER, 2005; WIGINTON, 2010; KETTER, 2013)
- Conventional Energy producer Companies producing Energy from conventional sources (PALMER, 2005; KETTER, 2013; WOLFE 2008)
- Energy Network: Owner of the Energy distribution network (WOLFE 2008)
- Distribution network operators: Operator of the low voltage energy distribution network (SOVACOOL, 2009; KETTER, 2013; WOLFE 2008)
- Transmission network operators: Operator of the high voltage energy distribution network (SOVACOOL, 2009; WOLFE 2008)
- Energy storage operator: Operator of an Energy storage system (WOLFE 2008)
- Metering and Monitoring operator: Operator in charge of measuring productions and consumption in an energy network (WOLFE 2008)
- Scientific Community: Universities, Institutions and Scientifics (WIGINTON, 2010; KIRUBI, 2009; MONDAL 2010; SOVACOOL, 2009; EDENHOFER, 2013)
- Investor: Bank or investing company (KIRUBI, 2009; PALIT, 2011; JACOBSON, 2007; MONDAL 2010; SOVACOOL, 2009)
- Urban Services: Education, access to communication, access to banking services etc. (KIRUBI, 2009)

- local water operator: Operator of a local production and distribution network of water (WILDER, 2006)
- NGOs: Non Governmental Organization, usually with sustainability objectives (OZAKI, 2011; SOVACOOL, 2009)
- Cooperatives: Operator of an energy production and distribution unit owned by its users (PALIT, 2011; HIREMATH, 2009)
- Independent overseeing: Overseeing agency for compliance with standards and regulations (WILDER, 2006)
- Energy broker: Intermediary agent in an energy network buying and selling energy between producers and consumers to optimize pricing (KETTER, 2013)
- Weather services: Weather forecast services to evaluate probable renewable energy production (KETTER, 2013)
- Renewable energy system provider: Industrial selling the solar panels or wind turbines or other renewable energy production systems. (DOBLINGER, 2016)

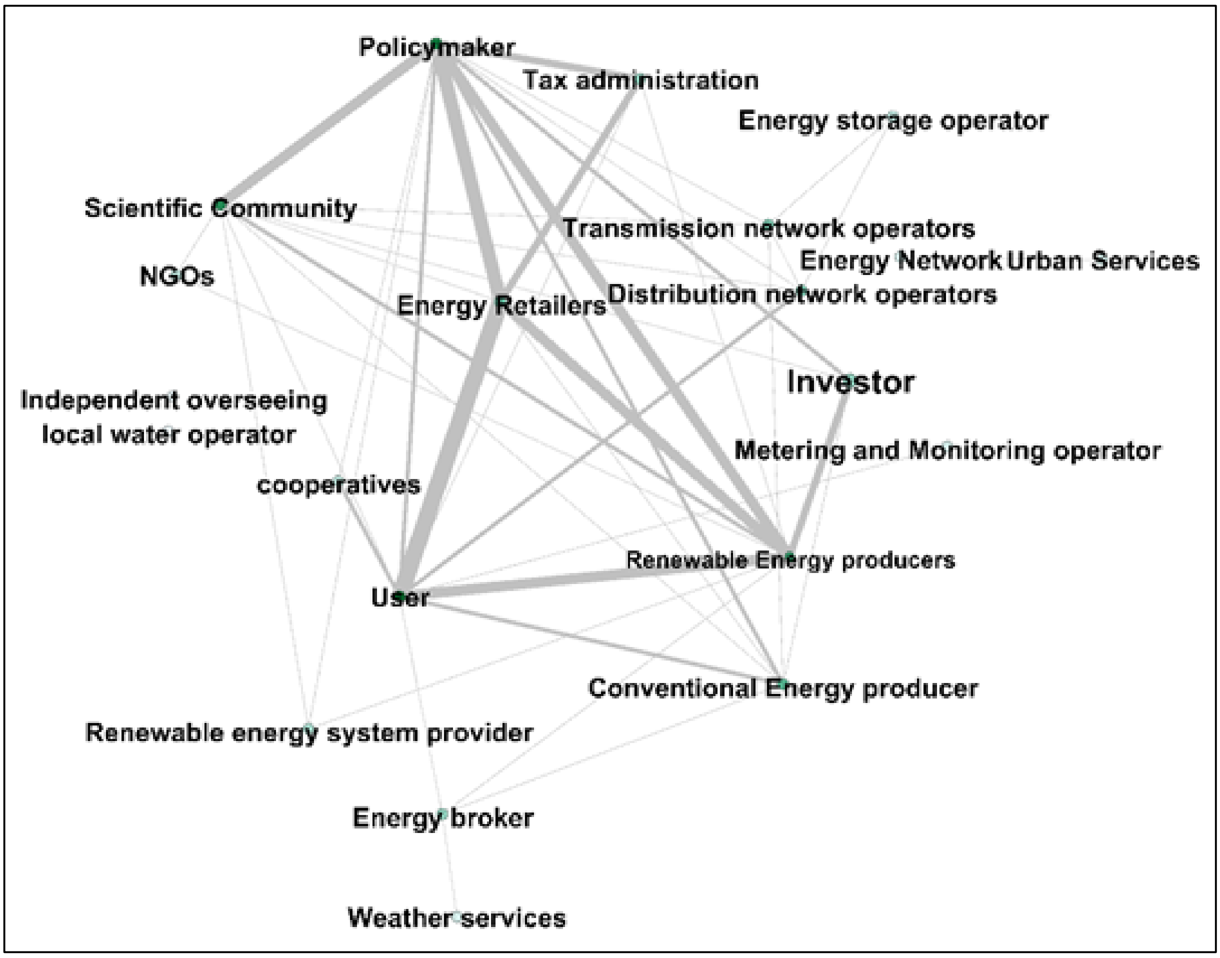

Figure 11: Ecosystem of Urban Utilities in the litterature

Figure 11 is a graphic representation of the ecosystem showing the relationships between the different actors found in the literature. All the relationships described in the figure are explicitly mentioned in the literature and the width of the links correspond to the number of papers mentioning the relationship; and thus the width of the links represent the relative importance of those links in the literature (or at least how much they have been at the center of studies).

In this Ecosystem, we can observe the central role of Policymakers: it seems they connect to all the relevant actors to give the incentives to go towards decentralization… or not. Energy retailers also seem to have a central role as today they are the one connecting Users to the existing grids.

Some biases appear in this ecosystem too. For example, Renewable Energy producers have a strong role here whereas in reality they are more marginal, at least in volume. Also transmission and distribution networks do not seem that relevant in this ecosystem. This is because our study is focused on decentralization of Urban Utilities and as such, centralized systems are under represented in the selected literature.

Water systems are also very thin here, in alignment with what we observed through the bibliometric analysis. This confirms further that decentralization of water utilities is not as mature as decentralization of energy utilities by far.

