Louvain School of Management

How to overcome financial barriers to the participation of Europe in a global electrical grid?

A feasibility study on a 'Global Grid'

Auteur : Maximilien de Le Hoye
Promoteur(s) : Sabine Denis

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It always seems impossible until it's done

Nelson Mandela

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List of abbreviations

ACER: Agency for the Cooperation of Energy Regulators

ADP: Adenosine Diphosphate

ATP: Adenosine Triphosphate

CAPEX: Capital Expenditure

CEER: Council of European Energy Regulators

CIGRE: Conseil International des Grands Réseaux Electriques

CPI: Consumer Price Index

CREG: Commission de Régulation de l'Electricité et du Gaz

CRR: Congestion Revenue Rights

DG ENERGY: Directory General Energy of the European Commission

EC: European Commission

EGI: Elia Grid International

ENTSOE: European Network for Transmission System Operators for Electricity

EROI: Energy Return On Investment

EU: European Union

FTR: Financial Transmission Rights

GDP: Gross Domestic Profit

GEI: Global Energy Interconnection

GEIDCO: Global Energy Interconnection Development and Cooperation Organization

GENI: Global Energy Network Institute

HDI: Human Development Index

HVDC: High-voltage direct current

IEM: Internal Energy Market

ISO: Independent System Operator

MENA: Middle East-North Africa

MS(s): Member State(s)

MTI: Merchant Transmission Investment

NIMBY: not-in-my-backyard opposition

NRA: National Regulatory Authority

PCI(s): Project(s) of Common Interest

RAB: Regulatory Asset Base

RES(s): Renewable Energy Sources

SDG(s): Sustainable Development Goal(s)

TCC: Transmission Congestion Contracts

TEN-E: Trans-European Networks for Energy

TO: Transmission Owner

TSO: Transmission System Operator

TYNDP: Ten-Year Network Development Plan

UN: United Nations

USA: United States of America

USD: United States Dollar

WHO: World Health Organization

WACC: Weighted Average Cost of Capital

Introduction

Our world is facing unprecedented challenges. Among them are the climate crisis and the need to decarbonize energy. These problems require systemic changes that will shape societies and the way they function. I believe one must be brave and propose bold solutions to tackle these issues. This is exactly what I enjoyed from Damien Ernst's talk at a conference I had organized with my student association Academics for Development in Louvain-la-Neuve. To solve problems from current energy systems and remove barriers to the development of renewable energies, Ernst presented a project he had been working on the previous years. The main idea was to connect continental electrical grids to form a global electrical grid. Expanding grids to merge with one another would help to increase the share of renewables by tapping into areas that are rich in RES while also countering the disadvantages of renewables.
As I thanked Ernst for his participation at the end of the event, I expressed how amazed I was by his idea. He mentioned that he was looking for students to study non-technical aspects around the global grid. I would not hesitate a second and decided this was a subject I would like to examine over the next year for my thesis. Graduating from a master's degree in Management, I decided I wanted to examine financial barriers to the realization of the grid.
The literature review I have consulted mostly covers the economics of interconnectors as other financial aspects are yet to be extensively studied. It was mostly undertaken from a European point of view and I therefore deemed wise to also adopt a European focus for my thesis. The practical analysis consists in semi-directional interviews of previously identified key stakeholders to the electricity market.

Literature review

The concept of a global electrical grid

All around the world, solutions are being evaluated to decarbonize the world's energy by replacing extensive fossil fuel use with renewable energy consumption. In "The Global Grid" (2013), Chatzivasileiadis, Ernst, and Andersson mention a number of studies which have examined possibilities to increase the share of renewables in energy consumption. All these works came to the same conclusion: a reinforcement of electricity grids is needed to efficiently integrate renewables and reliably satisfy energy demand. At the same time, the authors of "The Global Grid" (2013) cite other feasibility analyses on projects connecting remote renewable energy sources to major load centers. These analyses concluded such projects could be both feasible and economically competitive.

The idea of a global grid originates from these two insights and from the fact that most countries do not possess enough renewable energy sources to operate an energy transition with reasonable land use. To achieve the energy transition, it is vital for current grids to geographically expand and tap into remote areas rich in RES; as this process goes on, grids will eventually meet one another and ultimately result into a global grid. (Chatzivasileiadis, Ernst, & Andersson, Global Power Grids For Harnessing World Renewable Energy, 2017). The grid itself serves as the backbone and integrates all existing regional electrical systems into one system under a meshed nature. Most of the lines forming the global grid will be high-voltage direct current (HVDC) transmission lines. While the technology needed for these lines is already mature, other technologies, such as multiterminal technology, deep undersea cables, HVDC circuit breakers, protection and control systems, and a standardized operating voltage level, still need development. (Chatzivasileiadis, Ernst, & Andersson, The Global Grid, 2013). While the global grid could be a cost-competitive solution to energy decarbonization, it could additionally counter the negative characteristics of renewables (e.g. inter-seasonal and intra-day supply-demand mismatch, need for storage due to intermittency, electricity price volatility…) as will be explained further in this thesis.

Several studies and initiatives have so voiced the interest and highlighted the importance of a global electrical grid. Among others, we can cite the work from prof. Ernst and his colleagues Chatzivasileiadis and Andersson. Illustration of how they envision the grid can be found below (figure 1).

Figure 1: Example of a global electrical grid

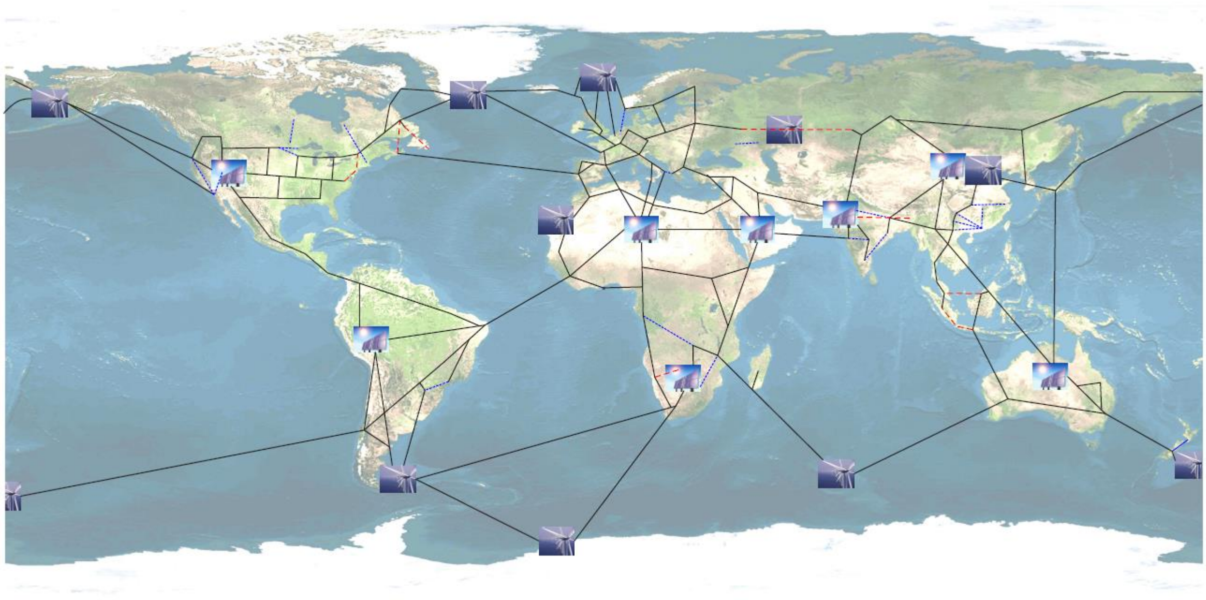


Illustration of the global grid imagined by Chatzivasileiadis, Ernst and Andersson in 2013. Blue dotted lines indicate HVDC lines longer than 500km already in operation while dashed red lines indicate lines longer than 500km that were at building or planning stage in 2013. The authors claim the list of illustrated HVDC lines was not exhaustive. RES power plants shown on the map were selected according to solar radiation maps, average wind speeds and sea depths.
Source: *Chatzivasileiadis, S., Ernst, D., & Andersson, G. (2013). The Global Grid.*

GEIDCO, CIGRE and GENI have also studied the relevance and potential application of a global electrical grid. Please refer to appendix C to observe the specific projects they put forward in their studies, which illustrate other representations of the global electrical grid concept.

The importance of energy for society

Although most people are aware of its importance for our daily lives, energy remains a difficult concept to explain as it is abstract and intangible.

As stated by Tzafestas (2018), energy is the “most fundamental prerequisite for all living organisms on Earth and engineered (man-made) systems to live, operate, and act” and it can be defined as “the ability to do work”. In this section, I will first highlight its importance for nature and all living beings before pointing out its relevance for humanity and contemporary societies.

First of all, it should be noted that energy is the foundation of nature and defines it. Smil (2004) claims that energy through solar flux and resulting temperatures have always shaped nature, the environment and the limits of performance of organisms. Additionally, all living organisms need energy to maintain themselves. All this energy used by the living comes from the sun and is captured by the photosynthesis of plants in the first phase through the following three chemical reactions, as explained by Tzafestas. (2018) Through photosynthesis, plants first convert energy from the sun into carbohydrates or glucose through the following reaction:

$6\ CO_2 + 6\ H_20 + \text{Light energy} \rightarrow C_6H_{12}0_6 + 6\ O_2$

The glucose is then used by living organisms through the following reaction:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 36\ ATP$

which is commonly known as (aerobic) respiration. The reader must note that plants consume oxygen for their own respiration, but they produce more oxygen than what they use. While plants use glucose that they have produced themselves (as they are autotrophs), heterotrophs find their glucose by eating other living organisms. ATP molecules are derived from the breaking of bonds from the food molecules (glucose) through oxidation during the respiration.

The ATP molecules are then converted into ADP with the following reaction, which releases energy:

$ATP + H_2O \rightarrow ADP + H_3PO_4 + \text{energy (30.5 kJ/mol)}$

These three reactions are fundamental for the metabolism of the living, which consists in all chemical processes operated by living cells to maintain life. (Tzafestas, 2018)

This process of flowing energy goes on through food chains, which ensure an equilibrium of nutrients and energy within ecosystems. This flow of energy is inefficient because less energy becomes available when moving up the food chain as there is a loss of energy into heat at each link in the chain. This explains why predators, which are typically bigger than their preys, typically encompass much smaller populations than their preys. (Tzafestas, 2018)

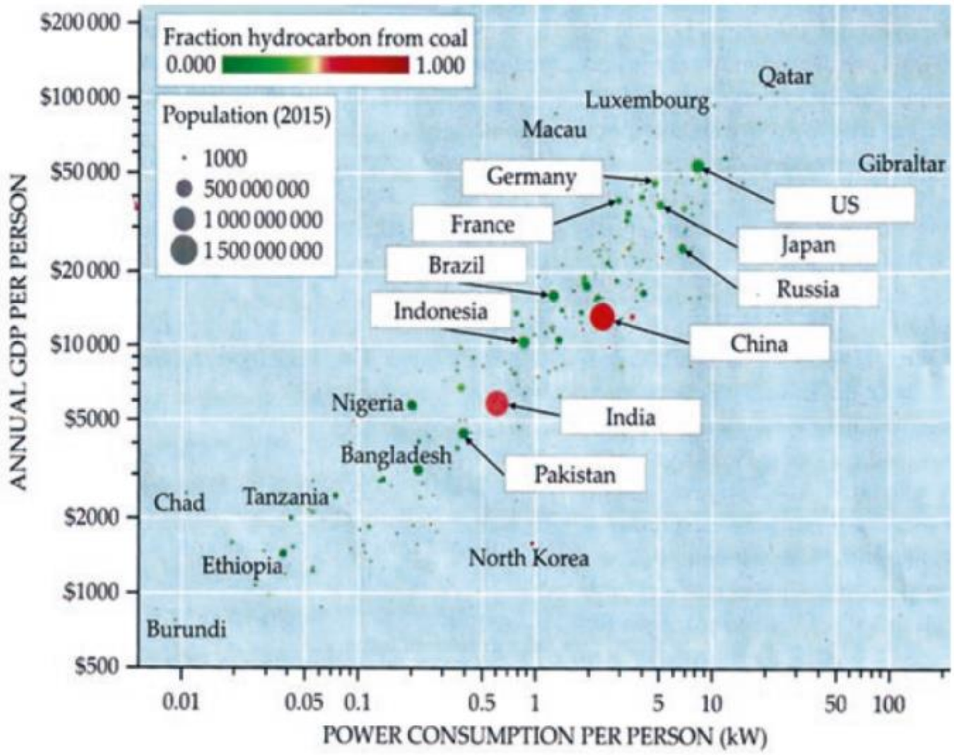
Humans too have always needed energy for their metabolism. Additionally, humans have managed to master several forms of energy that led to progress and increased welfare. This has been highlighted by many authors who highlight several periods and transitions regarding human use of energy.

Smil (2004) has defined several energy eras and transitions that occurred since the beginning of mankind and that tend to be shorter and to replace each other acceleratingly. The first era took place during prehistory when man discovered fire, which he could only handle with difficulty and inefficiently until roughly 8 000 BC. The first energy transition materialized at that time as humans domesticated draft animals and mastered fire while settling in sedentary societies, hereby also taking advantage of increased energy from the soil through agriculture. The next transition occurred as man invented technologies to harvest energies from water and wind through windmills and waterwheels. These technologies surpassed the efficiency of draft animals because of the energy that was spent in feeding the latter and they so generated greater power at a lower cost. (Pimentel & Pimentel, 2008) The next transition is marked by the use of fossil fuels and invention of machines (particularly the steam machine at first) and occurred within all developed countries throughout the 19th and 20th centuries, while it is yet to materialize in other developing regions of the world. Finally, Smil (2004) says the last transition occurred with the invention of electricity, including all different energy sources brought to generate it (characterized by an increased fossil fuels consumption but also the invention of nuclear power, wind power and photovoltaic cells, …) With this transition also comes a decrease in coal consumption, which is progressively replaced by an increase in oil and natural gas consumption. (Smil, 2004)

As humans discovered other forms of energy (food from agriculture, draft-animals, energy from wind and water captured by windmills and waterwheels, from burning fossil fuels, etc), the time they spent securing shelter and food, which primarily occupied most of their time, was consistently and drastically reduced over time (Pimentel & Pimentel, 2008). Hereby, humans had an increased amount of energy surplus available for society. They started to engage in various activities that are linked to prosperity (trade, transport, …), and created more complex societal structures. (Pimentel & Pimentel, 2008) Many academics have contributed to create the hypothesis of an 'energy-civilization equation', which induces that societal achievements have been possible because of increased energy consumption. (Möllers & Zachmann, 2012) Smil (2004) also claims that the quality of life has increased through this energy quest by generating more food, educational and leisure opportunities, etc. This comes as an autocatalytic process: in line with what has happened when every energy source was discovered, energy and production efficiency have led to higher wages and more leisure time since the industrial revolution. This has derived a higher demand for goods and services, which in turn created a higher output and innovation that lead to always increasing productivity. (Mattick, Williams, & Allenby, 2010) One can thus sense the link between energy and growth and how energy consumption is necessary for economic growth in our societies. There is in fact a linear correlation between energy consumption and economic growth. This is shown in the graph below (figure 2), which plots the power consumption per capita against the GDP per capita. (Christophorou, 2018) The same result was also highlighted by Mattick, Williams, & Allenby

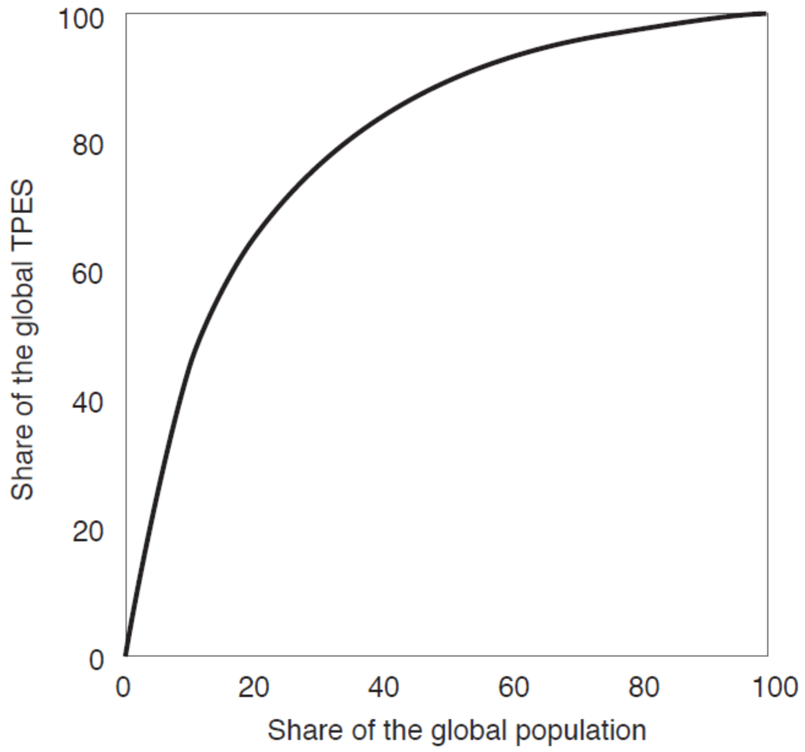
(2010). It is therefore not surprising that energy fuels all the sectors that sustain contemporary societies such as industry, transport, residential, commercial and public services, agriculture, forestry and fishing. (IEA, 2019)

Figure 2: GDP and power consumption



Graph plotting countries' annual GDP per capita (in USD) against their power consumption per capita (in kW) for the year 2015. The dots' size on the chart reflect the population sizes and the dots' color reflect the shares of hydrocarbon from coal. Source: Christophorou, L. G. (2018). Emerging Dynamics: Science, Energy, Society and Values. p.166. Athens: Springer

Figure 3: Energy inequality



The Lorenz curve shows the energy use inequality by plotting the share of global Total Primary Energy Supply (TPES) (in %) agains the share of global population (in %) in 2000. Perfect equality would be represented by a diagonal line. Inequality is represented by a highly convex shape of the curve. From the figure, one can see the richest 10% of the world's population consumed approximately 45% of all commercial primary energy, whereas the poorest 50% had access to just 10% of the total. Source: Smil, V. (2004). World History and Energy. Encyclopedia of Energy, Volume 6. p.557.