A very interesting observation lie in the fringes of the ecosystem:

- Energy brokers and weather services are emergent in the bottom of the graph. Their role could be a market facilitator in an open energy free market but it supposes the installation of smart meters at least, or smart grids at best to gain its full potencial. Most developed countries have their own smart grid project in happening so their role might get central in the next years or decades.
- Urban services appear to the fringe also as facilitated by the emergence of energy networks. This is mainly an effect that can be seen in rural electrification in the developing world, but that effect could definitely be studied further to prove the benefits and return on investment of rural electrification.
- Energy storage operator is also emerging here, as is the field on the market. This is a very promising sector with huge demand but technology is only maturating now and the first projects being built this very year.

- Cooperatives is a small agent in the ecosystem and it is one of many possible models for decentralized micro grids. It can develop either for micro grids in developed countries or for rural electrification in developing countries.
- Scientific communities seem to have mostly a role of advisor for policymakers in this ecosystem. It could be an interesting opening for them to try and turn to other actors of the ecosystem.
- NGOs do not have a strong role either and they mostly appear as facilitators and financers for rural development projects in developing countries.

Finally, it is interesting in the ecosystem to look at the absent actors for gaps in the literature. Construction and maintenance actors are completely absent of this ecosystem although they are very relevant in the value chain of decentralized utilities. Their roles of prescriber and enablers in this ecosystem could be a very interesting subject to further look at. Table 3 summarizes those findings.

Table 3 Summary of actors' relevance according to the ecosystem analysis

PREVALENT ACTORS	EMERGING ACTORS	ABSENT ONES?
• Policymakers	• Decentralized water operators	• Promoters of solutions
• Users	• Energy storage operators	• Architects and urbanists
• Energy retailers	• Energy brokers and weather services	• Contractors
• Renewable energy producers	• Metering and monitoring operators	• Real estate
• Scientific community		

5.3 IDENTIFIED DYNAMIC FORCES

Although we were initially searching for common forces for all urban utilities, the only relevant forces that appear for water and energy altogether are cost effectiveness and policy inclination towards decentralization. There seem to be a very relevant difference between developing countries and developed ones so we will analyze them separately, and as we observed that water utilities' decentralization maturity is far behind, we will look at it separately.

Finally, no relevant telecommunication decentralization drivers were found. All literature on the subject in our sample is revolving around protocols for decentralized networks of heterogeneous entities without entering into the reasons why those networks should be decentralized. (GHOSH, 2007; GOMEZ, 2010; ILARRI, 2008;

BAE, 2009) Those concepts might prove useful for connecting smart utility networks as micro-grids or smart grids, but this link is still to be made.

5.3.1 Energy in developed countries

The main drivers defining the adoption of decentralized energy production means are *Policy* (influencing either positively or negatively) *Cost effectiveness*, *Good Information*, and *Technology maturity* as can be seen in Figure 12.

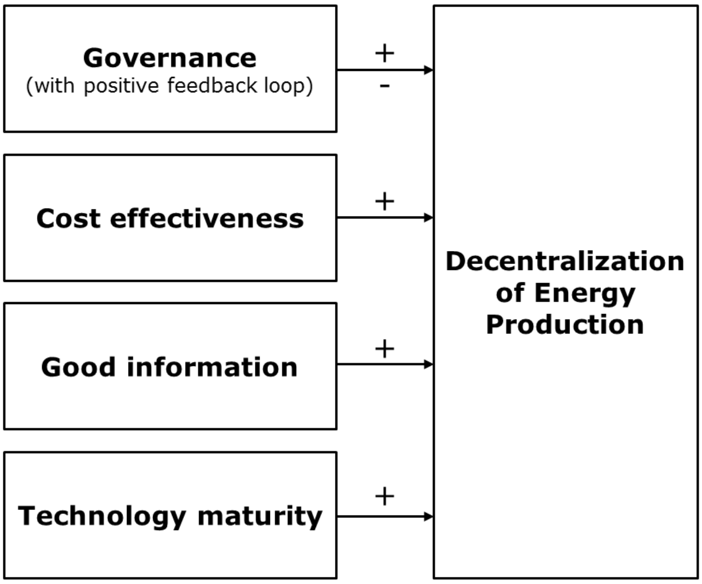

Figure 12: Main forces driving energy production decentralization

Policy is with Economic effectiveness the most studied reason for decentralization appearing in literature. Policy aims to change behavior of the different actors by changing the rules in which they operate. Policies can either be of authorization nature or of obligation nature, meaning they can either tell what can be done, or what must be done. (SLOMAN, 1994) For Decentralized solutions to be able to strive, Policy must establish clear rules in the network to avoid yield loss associated to its decentralized nature (JOHARI, 2004). It is necessary to have a well functioning and equitable socio economic system in which the actors have faith for them to invest in decentralized solutions (CHOW, 2003) One key aspect is to give visibility on the future evolutions of policies to the actors that operate within them. (AMER, 2010). Finally, Policies must provide adapted market structure to economic actors to foster decentralization (KETTER 2013).

As Policies must be aligned with the country’s Economic, Social and Environmental goals, (EDENHOFER, 2013), Policies can either have a positive impact on decentralization or a negative one depending on goals alignment.

It is interesting to note that when Policies tend to environmental and social objectives, there is a positive feedback loop in place:

Decentralized solutions have positive impact on Climate change and environmental externalities (WIGINTON, 2010; WOLFE, 2008) They also have positive impact on energy security and protection against oil and gas volatility, they protect against blackouts risks, lower transmission costs (WIGINTON, 2010; DAIM, 2008) and are more flexible by having a much lower lead time for installation of new production capacity (SOVACOOL, 2009).

EDENHOFER et al. (2013) sum it up saying decentralized power production is a mean to an end to solve those various policy goals:

> Climate change mitigation, energy security, green jobs, green growth, reduced local environmental damages and poverty reduction are potential public policy objectives highlighted by decision makers that can, in principle, justify the deployment of Renewable Energy technologies as a means to an end.

Economic effectiveness is the second most studied effect on decentralization of energy utilities. Researchers observe that the costs of decentralized energy production limits its installation (WIGINTON, 2010; OZAKI, 2011) transaction costs in a decentralized grid also limit the cost effectiveness of decentralized solutions (WOLFE, 2008) and finally, the cost of replacing existing infrastructure also limits decentralization (CHOW, 2003).

Furthermore, there is a pervasive economic effect on decentralized energy production called merit order effect. Practically, the market value of renewable energy production systems drop with penetration thus limiting their cost effectiveness. (HIRTH, 2013; WURZBURG, 2013; CLUDIUS, 2014)

As Cost effectiveness is fundamental to deploy decentralized energy systems and compete with centralized solutions (CHEN, 2012), Policymakers have used various financial and non financial incentives to help their agenda, for example, tax credits, portfolio obligations, of feed in tariffs. (PALMER, 2005; WIGINTON, 2010, MCELROY, 2009).