The energy problem

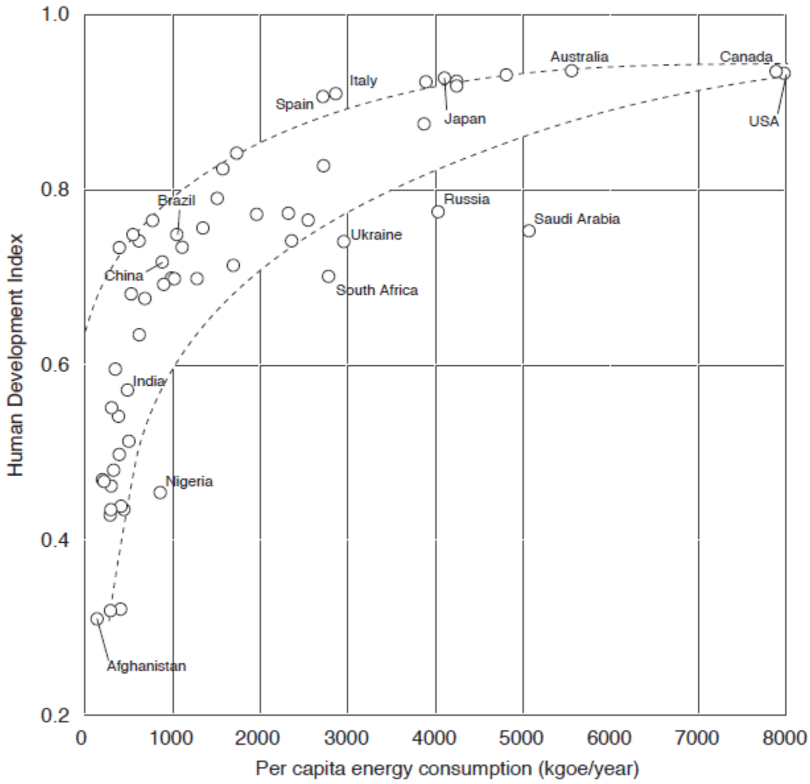
First of all, one must realize that the current energy system is very unequal in its consumption among countries. In countries such as the United States of America, the energy consumption per capita was above 75,000 kWh, while it was lower than 1,000 kWh in certain countries for the year 2015. (Our World in Data, 2019) Another way to understand the inequality problem inherent to energy consumption stems from the figure above (figure 3). This figure shows the Lorenz curve corresponding to the global energy consumption in 2000 and it can be seen that the 10% richest people worldwide accounted for 45% of the total energy consumption while the poorest 50% accounted for only 10% of the total. (Smil, 2004) Not only is there a difference in absolute values, there is also a difference in the quality of energy used among regions of the world. While richer countries depend on fossil fuels and electricity, poorer countries depend on biomass and animal waste. (Christophorou, 2018)

The reason why this unequal access to energy sources is problematic becomes obvious through the following arguments. Christophorou (2018) claims that people's poverty is in fact people's energy poverty, precisely stemming from a lack of access to clean, abundant and affordable energy, especially electricity. He explicitly defines energy poverty as "the situation of large numbers of people in developing countries whose wellbeing is negatively affected by very low consumption of energy, use of polluting fuels and excessive time spent in collecting fuel for their basic needs." Quantitatively, the energy poverty line has been drawn by several authors. For example, the International Energy Agency sets the energy poverty line at an annual energy consumption of 250 kWh per rural household or at 125 kWh for urban households, although such levels have been criticized for not even fulfilling basic human needs.

The United Nations claim that, although the percentage of people with access to electricity dramatically rose from 78% to 87% during the 2000-2016 period, there are still around a billion people lacking access to electricity. (The United Nations, 2019) Additionally, 2.4 to 3.0 billion people rely on traditional use of biomass for cooking and heating and have incomes of less than $2 per day, Christophorou (2018) says. He further claims that people who lack access to modern energy traditionally lack provision of clean water, sanitation, healthcare, and economic development. These people also heavily rely on polluting options for lighting such as kerosene. (WHO, 2012) Access to energy has a positive impact on quality of life as it enables building infrastructure for clean water, heavily supports food systems and ensures access to essential medicine; as such, energy access reduces infant mortality, fights hunger, and ultimately lifts up populations from poverty and helps establish steady population rates. (GENI, 2019) Vera and Langlois also highlighted the importance of energy as being "vital for eradicating poverty, improving human welfare and raising living standards" (Vera & Langlois, 2017)

The importance of energy for human wellbeing can be further drawn from the following graph (figure 4), which plots the relationship between the annual energy consumption per capita in kilograms of oil equivalent (kgoe) against the Human Development Index (HDI) of each country for the year 2000. The HDI is derived from the life expectancy, literacy education enrollment rates and GDP per capita. (Healy, Stephens, & Malin, 2019) From this graph, it can be seen that the countries which score the lowest on HDI are the countries that consume the least energy per capita.

Figure 4: Human Development Index and energy consumption

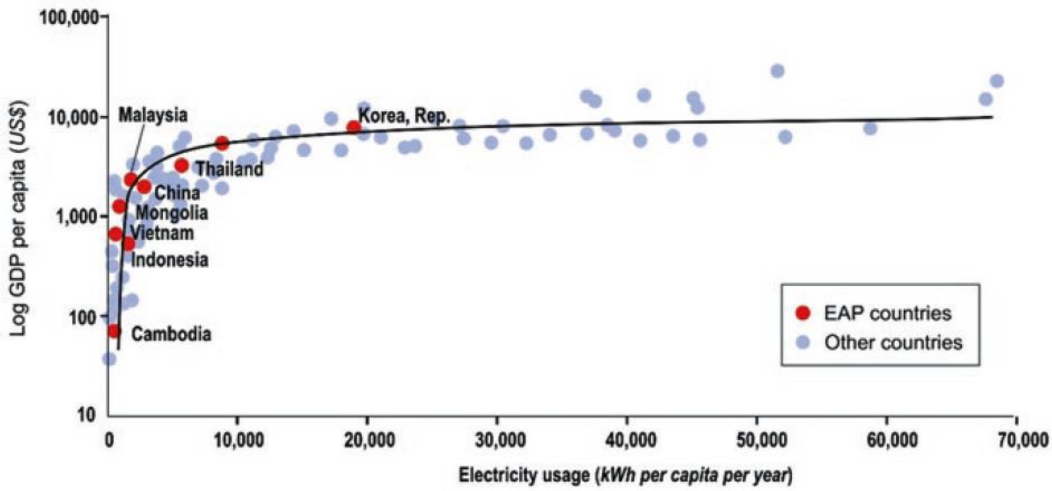


Graph plotting countries' Human Development Index against their average per capita commercial energy consumption (in kgoe/year) for the year 2000. Virtually no quality-of-life gains accrue with consumption above 2.6 metric tons of oil equivalent. Source: Smil, V. (2004). World History and Energy. Encyclopedia of Energy, Volume 6. p.560.

As seen above, energy consumption and GDP per capita also follow a linear correlation. One could thus wonder if people's quality of life would also linearly increase with the energy consumption. Assuming the quality of life can be drawn from the HDI as Smil (2004) and Mattick, Williams, & Allenby (2010) did, the graph shows that this assumption should not hold and that the link would rather be hyperbolic. Indeed, countries such as Spain, Italy or Japan, which have energy consumption per capita levels that are at least twice as low as that of the USA, score similarly to the USA on the HDI. It is thus erroneous to think that people in a certain country who consume twice as much energy than the people of another country are twice as wealthy and happy. In fact, the USA scored worse than Japan in terms of infant mortality rates, homicides rates, scientific literacy, and amount of leisure time. (Smil, 2004) Similarly, Mattick, Williams and Allenby (2010) concluded that a country can reduce its energy consumption per capita by as much as 400% and just slightly lower its HDI. It can thus be expected that a better and fairer allocation of the current energy consumption could ensure poorer countries which lack energy access to increase their HDI while richer countries' HDIs would hardly be impacted.

Simultaneously, another observation regarding fairer allocation of energy resources can be made from the graph below (figure 5). If people from countries that annually use less than 1000 kWh per capita in electricity were given such access levels, it could substantially increase their GDP per capita and standards of living above poverty level; reducing electricity use with the same rates for the countries which have an annual electricity usage level above 20,000 kWh per capita could be done without significantly impacting their income. (Christophorou, 2018)

Figure 5: GDP/capita and electricity usage



Semi-logarithmic plot of the GDP per capita (in USD) as a function of electricity usage (kWh/person/year) in 2008. Red dots represent countries from East Asia Pacific while blue dots represent countries from other regions. One can see richer countries have a high electricity usage, a strong difference in the slopes of rich and poor regions and a large spread in the data for countries with a high energy use. Source: Christophorou, L. G. (2018). Emerging Dynamics: Science, Energy, Society and Values. p.168. Athens: Springer

There are a few additional issues inherent to the contemporary energy system. First, it is unstable because of a growing global energy demand and an increased dependence of countries on few producing countries that face fierce competition and are politically unstable. (Möllers & Zachmann, 2012) Furthermore, current electricity grids experience losses to around 50% of their production, making it particularly inefficient and indicating an area for potential improvement. (WHO, 2012)

One major problem arising from the current energy system is the fact that it heavily relies on fossil fuels. Oil, coal and natural gas currently account for 40%, 28% and 20% of global energy used, respectively. (Tzafestas, 2018) The problem with fossil fuels is two-fold.

First, fossil fuels are the main cause to the generation of $C0_2$ and other greenhouse gases which cause climate change. Christophorou (2018) claims that over two-thirds of greenhouse gas emissions come from energy production and use. This is caused by the fact that around 80% of global energy production comes from coal, oil and gas. (WHO, 2016) Transformation, transport and use of energy "have affected the environment and have contributed to climate change more than any other single factor in human history", he adds. Global emissions are expected to keep increasing until 2100, mainly through contributions from developing countries. (Christophorou, 2018) Frick and Thioye (2018) state that the energy sector is accountable for 70% of all emissions of anthropogenic greenhouse gases. As such, the energy transition is a key aspect to fight climate change, which is expected to cause around 250 000 additional deaths per year between 2030 and 2050. (WHO, 2018)

The other issue with fossil fuels is the fact that these energy sources are exhaustible and are being depleted at a fast rate. In the past 50 years, the world energy consumption has increased over 4 times. (Christophorou, 2018) Tzafestas (2018) highlights that, in 2003, the available reserves remaining of fossil fuels equaled around 1000 billion barrels of oil (sufficient for about 38 years), 5400 trillion cubic ft natural gas (sufficient for about 59 years) and 5000 billion metric tons of coal (sufficient for about 245 years). The consequence of depleted resources of fossil fuels is an increased cost of all commodities that are made of fossil fuels. Another critical issue is the diminishing energy return on investment (EROI) of fossil fuels. The EROI is the ratio of the amount of a specific energy resource acquired divided by the amount of energy expended in obtaining that energy resource. A 100 years ago, the EROI of oil was 100. In the 1970s, the EROI dropped to 30. In 2015, the EROI of oil was at 15. (Ernst D. , 2015)

In addition to the above, Tzafestas (2018) identified three main impacts fossil fuels have on the environment. First, they generate air pollution (particularly from the burning of coal), which affects human health and crop sustainability. Healy, Stepehens and Malin (2019) claim this air pollution from fossil fuels combustion leads to around 7 million premature deaths globally each year: 3.3 million deaths due to outdoor air pollution and, less-known but at least equally serious, 3.5 million deaths due to household air pollution arising from rudimentary polluting fuel stove (WHO, 2012). The UN state that there is still 3 billion people cooking with polluting fuel to date. (The United Nations, 2019)

Fossil fuels also generate water pollution through their extraction, transport, storage and disposal. (Tzafestas, 2018)

Finally, another main problem induced is the disposal of solid waste that is generated through the conversion of fossil fuels in agricultural, industry and domestic operations. Some additional, less major problems incurred by fossil fuels consumption include land subsidence (the fact that large cavities remain in the ground after fossil fuels have been pumped out, which threatens the land to collapse), land and wildlife disruption through large infrastructure works and the release of harmful chemicals contained in drilling-muds which are used in the activity. (Tzafestas, 2018)

As another non-renewable energy source, nuclear energy also generates a problem of radioactive-waste-handling. Since its contribution towards global energy consumption levels remains low (accounting for only 10.5% of electricity generation in 2018) and since there is a decreasing trend in nuclear energy since the 1980s (World Nuclear Report, 2019), this problematic won't be covered deeper.

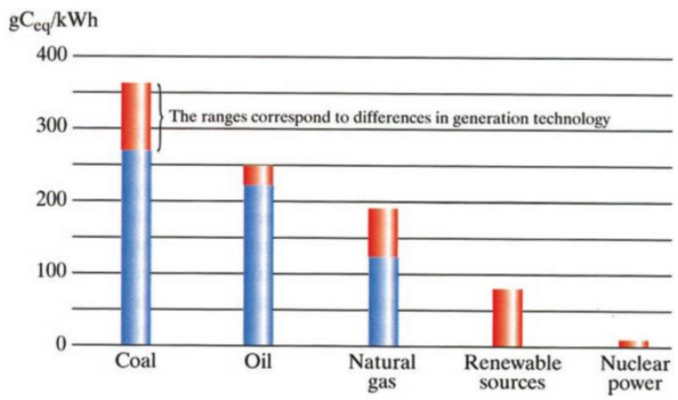
The contemporary energy system has created an unprecedented rise in human population and particularly in urban population. The functioning of infrastructures that support these communities is complex and requires enormous amount of energy, which makes it fragile. (Christophorou, 2018) In parallel, modern society bases its evaluation of progress on the growth of the Gross Domestic Product (GDP), fundamentally neglecting the fact that the earth's energy sources are finite and the impact on the environment. (Christophorou, 2018) On the other hand Christophorou (2018) says that the fall of civilizations in the past (in China, India or the Middle East) took place when these civilizations could not face the consequences of an energy demand that exceeded the available energy supply. As such, "modern civilization's blind belief in the necessity of continuous development ("progress") engenders dangers for its sustainability and its cherished freedoms. It is certainly a major challenge to humanity," Christophorou (2018) adds. Indeed, as seen above, world energy consumption has been experiencing a drastic rise and is still forecasted to rise up to 55% by 2035 compared to 2000-level. (Christophorou, 2018) By contrast, Smil (2004) tames the energy-civilization equation by indicating that other civilizations experienced a demise that was not caused by a loss of energy supplies, including the Western Roman Empire, the fall of the French Monarchy or the Nationalist retreat from mainland China. He further adds that some civilizations also suddenly throve although no significant new energy sources or efficient conversions were discovered.

Despite the last, it seems clear that societies rely on interdependent systems which all need important amounts of energy to operate. The malfunctioning of one of these systems could cause a failure of the whole system and make civilization collapse, and sufficient energy amounts seem therefore crucial to support civilization. (Christophorou, 2018) The challenge will therefore consist in securing enough energy from reliable, safe, clean and profitable energy sources to meet civilization's energy needs (especially from developing countries) without further threatening the Earth and humankind. (Christophorou, 2018)

Renewable energies: benefits and setbacks

First of all, the main benefit of renewables is the fact that they emit few greenhouse gases through their electricity generation. As can be seen from the graph below (figure 6), renewable energy sources can have a carbon footprint (given in units of gram-carbon-equivalent per kWh) that can approach zero-level depending on the generation technology and the type of renewables. According to the WHO, access to and use of modern energy that emits less pollution, both in household and community, can benefit the health of millions of people today and contribute to long-term health by tackling climate change. (WHO, 2012). Renewable energies such as solar and wind power are two of the low-carbon energy sources that represent an alternative to fossil fuels and will contribute to fighting climate change. (WHO, 2016)

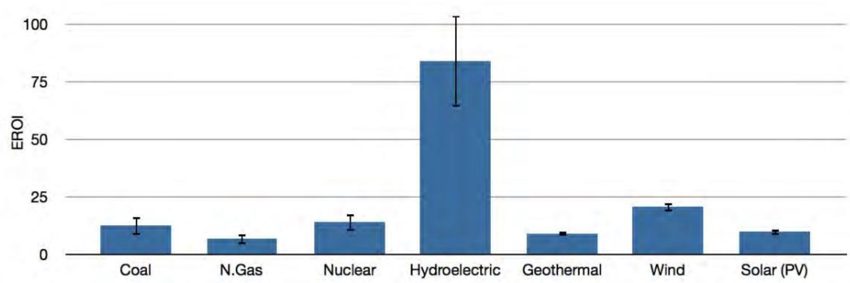
Figure 6: Greenhouse gas emissions per energy type



Total emission of greenhouse gases (in units of gram-carbon-equivalent per kWh - gCeq/kWh) of the electricity production of electricity from fossil fuels, renewables and nuclear power. Source: Christophorou, L. G. (2018). Emerging Dynamics: Science, Energy, Society and Values. p.134. Athens: Springer

According to Damien Ernst (2015), the EROI of solar power and wind power in optimal environmental conditions in 2015 was around 10 and between 20 and 30, respectively. At the same time, the EROI of oil was at 15. EROIs of renewable energy are expected to further be positively impacted by technological improvements. The graph below (figure 7) resonates similarly with Ernst findings: wind energy has a higher EROI than fossil fuels and nuclear energy, while solar energy has an EROI that is similar to fossil fuels. However, it is unsure whether technological improvements will compensate for the less suitable locations due to a shortage in optimal locations for renewable energy, especially wind energy. In Spain, technological improvements were not able to compensate the drop in wind EROI arising from suboptimal location. Further storage needs will also make the EROI of renewables drop. This lack of optimal locations and the need for electricity storage explain why Ernst advocates for a global electrical grid. (Ernst D. , 2015)

Figure 7: Energy Return on Investment per energy source



Mean EROI (and standard error) values for known published assessments of electric power generation systems. Source: Balogh, S., Hall, C. A. S., Lambert, J. G. (2013) EROI of Global Energy Resources: Status, Changes and Social Implications. p.32.[1]

Moreover, their sourcing cannot be depleted since they rely on natural sources. Biomass (if properly managed), wind and sun energy are, so far we know, non-exhaustible while water and geothermal energy won't dissipate either. Not only are these sources non-depletable, they are also incredibly abundant. As an example, there is enough solar energy that strikes the earth every day to cover all energy needs of humanity for 30 years. (Christophorou, 2018)

While renewable energy sources should be prioritized over fossil fuel sources to fight global warming and ensure energy systems sustainability through non-depletable energy resources, one should not overlook the fact that renewables also have an impact on the environment. We briefly handle the most significant renewable energy sources separately. (Tzafestas, 2018)

[1] Retrieved on October 15th, 2019 from:

https://assets.publishing.service.gov.uk/media/57a08a0340f0b652dd000508/60999-EROI_of_Global_Energy_Resources.pdf

First of all, biomass releases carbon dioxide through its combustion. It can also lead to sterile soils through unwise trees and plants cutting while also reducing natural absorption of carbon dioxide by flora. Within biomass, specific attention can be given to biofuels. Biofuels require an extensive land use and are particularly inefficient in their energy conversion from the sun: they need about 100 times more land to produce the same energy as for the conversion of solar energy to electricity. (Christophorou, 2018) Additionally, ethical concerns arise as biofuels compete with food while a solid share of human population still suffer from hunger.

Geothermal activity poses a threat of toxic substance releases from underground, land subsidence (same as for fossil fuels), air, water and noise pollution as well as localized climate change through heat release.