Proper information is key to decentralization acceptance. For example, the culture of abundance in the United States of America goes against the evolution towards decentralization, fostering apathy, and inertia through misinformation. (SOVACOOL, 2009) Often, this misinformation is filled with centralized incumbent's biases, that need to be overcome to make decentralized solutions attractive. One of those biases is that the intermittency of renewables is not compatible with grid stability. Research and case studies showed the opposite: (SOVAKOOL, 2009)

> It was concluded that the intermittency of renewables can be predicted, managed, and mitigated, and that the current technical barriers are mainly due to the social, political, and practical inertia of the traditional electricity generation system.

This kind of biases foster institutional inertia and lead to slowing down the transition to decentralized production. (CHOW, 2003; SOVAKOOL, 2009; HIGGS, 2008)

As a side note, it is interesting to see that even green biased individuals do not necessarily favor decentralized production due to lack of proper information on costs, impacts, and functionalities. (OZAKI, 2011)

Finally, as for every innovation, the technological maturity is very important for acceptance and spread. (WOLFE, 2008) Not only should the energy production technology be mature, but also related support technologies need to be ready too:

- Grid upgrade to smart grids will definitely facilitate the installation of decentralized systems (WIGINTON, 2010; MCELROY, 2009, ALVIAL-PALAVICINO, 2011; WOLFE, 2008)
- The availability of storage solutions will also facilitate decentralized energy production by helping management of intermittence (WIGINTON, 2010; DAIM, 2012)
- Having energy efficient infrastructures will also help by limiting the necessary installed capacity (MISHRA, 2009)

There are some interesting – though not very much studied – network effects helping with decentralization. First, there are positive feedback loops for users entering into micro grids or going to complete autarky. (KUBLI, 2016)

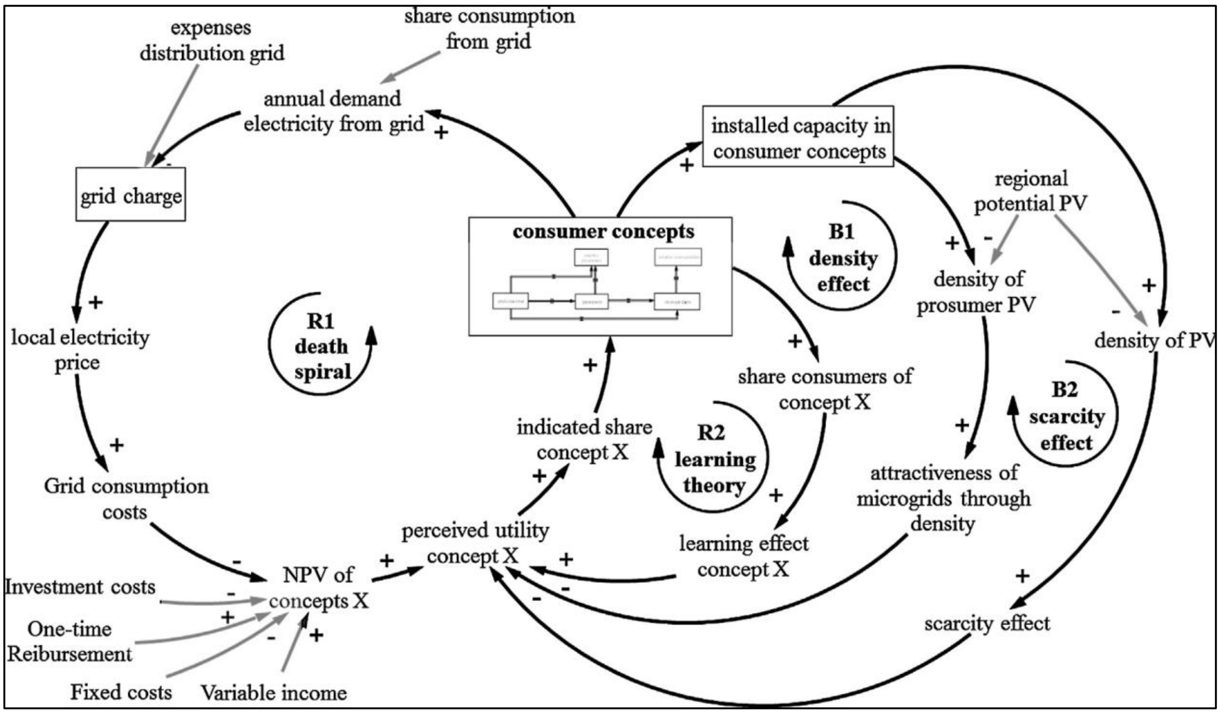

Figure 13: Positive network effects for consumer transition to micro grid or autarky (KUBLI, 2016)

KUBLI shows in his study that consumers going off grid have positive reinforcement network effects:

- by limiting the repartition of fixed grid costs and redistributing them to users who do not transition. This makes transition to autarky more appealing for each user that transition.
- By helping with learning

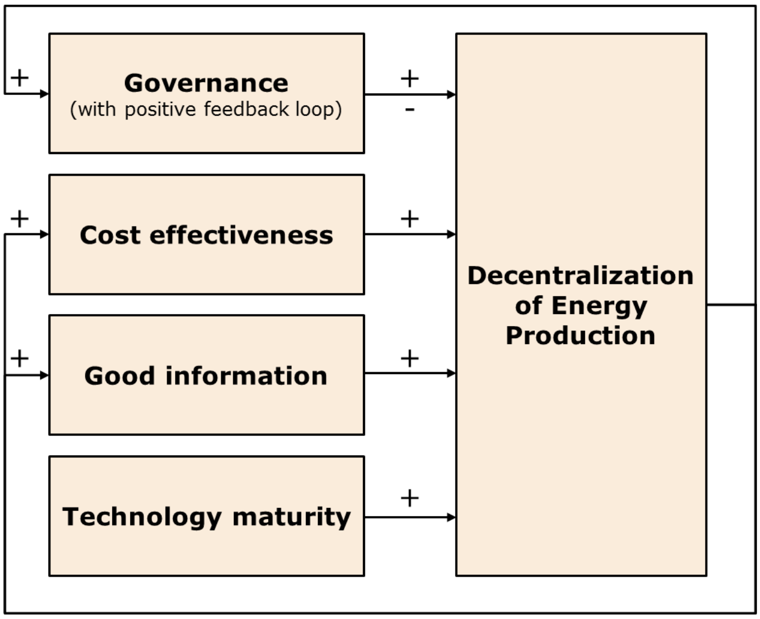

Figure 14: Main forces driving energy production decentralization with feedback loops

There are also negative feedback loops happening with effects of density of installation limiting the relevance of micro grids and scarcity effect limiting the availability of the technology.

KUBLI's study is very interesting and peculiar as it is the only one in the literature looking into the ecosystem around decentralized energy organizations and the network effects associated with it.

KUBLI's findings can complement greatly our model with feedback loops reinforcing of weakening the decentralization of energy production.

Figure 14 shows an updated version of our model including the main feedback loops.

5.3.2 Energy in developing countries and rural electrification

There is extensive literature and case studies available on rural electrification in developing countries studying how to connect the most remote areas to modern electrical supply and how communities benefit from it in terms of human development and growth. (KIRUBI, 2009; JACOBSON 2007; AMER 2011)

The relevant drivers we found for Rural electrification are mostly the same as developed country, but with an additional one: *Fund availability*.