Hydropower infrastructures have a negative impact on fish populations and on the ecosystems around reservoirs as well as rivers. Because of increasing pressures for environmental protection as well as a demand for potable and agricultural water, hydropower capacities are expected to grow by not more than 20% or could even be reduced.

Solar power systems generate toxic substances for humans for the manufacturing of photovoltaic cells. Their production also relies on fossil fuels, although emitting much fewer greenhouse gases than would have been generated through fossil fuel systems for the same amount of energy created. Finally, solar power systems require an extensive land use.

Wind energy result in visual and sound pollution which impact wildlife through the operation of wind turbines. It is also not easy to find suitable places for wind farms because of conflicting land use. It is best used in farms, but rather more difficult to implement in forests or other developed areas as trees would have to be cleared or roads cut. Finally, massive birds' deaths have been witnessed in areas around windfarms due to collisions with turbines.

As the ecological impact of specific renewable energy generation has been discussed, it is wise to also introduce the setbacks that come with their systemic use and large-scale implementation. Solar and wind power are stochastic, intermittent and dispersed energy sources, which can be problematic. Christophorou (2018) says that the high stochasticity has negative consequences on the stability of electrical distribution and transportation systems as these are very sensitive to variation in voltage and frequency. This is not too much of a problem when the stochastic energy sources account for a minor share of the total electricity generation, but it becomes a key issue for the large-scale implementation that is required for the energy transition. To solve this problem, the system could opt for two different solutions. It could either be changed from a centralized power system control to a distributed and stochastic control in order to be able to handle stochastic supply and volatile demand. This would raise challenges such as accommodating the active role of the consumer and decentralized small-scale energy generation. The other option is to massively depend on storage facilities which are believed to improve power quality, increase reliability of the grid and asset utilization. (Christophorou, 2018) Li and Jiang (2018) also highlight the problem of load balancing and grid safety and they also point out the need for extensive energy storage facilities as a solution.

Furthermore, areas with average-to-low renewable energy sources would need extensive use of land to cover the population’s energy needs. As an example, it has been calculated by Ernst (2013) that no less than 11% of Belgium’s territory would have to be allocated to wind farms to cover its energy needs. This, combined to not-in-my-backyard (NIMBY) opposition motives which impede exploitation of areas rich in renewable energy sources, poses a major threat to energy transition at local level in such countries. (Ernst, 2013)

Additionally, areas rich in wind and solar energy sources are unevenly distributed across the globe, mainly concentrated in polar and equatorial regions. These areas are typically located hundreds or thousands of kilometers away from load centers. (Li & Jiang, 2018)

Aware of the importance of the energy transition for a sustainable future, the United Nations have implemented their 7th Sustainable Development Goal (SDG) to address its challenges. The objective of SDG7 is to “ensure access to affordable, reliable, sustainable and modern energy for all” by 2030. In order to monitor progress and meet this objective, the UN have set specific targets and indicators (see appendix A). These indicators are reviewed annually to analyze progress towards meeting the goal. I argue below that a global electrical grid would contribute to meet all 5 targets of SDG 7.

Advantages and challenges of a global electrical grid

Advantages

A global grid would simultaneously address the intrinsic shortcomings of renewable energy sources which pose a threat to the energy decarbonization.

First the stability problem intrinsic to renewable energies would be solved. RESs’ supply reliability is enhanced when these RESs are interconnected. (Chatzivasileiadis, Ernst, & Andersson, 2017) Local shortages or outages can be compensated by energy generated elsewhere in the grid (Gellings, 2015), thereby reducing global peaks and lows and improving the system’s security. (Brinkerink, Deane, Collins, & O Gallachoir, 2018) On the other hand, excess electricity generated from renewables (such as wind power at night) can be reallocated through the grid and ensure a 100% exploitation with no waste (except for the transport losses). (Chatzivasileiadis, Ernst, & Andersson, 2013) This interconnectivity would additionally result in lower needs for storage that are inherent to counter RESs' intermittency (thereby lowering the price) and in a more constant energy price over the grid, thereby lowering the price volatility for the consumer. (Chatzivasileiadis, Ernst, & Andersson, 2013)

The global grid would enable long-distance energy transfers. According to Gellings (2015), the technology to transmit a huge amount of electricity over long distances with non-significant losses already exists. The global grid would thus make it possible to access remote areas and tap on their massive renewable energy potential with low energy losses. As an example, Liu Zhenya, CEO of the Global Electricity Interconnection Development and Cooperation Organization (GEIDCO) noted that the world global power needs could be met with solar energy harvested in only 7.7% of the Sahara Desert. (Simon, 2018).

The global grid and its contributions to the targets of SDG 7

We analyze hereunder how a global electrical grid can contribute to achieving SDG 7's targets (see appendix A):

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

With greater interconnection and infrastructure arising from a global grid, the GEIDCO (Global Energy Interconnection Development and Cooperation Organization) expects the number of people without access to electricity to drop below 500 million in 2030, down from 1.06 billion in 2014. (GEIDCO, 2017) It is further argued that the global grid would generally make renewable energy cheaper than energy currently sourced from fossil fuels. As such, Chatzivasileiadis, Ernst and Andersson (2013) computed that it would be cheaper for the USA to import electricity from renewable energy sources in Europe under a global grid than operating its own fossil fuel power plants. Indeed, they estimate the cost of conventional power generation amounts to 0.14USD/kWh while importing renewable power from Europe would cost between 0.063USD/kWh and 0.165USD/kWh (including generation and transmission). Importing renewable power from Europe would thus be more economical, except for the most expensive generation units. It is further believed that the renewable energy price will continue to drop as technology should further improve over the years. (Li & Jiang, 2018)

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

Multiple studies have shown that the development of the electricity network is crucial to increase the share of renewables in the global energy mix. (Chatzivasileiadis, Ernst, & Andersson, 2013) The share of RES in primary energy consumption could amount at 35% by 2030 compared to only 16% in 2015. (GEIDCO, 2017)

7.3 By 2030, double the global rate of improvement in energy efficiency

The GEIDCO (2017) claims the 2015 efficiency rate will double by 2030 under its GEI plan and the goal would thus effectively be met by switching from oil and gas to electricity and by promoting efficiency-enhancing practices in network countries.

7.A By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

Cooperation among regional grid operators will be needed to establish the financing, operating and technical characteristics as well as rules and standards to ensure a reliable and safe operation of the grid. (Gellings, 2015) This component also echoes with SDG 17: partnerships for the goals.

7.B By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

The grid will be an infrastructure itself and will grant enhanced access to clean energy worldwide (see 7.1). Zhenya further claims that it would "enable developing countries to avoid the carbonization-process of their economy by accessing the same resources, which would result in a reduction in global income inequalities." (Simon, 2018)

Beside SDG7, a global electrical grid would also seem to strongly resonate with SDG 17: partnerships for the goals. This SDG serves as a support for achieving the other SDGs and consists in 19 indicators around finance, technology, capacity building, trade and systemic issues (see appendix B). It would be overflowing to cover all these indicators here, but one can reasonably assume that a global electrical grid, by its nature and inherent need for international and intercontinental cooperation, would help to foster global partnerships and pave the way to achieve SDG 17. (The United Nations, 2020) According to Simon (2008), a global grid would indeed contribute to world peace by cooperating rather than competing on energy supply.

Challenges to the realization of the global grid:

Jacobson and Delucchi (2011) found out that the main barriers to providing worldwide energy from renewables were social and political, rather than technological. As of today, there is no regulatory framework to fund and invest in such project. (Ernst & Fonteneaux, 2019) Furthermore, global cooperation will be needed to organize and regulate the new electricity trade resulting from a global grid. (Gellings, 2015) One might also wonder to which extent energy-importing countries would be willing to become dependent on other countries or continents for their energy supply by participating in such a grid, especially with the ones they do not share strong diplomatic ties with. Other challenges might arise from the resulting market characteristics. (Chatzivasileiadis, Ernst, & Andersson, 2013) Additionally, there is a risk that the global grid could become a target for terrorist attacks and put global power security at stake in case of blackouts. (Chatzivasileiadis, Ernst, & Andersson, 2013)

In short, great collaboration is needed at investment, planning, implementing and operating stages of the global grid. (Chatzivasileiadis, Ernst, & Andersson, 2013; Gellings, 2015) As such, one can realize some of the most critical challenges to a global grid might rather be financial, geopolitical and regulatory.

The aim of this master thesis is to identify the existing and potential barriers to the financing of the global grid and to find ways to overcome them. The choice for this thesis to mainly focus on the financial barriers stems from the relevance to the business and management studies of its author. Furthermore, the complexity of the issue and the restricted word count of a master thesis make it difficult to handle financial, regulatory and geopolitical components altogether within this work, though one will observe their presence and at times strong overlaps among these.

Financing a global electrical grid

Chatzivasileiadis, Ernst and Andersson justify the relevance of a global electrical grid by computing estimates which prove it is financially viable. First of all, they researched whether connecting a wind farm in the Kerguelen Islands with South Africa would be profitable. This group of Islands lie in the Indian Ocean at an equal distance between Australia and South Africa. Their results showed that, by 2020, such an interconnection would be competitive with local South African wind energy farms, due to the expected drop in wind energy generation costs. Even in the worst-case scenarios (i.e. with the highest-cost cable at 0.054USD/kWh and lowest capacity factor at 40%), the maximum cost for wind energy generation for delivering wind energy to South Africa and making a profit would amount at 0.033USD/kWh, which the authors claim is highly probable by 2020 and beyond. They argue that additional revenues and profits will flow from further connecting the Kerguelen Islands with Australia due to time zone diversity and potential electricity trade. (Chatzivasileiadis, Ernst, & Andersson, 2017)

This is shown by the other case they analyzed: the interconnection between North America and Europe through a wind farm in Greenland. Assuming the wind farm is already connected with Europe, they researched whether it would be profitable to connect it with the other side of the ocean. For this purpose, it is assumed the energy generated by the wind farm can always be sold at peak price (50% of the time to Europe and 50% of the time to North America) and that the peak price is twice as high as the off-peak price. They found out that, while the cost per delivered kWh would increase by 21% to 25%, the wind farm's revenues would increase by 31% to 33%. This altogether would result in an additional profit increase of 7% to 12%. Additionally, they point out that the energy produced by the wind farm could only occupy 50% of such interconnection cables capacity. This leaves room for significant additional revenues from energy trade between the continents. (Chatzivasileiadis, Ernst, & Andersson, 2013)

The benefits from trade have been estimated as follows. In the favorable case where electricity trade occupies its maximal utilization rate (i.e. 50%), the route between Greenland and North America could be amortized in 10 to 12 years with the generated revenues from trade. In the less favorable case where the utilization rate for trade would amount for only 30%, the connection could be amortized in 14 to 17 years. In comparison with the case where the wind farm only sells its electricity to Europe and the UK amount, additional profits of 24-27% under a 30% cable utilization rate and up to 42% under a 50% utilization rate for trade would arise. (Chatzivasileiadis, Ernst, & Andersson, 2017)

Ernst and his colleagues then calculated the financial data arising from a direct interconnection between continents. As an example, they took a 5500km-long cable that would span between Europe and the USA. Assuming HVDC lines infrastructure are already present on both continents, they found out that such a cable could be amortized within 18 to 28 years with an 80% utilization in the best case and within 23 to 35 years with a 50% utilization rate in the worst case. (Chatzivasileiadis, Ernst, & Andersson, 2017) Assuming revenues similar to the ones generated by NorNed (which generated about 12% of its invested capital in the first two months), the income for each delivered kWh along such a 5500km line would exceed 2-4 times its cost. (Chatzivasileiadis, Ernst, & Andersson, 2013)

Background information on electricity transmission

Originally, interconnectors were solely built for security of supply purposes: they constituted a backup option for national energy systems. This reason was later joined by economics, social welfare and sustainability arguments as interconnectors induce electricity price convergence and favor renewables implementation. (Puka & Szulecki, 2014) Recently, there has been a liberalization process going on in many countries to regulate the electricity industry that was traditionally highly characterized by monopoly. In the EU, this was materialized by Directive (19 December 1996: 96/92/CE). (Meeus, Purchala, Van Hertem, & Belmans, 2006) Companies which previously controlled all activities of the industry (generation, transmission, distribution, supply) had to be unbundled and these activities were separated. While competition was introduced in generation and supply (Meeus, Purchala, Van Hertem, & Belmans, 2006), electricity transmission remained a natural monopoly operated by an Independent System Operator (ISO) that had to be regulated by a ‘regulator’. (Littlechild, 2012). This supervision obliges the ISO to guarantee network access in a non-discriminatory way and overall service quality. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) Furthermore, the ISO balances power input and supply and keeps the voltage at the correct frequency. (Meeus, Purchala, Van Hertem, & Belmans, 2006)

Following the unbundling, two different types of schemes emerged: one where system operation and ownership were kept together under a Transmission System Operator (TSO) and one where ownership was separated from operation of the ISO and remained with the incumbent owner, i.e. the Transmission Owner (TO). While the TSO is responsible for grid investments in the first scheme, investment decisions in the second scheme fall under the TO. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) Such investments are undertaken to ensure security of supply and market facilitation. Investment decisions are nowadays challenged; while they were undertaken in accordance with generation decisions under a vertically integrated company, such decisions are now taken independently from generation decisions. This generates uncertainty that is further reinforced by uncertainty arising from regulation. (Chatzivasileiadis, 2012; Meeus, Purchala, Van Hertem, & Belmans, 2006; Kapff & Pelkmans, 2010) Similarly to Ernst et al (2013), Meeus et al. (2006) describe the electricity industry as high-risk, long-term, capital sensitive and generating moderate returns.

Two main schemes emerged for transmission investments: regulated and merchant transmission investment. To date, the regulated investment is the most common and has been prioritized in accordance with the political will to encounter the monopolistic character of electricity transmission. In the EU, regulated transmission is the default scheme and investors must apply for an exemption to benefit from the merchant investment scheme.

Main investment schemes

Regulated transmission investment

Historically, the most common investment scheme was the regulated model. Identified investments opportunities are assessed by the regulator through a cost-benefit analysis. If approved, investors would traditionally be the transmission system owners (i.e. the TSO or the TO). However, if these are reluctant to undertake the investment, the regulator can potentially issue a tender procedure as the investment is also open to third parties. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012)

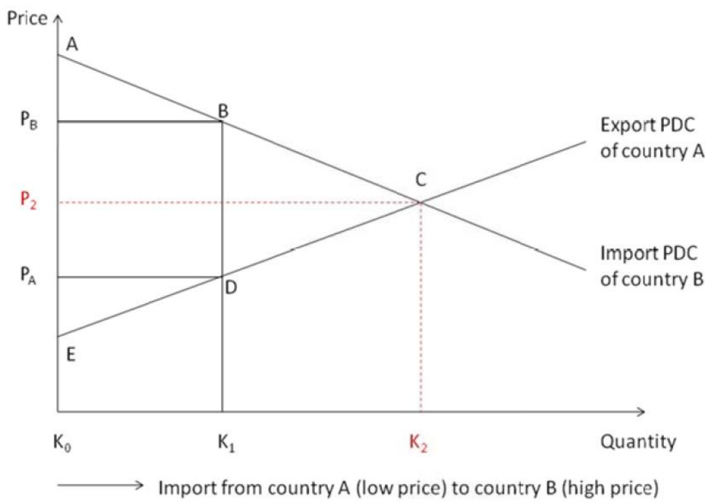
This model implies that costs are solely recovered through the regulated network tariff, which means that an investor’s revenue does not depend on the congestion level but only depends on the flow of power. (Poudineh & Rubino, 2017; Jacottet, 2012) This materializes in two different ways. It can either take the form of a “cost-of-service” mechanism where the investor is compensated for all its incurred costs and nothing more; this approach implies no managerial effort from the transmission owner to reduce costs and operate efficiently. Additionally, it can take the form of a price-cap mechanism which consists in determining a fixed price ex ante that the firm will be allowed to charge; this approach results in efficient operations but consumers do not benefit from resulting cost reduction. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) Under a regulated investment, congestion rent cannot be perceived as a revenue. It is captured by the TSO and put in a separate fund. The regulator has as main objective to guarantee affordable electricity prices for customers. In this sense, EU regulations oblige congestion rents to be used to ensure availability of capacity, to fund interconnection capacity or to be redistributed to grid users under rebated tariffs. (Poudineh & Rubino, 2017; Jacottet, 2012; Kapff & Pelkmans, 2010) The regulated model has been and still is favorized by the EU because of the maturity of its institutions, the regulating power over the business plan and the guaranteed return on investment for interconnector developers. (Poudineh & Rubino, 2017)

Merchant transmission investment

Alternatively, a merchant transmission investment (MTI) relies on competition, free entry and decentralized property-rights based institutions. (Joskow & Tirole, 2005) It is further not coordinated nor regulated by an entity. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) In this model, investors receive property rights which entitle them to receive congestion revenues from the difference in energy prices. Alternatively, the right to these revenues can also be sold as Congestion Revenue Rights (CRRs), Transmission Congestion Contracts (TCC) or Financial Transmission Rights (FTRs). This helps investors cover the costs of capital and operations of the interconnection and provides the financial incentives to a market-based interconnection investment. (Joskow & Tirole, 2005) Any interested party, including the TSO and TO can undertake an MTI (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) These congestion revenues are the only means by which merchant investors recover their costs. (Jacottet, 2012)

To illustrate this model, one can look at the figure below (figure 8). The figure depicts electricity trade between two countries. Country North has cheap electricity generation while Country South has customers willing to buy cheap electricity from North since its own electricity generation is more expensive. In a first instance, transmission capacity between North and South is limited to K. In this case, there arises a congestion rent that is equal to the rectangle pSACpN and captured by the transmission owner. There is congestion because the transmission line is used to its fullest capacity and further trade remains undone due to the capacity constraint. This unrealized trade generates a congestion cost for society. This congestion cost is the triangle ABC that represents the loss of welfare from the social welfare optimum point B under capacity $\bar{K}$. (Joskow & Tirole, 2005) Merchant investors tend to underinvest in transmission with regard to socially desirable capacity. This is explained by the fact that their investment generates larger benefits for society than for themselves. Indeed, by creating a capacity K_1 to link both countries, the investment reduces the original congestion cost by area ABDE while the merchant investor only captures P_BBDP_A. Thus, the investment generates positive externalities for society, but since these are not captured by the investor, it is likely to result in an underinvestment. These externalities include an enhanced security of supply and dilution of local market power. Another explanation comes from the fact that the investor aims at maximizing his profit. From a certain capacity point on, the increase in revenues from capacity expansion will be lower than the decrease in revenues due to the resulting lower price differentials. In the social optimum for example, prices converge and the revenue from the congestion rent equals zero. As such, merchant investors will invest up to a capacity K* that corresponds to a lower level where the marginal cost of an incremental unit equals the marginal revenue (i.e. the marginal price of congestion). They have an intrinsic interest to maintain markets disintegrated to keep price differentials large enough and reap the benefits from congestion rent. (Kapff & Pelkmans, 2010) Capacities are therefore likely to be constrained and below social optimum.

Figure 8: Private and social revenues of interconnection capacities



The figure shows the import and export price dependency curves (PDC) (also known as excess curves) for both countries based on aggregated supply and demand curves. The vertical axis reflects the electricity price and the horizontal axis reflects the interconnection capacity. Source: Kapff, L., & Pelkmans, J. (2010). Interconnector Investment for a Well-functioning Internal Market. p.10. Bruges: Bruges European Economic Research Papers.

Joskow and Tirole (2005) argue that all profitable merchant investments are socially efficient under a stringent set of assumptions that are equivalent to a model of perfect competition, which is very rarely met in practice. Indeed, attributes that lead to merchant investment, stochastic properties of transmission networks and market imperfections rather suggest market conditions far from corresponding to perfect competition.

Institutional context

Historically, the European electricity network relied on self-sufficient national systems and interconnection were designed to promote security of supply. (Jacottet, 2012) Interconnection investments were done according to generation decisions, import and load characteristics.

(Meeus, Purchala, Van Hertem, & Belmans, 2006) This resulted in strong but weakly interconnected European national grids.

Electricity market regulation in the EU since the 1990s has been shaped by two additional main trends. First, the formation of an Internal Energy Market (IEM) to liberalize the electricity market, which would increase overall welfare by stronger competition and trade. Second, the EU started promoting decarbonization and massive expansion of RES. (Jacottet, 2012) For both these trends, electricity interconnection plays a crucial role and, in 2002, an objective to reach 10% interconnection capacity by 2005 was set. This leaves 90% of production to be available to domestic demand only and achieving a level of openness far below most other production sectors. (Jacottet, 2012) This was reinforced in 2014 as the European Commission set a binding 15% capacity interconnection goal to be met by 2030. (Dutton & Lockwood, 2017) The pursuit of the IEM resulted in several electricity market and regulatory reforms including ownership unbundling, creation of independent regulators and, recently, market coupling. (Dutton & Lockwood, 2017) Market coupling consists in the coordination of power exchanges. Instead of explicit auctions, cross-border capacity is fully available under implicit auctioning (see below). If sufficient capacity has been developed, prices equalize. This has been going on under the Nordpool group that comprises Denmark, Estonia, Finland, Norway and Sweden, and in Western Europe between Belgium, the Netherlands, France, Germany and Luxembourg. (Jacottet, 2012)

The EU now highlights the three main benefits from greater interconnection: higher security of supply, stronger competition in generation and supply, and better connections for sustainable power. (Jacottet, 2012) European authorities recognized that it is crucial to use existing grid infrastructure effectively while expanding the trans-European grid. (Meeus, Purchala, Van Hertem, & Belmans, 2006) The expert group recognizes the importance of having a well-functioning market for an efficient use of current interconnections. They argue for the implementation of a coherent electricity market that will provide clearer price signals and stronger investment incentives. (CEER, 2017)

The Third Energy Package was launched by the EU in 2009 and it laid the basis for European electricity network planning and investment. Key components from the Third Energy Package include the commitment towards a Ten-Year Network Development Plan (TYNDP) for electricity and gas achieved by cooperation under the European Network for Transmission System Operators for electricity (ENTSO-E) and gas (ENTSOG) as well as the creation of a new entity, the Agency for the Cooperation of Energy Regulators (ACER). (CEER, 2017)

Founded in 2011, ACER's role is to facilitate greater interconnection development. So far, it is mainly mandated to coordinate interconnectors agreements and its powers are limited. Authors plead for ACER to receive higher powers. (Kapff & Pelkmans, 2010; Jacottet, 2012) Additionally, the Third Energy Package reemphasized the importance of ownership unbundling and regulators' independence and set some limits on the use of congestion rents to rebate tariffs as abuse of this option is a barrier to optimal grid development (see hereafter). (Kapff & Pelkmans, 2010) ACER is currently entitled to provide cooperation frameworks for NRAs (National Regulatory Authories), oversee ENTSO-E and intervene in exemption decisions for merchant investments. However, nor TYNDP nor ACER hold binding power which will not help to solve the interconnection investment failure. (Kapff & Pelkmans, 2010)

From 2013, the EU implemented a more holistic view under new guidelines for the trans-European energy infrastructure, the so-called TEN-E (Trans-European Networks for Energy) Regulation. This regulation identified and addressed Projects of Common Interest (PCIs) for the first time. These are cross-border projects that impact cross-border flows, the so-called bottlenecks. (Kapff & Pelkmans, 2010) These bottlenecks can be identified according to the severity and frequency of cross-border congestion as well as countries' low interconnectivity rates. Meeus et al (2006) note that both characteristics are independent. The Expert Groups on electricity interconnections argue that investment to remove these infrastructure bottlenecks are needed to improve security of supply, competition and enhanced renewable integration. (CEER, 2017) The TEN-E regulation advocates for early public involvement (particularly of local communities) to achieve collaborative decision-making, build trust and reduce public opposition in order to deliver better and faster projects. (CEER, 2017) The TEN-E project uses funding (see hereafter) to ease interconnection development, yet the fund is not large enough to offer a credible alternative for EU-scale interconnector investment facilitation. This is partly explained by the will to let energy infrastructure to be primarily ruled by market principles and to keep EU funding intervention to a minimum. Kapff and Pelkmans (2010) argue, however, that larger funding could help the EU to break the most severe bottlenecks in a rapid manner.

Meeus et al (2006) identify the policy instruments that are implemented by the EU to support investment for bottleneck alleviations. First, the TEN-E programme comprises a subsidies budget of around 20 million € to support feasibility studies up to 50% of their amount. To a lower extend, this budget could also help finance some of the projects for up to 10% of their costs. As such, the TEN-E support financing acts as an important stimulator in the early and risky steps of a project. Furthermore, it can help projects to access new financing opportunities through the "TEN-E label" or to receive additional TEN-E funding to finance up to 50% of the project. (Kapff & Pelkmans, 2010) Second, it was imposed by the EU that congestion revenues cannot be perceived as additional income by the TSO under a regulated investment. Such congestion revenues can be used for three purposes: to guarantee actual availability of current capacity; to maintain or expand interconnection capacities; to be taken into account by regulators and lead to reduced consumer tariffs. Meeus et al (2006) argue that regulators tend to be biased by short-term benefits arising from reduced consumer tariffs instead of prioritizing interconnection expansion. This is confirmed by findings by the expert group on electricity interconnection as less than a third of congestion rents were allocated to new capacity or interconnectors during the period 2011-2015. (CEER, 2017) Furthermore, only 16.2% of congestion rents collected in 2007 were invested in interconnectors. (Kapff & Pelkmans, 2010) Another explanation for such results can be found under insufficiently unbundled TSOs that prefer not to invest in interconnectors that would harm their affiliated generation and supply units. Interconnection expansion is in the benefit of the market since the low interconnectivity level in Europe is still below optimal congestion levels (where remedying costs equal benefits). (Meeus, Purchala, Van Hertem, & Belmans, 2006) Kapff and Pelkmans (2010) argue interconnection expansion is the only option that improves social welfare beyond the short-run. The authors and the Council of European Energy Regulators (CEER) and Kapff and Pelkmans (2010) further advocate for clear regulatory guidelines and more investment coordination beyond the Third Energy Package as leaving options for congestion rent use open leads to underinvestment. Finally, the EU implemented a cross-border compensation system to make up for the transmission charges it removed to stimulate cross-border electricity exchange. This compensation system lowers operational costs and indirectly supports expansion investment as TSOs would not be able to bear costs linked to increased transit implied by increased interconnector capacity. (Meeus, Purchala, Van Hertem, & Belmans, 2006)

As of 2010, Kapff and Pelkmans argued that Europe comprised eight insufficiently interconnected sub-markets that also feature weak cross-border interconnection internally.

Finance basics

The CEER (2019) introduces the different types of regulation approaches. Cost-based approaches were first widely used for tariff regulation means. Among these were rate-of-return regulation, where the regulated TSO was guaranteed a certain rate of return on its regulatory asset base, and cost-plus regulation where a profit margin was added to the company's costs. These led to inefficient and wasteful practices as TSOs' profits increased with their asset or cost base. (CEER, 2019) In reaction to these drawbacks, incentive-based regulations were launched. These are characterized by financial rewards and penalties with regard to desired goals to be achieved by TSOs; extra-profit is shared with the TSO in case it over-fulfills the goals set by the regulator. Today, the majority of European countries operate under an incentive-based regulation that consists in a mix between a cap regulation and a guaranteed rate of return. Countries can also set efficiency requirements to force TSOs to reduce costs and be more efficient. This can take place under a forced reduction of the allowed cost year by year.

To calculate the rate of return, most regulators base themselves on the Weighted Average Cost of Capital (WACC). The WACC is computed as follows:

$$WACC = \frac{Equity}{(Equity + Debt)} \times Cost\ of\ equity + \frac{Debt}{(Equity + Debt)} \times Cost\ of\ debt$$

And it is used as a factor applied to an asset volume for the rate of return computation. Typically, the rate of return is determined during the year before the start of the regulation period, which typically runs for 3 to 5 years.

Costs of equity and capital are calculated following several steps. Regulators start with the risk-free rate which can be either nominal or real under the following equation:

$$(1 + nominal\ \text{risk} - \text{free}\ rate) = (1 + real\ \text{risk} - \text{free}\ rate) * (1 + inflation)$$

Risk-free rates are the rates that are bound with assets that bears no risk at all and therefore purely reflect the time value of money. While such assets do not exactly exist in practice, they are usually associated with government bonds which are generally regarded as having default and liquidity risks close to zero. Most European countries use nominal risk-free rates for their calculation. On top of the risk-free rate, a debt-premium is added to arrive at the cost of debt and to reflect the increased risk from the corporate bond as an incentive to invest in the TSO over a government, risk-free bond. For the cost of equity, a market-premium is added to compensate for the risk inherent to the overall stock market. Additionally, a beta also adjusts the equation to reflect specific risk and volatility of a given stock relative to overall market. A beta above 1 is more volatile while a beta below 1 is less volatile than the average market stock. An asset beta removes the debt component and its effect on the capital structure due to tax rate adjustments that benefit the company and enables investors to compare the base level of risk among TSOs. An equity beta represents the systematic (combined market and financial) risk attached to returns on ordinary stocks. The equity beta is equal to the asset beta for an ungeared firm and adjusted upwards for a geared firm in order to reflect the extra stock risk according to the following formula:

$$e\beta = a\beta * [1 + (1 - t) * \left(\frac{D}{E}\right)]$$

With

Eβ = equity beta

Aβ = asset beta

T = tax rate

D = debt

E = equity

The Regulatory Asset Base (RAB) is a fundamental parameter in utility regulation used to calculate the allowed profit. It serves as a base for remuneration of historic and current investment and should therefore comprise assets necessary for the service in their residual value, which can include fixed assets, working capital or construction in progress depending on national regulation. It can be identified according to different methods which can influence CAPEX determination. RAB is very important in tariff calculation as the allowed revenue is determined by the WACC multiplied with the RAB.

Kapff and Pelkmans (2010) explain that a merchant investor will pursue a project if the latter yields a positive net present value according to the discount factor determined by the Weighted Average Cost of Capital (WACC), possibly adjusted with a project-specific risk factor. In such an analysis, the incurred building and operating costs are compared to the estimated private revenues (i.e. the congestion rent or regulated tariff multiplied by the flow). (Kapff & Pelkmans, 2010) Since a TSO can include its investment costs in its regulated asset base, its WACC will be lower than for a merchant investor. It has a relatively more guaranteed revenue stream as these costs will be recovered through the regulated network tariff (Jacottet, 2012; Poudineh & Rubino, 2017) The regulated investor's revenues do not depend on the amount of congestion but only on the flow of power.

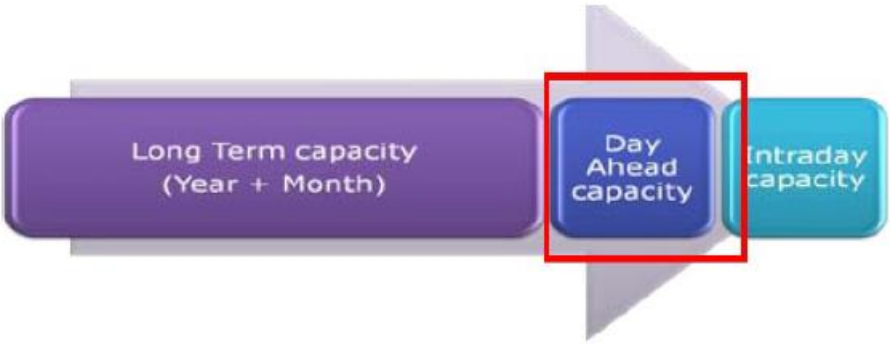
Electricity and capacity markets

Net transfer capacities between countries are allocated annually, monthly or daily (day-ahead and intraday) according to two auction schemes. Explicit auction schemes imply that net transfer capacities be allocated independently from electricity markets. This separate allocation generates information asymmetry that causes sub-optimal interconnection use, meaning less social welfare, less price convergence, more frequent adverse flows, etc.

On the other hand, day-ahead and intraday exchanges can happen through implicit auctions. Implicit transmission capacity auctions imply the integration of net transfer capacities into the electricity spot market. This results in an optimal interconnection use and the resulting electricity prices reflect both the cost of congestion and the cost of energy. (NordPool Group, 2011) Interconnection use is enhanced thanks to an improved market design and to integrated markets. (CREG, 2011)

The image below (figure 9) gives an overview of the different products that are traded on the market. Electricity generators have strong arbitrage opportunities. They must inject the capacity they committed the day before on the day-ahead market using their own generation units, forward products (annual and monthly auctions), day-ahead products or intra-day products (on that same day). (CREG, 2011)

Figure 9: Electricity exchange timeline



Different capacity auctions types plotted successively on a timeline. Source: CREG. (2011). Etude sur l'impact du câble NorNed sur les prix day-ahead d'électricity aux Pays-Bas, en Allemagne et en Belgique. p.33. Bruxelles.

Financial barriers to transmission investments

General barriers

An intrinsic obstacle to interconnection investments comes from the fact that the value of an interconnection is uncertain. It depends on subsequent generation investment decisions, changing network and technology mixes. The stochastic nature of wind and solar power makes such value calculation complicated and a cost-benefit analysis of a potential interconnection is therefore incomplete most of the time. (Dutton & Lockwood, 2017; Lamadrid, Maneevitjit, & Mount, 2016) Investment decisions are as such made without sufficient information regarding costs and benefits and the question on how to best determine the desirability of new interconnections remains unresolved. (Puka & Szulecki, 2014)

A straightforward potential problem for grid expansion is the lack of available capital. Despite the argument from Chatzivasileiadis, Ernst, and Andersson (2013) that most current investments in energy infrastucture and maintenance already amount for billions of euros, it might become difficult when costs add up. It has been calculated that €25 billion would be needed for the expansion of the German grid. These figures become problematic when one TSO is faced with several transmission projects at the same time. Management resources and investment capacities are finite and TSOs cannot invest in all desirable TSOs simultaneously. While this might not be a major problem yet, it could very well become a challenge as overall grid investment volume is expected to steadily increase. (Puka & Szulecki, 2014) In the UK, the growth of capital expenditure for electricity transmission was estimated at 125% over the period 2007-2012 and this should only be the beginning of increased network investments to support higher shares of renewables. (Pollitt & Bialek, 2007) ENTSO-E’s TYNDP implied necessary investments at €104 billion for project of pan-European significance in 10 years. (Henriot, 2013) The necessary European transmission infrastructure investments until 2030 are estimated at 125-148 million € and 300-420 million € until 2050. Although this still represents less than 1% of the total electricity bill, it represents a serious volume as TSOs are expected to more than double their annual investment volumes. (CEER, 2017)

According to Joskow and Tirole (2005), information asymmetry and agency problems could create distortions from efficiency in any electrical market. An example was brought up by Littlechild (2012). In an importing market, retail prices could be artificially high, inflated by market power in the importing market. Consequently, investors would tend to invest excessively in transmission and create overinvestment. This would be a problem for both regulated and merchant investments.

Meeus, Purchala, Van Hertem and Belmans (2010) pointed out regulatory uncertainty as a major obstacle to grid investments. There is regulatory uncertainty around tariff systems, policies towards renewables and nuclear. Projects typically run for a very long time, generally around 10 years, and there is a danger of changing regulation during that time. This threat is also triggered by a lack of public acceptance which represents a major obstacle for grid investment. This aspect was also pointed out by Dutton and Lockwood (2017), while Kapff and Pelkmans (2010) indicate that planning and authorization procedures can result in substantial delays. Additionally, they argue that regulatory uncertainty can come from a regulatory gap as national regulators can fail to reach an agreement and to grasp supra-national, European-wide benefits. This is considered one of the main problems to the realization of a European Integrated Energy Market by Jacottet (2012) Puka and Szulecki (2014) advocate for an appropriate regulatory framework which helps lowering financial risk and secure sufficient funding. Finally, the financial rate of return from grid investments are largely determined by the regulator or government setting the tariffs.