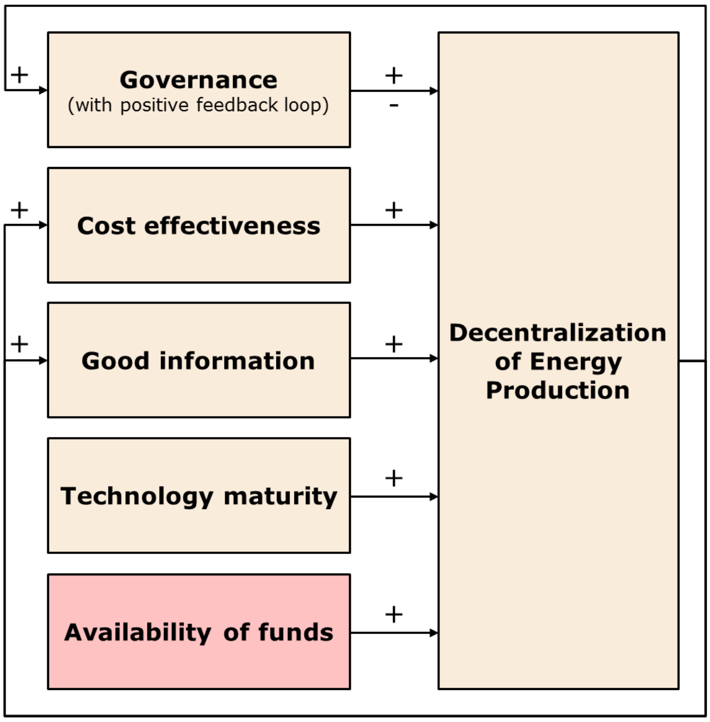

Figure 15: Main forces driving energy production decentralization in rural electrification

Cost effectiveness remains the main driver in all studies, but very often the cost of decentralized solutions is better than its grid extension counterpart. (KIRUBI, 2009; PALIT, 2011; JACOBSON, 2007; MONDAL, 2010; HIREMATH, 2009; BALA, 2009; AMER, 2011; DASAPPA, 2011; ADARAMOLA, 2014; COOK, 2011; MAHAPATRA, 2012; PALIT, 2013). In some cases, decentralized renewable energy solutions has been cost effective against grid extensions of only 10 kilometers and the gap is closing (HIREMATH, 2009).

Fund availability is a problem in rural electrification because the investor has to be convinced of the possible return on his investment. (PALIT, 2011; JACOBSON, 2007). In recent years, Banks have matured their point of view and are now mostly convinced that this kind of investment is worth their money. (KIRUBI, 2009)

5.3.3 Water

Although pilot installation of fully functional decentralized water systems already exist, there is no literature looking into the reasons why one might want to go off grid for water supply and sewage treatment.

Studies about decentralization of water management revolve around decentralized governance and its benefits and drawbacks. Water management decentralization seems to be pushed by liberal policies through recommendations of the world bank. (WILDER, 2006) Researchers observe that for this model to work, there is a great need for proper governance (BIRKENHOLTZ, 2009) and it seems to come with more ease when the resource is scarce because the local communities get more involved. (ARARAL, 2009).

When good governance is not in place, there seem to be no gain in decentralizing water governance as the Mexican example shows. (WILDER, 2006) To counter this, Wilder proposes that local management of water resources should be monitored by an independent overseeing body to enforce accountability, transparency, equity and sustainability.

There seem to be a negative feedback loop with decentralized management of water resources: it seems to hinder innovation and implementation of new treatment and distribution systems. (BAKKER, 2011)

6 CONCLUSION

This extensive literature review helped us understand better the dynamics at play in decentralization of urban utilities. We observed through bibliometric studies and in depth studies that the subject has a fast growing relevance but that the maturity is very different for different kinds of utilities. As Energy decentralization seems to get much traction today, water decentralization seems to be of low interest to the market and to the research community. Telecommunication decentralization seems to be only emerging as an issue.

We found that central actors to decentralization are the policymakers, the users, and network operators. We also observed that new players are appearing in this ecosystem with the transition to decentralized solutions, for example, energy brokers, smart grid monitoring operators, and energy storage operators. We saw also that the scientific community has a great role to play in facilitating understanding of this new paradigm for policymakers and all the ecosystem actors.

The main elements determining decentralization of utilities seem to be policy orientation, cost effectiveness, information spread, and technology maturity. In the case of rural electrification, the question of funds availability seems to be also a very relevant element.

This dissertation is innovative in mixing methods to emerge a model from the information that lies in between the lines of literature related to the subject. Almost nothing existed on the topic of decentralization of utilities, but from the articles about decentralized utilities rose the pattern of a new model predicting what can favor or disadvantage decentralized utility solutions in the future.

It is a fundamental topic to be addressed being that decentralization of utilities favors renewable solutions and thus answers to both sustainable objectives and human development objectives in less developed regions.

As resources go scarce, their prices are rising and being independent or partly independent for your resource production can help mitigate the utility related inflation in the future. Also, distributed systems bear lesser transmission losses and as such will tend to be cheaper. Finally, distributed systems are more robust and resist to blackouts and disturbances. In a globally warmed world with more and more climate related catastrophes, it is a sound idea to invest in robustness.

6.1 THEORETICAL IMPLICATIONS AND FUTURE RESEARCH

We observed in this study the emergence of a framework to decentralization dynamics in the energy sector. This first hypothesis should be tested further through field work to see if the model is complete and robust. It would also be very relevant to see if this model can be applied to water utilities decentralization or not.

After this testing, the framework could be calibrated through case studies of successful and failed attempt to decentralization in order to provide valuable insight to policymakers.

There seem to be various internal and network feedback loops in this framework and their respective strength should be tested further to help refine the decentralization model.

Water decentralization systems do not seem to have been studied beyond technical features and it would be interesting to do some case studies to understand the forces at play, what drove to their installation, successes and failures and how this could or should be replicated at a higher scale.

Telecommunication decentralization is also emerging and should receive the same treatment as water utilities decentralization through case studies.

We saw in the ecosystem that a set of actors is absent and it would be very relevant to research their role in the utilities ecosystem: Prescriber. In this category goes the architects, real estate industry, facility managers etc. that have a role to play in building and renovating our cities although they do not appear in our literature sample.

Finally, using the framework we built, it would be interesting to do some scenario planning analysis to understand in which conditions the utility system will tend to a decentralized production connected to a macro grid, micro grids, or individual autarky.

6.2 MANAGERIAL IMPLICATIONS

We have seen that policy can enable decentralization or block it altogether. It is very relevant for businesses entering the utility decentralization market to be very aware of policies and their potential future evolution to anticipate the associated risks.

The importance of cost effectiveness shows that this should be on the top of priorities for businesses entering this market. After all, they are competing with a sector that is a complete commodity all around the world and users will not accept to pay much premium for the service in most cases.