Another problem to grid investment is the fact that interconnectors typically involve two or more jurisdictions with different regimes and institutional architectures. This is problematic because each regulator has incentives to focus only on national costs and benefits and there is a need for a supra-national supervision to ensure overall benefits are achieved and fill this regulatory gap. (Dutton & Lockwood, 2017; Kapff & Pelkmans, 2010)

A potential problem occurs when a transit country hosts an interconnector between two third countries and the transit country does not benefit much from the line to import or export electricity. (Oseni & Pollitt, 2016) This was illustrated by Kapff and Pelkmans (2010): if we assume that inflows from country A are equivalent in volumes with outflows to country B, electricity prices in the transit country X will remain the same. However, the cost of the transmission investment in X are likely to fall on grid users of country X. From the perspective of the transit country X, the operation is welfare-reducing; inter-TSO compensation mechanisms and congestion rents are also insufficient in solving the matter. (Kapff & Pelkmans, 2010)

One must see that electricity transmission projects are substitute to local electricity generation. There is therefore competition between the two and potential generation investment must seriously be considered as threats during transmission planning stage as such projects require shorter administrative and construction times than transmission investments. (Kapff & Pelkmans, 2010; Chatzivasileiadis, 2012)

Despite implementation of ownership unbundling requirements under the EC's Third Energy Package, full ownership unbundling has not been achieved yet. In practice, TSOs are managed independently from the energy group but they are still owned by the same parent company. This creates conflicts as competition in electricity supply and generation introduced by new transmission affects the TSO's holding company. The TSO thus has less incentive to invest in new transmission if it is not fully unbundled. The same problem goes for merchant investments as the merchant lines that have so far been constructed in the EU also have common ownership with TSOs, though the TSO is again managed independently. (Jacottet, 2012)

Although interconnections induce an overall welfare increase, they create losers and winners. Indeed, connecting a low-price country with a high-price country will benefit consumers in the high-price country but harm those in the low-price country because prices will tend to converge as markets will tend to integrate and harmonize. A National Regulatory Authority (NRA) from a low-price country, whose role is to ensure low electricity prices for its consumers, might not be willing to encourage an interconnection with a high-price country. Such internal opposition can also come from trade unions of electricity intensive industries and is likely to be one of the reasons for the low levels of global electricity exports. (Oseni & Pollitt, 2016) This explains why some European member states might be reluctant towards interconnector while the EC will advocate for interconnections as it focuses on the broader welfare increase atop of the positive externalities along. (Jacottet, 2012) On the other hand, electricity generators from a low-price country will benefit since price will harmonize and they will export to the high-price country while generators from high-price country will be harmed and lose market power. (Dutton & Lockwood, 2017) It is therefore important to pay attention for ethics and solve the problem arising from an uneven burden sharing to ensure fairness. (Puka & Szulecki, 2014) Trade can indeed always be made beneficial as long as tax mechanisms are put in place to compensate losers. (Oseni & Pollitt, 2016)

Another main issue arises from the financial model. Indeed, when undertaking such project, the way investment is recovered and the payment for interconnector use must be determined. Establishing these variables comes down to answering the question “who pays for the new line?” which can bring up a lot of political debate. At the same time, it was shown there is a need for a significant increase in tariffs to achieve a really integrated European system. (Puka & Szulecki, 2014; Henriot, 2013)

Electricity flows follow physical laws (i.e. Kirchhoff laws), not contracts and these flows are uncontrollable in a meshed network. These effects have several negative consequences. First of all, business plans are inaccurate as they do not take the diverted power transfer into account and they therefore exhibit inflated revenue streams. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) Furthermore, electricity might flow through a third country when flowing from a generating country to another country on the demand side. At the moment, there is no compensation mechanism for the use of the third-country's transmission network. This phenomenon creates costs that are difficult to estimate but are thought to range in billions of euros. (Jacottet, 2012)

In connection with the latter, one must note that interaction between cross-border interconnections and national grids generate subsequent problems as well. For example, congestion in national markets can be amplified by new imports from interconnectors while national markets can also push congestion to their borders to deal with internal congestion. When international electricity trade is imposed on top of inefficient national networks, the overall welfare results are worse than under the scenario with no interconnection. (Oseni & Pollitt, 2016) The expert group on electricity interconnections also advocate that sufficient coordination is needed in this matter and point out that cross-border congestion is due to internal constraints 72% of the time. (CEER, 2017) Sufficient investment in national transmission is therefore necessary to fully benefit from new interconnectors. (Jacottet, 2012)

Transmission grid expansion can be slowed down due to conflicting interests or disinterest among stakeholders. We already know that countries adopt different attitudes towards interconnections. In fact, a project that will bring benefits to one country but hardly any to another country has a very small chance to be undertaken. (Puka & Szulecki, 2014) Additionally, group of stakeholders should also be taken into account. We have already mentioned above that interconnectors can face opposition from local residents. It is crucial for interconnection projects to study the interests of stakeholders and the cost-benefit analyses that they make with regard to the project. Within such analyses, the cost estimation is complicated as for any large engineering project, but the benefits estimations of interconnector projects are even more prone to uncertainty. These uncertain analyses and the different models used to elaborate them lead to suboptimal investment. (Puka & Szulecki, 2014) Dutton and Lockwood (2017) suggest to go further and to analyze the way stakeholders get their interests represented by looking at factors such as coordination between groups of actors, entry points they have to influence the decisions, veto powers, etc. They highlight that there must be sufficient alignment between a large group of various stakeholders for a successful launch of the project. A key prerequisite thereof is that stakeholders be able to identify their interests. This must all be looked at in the institutional context. Indeed, the value that stakeholders will give to an interconnection and its desirability will depend on the institutional context and available information. For example, the current institutional context in Europe is one of a development of the integration of an internal energy market and of the decarbonization of the energy industry, as explained above. Such institutional context favorizes interconnection development. (Dutton & Lockwood, 2017)

Barriers inherent to regulated investments

Regulated investments present several barriers which merchant investments have tried to solve later on.

First of all, Chatzivasileiadis (2012) points out that regulated investments have led to underinvestment. This relates to the industry reform that induced the vertical unbundling of the electricity industry. Before the reform, transmission companies' priorities were to ensure a quality service and security of supply, combined with the fact that companies were operating under a 'cost-of-service' scheme. As seen above, such a scheme consists in companies being solely reimbursed for the cost they incur. This trend led to an inefficient overinvestment in the network. Following the reform, companies operated under incentive regulation mechanism like the 'price cap'. This incentivized them to minimalize cost and led them to neglect transmission investment which resulted in an underinvestment in the network. Littlechild (2012) supports this argument by stating that there is less incentive to efficient construction costs and that transmission companies show more conservatism towards new technologies and new ways of regulating. Through his analysis of Australian interconnectors, he noted that regulated interconnections relied on existing technology while merchant interconnections used novel technology. This conservatism towards new and risky technology can also come from the regulator in the form of a lack of regulatory credibility. (Gerbaulet & Weber, 2017) As a consequence, such investments could be prevented and, to overcome this barrier and to deliver quicker delivery, temporary "access holidays" (an exemption from regulation) could be granted. However, Gerbaulet and Weber (2018) claim that technology now seem to be sufficiently well understood by both TSOs and regulators.

Another main issue arising from regulated investments originates from information asymmetries. This aspect was already pointed out as a general problem for interconnection investments. In this section, attention is given to how this materializes for regulated investments specifically. In an ideal case, a national regulator would be able to completely oversee the transmission company, therefore being able to understand (and overrule) its investment decisions (Gerbaulet & Weber, 2017) In reality, asymmetric information exists as the TSO possesses some information (regarding technology, costs, consumer demand, …) of which the regulator is not aware of and can use it to generate additional rents for itself. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) This issue was also pointed out by Littlechild (2012). One option to escape from this inefficiency trap is to introduce merchant-type incentive schemes; by choosing appropriate investment rules for the transmission company, higher welfare levels can be achieved, though with larger rents falling under the transmission company. (Gerbaulet & Weber, 2017) Although this problem seems credible, Gerbaulet and Weber (2017) claim that information asymmetry in practice does not materialize as much. In Europe, particularly, they argue that regulatory oversight has been improved and that knowledge can be built to exercise effective oversight. Inefficient planning could be explained by information inadequacy and uncertainty at forecast and planning stage rather than by information asymmetry between the TSO and the regulator. In his review of Australian transmission projects, Littlechild (2012) notes that imperfect information resulted in inaccurate estimates of future price differentials and so in economically unjustified decisions.

Chatzivasileiadis (2012) notes that regulated investments incur another undesirable element as they might imply political interference. This is also pointed out by Littlechild (2012). In his analysis, he points out how the government of New South Wales was eager to expand interconnection to export surplus generation from the state-owned generation units and derive greater revenues. This would however imply higher consumer prices in New South Wales. Motivations for regulated interconnectors were as such as much political as economic. In some countries, industries might be highly dependent on cheap local electricity generation and a higher electricity price resulting from market opening might seriously undermine their competitive advantage. (Oseni & Pollitt, 2016) Specific interconnectors can become election commitments, while governments can also become quite interventionist and set up new reforms and regulatory tests. (Littlechild, 2012) A specific example is pointed out by Kapff and Pelkmans (2010) in the case they present about the German-French interconnection. While being owned at 84.5% by the French State, EDF controls the TSO on both sides of a German-French interconnection and the French State is therefore not deprived of discretionary power in deciding whether to reduce congestion or not by upgrading interconnectors. It is clear to see how politics can strongly influence regulated investments.

Regulated investments can be influenced by interest group pressures. Littlechild (2012) points out consumer group pressure in particular. Additionally, incumbent state-owned grid companies can be eager to protect and expand their existing networks following liberalization. As such, TransGrid in Australia was criticized for its way of assessing projects that favored unnecessary investments. This ensured TransGrid owned a large base of transmission lines and helped it prevent competition to establish itself in the market, this all despite TransGrid's statutory objectives of efficient grid operations and promotion of grid access. (Littlechild, 2012) On the other hand, Gerbaulet and Weber (2018) state another potential interest group pressure arising from the presence of vertically integrated transmission companies. As stated above, transmission companies might be managed independently, many are still owned by an energy group that also own electricity generation and supply entities. In the case of vertically integrated transmission companies, grid investments interfere with generation position and can therefore be distorted. Indeed, a transmission company has little incentive to invest in interconnections that will introduce competition against generation entities from the same holding company. (Poudineh & Rubino, 2017) The materialization of such events indicates a lack of power from the regulator if the latter cannot ensure the prosecution of socially advantageous investments. (Gerbaulet & Weber, 2017)

Inter-jurisdictional coordination materializes as an important barrier for regulated investments. While all barriers to regulated investments highlighted above can be expected to worsen in an international context, there is also an increased need for international coordination, which can be highly complex for transmission investment. This coordination can be hampered for political reasons and agreements may be difficult to be reached, among other reasons because of the redistributive effects of interconnections explained above. (Gerbaulet & Weber, 2017) As an example, financing new interconnections by uplifting regulated tariffs might face political resistance. (Poudineh & Rubino, 2017) It will therefore be difficult to agree on tariffs and these might have to be set by a transnational entity. (Jacottet, 2012) Littlechild (2012) also mentions the problems arising from having to deal with multiple regulatory jurisdictions, the bureaucratic costs and the time-consuming decision-making. This can also partially be explained by legal appeals and reviews. He further argues that the period between investment decision and construction is longer for regulated investments than it is for merchant investments. He also suggests that the different regulatory jurisdictions brought a lot of hassle to the Australian regulated investments. On the other hand, Gerbaulet and Weber (2018) note that the coordination problem between different jurisdictions can be overcome and that it was proven by the number of successful interconnectors launched in the Baltic Sea Region since the 1990s. Nevertheless, Jacottet (2012) argues that regulatory uncertainty is stronger for regulated investments than for merchant investments in the sense that their rates of return might change over time, particularly for interconnectors as multiple regulators are involved. Poudineh and Rubino (2017) explain that regulated uncertainties disincentivize investment and regulated investors need a credible commitment from the regulator to the terms agreed upon in the approval process.

Finally, regulated investments are not accessible for merchant investors at the moment. Indeed, it is not interesting for private investors to engage in regulatory investments since they cannot benefit from congestion revenues while also not being guaranteed to have their costs covered as they are not part of the national electricity network. (Rubino & Cuomo, 2015)

Barriers inherent to merchant investments

The main issue from merchant investments relates to the fact that they rely on price differentials that arise from a disintegrated network. As seen above, the more two countries get interconnected, the less the price differentials will be and the less the profits of the merchant investors will be. The goal of a global grid is precisely to build a global network and move towards integrated electrical systems. Therefore, not only do merchant transmission investments result in suboptimal capacity transmission lines because of the uncaptured positive externalities (Dutton & Lockwood, 2017; see above) and because of the inherent financial unattractiveness of social optima for merchant investors, they are also not a viable solution in the long run to build a truly integrated global grid that will make price differentials shrink. Jacottet (2012) explains that MTIs can supply more interconnection capacity in the short-term but not in the long term as they have an interest in disintegrated markets. Chatzivasileiadis (2012) therefore expects that MTIs would not allow for the benefits of a fully integrated European grid to be realized. In this regard, Gerbaulet and Weber (2017) point out that welfare-optimal transmission expansion alternatives cannot be financed by arbitrage revenues.

In accordance with the previous point, the merchant investment model requires the electricity market to operate under a nodal pricing system (Chatzivasileiadis, 2012) Such pricing system is unlikely to be politically viable in the EU. The EU is indeed advocating for market coupling, which implies price convergence across the EU. (Oseni & Pollitt, 2016) However, it has been seen that zonal pricing does not present a problem in practice when the merchant investment connects two neighboring grids as was the case with NorNed and BritNed (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012)

A major characteristic to transmission investment is the fact that such investments are lumpy. This means that they are subject to economies of scale: the average cost of a new interconnection declines as its capacity increases, ceteris paribus. However, while capacity increases, the cost reduction is only partially captured by the grid owner. The investor only captures the transmission rights (i.e. the congestion rents) while it also creates a social surplus by reducing congestion costs. Lumpiness therefore results in an under-incentive to reinforce the system. (Joskow & Tirole, 2005)

Where there is a ‘scarcity of way’ (e.g. if there is only one corridor which can connect two regions), merchant investments can create a problem of preemption where a first investor will invest in a small capacity to establish a toehold. While he can always expand capacity later on, this “preemption and monopoly” situation will impede investments from other investors and result in underinvestment. This problem can partially be solved by organizing a call for tenders and choosing the bid with the highest capacity (though such initiative would harm the decentralized nature of the MTI). (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012) Even when there is no scarcity of way, a suboptimal investment from a merchant investor might well foreclose the market for new entrants because of economies of scale inherent to transmission investment: it would be unprofitable for a second project to “complete the job” with a second interconnector. (Jacottet, 2012) On the other hand, a regulator could also impose a minimum capacity requirement on a specific project, implying a step aside from a perfect merchant model but difficult to realize with the information asymmetry assumption about line desirability. (Gerbaulet & Weber, 2017)

It has been seen that market power exertion by existing generators can distort nodal prices, therefore sending wrong signals which lead to under- or overinvestment in transmission capacity. This problem is also present under the regulated scheme, but the investor’s income will be much more impacted under the merchant scheme than the TSO’s income under the regulated scheme since it exclusively depends on congestion rent derived from price differentials. (Chatzivasileiadis, 2012; Joskow & Tirole, 2005) Littlechild (2012) also notes there may be a problem of imperfect information regarding the desirability of transmission in terms of where, when and which new lines to build. Regulatory mechanisms such as price caps and slow market clearing processes can also distort prices and give wrong signals regarding the line desirability. (Joskow & Tirole, 2005)

Chatzivasileiadis (2012), Joskow and Tirole (2005) introduce an issue for MTIs arising from complementary investments. When two complementary lines, say one from point A to point B and the other one from point B to point C, are built, each of these two lines has the incentive to become the bottleneck to collect all the congestion rent while the other would exhibit excess capacity and generate no income. Each investor will therefore aim at dimensioning its project slightly smaller than the other project. However, DC interconnections could prevent such issue from materializing itself. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012)

Merchant line ownership presents a threat. Particularly, limits should be set regarding participation of dominant generators in merchant line ownership. Generators from either side of the line could indeed exert market power to maximize their profits (e.g. by withholding capacity). In Australia, such ownership is limited as transmission line owners cannot control more than 35% of the generation capacity on either side of the line. (Chatzivasileiadis, Transmission Investments in Deregulated Electricity Markets, 2012)

Although MTIs are claimed to increase overall social welfare, Gerbaulet and Weber (2018) computed that merchant investors would capture close to 100% of the welfare increase under a scenario in the Baltic Sea region. Such investing scheme therefore does not seem to be politically justifiable and it can be expected that jurisdictions will favor regulated options at almost any cost for MTIs hardly seem to increase social welfare.

Littlechild (2012) also identified several MTIs shortcomings. First of all, he denotes that market power arising from transmission expansion can reflect in lower capacity, delayed investment and higher prices, thus impeding achievement of socially desirable outcomes. Transaction costs can also hinder transmission expansion as these create problems for investors regarding stakeholders' preferences, negotiations, gaming behavior from entities and the separation of control and ownership. (Littlechild, 2012) Finally, other factors such as long lead times, lack of forward market and commitment result in financing difficulties, lack of credibility against shorter projects and regulatory uncertainty and opportunism. (Littlechild, 2012)

Jacottet (2012) argues that the current framework for merchant investment approvals adds to the complexity and regulatory uncertainty that go with any investment decision. An investor seeking exemption from regulation has to deal with at least two National Regulatory Authorities and potentially also with ACER and the EC. The EU strongly favors regulated investments over merchant investments and MTIs are considered as an exception for projects that would not take place under a regulated investment because of its limited regulated returns not owning up to the high risk-level. Potential projects must satisfy this and five other conditions (see appendix D), which compose the so-called 'threshold test', to be eligible. The decision whether the project passes the threshold test and is eligible for exemption is first taken by NRAs since they are most entitled to evaluate the different risk forms that the project can generate. The decision is then affirmed, amended or overturned by the European Commission. ACER has an advisory role and can also decide on behalf of the NRAs if these cannot come to an agreement. (Rubino & Cuomo, 2015) Some problems arise from ACER only being a last resort party. First, NRAs can veto a socially optimal interconnection. Second, ACER cannot put pressure with merchant investments on TSOs that fail to deliver projects. (Kapff & Pelkmans, 2010) Each project can be exempted in full or partially from one or more restrictions that are incumbent on regulatory investments. (Rubino & Cuomo, 2015) The four restrictions (see appendix E) are a restriction on the use of congestion charges; ownership unbundling of transmission and generation facilities; non-discriminatory third-party access to interconnector capacity; and regulation of tariffs (Poudineh & Rubino, 2017) As already explained, congestion charges are supposed to be used to secure the current network, invest in new interconnections or to rebate tariffs under regulated investment. Following an exemption, they constitute the basis of a merchant investor's revenue. Vertical unbundling relates back to the separation of transmission systems with interest in generation and supply, while regulated-third party access consists in making capacity available to the market under published tariffs. Regulation of tariffs by the regulator comprises prior approval as the NRAs are responsible for setting or approving tariffs. (Rubino & Cuomo, 2015)

One must note that the European Commission is traditionally not that enthusiastic about granting exemptions. Indeed, exemptions harm competition as the investor has full control on the rate of amortization of the project. This explains why MTIs are still considered an exception under EU regulation. (Rubino & Cuomo, 2015) However, Rubino and Cuomo (2015) also highlight the flexible nature of the process that helps the Commission grant exemptions even when a project does not strictly conform with all conditions. Exemptions are often partial, meaning that part of the capacity will be exempted from regulation while the remaining capacity will be subject to a regulated regime. (Rubino & Cuomo, 2015) The regime has become increasingly stringent: conditions became stricter for exemptions over time. This had a dampening effect on MTIs, which works against the ambitious interconnection targets set by the Energy Union packages. (Rubino & Cuomo, 2015)

Potential solutions

To begin with, the expert group on electricity transmission stresses the importance of an efficient use of the existing electricity market and interconnectors before anything else. (CEER, 2017)

We introduced the problem arising from complementary lines from A to B and from B to C. Both investors have an incentive to build a capacity that is slightly lower than the other one in order to benefit from congestion rents, leading to underinvestment and to both investors waiting for the other one to move first. Littlechild (2012) suggests the whole line should be built by a single merchant interconnector, whether under a sort of consortium or not.

To undermine the underinvestment problem from lumpy merchant investments, Littlechild (2012) suggests exporting generators and importing customers should support line construction to a certain extent since they both benefit from the interconnection. One could also expect beneficiaries from an interconnection line to enter negotiations to make the line a reality, i.e. the so-called Coase theorem applies. Littlechild (2012) analyses whether barriers to the Coase theorem materialized in Argentina where such negotiations were undertaken. Argentina adopted a Public Contest method that consisted in market participants proposing, voting and paying for all major expansions which would be undertaken following a call for public tender. This method has been extensively used and was proven to enable substantial investment in better transmission control systems. Voters for particular expansions are the beneficiaries from that expansion and are identified according to a certain method. They also proportionally pay for it according to the benefits and vote they receive. Negotiations were not problematic, and tenders generated significant competition. Control by the beneficiaries happened to be successful as costs halved compared to the previous scenario with the incumbent state-owned company. Littlechild (2012) argues none of the potential market imperfections identified in his work (lumpiness, market power, information imperfections, transaction costs, regulatory uncertainty, long lead times, lack of forward markets, lack of commitment, lack of credibility vis à vis shorter projects and opportunism) materialized under this scheme. He argues that the method is also transposable to meshed networks like the US network and Europe. Another example of successful negotiated agreements can be found in the US where transmission companies file cases before the regulator and stakeholders can submit their views. The different parties are able to agree on most contentious issues and 90% of the cases are settled between them. This reduces the time lost in bureaucratic processes and enables to achieve better outcomes for the informed parties. Imperfect information does not arise from information asymmetry as transmission costs and benefits are uncertain to all players. Rather can it result from a lack of coordination and generate costly misinvestments. (Littlechild, 2012) This aspect was also deemed crucial by the expert group as they too advocate for an early public and stakeholders' involvement which will minimize impact of procedural delays and encourages the EC to further expands actions in this regard. It was also a key point of the TEN-E regulation, as stated before. (CEER, 2017)

Furthermore, the expert group also emphasize the importance of a cost-benefit analysis to assess welfare generation of new interconnections prior to their construction. (CEER, 2017) Generally, most authors advocate for sound cost-benefit analyses as key enablers for efficient grid investing.

Oseni and Pollitt (2016) identified several preconditions that facilitate international electricity trade from their comparative study on power pools. Among these, the existence of general trade agreements and specific electricity trade agreements is essential to eliminate barriers and reduce planning time; the greater the trade openness, the greater the cross-border electricity trade. They claim that common currency, on the other hand, is not a pre-condition for electricity trade, while a price differential is necessary for trade to occur. Additionally, they found out that independent institutions that ensure an effective functioning power market are crucial and they advocate for an appropriate combination of regulation and market design. Finally, they stress the importance of the day-ahead and real-time market which lead to more competition, flexibility and efficiency than bilateral agreements.

An interconnector between an EU Member State and a non-Member State will present several characteristics. It will link a country with a competitive electricity market (the MS) and one with a monopolistic electricity market where vertically integrated companies persist (the non-MS), will reserve the majority of its capacity via an open season process type auction and such capacity will be reserved via long-term contracts (over 10 years). (Rubino & Cuomo, 2015) Market liberalization in EU neighboring countries is still in its infant stages and does not conform to the provisions of the Third Energy Package. A sufficient set of shared legal and regulatory provisions will be needed and pose a challenge for further grid development. Rubino and Cuomo (2015) therefore advocate for an adequate regulatory framework to allow interconnection development with non-EU countries.

In connection with the latter, Poudineh and Rubino (2017) point out the disparities in market maturity, stage of development, regulations and political stability between the EU and non-EU states to be the main barriers for interconnection development. As such, they introduced a new business model characterized by incentives for efficient investments and operations, risks and uncertainties management and coordinated planning and governance. Incentives are needed to overcome some of the major barriers previously mentioned (transit country problem, distributive effects, underinvestment, …) and the authors propose specific solutions for each problem. Risks can be project-specific or arise from a changing market or regulation as seen previously. Governance-wise, authors advocate for a new organizational model in which

European and non-European planning are aligned and new investment mechanisms are introduced. This is especially important in the regard that TSOs lack funding to meet the required investment levels and increasing debt and capital present an issue as they would worsen their credit rating and dilute state-ownership proportions respectively. Furthermore, the authors' model only addresses security of supply issues and does not impose market liberalization or structural rules, which makes it widely applicable. It embodies a hybrid approach in which line ownership falls under the exporting TSO for a proper integration with the existing domestic market. The approach combines the retained regulatory risk and the less restrictive merchant remuneration under a long-term, indexed range of return agreed upon by the NRA and within which generators and importing TSO can settle. Such model would also imply a long-term contract through which the buyer bears the volume risk and the seller takes the price risk; this keeps consumers, developers and importing TSO protected from an excessive cost, risk, or increased quantity respectively. There is an inherent risk, though, for an investor that the floor is set too low; this can be countered by allocating capacity to the winner of an open season process type auction where the winner acquires long-term capacity. While such a model addresses regulatory and market risk, it must be noted that project-specific risks remain unaddressed.

Puka and Szulecki (2014) claim stakeholder mapping and analysis are crucial for interconnector projects. One should analyze the individual, collective and perceived cost-benefit calculations done by stakeholders to understand their interests in a project and address potential contradictory interests or disinterests, as stated hereabove. In this matter, one should note that the benefits estimations of interconnectors are prone to much more uncertainty than for other large infrastructure projects, as pointed out before. In their analysis of the German-Polish case, they established an analysis based on Sovacool's critical stakeholder analysis with a focus on mapping. They note that stakeholders' interests evolve and are fluent and should therefore not be considered as "given". However, they nuance the role played by such analyses as in-depth stakeholder studies are very time-consuming and it is not sure they would even be fruitful. Dutton and Lockwood adopt a two-stage framework. The first stage consists in analyzing the institutional context since the way it evolves will determine the value of the project; the second, building up on the first one, consists in assessing how stakeholders' interests can be identified and coordinated and how they can influence investment decisions. Indeed, for an interconnector to be successful, there must be sufficient alignment of interests between stakeholders who must have been able to identify and coordinate their interests. Finally, there must also be sufficient entry points for stakeholders to voice their interests and influence outcomes. (Dutton & Lockwood, 2017)

Kapff and Pelkmans (2010) introduce several reforms they advertise to solve the market shortcomings they sum up in their article. First of all, they argue for the elimination of the tariff rebating option among the possible uses of congestion rent. Congestion rent could then only be used to guarantee actual capacity availability or to invest in interconnectors. Exemption decisions for MTIs would be taken by ACER which would make sure that decisions are taken on “European social welfare” grounds and fairly implemented over Europe enabling to a level-playing-field. Jacottet (2012) also advocates for higher powers being given to ACER. Kapff and Pelkmans (2010) further argue that, to avoid underinvestment from MTIs , the EU should organize tenders for the highest capacity or negotiate the amount of capacity with the merchant investor, eventually involving a certain part of the positive welfare effects to be passed on to the merchant investor. To counter the two regulatory issues they introduced (network planning and interconnector cost allocation in case of a transit country problem), they argue that more power centralization is necessary in the EU, backing this claim up with a subsidiary test. In this regard, they introduce another framework that would be composed of a European TSO organization which would undertake supra-national planning basing itself on national network plans, market forecasts and public consultation efforts, in connection with the current ENTSO-E. This would enable a pan-European view towards network planning and help identify the most needed interconnectors. Membership to this organization would be mandatory for national TSOs, voting would occur under a qualified majority voting and such system would be a complement to national TSO network planning. Hereby, they stress the importance for supra-national network planning to have some binding power, by setting targets for example. European-wide planning would be reviewed by an independent European regulatory agency, ACER, that would decide on cost allocation between Member States according to transparent guidelines. There would also be a European interconnector fund to settle compensation payments fed by Member States’ and TSOs’ contributions (e.g. to tackle the transit-country problem, see above). The European regulatory agency would also call for tenders, financed by the fund, in case TSOs and NRAs fail to deliver priority projects, including under MTIs.

Kapff and Pelkmans (2010) also discuss the ways to incentivize TSOs to foster market integration and security of supply. While a patchwork of different national schemes makes it difficult to achieve market integration, national specificities should also be taken into account. As such, they advocate for best practices to be promoted at European level in a non-binding way. Indeed, the perfect solution does not exist. Authors mention four types of incentives (market-based, rate of regulation, performance-based and investment funding) which all have their strengths and weaknesses. Jacottet (2012) also argues for a harmonization of rates of return allowed to TSOs. Simultaneously, effort should be made to reduce regulatory uncertainty and NRAs' independence should therefore be guaranteed. Finally, rules on unbundling should be stricter and more coordination and consistency at EU-level is needed for better results. (Kapff & Pelkmans, 2010)

Henriot (2013) analysed the financial structure of TSOs and the challenges that lie ahead with regard to the large grid investment volumes expected. In order to acommodate for the new investment volumes, TSOs have three strategies: raise their debt levels, issue new equity or retain equity internally (i.e. by issueing lower dividends pay-out). However, each strategy faces limitations. Raising debt levels leads to degradation of financeability; TSOs already typically have a debt level around 60-70% and acquiring more debt would lead to a degradation of their credit rating. According to Moody's methodology, TSOs could only develop 47% to 61% of new investments (depending on the scenario) with debt financing while maintaining their current credit rating. A credit rating degradation would mean that TSOs will face increasing difficulties to repay their debts as they would be extremely vulnerable to small perturbations of the allowed rate-of-return. Financing institutions would only proceed in such situations if the regulatory framework is stable and induces guaranteed returns in the long-run. In order to be able to finance integral grid development under an "extended TYNDP" for the period 2012-2030, debt raising should be accompanied by an annual increase in tariffs of CPI (Consumer Price Index) +3.4%. This growth rate is three times higher than current trends.

TSOs could finance grid development with additional equity. This can be done internally or externally. By issueing lower dividends, TSOs can retain more equity internally to finance additional investments. However, amounts which could be retained cannot be sufficient at times when investments needs significant increases. Moreover, TSOs' investors traditionally expect high dividends (average around 70%). TSOs can also raise external equity but this option also faces reluctance as TSOs are typically publicly owned and states are cash-constrained and usually reluctant to dilute their ownership. Although equity financing ensures no credit rating degradation, it is important to note that both external and internal equity financing methods lead to lower return on investment (ROE) if tariffs are kept at the same levels. This is explained by the fact that the cost of equity is higher than the cost of debt. However, it is possible to finance grid development with only a small external equity injection (4% to 8%) or internal equity retention (corresponding to a 55% to 65% dividend payout) along with a lower tariff increase (CPI+2.9% to 3.25%) than under debt issueing and realize similar ROE levels (8-10%). This scenario implies that TSOs owners will have to be open to external equity sources and new investors types attracted by growth entities. It is important to note that, no matter the strategic choice for grid financing, a significant increase in tariffs would have to take place. (Henriot, 2013)

Alternative/Hybrid schemes

Chatzivasileiadis (2012) notes there are other systems possible than the regulated and merchant schemes. First, a line could be funded by a mix of both where part of the capacity would be subject to regulation and the remaining capacity would generate profit from trade. Second, owners of a remote generation power plant could fund a transmission line under a consortium to connect the plant to the network. Poudineh and Rubino (2017) say that hybrid approaches with market and regulated elements are also possible. For example, one model could consist of a price cap with fixed and variable parts where the variable component would be recovered through the sale of transmission rights. This way both the investors' and consumers' risks are covered. Another alternative proposed by Ofgem is a hybrid scheme with a long-term cap and floor imposed on the revenue from the capacity auctioning to ensure guaranteed revenues for investors. (Poudineh & Rubino, 2017) On the other hand, the cap ensures that excessive revenues are passed on to consumers and the regulator. (Dutton & Lockwood, 2017) The cap-and-floor mechanism used under Nemo Link is discussed further in the interview analyses.

Concluding remarks from the literature analysis

The consulted literature gives a good overview on the current debate around regulated and merchant transmission investments. Each solution has its own proponents and critics. Regulated investments are rather backed up by Joskow, Tirole (2005), Gerbaulet and Weber (2018). On the other hand, MTIs are favored by Littlechild (2012), Rubino and Cuomo (2015). It seems though clear that each scheme features obvious shortcomings. Littlechild (2012) claims that choosing between the two comes down to choosing between imperfect alternatives and Chatzivasileiadis (2012) recognizes the shortcomings of both schemes. As such, none of these two solutions seem to be able to stand in their pure form. This is also the conclusion made by Poudineh and Rubino (2017) in their analysis of a suitable business model for transmission in the Mediterranean basin and by Hogan (2003). Furthermore, none of them seems to be able to support grid development on its own and there seems to be a general consensus that the two schemes are complementary to each other. (Chatzivasileiadis, Transmission Investments in

Deregulated Electricity Markets, 2012) Joskow and Tirole (2005) advocate for good regulatory mechanisms for regulated TSOs while leaving the door open for merchant investments when the latter are more appropriate. Kapff and Pelkmans (2010) argue for a similar approach, prioritizing regulated schemes but authorizing merchant investors to invest in projects that would otherwise not be delivered and to put pressure on regulated TSOs to play their part. Littlechild (2012), on the other hand, prioritizes private companies over state-owned ones and market-based system over a regulated system. Regulation is meant to “assist this market discovery process” rather than to replace it, he says.

Further criticism was voiced towards the current state of EU regulation with regard to financing interconnection with neighboring countries. Current EU regulation was developed with the aim to enhance regional competition. However, the future connected areas might have other more urgent needs for their electricity systems; in the Mediterranean basin, for example, quality of energy supply and continuity are the main objectives. (Poudineh & Rubino, 2017) Interconnections with neighboring countries could feature characteristics that are not exhibited by any interconnector within the EU: the linking of a liberalized electricity market, typically in a Member State, with a vertically integrated monopolistic system, typically in a non-EU country; the possibility that a majority of the capacity will be allocated to a single user with an open season process type auction; and the allocation of such capacity via long-term contracts. (Rubino & Cuomo, 2015) Substantial disparity of electricity market openness and competitiveness will hinder the application of the current regulation, including the exemption regulatory framework and a new framework is therefore needed. (Rubino & Cuomo, 2015) Finally, the fact that the current framework extensively favors the regulated regime might hinder development since the regulated regime may not be efficient to bear the risk that come along interconnection with neighboring countries. As an example, regulatory and legal uncertainty, market reform and political instability drive up the risk of interconnection development in the Mediterranean basin. (Poudineh & Rubino, 2017)

Practical part

Methodology

I opted for a qualitative analysis of the topic for multiple reasons. First, it was more suited to the approach I wanted to give to the topic: identifying barriers and finding solutions to overcome these. The broad nature of the topic makes the qualitative approach legitimate because of the interconnections that exist between financial, regulatory and geopolitical aspects. I believe it was a sound decision to get insights from key stakeholders of the electricity market sector to understand which barriers identified during my literature review were most prone to materialize.

The second reason stems from my literature review. The article I have analyzed all mention barriers that are difficult to measure, not quantifiable. It became therefore logical to go forward with a qualitative review.

Interviews

The qualitative analysis consists of interviews from qualified professionals representing key market entities to the electricity sector. These key entities were identified from my literature review, in particular in the articles that covered a stakeholder analysis (Dutton & Lockwood, 2017; Puka & Szulecki, 2014) and are the following: regulators (the Belgian Federal Regulator (CREG) and the European Agency for the Cooperation of Energy Regulators (ACER)), TSOs (Belgian National TSO (Elia) and the European Network of Transmission System Operators for Electricity (ENTSOE)), electricity generators (Engie Impact, consultancy wing of Engie), merchant (BritNed) and regulated interconnectors (Nemo Link), power exchange (EPEX Spot) and government (Directory General (DG) Energy of the European Commission). Throughout my interviews, I was advised to also include somebody from Elia Grid International (EGI), which is the consultancy wing of the Elia Group advising on interconnection development worldwide. The list of interviewees along with their position and the corresponding entity can be found in appendix in chronological order. More information on the interviewees' background and their entity can be found in the first question of all interviews, which I have included in appendix F.

The interviews were conducted according to a semi-directional interview process. The semi-directional process is favored in management faculties and helps to gain flexibility in the interview process and qualitative information and analysis. This type of interview helps to compare answers among respondents to arrive at rich conclusions. It also enables to cover more key aspects identified in the literature review (mainly the regulated and merchant investment schemes, market structure) in specific and gain the interviewees' opinions on these matters. The flexibility of the interview process helped me to change questions in accordance with the interviewee's specific background as well as to go further in details if some answers needed more clarifications or to drop some questions that would not have been relevant in some interviews. I was also able to make the interview guide richer over time as interviews happened. The interviews took place in English except for the interviews with Brice Libert (CREG), Isabelle Gerkens (Elia Grid International) and Gérald Sanchis (ENTSOE) which took place in French as I thought it would be more interesting to have my interviewees speak in their mother tongue. The interview guide which I have used as a template to conduct the interviews can be found under appendix G.

Results

First, I requested my interviewees on their overall view of a participation of Europe to a global electrical grid. I asked them if they thought it was realistic and desirable. I also asked them the main barriers they would expect. I wanted to have a broader picture than the mere financing aspects. Indeed, from the literature review, I expected other aspects (geopolitical, regulatory, etc) to be as important as the financials, if not more. Four main areas were continuously pointed out by the respondents: operational and technical, regulatory, political and geopolitical and timing. Following this general view, financial barriers were examined. While some of them were spontaneously put forward, opinions were also asked on specific aspects (merchant and regulatory investment scheme, market characteristic and structure). After covering the barriers, the solutions identified during the interviews will be discussed.

Main barriers to the participation of Europe to a global electrical grid

Operational and technical barriers

According to the interviewees, there are a lot of questions remaining about the operations and the technology needed to build a global grid. The first operational barrier identified by Bert Maes stems from the fact that onshore grids might currently not be able to absorb enough renewable offshore winds. He claims that this problem already materializes in Europe and is due to the high volatility of wind energy production. The onshore grid would first have to be strengthened. This aspect is also pointed out by Maximilian Rinck and illustrated with the German grid which is unable to absorb all the wind electricity generated in Northern Germany during production peaks. Wind production must then be curtailed, and conventional generation must be run in Southern Germany because connections are not well built. This puts financial strain on all the actors because they are producing renewables but throwing them away and they must pay for the unused renewable as well as the conventional energy. It is inefficient and so the challenge is to have grid connections that are actually capable of transporting the electricity.

Another operational issue originates from the difficulty to connect two large systems, as pointed out by Kristof Sleurs (Elia) and Jan Kostevc (ACER). Each grid would affect the other in terms of stability and overall operational security. This was the case with the connection of Turkey to continental Europe, which caused a lot of power oscillations. In part, these problems are solvable through the usage of HVDC technology, but this further increases the already high costs, as Kostevc points out.