Education of the users is key to acceptance so businesses should get closer to academics to get the right information on the market and help their market entry.

Positive feedback loops on several aspects of decentralization show potential for fast growing market if the businesses play on the strength.

In a mini grid scenario, local communities will not have the competence to monitor, maintain and operate the decentralized systems and they will need help from a facility manager. There is a business opportunity in this emerging sector to provide a new service to the end users.

Intelligent brokerage of energy in open markets with weather forecast should grow with the portion of installed renewable energy systems, especially in grid-connected systems. There are opportunities for both brokers and weather forecast agencies to enter new markets.

Finally, as the solutions for water and telecom utility decentralization are only emergent, there is opportunity to pioneer in this sector with the proper product development and value proposition.

7 REFERENCES

Coutard O. (2010) *Services Urbains: la fin des grands réseaux?* Ecologies Urbaines, Paris

Féré C., Scherer F. (2010) *L'eau urbaine après les réseaux? Villes du Liban et des nouveaux Länder allemands*, L'eau Mondialisée. La gouvernance en question, Paris

Petitet S., Schneider-Madanes G. (2005) *Le modèle du réseau face aux enjeux du développement durable*, Economie & Humanisme 373

Jaglin S. (2011) *Continuums socio-techniques et urbanization des Suds: des réseaux à la carte?*

United Nations, Department of Economic and Social Affairs, Population Division (2014). *World Urbanization Prospects: The 2014 Revision, Highlights.* ISBN 978-92-1-151517-6

International Energy Agency (2014). *Technology Roadmap: Solar Photovoltaic Energy*, www.iea.org

Global Wind Energy Council (2016) *Market forecast for 2016-2020 report*. www.gwec.net

Hutter F. (2013) *Peak Oil depletion scenarios compilation.* http://trendlines.ca/free/peakoil/Scenarios/scenarios.htm

Guppy L., Kelsey Anderson K., (2017) *Global water crisis: the facts.* United Nations University Institute for Water, Environment and Health, Hamilton, Canada**.**

UN, (2015) *Sustainable development goals*. http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Jesson J.K., Matheson L., Lacey F.M. (2011) *Doing Your Literature Review Traditional and Systematic Techniques.* SAGE Publications. ISBN 978-1-84860-153-6

Moore J.F., (1993) *Predators and Prey: A New Ecology of Competition*. Harvard Business Review article

Adner R. (2016) *Ecosystem as Structure: An Actionable Construct for Strategy*. Journal of Management Vol. 43 No. 1, January 2017 39–58 DOI: 10.1177/0149206316678451

Adner R. (2006) *Match Your Innovation Strategy to Your Innovation Ecosystem*. Harvard Business Review

Iansiti M., Levien R., (2004) *Strategy as Ecology*. Harvard Business Review

Sloman M. (1994). *Policy driven management for distributed systems.* Journal of Network and Systems Management

Chow J., Kopp R.J., Portney P.R. (2003). *Energy Resources and Global Development.* Science

Johari R., Tsitsiklis J.N. (2004). *Efficiency loss in a network resource allocation game.* Mathematics of Operations Research

Palmer K., Burtraw D. (2005). *Cost-effectiveness of renewable electricity policies.* Energy Economics

Hirth L. (2013). *The market value of variable renewables. The effect of solar wind power variability on their relative price.* Energy Economics

Wiginton L.K., Nguyen H.T., Pearce J.M. (2010). *Quantifying rooftop solar photovoltaic potential for regional renewable energy policy.* Computers, Environment and Urban Systems

Ghosh D., Sharman R., Raghav Rao H., Upadhyaya S. (2007). *Self-healing systems - survey and synthesis.* Decision Support Systems

Kirubi C., Jacobson A., Kammen D.M., Mills A. (2009). *Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya.* World Development

Wilder M., Romero Lankao P. (2006). *Paradoxes of Decentralization: Water Reform and Social Implications in Mexico.* World Development

McElroy M.B., Lu X., Nielsen C.P., Wang Y. (2009). *Potential for wind-generated electricity in China.* Science

Ozaki R. (2011). *Adopting sustainable innovation: What makes consumers sign up to green electricity?*. Business Strategy and the Environment

Gómez Mármol F., Martínez Pérez G. (2010). *Towards pre-standardization of trust and reputation models for distributed and heterogeneous systems.* Computer Standards and Interfaces

Palit D., Chaurey A. (2011). *Off-grid rural electrification experiences from South Asia: Status and best practices.* Energy for Sustainable Development

Jacobson A. (2007). *Connective Power: Solar Electrification and Social Change in Kenya.* World Development

Daim T.U., Oliver T. (2008). *Implementing technology roadmap process in the energy services sector: A case study of a government agency.* Technological Forecasting and Social Change

Chen C.-W., Fan Y. (2012). *Bioethanol supply chain system planning under supply and demand uncertainties.* Transportation Research Part E: Logistics and Transportation Review

Mondal A.H., Denich M. (2010). *Hybrid systems for decentralized power generation in Bangladesh.* Energy for Sustainable Development

Sovacool B.K. (2009). *The intermittency of wind, solar, and renewable electricity generators: Technical barrier or rhetorical excuse?.* Utilities Policy

Hiremath R.B., Kumar B., Balachandra P., Ravindranath N.H., Raghunandan B.N. (2009). *Decentralised renewable energy: Scope, relevance and applications in the Indian context*. Energy for Sustainable Development

Ilarri S., Mena E., Illarramendi A. (2008). *Using cooperative mobile agents to monitor distributed and dynamic environments*. Information Sciences

Bala B.K., Siddique S.A. (2009). *Optimal design of a PV-diesel hybrid system for electrification of an isolated island-Sandwip in Bangladesh using genetic algorithm*. Energy for Sustainable Development

Mishra V., Smyth R., Sharma S. (2009). The energy-GDP nexus: Evidence from a panel of Pacific Island countries. Resource and Energy Economics

Amer M., Daim T.U. (2011). Selection of renewable energy technologies for a developing county: A case of Pakistan. Energy for Sustainable Development

Araral Jr. E. (2009). What Explains Collective Action in the Commons? Theory and Evidence from the Philippines. World Development

Amer M., Daim T.U. (2010). Application of technology roadmaps for renewable energy sector. Technological Forecasting and Social Change

Bae C., Stark W.E. (2009). End-to-end energy-bandwidth tradeoff in multihop wireless networks. IEEE Transactions on Information Theory

Edenhofer O., Hirth L., Knopf B., Pahle M., Schlömer S., Schmid E., Ueckerdt F. (2013). On the economics of renewable energy sources. Energy Economics

Würzburg K., Labandeira X., Linares P. (2013). Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. Energy Economics

Dasappa S. (2011). Potential of biomass energy for electricity generation in sub-Saharan Africa. Energy for Sustainable Development

Adaramola M.S., Paul S.S., Oyewola O.M. (2014). Assessment of decentralized hybrid PV solar-diesel power system for applications in Northern part of Nigeria. Energy for Sustainable Development

Alvial-Palavicino C., Garrido-Echeverría N., Jiménez-Estévez G., Reyes L., Palma-Behnke R. (2011). A methodology for community engagement in the introduction of renewable based smart microgrid. Energy for Sustainable Development

Ketter W., Collins J., Reddy P. (2013). Power TAC: A competitive economic simulation of the smart grid. Energy Economics

Cook P. (2011). Infrastructure, rural electrification and development. Energy for Sustainable Development

Mahapatra S., Dasappa S. (2012). Rural electrification: Optimising the choice between decentralised renewable energy sources and grid extension. Energy for Sustainable Development

Sovacool B.K. (2009). The cultural barriers to renewable energy and energy efficiency in the United States. Technology in Society

Higgs G., Berry R., Kidner D., Langford M. (2008). Using IT approaches to promote public participation in renewable energy planning: Prospects and challenges. Land Use Policy

Cludius J., Hermann H., Matthes F.C., Graichen V. (2014). The merit order effect of wind and photovoltaic electricity generation in Germany 2008-2016 estimation and distributional implications. Energy Economics

Apergis N., Payne J.E. (2014). Renewable energy, output, CO2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. Energy Economics

Palit D. (2013). Solar energy programs for rural electrification: Experiences and lessons from South Asia. Energy for Sustainable Development

Birkenholtz T. (2009). Groundwater governmentality: Hegemony and technologies of resistance in Rajasthan's (India) groundwater governance. Geographical Journal

Bakker K., Cook C. (2011). Water governance in Canada: Innovation and fragmentation. International Journal of Water Resources Development

Siddiqui A.S., Maribu K. (2009). Investment and upgrade in distributed generation under uncertainty. Energy Economics

Lemaire X. (2011). Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. Energy for Sustainable Development

Fanone E., Gamba A., Prokopczuk M. (2013). The case of negative day-ahead electricity prices. Energy Economics

Daim T.U., Li X., Kim J., Simms S. (2012). Evaluation of energy storage technologies for integration with renewable electricity: Quantifying expert opinions. Environmental Innovation and Societal Transitions

Nadai A., van der Horst D. (2010). Introduction: Landscapes of energies. Landscape Research

Pasqualetti M.J. (2011). Social barriers to renewable energy landscapes. Geographical Review

Nadaï A., Labussière O. (2009). Wind power planning in France (Aveyron), from state regulation to local planning. Land Use Policy

Wolfe P. (2008). The implications of an increasingly decentralised energy system. Energy Policy

Kalkuhl M., Edenhofer O., Lessmann K. (2013). Renewable energy subsidies: Second-best policy or fatal aberration for mitigation?. Resource and Energy Economics

Karnøe P., Garud R. (2012). Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster. European Planning Studies

Guest G., Bright R.M., Cherubini F., Michelsen O., Strømman A.H. (2011). Life cycle assessment of biomass-based combined heat and power plants: Centralized versus decentralized deployment strategies. Journal of Industrial Ecology

Jackson A.L.R. (2011). Renewable energy vs. biodiversity: Policy conflicts and the future of nature conservation. Global Environmental Change

Burke P.J. (2010). Income, resources, and electricity mix. Energy Economics

Devine-Wright P., Batel S. (2013). Explaining public preferences for high voltage pylon designs: An empirical study of perceived fit in a rural landscape. Land Use Policy

Bohn C., Lant C. (2009). Welcoming the wind? Determinants of wind power development among U.S. States. Professional Geographer

Schiermeier Q. (2013). Renewable power: Germany's energy gamble. Nature

Mendu V., Shearin T., Campbell Jr. J.E., Stork J., Jae J., Crocker M., Huber G., DeBolt S. (2012). Global bioenergy potential from high-lignin agricultural residue. Proceedings of the National Academy of Sciences of the United States of America

Buchholz T., Da Silva I. (2010). Potential of distributed wood-based biopower systems serving basic electricity needs in rural Uganda. Energy for Sustainable Development

Ferrer-Martí L., Domenech B., García-Villoria A., Pastor R. (2013). A MILP model to design hybrid wind-photovoltaic isolated rural electrification projects in developing countries. European Journal of Operational Research

Wolsink M., Breukers S. (2010). Contrasting the core beliefs regarding the effective implementation of wind power. An international study of stakeholder perspectives. Journal of Environmental Planning and Management

Buchegger S., Mundinger J., Le Boudec J.-Y. (2008). Reputation systems for self-organized networks. IEEE Technology and Society Magazine

Bambawale M.J., D'Agostino A.L., Sovacool B.K. (2011). Realizing rural electrification in Southeast Asia: Lessons from Laos. Energy for Sustainable Development

Zhang Z. (2010). Is it fair to treat China as a Christmas tree to hang everybody's complaints? Putting its own energy saving into perspective. Energy Economics

Harmon R.R., Cowan K.R. (2009). A multiple perspectives view of the market case for green energy. Technological Forecasting and Social Change

Stamford L., Azapagic A. (2014). Life cycle sustainability assessment of UK electricity scenarios to 2070. Energy for Sustainable Development

Neuhoff K., Barquin J., Bialek J.W., Boyd R., Dent C.J., Echavarren F., Grau T., von Hirschhausen C., Hobbs B.F., Kunz F., Nabe C., Papaefthymiou G., Weber C., Weigt

H. (2013). Renewable electric energy integration: Quantifying the value of design of markets for international transmission capacity. Energy Economics

Popp D. (2010). Innovation and climate policy. Annual Review of Resource Economics

Jessup B. (2010). Plural and hybrid environmental values: A discourse analysis of the wind energy conflict in Australia and the United Kingdom. Environmental Politics

Wittman H.K., Caron C. (2009). Carbon offsets and inequality: Social costs and co-benefits in Guatemala and Sri lanka. Society and Natural Resources

Lemaire X. (2009). Fee-for-service companies for rural electrification with photovoltaic systems: The case of Zambia. Energy for Sustainable Development

Farahnakian F., Ashraf A., Pahikkala T., Liljeberg P., Plosila J., Porres I., Tenhunen H. (2015). Using Ant Colony System to Consolidate VMs for Green Cloud Computing. IEEE Transactions on Services Computing

Dunlop C.A. (2010). The temporal dimension of knowledge and the limits of policy appraisal: Biofuels policy in the UK. Policy Sciences

Ohl C., Eichhorn M. (2010). The mismatch between regional spatial planning for wind power development in Germany and national eligibility criteria for feed-in tariffs-A case study in West Saxony. Land Use Policy

Tyner W.E., Taheripour F. (2007). Renewable energy policy alternatives for the future. American Journal of Agricultural Economics

Khalaf R. (2007). From RosettaNet PIPs to BPEL processes: A three level approach for business protocols. Data and Knowledge Engineering

Urpelainen J. (2014). Grid and off-grid electrification: An integrated model with applications to India. Energy for Sustainable Development

Mondal A.H., Klein D. (2011). Impacts of solar home systems on social development in rural Bangladesh. Energy for Sustainable Development