Jan Hoogstraaten (BritNed) states the importance of losses along the way. For BritNed, losses are as high as 3% while it runs for just a few hundred kilometers. He is therefore skeptical towards the energy efficiency of interconnections that span continents, more so that the depth of the sea and oceans could also hamper electricity efficiency. Additionally, questions remain regarding the technological readiness to lay cables deep in seas or oceans, as Bert Maes (Nemo Link) explains. Gérald Sanchis (ENTSOE) agrees as he says technical constraints related to sea depths remain. This is further backed up by Isabelle Gerkens (EGI) who thinks there are enormous technical challenges left, despite most people stating “it just has to be done”.

Finally, Rinck (EPEX SPOT) highlights the issue with loop flows and illustrates it again with the German example. Electricity flows due to congestion in Germany might put a strain on neighboring grids (Poland, the Netherlands, Belgium, etc). These countries are impacted by congestion in Germany and in turn struggle to transport their own electricity. The more different countries or routes become interconnected, the more commercial exchanges become key to make sure third countries are not disadvantaged. Rinck explains it is already quite difficult to achieve this within Europe, so this would be a more important question and would give rise to negotiation and frictions when expanding to other continents.

Regulatory

Regulatory issues have been put forward by most interviewees. Isabelle Gerkens (EGI) thinks regulatory agreements will pose a key challenge. As, many countries only have a few interconnectors aimed to limit black-out risks, regulatory setups (legislation, access terms, price, etc) for commercial exchange on new interconnections will start from zero. If they do not start from zero, it will be nonetheless difficult. From his experience with PCIs, Samson Hadush (ENGIE Impact) explains that the regulated nature of the electricity market is an issue because regulation is different across countries. Countries apply different approaches, different tariffs or market mechanisms. This is already a challenge within Europe and one can imagine how challenging it would get in a global scale. There are many different regulatory aspects that must be agreed upon (how and by whom will interconnectors be run?). In Europe, the electricity market has a lot of restrictions and requirements; these will not change overnight. Integrating European and all different markets will therefore be the main difficulty, as Hoogstraaten (BritNed) and Maes (Nemo Link) claim.

Specifically, Oliver Koch (DG Energy) says there is a need to have rules on how electricity is traded. Currently, this is happening through a sophisticated system in the EU. The day-ahead and intraday market coupling system has a European-wide legislation with specific conditions (only unbundled TSOs may take part, there needs to be an independent regulator, etc). It is characterized by close cooperation with a high degree of integration with majority decisions. As a consequence, EU TSOs can be outvoted by the majority of other grid operators when deciding about certain rules and deciding about resource allocation. It remains to be seen whether TSOs worldwide would accept the risk to be outvoted.
In this regard, Maximilian Rinck (EPEX SPOT) highlights the need for harmonization or at least finding basic competences between regulators regarding electricity, not just within the member states or at EU-level, but also spanning continents. Samson Hadush (ENGIE Impact) agrees harmonization is needed to create a market around the grid when connecting continents. This is important as it will determine the electricity prices and therefore the revenues from the lines. The problem is that a global grid would be spanning a lot of jurisdictions. In Europe, there are already political frictions between Switzerland and the European Union for example. This gets reflected in the efficiency of the market, Rinck states. The European Commission uses participation in the market coupling as a leverage or a bargaining tool to get commitments from the Swiss government in other areas like the Schengen contract. Oliver Koch (DG Energy) also stresses the importance of agreements and how difficult it already is to negotiate an electricity agreement with Switzerland. The E.U. wants to ensure a level playing field, meaning that external countries also have an independent regulator so that others do not have an unfair advantage over E.U. generation and transmission companies. By doing so, the E.C. wants to ensure fair competition and that E.U. Member States and third countries are bound by the same legal rules. Koch says the need for a regulatory framework that is intergovernmental is the main problem in achieving a global grid as it is something the European Commission has been trying

to do with Switzerland since 2006 and it is yet to be realized because it's politically very contentious.

On the other hand, Libert (CREG) raises the issue to determine who will be paying for the infrastructure and to which extent. He refers to the high number of involved parties (governments, TSOs, etc) and the difficulty it brings to negotiate among them. For national lines and cross-border infrastructure between countries that have close diplomatic ties such as Germany and Austria, cost-sharing remains feasible though already not so easy to solve, Rinck (EPEX SPOT) says. Libert says negotiations are already very difficult in Europe and take a lot of time. He highlights the discussions are very sensitive because a 1% difference in such large infrastructure and costs have huge impacts for all parties. Rinck thinks the more global the grid becomes, the more complicated this question will become, in particular for two countries or economic areas that are not as close as Member States of the European Union are. This aspect is also pointed out by Kristof Sleurs (Elia), who stresses the difficulty to find agreements that fit all parties around the table.

Rinck (EPEX SPOT) believes market coupling has to be extended outside the E.U. but realizes how difficult this will be. Within Europe, it is already very difficult to harmonize and obtain consensus between different jurisdictions on a market foundation, despite the overarching framework. It is already tricky to expand it to the Baltics countries and Russia, so one can imagine how difficult this would go on.

Bert Maes (Nemo Link) stresses the long lead times as a consequence from settling of regulatory agreements among TSOs and governments. And this is likely to worsen with the geographical expansion. The further the grid and the market expand, the more regulatory or political frictions appear, Rinck (EPEX SPOT) says. To establish a global electricity grid, completely new commercial agreements with minimum consensus would be necessary: not just in North America or Europe, but taking Russia, Asia and Africa into account.

Finally, Bert Maes (Nemo Link) indicates a global grid would bring new market designs with their own regulatory challenges. For example, it might create hybrid interconnections which would consist in offshore wind farms being directly connected on an interconnector. Apart from the fact that all European countries have their own subsidy systems for offshore wind farms, it is also difficult to convince wind farms to be connected to an interconnector rather than directly to countries. It is also very difficult to convince the European Commission, and national regulators of the societal interest. Wind farms want to maximize their wind output and their revenues, local authorities only want to pay subsidies for wind farms that bring offshore wind to *their* country and local TSOs are always afraid to receive too much wind energy because their grid is not ready to absorb that much wind. Finally, there would also be a need to create offshore bidding zones.

Geopolitical and political barriers

First of all, Brice Libert (CREG) highlights the importance of the geopolitical context. As an example, he mentions the Desertec project which consisted in massively developing solar energy in North Africa and interconnecting it to Europe through the Mediterranean Sea. This project was in all minds a decade ago but has been abandoned since. He says it was mainly due to the Arab Spring that destabilized the MENA (Middle East-North Africa) region. Political and geopolitical instability are therefore key risks to take into account and the reigning instability in neighboring areas that are key for the expansion of the grid therefore represent an important barrier. Gérald Sanchis (ENTSOE) points out to other reasons for failure. He explains the Desertec project failed because it only aimed to fulfill Europe’s electricity needs (mainly to replace Germany’s nuclear power plants supply by solar power from North Africa). He suggests attention should be given to the other party as well, so that the project creates a win-win situation. Moreover, there was not much interest at that time for Northern African and Middle Eastern countries to interconnect. That interest has risen in recent years due to these countries preparing for a post-oil era, replacing their oil export by solar power export. The shared interest is thus present nowadays.

Furthermore, a global electrical grid puts energy sovereignty at stake. While some countries would like to connect to others or are already connected, others could feel they would lose that energy sovereignty by doing that. Samson Hadush (ENGIE Impact) explains the reason for this reluctance. Although it might be more cost efficient for a country to rely on electricity imports, this would pose a great risk with severe consequences. In case a critical line gets cut or broken, the population would be left out without electricity. More and more countries might therefore adopt this more nationalistic way of thinking and favor their own energy independence. Within Europe, this barrier seems to have vanished, but it remains a key question as the grid expands to other regions with weaker diplomatic ties like China. Though this aspect is already present today with the EU’s dependence on fossil fuel imports such as oil, a global grid would replace this fossil fuel dependency by an electrical dependency. This is politically less desirable because you can store fossil fuel, but you cannot store electricity as easily. Importing countries therefore become immediately dependent and more vulnerable to exporting countries. Jan Kostevc (ACER) therefore suggests there must be strong political support to counterbalance and achieve such interconnections. Jan Hoogstraaten (BritNed) states this problem also has to do with the importance of governance and trust. There needs to be trust in the other parties and their promises to go forward with such a grid. Some important decisions must be made, such as deciding about an entity that will run and control the interconnector. This gets critical if a country does not know the counterparties well. Gérald Sanchis (ENTSOE) thinks this will need a change of mentality and it would take time. In the past, EU Member States were reluctant to depend on each other for their electricity supply. This is much accepted nowadays within the E.U. but the same time will be needed to accept it with third countries.

Other political aspects may hinder further development of the grid. Oliver Koch (DG Energy) indicates there must be sufficient drive to build an interconnector, but very often political barriers can be proven too strong for this drive. Among the political aspects mentioned, Koch states the reluctance to introduce competition for companies which have a leading role in their country. He claims direct neighbors do not always want to connect and that is why there is a need for strong regulation to sometimes force connection and force opening the borders. This problem is referred to as 'underinvestment' in the E.U. and is prevented by specific rules and competition cases. While this problem already materializes for a highly interconnected grid like the EU, Koch suggests this would be worse with neighboring regions as the grid expands. For example, the Baltic countries have been refusing to integrate nuclear energy from Belarus because they deem it not to be safe. Spaniards are also reluctant towards Moroccan energy because it is produced from cheap coal which is not bound by the same ETS system and boundaries. Koch explains that the impact on competition prevents interconnections in most cases.

Timing

Finally, the most obvious barrier might be that it is just not time yet to proceed to such a grid. Bert Maes (Nemo Link) thinks it has to go step-by-step and that today's focus should first be on interconnecting all European countries (including England and Eastern Europe) further and optimizing the European grid. Once the integrated electricity market is achieved, one can think of interconnecting with other continents. Kristof Sleurs (Elia) shares the same view. He thinks building a global grid should not be the first step in the global decarbonization process. He believes global interconnections might serve to further integrate renewable energy all over the world, but he claims we should first build renewable energy production on a massive scale before building these interconnectors. Although it is probably true that the renewable energy potential in Europe is not sufficient to meet its demand, it also still has a lot of untapped RES potential, Sleurs says. He thinks we will first have to find solutions to tap into that European potential before we start thinking of going further to a global grid because the further the grid goes, the more expensive it gets. Oliver Koch (DG Energy) confirms there are other problems at the E.U. level that have to be solved first. Connecting EU countries together, let alone with third countries, is already a struggle. He explains it was not possible to build an interconnection for twenty years between Northern and Southern Germany which are only 400 km apart. One can imagine that aiming for a global grid with interconnections over thousands of kilometers at this point might sound like aiming for too much too soon.

Financial barriers to the participation of Europe to a global electrical grid

Cost-base analysis

The first financial aspect that was pointed out by interviewees was the importance of the cost-base analysis (CBA) of an interconnection. This simply means that the benefits from building an interconnector must outweigh its costs. Despite calculations done by Chatzivasileiadis, Ernst and Andersson presented before, interviewees were skeptical towards positive CBAs. Costs are typically extremely high and require benefits to be even higher. Jan Kostevc (ACER) says the monetized benefit can be roughly approximated by the price difference between the markets connected by the interconnection. If the price in Europe is X €/MWh and in North America it is Y €/MWh, then benefits = (X-Y) * (transmitted energy in MWh). Kostevc gives an example of a 1000MW cable that connect countries with a price difference of 10€/MWh. This brings a benefit of 10.000€ per h (assuming the total capacity is always in use). If its economic lifetime is 25 years, benefits amount for 2.2 billion € (=25x8760hx10.000), which would be far from covering the investment costs (CAPEX), let alone costly maintenance in the middle of the Atlantic.

Hoogstraaten (BritNed) indicates this problem is likely to worsen over time. He suggests the main purpose of the interconnector is to take advantage of price arbitrage between countries. This, in fine, equalizes the prices between different markets. With the global grid, as prices converge, interconnectors will become less profitable over time. Hoogstraaten insists the main reason to build interconnectors is to get affordable electricity prices. Despite the possibility to subsidize these interconnectors, it would be difficult to justify subsidies to build interconnectors that will not reduce the electricity price but increase costs. The benefits would still have to somehow outweigh the costs, Hoogstraaten says. Sanchis (ENTSOE) agrees that there is a limit to interconnection development. At a certain point, if there are not enough electricity flows on interconnections, value and profitability are being destroyed, even on existing lines. The optimal point must be found in the grid. Even with still a certain price differential, it might become not profitable to build an interconnection at some point due to its high cost (e.g. through the Pyrenees mountains between Spain and France). Building a new generation plant is then a more efficient solution.

Bert Maes (Nemo Link) is more positive than Kostevc with regard to CBAs. He gives the EuroAsia and EuroAfrica interconnectors as another example to illustrate it. They aim at interconnecting Greece, Crete and Cyprus, branching further to Israel and Egypt. Maes states that the CBA of connecting Crete and Cyprus to continental Greece is not positive as the energy generation from Crete and Cyprus is too low and the interconnection costs, which amount to a couple of billion euros, are too high. The spread in electricity prices between the islands and Greece is also not large enough to generate sufficient revenues. However, if Cyprus can be connected to Egypt and the Middle East, the business case becomes extremely positive, Maes says. One can then make use of the tremendous amount of renewable energy sources from the Middle East and take advantage of the existing infrastructure between Saudi Arabia and Egypt for example. So, Maes believes finding sufficient funds in such a case will not be a hurdle if local authorities can give some guarantees on the building of the interconnection. While smaller projects with a negative CBA might need to benefit from subsidies, Maes believes spreads between continents will be rather large and so the business case would easily be profitable, especially at the beginning. He therefore believes that there should be plenty of money available, especially if the interconnections are regulated.

This aspect is also stressed by Brice Libert (CREG). He expects costs to be very high due to the technical complexity of laying the cables deep in seas and indicates price differentials must be high enough to cover these. For the CBA, he stresses the importance to analyze both the average prices and price volatility to determine congestion rents, though comparing average prices can already be an important signal to whether it makes sense or not to interconnect.

Against most interviewees' skepticism, Gérald Sanchis (ENTSOE) points out to a study done by CIGRE (see appendix C) which investigated whether it would make sense to interconnect grids of continents. The results showed that it would indeed make sense to interconnect continents as this would reduce the average electricity cost globally while also helping to increase the share of renewables.

Affordability and costs level

Another issue stems from the level of investments and costs such projects incur. As one can imagine, an extra-long-distance interconnector would bring extremely high costs. These costs are difficult to put on the shoulders of a merchant investor (who would have to get a loan for billions of euros) or to be passed on to tariff payers, Kostevc (ACER) says. EU projects often already cost more than €1 billion, so one can easily imagine where the costs would end up with such long-distance projects. Therefore, the overall cost of building such a project raises questions.

Brice Libert (CREG) also stresses the impact of the amounts of money needed for the investments. These costs come on top of high investments already taking place at national grid level for E.U. Member States to enable the energy transition. Some countries like Germany currently invest massive amounts in their transmission system to interconnect its Southern and Northern part. He is skeptical whether investments in a global grid can be passed on to end consumers or industries who are already paying a lot for their national electricity grid. Germans already have electricity bills that are much higher than most other Europeans. It is unlikely they will accept to see these costs rise even more, at least in the short term. Sleurs (Elia) also agrees it might be difficult for TSOs, depending on their structure and legal state, to welcome additional investments in the short-term. Moreover, the amounts of money involved can never be financed by a single TSO or a single country. It would have to be a European project, which adds difficulty to the realization of the project, Sleurs believes.

He further thinks institutional investors usually prefer to invest stepwise, little by little, to already generate some return and to reduce the risk. However, this will be very difficult in practice with intercontinental interconnectors and it will be a big lump sum that will have to be put on the table. It will get institutional investors to be even more cautious and get things to proceed slowly.

Risk

Interviewees indicate the high risk corresponding to the construction of a global grid as a critical barrier. As it implies very large investments, developers want their investment to generate benefits as soon as possible and make sure they do not end up as a stranded investment. Sleurs (Elia) therefore insists again on the fact that one might need to first develop massive RES generation units before interconnecting them. Libert (CREG) also points out at the risk of stranded investment. Specifically, the geopolitical risk he mentioned earlier plays a role as political instability could suddenly make the investment stranded. Infrastructure would instantly become useless and billions of euros would have lost all their values.

Another risk is related to the trend the energy landscape is taking. Samson Hadush (ENGIE Impact) indicates that there is a debate going on between centralization and decentralization of energy communities. It must be seen how a global electrical grid fits into the context of the current decentralization and digitalization trends. Building large infrastructure transmission lines and generation plants was the conditional way of thinking about the future of the electricity sector, but this has changed. The system is more and more going towards decentralization: individuals are putting rooftop solar panels and trading electricity with their neighbors. There is a mentality of local energy communities being created. If this trend goes on, would the huge transmission investments of a global grid still be relevant? The trend towards decentralization of the electricity system can have a negative effect and make intercontinental grid investments somewhat irrelevant, let alone stranded. Potential investors have to seriously take uncertainty around the future of electricity systems into account as well as its associated risk for revenue losses or stranded assets.

There is also an important regulatory risk involved. Sleurs (Elia) indicates profitability of an interconnector depends also a lot on the market set up at both ends because it cannot be stored in large quantities. Changes in these market setups can have important impacts on its profitability. Stability of market setups and regulatory schemes are therefore required before any party will decide on such investments. Hadush (ENGIE Impact) stresses the regulatory risk is even more important for regulated investments. Indeed, as TSOs invest in an interconnection, their costs are recovered through tariffs which are fixed by the regulator. There is a risk that price caps will hinder full cost recovery and there is a risk that regulators change the regulatory frameworks over time.

Merchant and regulated investments

Let us first consider merchant investments. Bert Maes (Nemo Link) thinks merchant lines can be a solution in the short term, but he agrees that it will be difficult to hold in the longer run. Indeed, the more continents get interconnected, the lower the price differentials become, as explained under the CBA section. This is especially harmful for merchant lines whose profits are driven from these price spreads. Samson Hadush (ENGIE Impact) agrees lowering spreads represent a major issue for merchant lines. Sleurs (Elia) goes further. He says that congestion rents and differences between market prices are in general very volatile as they depend on regulatory setup, generation mixes at both ends and parallel paths. For example, between the UK and the continent, the more interconnectors get built, the less profitable the existing interconnectors become. A merchant investor might be able to build a business case as first mover, but as soon as there is a second one coming, its profit gets halved. Sleurs (Elia) thinks this makes it very difficult for merchant investors and he believes the challenges get bigger for intercontinental interconnectors. Despite the potential large profits between continents, he thinks merchant will remain too risky. He explains that prices will be very volatile due to the high amount of RES on each continent and they will be affected by capacity mechanisms, therefore affecting merchant profits.