Rogers-Hayden T., Hatton F., Lorenzoni I. (2011). 'Energy security' and 'climate change': Constructing UK energy discursive realities. Global Environmental Change

Lhendup T. (2008). Rural electrification in Bhutan and a methodology for evaluation of distributed generation system as an alternative option for rural electrification. Energy for Sustainable Development

Domènech L., March H., Saurí D. (2013). Degrowth initiatives in the urban water sector? A social multi-criteria evaluation of non-conventional water alternatives in Metropolitan Barcelona. Journal of Cleaner Production

Diaz-Rainey I., Ashton J.K. (2011). Profiling potential green electricity tariff adopters: Green consumerism as an environmental policy tool?. Business Strategy and the Environment

Komatsu S., Kaneko S., Shrestha R.M., Ghosh P.P. (2011). Nonincome factors behind the purchase decisions of solar home systems in rural Bangladesh. Energy for Sustainable Development

Ramos J.S., Ramos H.M. (2009). Solar powered pumps to supply water for rural or isolated zones: A case study. Energy for Sustainable Development

Yang Y.-C.E., Zhao J., Cai X. (2012). Decentralized optimization method for water allocation management in the Yellow River Basin. Journal of Water Resources Planning and Management

Zhang D., Gersberg R.M., Wilhelm C., Voigt M. (2009). Decentralized water management: Rainwater harvesting and greywater reuse in an urban area of Beijing, China. Urban Water Journal

Rojas-Zerpa J.C., Yusta J.M. (2014). Methodologies, technologies and applications for electric supply planning in rural remote areas. Energy for Sustainable Development

Aylett A. (2013). Networked urban climate governance: Neighborhood-scale residential solar energy systems and the example of Solarize Portland. Environment and Planning C: Government and Policy

Grimsby L.K., Aune J.B., Johnsen F.H. (2012). Human energy requirements in Jatropha oil production for rural electrification in Tanzania. Energy for Sustainable Development

Tan B., Anderson Jr. E.G., Dyer J.S., Parker G.G. (2010). Evaluating system dynamics models of risky projects using decision trees: Alternative energy projects as an illustrative example. System Dynamics Review

Fisher J., Brown K. (2009). Wind energy on the Isle of Lewis: Implications for deliberative planning. Environment and Planning A

Chinese D. (2008). Optimal size and layout planning for district heating and cooling networks with distributed generation options. International Journal of Energy Sector Management

Bapna R., Umyarov A. (2015). Do your online friends make you pay? A randomized field experiment on peer influence in online social networks. Management Science

Allen J., Sheate W.R., Diaz-Chavez R. (2012). Community-based renewable energy in the Lake District National Park - local drivers, enablers, barriers and solutions. Local Environment

Stoeglehner G., Niemetz N., Kettl K.-H. (2011). Spatial dimensions of sustainable energy systems: New visions for integrated spatial and energy planning. Energy, Sustainability and Society

Veettil P.C., Speelman S., Frija A., Buysse J., Van Huylenbroeck G. (2011). Complementarity between water pricing, water rights and local water governance: A Bayesian analysis of choice behaviour of farmers in the Krishna river basin, India. Ecological Economics

Bagliani M., Dansero E., Puttilli M. (2010). Territory and energy sustainability: The challenge of renewable energy sources. Journal of Environmental Planning and Management

Parthan B., Osterkorn M., Kennedy M., Hoskyns S.J., Bazilian M., Monga P. (2010). Lessons for low-carbon energy transition: Experience from the Renewable Energy and Energy Efficiency Partnership (REEEP). Energy for Sustainable Development

Krauss W. (2010). The 'Dingpolitik' of wind energy in Northern German Landscapes: An ethnographic case study. Landscape Research

Ramirez Camargo L., Zink R., Dorner W., Stoeglehner G. (2015). Spatio-temporal modeling of roof-top photovoltaic panels for improved technical potential assessment and electricity peak load offsetting at the municipal scale. Computers, Environment and Urban Systems

Pan J., Jain R., Paul S., Vu T., Saifullah A., Sha M. (2015). An Internet of Things Framework for Smart Energy in Buildings: Designs, Prototype, and Experiments. IEEE Internet of Things Journal

Ahlborg H., Sjöstedt M. (2015). Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages. Energy Research and Social Science

Tepong-Tsindé R., Crane R., Noubactep C., Nassi A., Ruppert H. (2015). Testing metallic iron filtration systems for decentralized water treatment at pilot scale. Water (Switzerland)

Dierkes C., Lucke T., Helmreich B. (2015). General technical approvals for decentralised sustainable urban drainage systems (SUDS)-the current situation in Germany. Sustainability (Switzerland)

Simshauser P. (2016). Distribution network prices and solar PV: Resolving rate instability and wealth transfers through demand tariffs. Energy Economics

Moss T., Becker S., Naumann M. (2015). Whose energy transition is it, anyway? Organisation and ownership of the Energiewende in villages, cities and regions. Local Environment

Müller D., Monti A., Stinner S., Schlösser T., Schütz T., Matthes P., Wolisz H., Molitor C., Harb H., Streblow R. (2015). Demand side management for city districts. Building and Environment

Herreras Martínez S., Koberle A., Rochedo P., Schaeffer R., Lucena A., Szklo A., Ashina S., van Vuuren D.P. (2015). Possible energy futures for Brazil and Latin America in conservative and stringent mitigation pathways up to 2050. Technological Forecasting and Social Change

Reboredo J.C. (2015). Is there dependence and systemic risk between oil and renewable energy stock prices?. Energy Economics

Hirth L., Müller S. (2016). System-friendly wind power. How advanced wind turbine design can increase the economic value of electricity generated through wind power. Energy Economics

Inglesi-Lotz R. (2016). The impact of renewable energy consumption to economic growth: A panel data application. Energy Economics

Bertsch J., Growitsch C., Lorenczik S., Nagl S. (2016). Flexibility in Europe's power sector-An additional requirement or an automatic complement?. Energy Economics

Blum N.U., Bening C.R., Schmidt T.S. (2015). An analysis of remote electric mini-grids in Laos using the Technological Innovation Systems approach. Technological Forecasting and Social Change

Fang W., Yin X., An Y., Xiong N., Guo Q., Li J. (2015). Optimal scheduling for data transmission between mobile devices and cloud. Information Sciences

Zhou Z., Dong M., Ota K., Wang G., Yang L.T. (2016). Energy-Efficient Resource Allocation for D2D Communications Underlaying Cloud-RAN-Based LTE-A Networks. IEEE Internet of Things Journal

Calvert K. (2016). From ‘energy geography’ to ‘energy geographies’: Perspectives on a fertile academic borderland. Progress in Human Geography

Cancino-Solórzano Y., Paredes-Sánchez J.P., Gutiérrez-Trashorras A.J., Xiberta-Bernat J. (2016). The development of renewable energy resources in the State of Veracruz, Mexico. Utilities Policy

Kilinc-Ata N. (2016). The evaluation of renewable energy policies across EU countries and US states: An econometric approach. Energy for Sustainable Development

Killian M., Kozek M. (2016). Ten questions concerning model predictive control for energy efficient buildings. Building and Environment

Yahyaoui I., Yahyaoui A., Chaabene M., Tadeo F. (2016). Energy management for a stand-alone photovoltaic-wind system suitable for rural electrification. Sustainable Cities and Society

Yenneti K., Day R. (2016). Distributional justice in solar energy implementation in India: The case of Charanka solar park. Journal of Rural Studies

Lilliestam J., Hanger S. (2016). Shades of green: Centralisation, decentralisation and controversy among European renewable electricity visions. Energy Research and Social Science

Louie H. (2016). Operational analysis of hybrid solar/wind microgrids using measured data. Energy for Sustainable Development

Varho V., Rikkonen P., Rasi S. (2016). Futures of distributed small-scale renewable energy in Finland - A Delphi study of the opportunities and obstacles up to 2025. Technological Forecasting and Social Change

Vazquez A., Iglesias G. (2016). Grid parity in tidal stream energy projects: An assessment of financial, technological and economic LCOE input parameters. Technological Forecasting and Social Change

Pérez de Arce M., Sauma E., Contreras J. (2016). Renewable energy policy performance in reducing CO2 emissions. Energy Economics

Ueckerdt F., Pietzcker R., Scholz Y., Stetter D., Giannousakis A., Luderer G. (2017). Decarbonizing global power supply under region-specific consideration of challenges and options of integrating variable renewables in the REMIND model. Energy Economics

Andor M., Voss A. (2016). Optimal renewable-energy promotion: Capacity subsidies vs. generation subsidies. Resource and Energy Economics

Bravo D., Sauma E., Contreras J., de la Torre S., Aguado J.A., Pozo D. (2016). Impact of network payment schemes on transmission expansion planning with variable renewable generation. Energy Economics

Mandelli S., Merlo M., Colombo E. (2016). Novel procedure to formulate load profiles for off-grid rural areas. Energy for Sustainable Development

Xie M., Zhou J., Li C., Lu P. (2016). Daily generation scheduling of cascade hydro plants considering peak shaving constraints. Journal of Water Resources Planning and Management

Scholten D., Bosman R. (2016). The geopolitics of renewables; exploring the political implications of renewable energy systems. Technological Forecasting and Social Change

Lee J.-S., Kim J.-W. (2016). South Korea's urban green energy strategies: Policy framework and local responses under the green growth. Cities

Knuckles J. (2016). Business models for mini-grid electricity in base of the pyramid markets. Energy for Sustainable Development

Nachtigall D., Rübbelke D. (2016). The green paradox and learning-by-doing in the renewable energy sector. Resource and Energy Economics

Hottenrott H., Rexhäuser S., Veugelers R. (2016). Organisational change and the productivity effects of green technology adoption. Resource and Energy Economics

Feron S., Heinrichs H., Cordero R.R. (2016). Sustainability of rural electrification programs based on off-grid photovoltaic (PV) systems in Chile. Energy, Sustainability and Society

Zhang L., Pang M., Wang C., Ulgiati S. (2016). Environmental sustainability of small hydropower schemes in Tibet: An emergy-based comparative analysis. Journal of Cleaner Production

Bhagwat P.C., Richstein J.C., Chappin E.J.L., de Vries L.J. (2016). The effectiveness of a strategic reserve in the presence of a high portfolio share of renewable energy sources. Utilities Policy

Agostini C.A., Nasirov S., Silva C. (2016). Solar PV Planning Toward Sustainable Development in Chile: Challenges and Recommendations. Journal of Environment and Development

Kubli M., Ulli-Beer S. (2016). Decentralisation dynamics in energy systems: A generic simulation of network effects. Energy Research and Social Science

Binnie C. (2016). Tidal energy from the severn estuary, uk. Proceedings of the Institution of Civil Engineers: Transport

Flores C.C., Vikolainen V., Bressers H. (2016). Water governance decentralisation and river basin management reforms in hierarchical systems: Do they work for water treatment policy in Mexico's Tlaxcala Atoyac sub-basin?. Water (Switzerland)

Wright G., O'Hagan A.M., de Groot J., Leroy Y., Soininen N., Salcido R., Castelos M.A., Jude S., Rochette J., Kerr S. (2016). Establishing a legal research agenda for ocean energy. Marine Policy

Lynch M.Á., Curtis J. (2016). The effects of wind generation capacity on electricity prices and generation costs: a Monte Carlo analysis. Applied Economics

Doblinger C., Dowling M., Helm R. (2016). An institutional perspective of public policy and network effects in the renewable energy industry: enablers or disablers of entrepreneurial behaviour and innovation?. Entrepreneurship and Regional Development

Lavrijssen S. (2016). The right to participation for consumers in the energy transition. European Energy and Environmental Law Review

Whaley L., Cleaver F. (2017). Can ‘functionality’ save the community management model of rural water supply?. Water Resources and Rural Development

Johnson N., Strubegger M., McPherson M., Parkinson S.C., Krey V., Sullivan P. (2017). A reduced-form approach for representing the impacts of wind and solar PV deployment on the structure and operation of the electricity system. Energy Economics

Razaque A., Rizvi S.S., Khan M.J., Hani Q.B., Dichter J.P., Parizi R.M. (2017). Secure and quality-of-service-supported service-oriented architecture for mobile cloud handoff process. Computers and Security

Cramton P., Doyle L. (2017). Open access wireless markets. Telecommunications Policy

Guo S., Zhao H., Zhao H. (2017). The most economical mode of power supply for remote and less developed areas in China: Power grid extension or micro-grid?. Sustainability (Switzerland)

Zhang E., Li F., Niu B., Wang Y. (2017). Server-aided private set intersection based on reputation. Information Sciences

Marquardt J. (2017). Central-local Relations and Renewable Energy Policy Implementation in a Developing Country. Environmental Policy and Governance

Nicolini A.L., Lorenzetti C.M., Maguitman A.G., Chesñevar C.I. (2017). Intelligent algorithms for improving communication patterns in thematic P2P search. Information Processing and Management

Tak B.C., Kwon Y., Urgaonkar B. (2017). Resource accounting of shared IT resources in multi-tenant clouds. IEEE Transactions on Services Computing

Loßner M., Böttger D., Bruckner T. (2017). Economic assessment of virtual power plants in the German energy market — A scenario-based and model-supported analysis. Energy Economics

Narula S.A., Bhattacharyya S. (2017). Off-grid electricity interventions for cleaner livelihoods: A case study of value chain development in Dhenkanal district of Odisha. Journal of Cleaner Production

Samani P., Mendes A., Leal V., Correia N. (2017). Pre-fabricated, environmentally friendly and energy self-sufficient single-family house in Kenya. Journal of Cleaner Production

Sutter D. (2017). Propagandistic research and the U.S. department of energy: Energy efficiency in ordinary life and renewables in electricity production. Econ Journal Watch