Samson Hadush (ENGIE Impact) indicates the price convergence and lowering spreads are less important for transmissions system operators that build a regulated transmission because their profit is generated from tariffs. Sleurs (Elia) confirms regulated lines incur a more certain return on investment and, despite a potentially lower return, are therefore more likely to be implemented. Bert Maes (Nemo Link) adds that the full social welfare matters for regulated investments, not only the price differential. From that perspective, Maes believes the regulated scheme will be more promising as the entire societal value will prevail over the mere business profits in most cases and so make projects go forward even when private investors would not have undertaken a project due to negative expected profits. Sleurs agrees with the latter and the fact that regulatory lines are more likely to proceed, though there needs to be some regulatory setups or party. Bert Maes says he would favor regulated intercontinental interconnections, though he acknowledges some questions must still be answered (e.g.: to which extent should the E.U. and the affected Member State contribute to the investment?). With regard to regulated investments, Hadush indicates a lot of public support and political agreements will be needed. Sleurs points out at the difficulty of finding agreements that fit all parties and he questions TSOs' financial ability to add such costs on their plate in the short-term. Not all TSOs might be able to take up on such additional costs, depending on their structure, grid history, RES potential, their public or private state with corresponding access to the stock exchange, etc. Hoogstraaten (BritNed) is more skeptical towards the regulated scheme. He thinks it would be difficult to subsidize long intercontinental interconnections given the high cost and risk profile. He is doubtful whether worldwide cooperation can be achieved. A global grid would imply to have the same regulatory incentives everywhere. In Europe this is happening with all the TSOs and many different parties that all need to work together but this already takes a lot of time, cost and energy. Hoogstraaten expects taking this process worldwide will end up in a debate with people having different vision of the energy landscape with different regulatory incentives unable to compromise. Specifically, regulated tariffs to recover the costs of regulated lines are different everywhere. For the moment, there is no same regulatory regime for TSOs Europe-wide that gives incentives to expand or maintain the grid. Hoogstraaten does not see how something that cannot be achieved within Europe could be realized on a global scale. On the other hand, Bert Maes indicates the need to integrate market mechanisms can be more easily done with regulated lines than merchant lines.

Hoogstraaten (BritNed) believes the solution might lie in between the merchant and regulated approaches. Regions have different historical preferences: Europe is mostly regulated but the USA and the UK are not. Asia is again different, so the approach will mostly depend on who Europe is dealing with. Even within the European landscape, there are many different ways to regulate TSOs and countries adopt different incentives towards the electricity grid: Germany is more investment-driven while Italy is more maintenance-driven. Hoogstraaten therefore believes the solution for a global grid would be more of a hybrid model.

Brice Libert (CREG) explains how such a hybrid model could look like with the example of Nemo Link's cap-and-floor regime. The 1000 MW regulated interconnection connects the English and Belgian grids. The transport capacity generates congestion rents that amount to the price differentials multiplied by the interconnection capacity (1000 MW). Congestion rents indeed indicate that the capacity is fully used. Up to a certain level, the congestion rents perceived on the interconnection can be used by the TSO to finance that same interconnection. If congestion rents surpass that cap, the congestion rent excess is used to rebate tariffs for consumers. On the other hand, the TSO is guaranteed a minimum revenue if price differentials disappear by increased consumer tariffs. The regulator fixes caps and floors far enough from each other so that it is almost certain the end consumer does not receive nor pays anything for the interconnection. This approach stems in with the traditional merchant approach from Ofgem and the more regulated approach from CREG, the Belgian national regulator who did not want to make the end consumer contribute further to the already well-connected national grid. Just before that time, the E.C. had imposed a cap on BritNed, because it deemed future profits to be higher than what BritNed had reported. This was very negatively perceived because it was limiting profits without compensating for the risk. The cap-and-floor was a compromise to incentivize Belgian TSO Elia by allowing it more potential profits than under a pure regulated approach and to give more financial security to National Grid Holding while keeping the attractive components of the merchant approach. The remarkable character of Nemo Link's cap-and-floor regime is the innovation it brough which made it possible for the interconnection to finance itself (investment pay-back, amortizations, return on investment, workforce charges, etc) while still in line with the European regulations. It was replicated for England's other interconnectors with the continent.

Isabelle Gerkens (EGI) confirms the hybrid mechanism is getting more and more important in Europe and becoming the reference. It consists in a combination of both merchant and regulated models. The hybrid mechanism is characterized by the cap-and-floor mechanism and was initiated in Europe with Nemo Link, as stated above. She explains it is the fusion of Ofgem's merchant approach and CREG's rather regulated approach. Hybrid mechanisms help investors (which could be TSOs) keep profits but capping them at a certain level not to abuse consumers. Projects in Asia and the Middle East are seriously considering this mechanism which can be customized to a large extent with regard to the parameters (determining the profit the investor is allowed to make, etc). Hybrid mechanisms make it easier because major risks are covered, Gerkens says.

Hadush (ENGIE Impact) also believes cap-and-floor mechanisms are one way to deal with the risks associated with merchant lines. He notes any kind of commercial arrangements is possible between the merchant and regulated approaches, but many regulatory questions have to be settled (with regard to cost-recovery, financial arrangements, investors). Hadush believes the optimal design will depend on the context and that there is no one-size-fits-all solution. The solution will be influenced by political, legal and regulatory aspects from countries involved.

Market structure and characteristics

Market prices and price volatility depend on market structure. Changes in market structure such as bidding zones structure would influence these and in turn impact an interconnector's revenues as Kristof Sleurs (Elia) mentions.

Another issue pointed out by Kristof Sleurs is the fact that electricity markets only span up to three years ahead. Market players cannot really have a long-term risk hedging which is a challenge. As electricity cannot be stored, one must go with the instantaneous price and is therefore fully exposed to very volatile short-term prices without some financial hedging. Sleurs therefore expects it to be very difficult for a small market player to have interconnectors in its portfolio. Maximilian Rinck (EPEX SPOT) nuances the latter as you can buy up to six years ahead technically, though the price is only known up to three years ahead. He believes it is a difficult question because as a consumer or investor you want to have financial security as long as possible. Power Purchase Agreements (PPAs), which are bilateral long-time contracts for electricity, enable an around 15 to 30 years price stability. Covid19 and the Fukushima catastrophe have been externalities that the market had no chance to foresee. Risk hedging does not protect you from such externalities which can render any risk mitigation strategy void. Hedging also comes with an enormous risk premium. The longer one wants to hedge price risk into the future, the higher a risk-premium he would have to pay. At a certain cost, one will have to decide whether the cost of risk management is higher than the cost of risk itself. Liquidity also plays a role in long-term risk hedging. The further out into the future you want to secure your prices, the less liquid contracts become, which is due to the price uncertainty. Liquidity is a measure of getting the price you need for your own strategy to work. So low-liquidity means high transaction cost and high costs for risk management. In short, the risk of not getting the price right is so huge that it more than offsets any investment risk. Rinck therefore assumes the best way for a TSO to hedge long-term electricity prices is with the setting of tariff by the regulator. Indeed, there is no market price to interconnect the value of electricity 10 years in the future and he doubts there is a reasonable economic argument to have one.

Maximilian Rinck (EPEX SPOT) suggests there are two appropriate market mechanisms in Europe that could help achieve a global grid. The first one is the zonal market model which consists in huge market areas (usually coinciding with national borders) with their own electricity price. This is the market design that is currently in place over most of Europe with the exception to some countries like Switzerland. The zonal market design is opposed to the nodal market design, which exists in the USA for example. In the nodal market model, market areas correspond to transmission system nodes. Every major city has one market price, which gives a better integration of the grid states into the market. This makes it easy to see where congestions and constrictions are in the grid as they are reflected in the price. However, it involves quite a lot of small marketplaces, which is difficult to manage. It also results in a less efficient market in the sense that electricity flows across the market are more complicated. In a zonal market, the opposite is true. The grid situation is less accurately reflected but electricity flows as a commodity. Rinck explains that the zonal market is therefore more suited for a global grid, though it is important to also reflect the grid situation to know where investments are needed further. The second market mechanism pointed out by Rinck consists in market coupling. The way commercial exchanges on interconnectors took place before was that transmission had to be purchased separately. You would buy electricity in one market, sell it in another market and pay for transmission capacity. Rinck explains this corresponds to the explicit auction mechanism and it is like buying a train ticket in some way. It made it difficult for market players who had to have a good forecast of the national prices to know how much the value of the interconnector is. Market coupling on the other hand consists in integrating the import-export constraint into the overall European market clearing mechanisms. It corresponds to the implicit auction mechanism. A market player then does not have to worry about the interconnector and just buys the electricity in his market; the rest is done by TSOs. Market coupling is a concept that power exchanges have now spanned over all Europe. It consists in establishing connected markets on top of the grid that is already physically connected. Setting up a market on top of the physical grid to ease transmission and commercial flows is one of the enabler to a global grid because the more complicated the commercial exchange is, the higher the transaction cost and the less efficient the market. To summarize Rinck's thoughts, the challenge is to extend and implement zonal market design and market coupling on a worldwide scale. When establishing a global electric grid, Rinck thinks it is going to be a graduate approach. Once the infrastructure gets done, some sort of exchange would start happening under the explicit auction mechanism between two continents. This way, there would be a market on each side of an interface which will manage the interconnector or the exchange of electricity between these two areas manually. And once that is working, the next step would be to internalize these auctions. Rinck thinks it is similar to Excel sheets: you first build the process manually and then you automate it.

Brice Libert (CREG) advocates for under-sizing transport capacity with regard to generation capacity. Despite that an interconnector would not always be able to transport all electricity, this would ensure that congestion rents would always be generated, therefore generating more revenue and driving less cost by sizing the interconnection down. This way, the European end consumer does not see his electricity bill inflate.

Remaining barriers consistent with literature review

From their experience, Bert Maes (Nemo Link) and Samson Hadush (ENGIE Impact) believe local opposition can pose a serious threat to the materialization of the infrastructure needed for a global grid. Hadush explains that public acceptance is a challenge because individuals are reluctant that transmission lines are put next to their homes, mainly due to the visual impact.

The need to get a permit is not to underestimate as project developers have to make sure that that the community is on board. Gérald Sanchis (ENTSOE) explains this is indeed one of the main issues and the PCI framework helps to bypass the barrier as a project being labelled as PCI will have to be supported by Member States as much as possible to combat local opposition.

The literature review has shown that interconnecting markets, though increasing overall welfare, negatively affects some parties. As prices converge, consumers from the low-price country will be disadvantaged. So will electricity generating companies from the high-price country be. Market coupling could be hampered by a political unwillingness from a country to have its consumer price rise. Oliver Koch (DG Energy) gives the example of Iceland, which might be quite reluctant to interconnect given its low consumer prices that are expected to rise if they interconnect with the continent. On the same page, electricity generating companies could have an important role for some countries and it could be difficult to see their revenue drop. Koch indicates some of them are monopolists in their country and it will not be easy for them to let their market power go and welcome competition. Koch insists there must be enough economic incentive for countries to interconnect. The literature mentions the need to compensate losers from the interconnection, though this was not brought up by any interviewees.

It is also quite difficult to imagine the cost fall on the shoulders of tariff payers. The increase of tariffs such an investment would bring could indeed be unbearable, as Jan Kostevc (ACER) says. Isabelle Gerkens (EGI) also mentions the cost of renewable energy integration and grid development being passed on to tariff payers as a challenge. Brice Libert (CREG) says it is contentious to pass on costs to European consumers. Some Europeans, Germans for example, already pay a lot for their electricity. For this reason, he suggests interconnection capacities to be a bit under-sized compared to generation capacity to make sure the interconnection is always used to its maximum capacity and to make sure it always generates congestion rents. This also means a lower investment cost for public entities and ensures that, if end consumers have to contribute, their contribution would be minimal.

Solutions

Building a global electrical grid is a concept that is still relatively new to the sector and that is yet to be extensively researched. The lack of large intercontinental interconnections does not

enable one to draw lessons from previous cases either. Interviewees were all on the same page regarding best practices that we can draw upon. They either pointed towards projects yet to materialize such as the EuroAsia Interconnector, intra-European projects such as NorNed, or small-scale projects such as the interconnector between Spain and Morocco. Overall, more questions were further raised by interviewees than answers given. Solutions put forward are mainly resulting from extrapolations from interconnections in Europe. They can be deemed more exploratory and can serve as a starting point for further studies.
Jan Kostevc (ACER) indicates the need for subsidies and political support in case the interconnector's benefits would not exceed its costs to help push the investment through.
Brice Libert (CREG) mentions offshore wind hubs in the North Sea linking Denmark and Germany.

Best practice analysis

The Euroasia Interconnector project is interesting to learn from and to draw upon for future potential intercontinental interconnectors. Indeed, as mentioned above, it involves EU (Greece and Cyprus) and non-EU (Israel) countries for a total length of 1518km which makes it widely relevant for further analysis. The link between Crete and Cyprus at 879 km would also become the longest electrical sub-sea cable in the world. EuroAsia Interconnector Ltd was assigned as developer of the project and the interconnection was awarded the PCI status and included in the European Commission's Trans-European Network for Energy (TEN-E) policy which regulates PCIs. (NS ENERGY, 2020) PCIs are commissioned to realize the four prioritized electricity corridors in Europe, one of them being the North-South electricity interconnections in central eastern and south eastern Europe (NSI East Electricity), which comprise Greece and Cyprus. (European Commission, 2013)

The project is however yet to be realized. Estimated to cost €3.5bn ($3.9bn), the first development stage of the interconnection project will have a transmission capacity of 1GW, which would increase to 2GW in the next stage. Partial operations will start in 2022, while full-scale operations of phase one are expected to launch by end 2023. Exploratory studies for the EuroAsia Interconnector were covered for 50% by funding from the EU's Connecting Europe Facility (CEF) thanks to the PCI status. The status also makes the project eligible to have half of its construction covered by the CEF, along with supplemental grants from the European Investment Bank and remaining EU institutions. (NS ENERGY, 2020)

The European Commission has made good work in easing discussions between parties to make the project progress and offer a cost-efficient and affordable solution. This case also illustrates the importance of having a supra-national entity, in this case ACER, which can push to make the project go forward when parties' negotiations come to a standstill. For the first section joining Attica and Crete, project developer EuroAsia Interconnector Ltd and ADMIE (Greece's TSO), among others, could not manage to settle the share percentages in the SPV (Special Purpose Vehicle) of the project. The European Commission as such managed to interfere and unblock the project. (Michalopoulos, 2020)

The project has received support from the three state leaders for a timely project implementation. Remarkably, the EuroAsia Interconnector has been approached in a way to set off potential cross-sectorial synergies with applications in the form of gas pipelines and information broadband cables. Specifically, Israeli Prime Minister Netanyahu, Greek Prime Minister Tsipras and President of Cyprus Anastasiades praised the project to integrate fiber optics in the electricity cable. (EuroAsia Interconnector, 2020)

Finally, it should also be noted that all three countries are members of Med-tso (see infra) which might have helped to foster discussions.

What can we learn?

Isabelle Gerkens (EGI) thinks we could learn from the European example which started from national grids towards a European vision of the grid. Once the EU started to have a centralized European vision of the grid, it got a focal central point, issuing directives which had to be implemented at a national level. This way, national grids can support the overall European vision for an integrated grid. Otherwise, it cannot work because national grids would just integrate their national vision and interests and preferences and only energy exchange interfaces will help towards an international vision. Once grids start following national visions, it is hard to reconcile them. It is therefore important to have a global vision for a global electrical grid early on, as well as a supervising body. She indicates this way of thinking is already present in some parts of the world such as Europe, some electricity pools in Africa and the Mediterranean basin (connecting three areas with very different visions: Europe, Northern Africa and the Middle-East). Med-tso, an entity supported by the E.C. where neighboring TSOs, among others, come together to discuss possibilities and future vision (focus on technical aspects, investments and grid management). The importance of Med-tso is also supported by Gérald Sanchis (ENTSOE) as it identifies potential corridors for interconnections. Med-reg is more focused on regulatory and legislative aspects. It could be interesting to extrapolate from there because problems arising from global networks could be very similar to the ones tackled by Med-tso (with around 20 TSOs) in that region, Gerkens notes.

Gerkens (EGI) says ENTSOE helps to have a common approach to technical, market regulation and management aspects. She expects this effect to go on and expand to the Baltics and Eastern European countries, North Africa, etc. European funding is made available for pilot projects and test cases. Finally, Europe is also funding projects at these bordering grids with regard to developing renewables generation, grid reinforcement and grid interconnections, implementing European market mechanisms. She expects the integrated European electricity market to geographically expand over time to neighboring areas implementing bilateral agreements with compatible market regulation and legislation.

Gérald Sanchis (ENTSOE) insists there is a strong push from the EC to develop infrastructure and integrate the European grid, among others through the PCIs. PCIs are Projects of Common Interest which are not profitable in the short term, therefore not likely to go through, based on national investment only. EU investments help the investment go forward for so long it can generate a profit in a longer term. This is an innovative mechanism which does not exist anywhere else according to Sanchis. For an interconnector to be awarded the PCI status, it must generate an overall welfare increase for at least two Member States. This condition can be verified with ENTSOE’s cost-benefit analysis models. These rules are expected to evolve and are currently being revised, also due to the European Green Deal. The European Green Deal reserves a budget aimed at helping Africa because the EU knows it is useless to fight climate change on its own and therefore helps poorer regions. There might be projects with non-European countries which could benefit from a new PCI mechanism in the future even if only benefitting one EU country, future will tell. The EC tries to also leverage as much private money as possible and private interconnectors are also eligible as PCIs, such as cable from the continent to Cyprus for example. Sometimes a mix of public and private funding happen, every combination is possible. However, there are not many private projects for the moment because private investors usually want transparency regarding profits. Overall, Sanchis thinks the PCI mechanism could be transposed to other continents in the grid to facilitate intercontinental interconnection development.

Bert Maes (Nemo Link) believes the EC is also working hard in this direction and approves the importance of the PCIs to achieve the Internal Energy Market.

The Euroasia example brought forward by Bert Maes (Nemo Link) can let us think the existence of local electricity infrastructure is an important drive. Since Egypt is connected with Saudi

Arabia, connecting Europe with Egypt would enable the continent to massively import solar power from Saudi Arabia. The existence of these infrastructures reduces the risk of the interconnection between Egypt and Cyprus to be stranded.

Kristof Sleurs (Elia) thinks the difference between European and intercontinental projects is the distance and so the interconnector cost. The risk in revenue because of the volatility is similar (and even much greater for the intercontinental case), so one should look for solutions and practices to mitigate the volatility of revenues.

Hadush (ENGIE Impact) thinks Europe has good experiences, especially in dealing with risks. ACER also plays an important role in bridging the gap between differences in regulatory frameworks in countries and making sure these projects go ahead, so this is an interesting solution to maybe extrapolate. For best experiences especially in dealing with risks, he points out at PCIs. Hadush thinks the European approach of having a common approach and drive from the DG Energy as well as a regulatory body works and should be replicated at the global level.

Conclusion

Energy is crucial for life, humankind, and human societies. It is the fuel to prosperity, welfare, and development. Moreover, energy is vital to eradicate poverty and is so a key aspect to sustainable development globally. The energy decarbonization needed to mitigate climate change represents an immense challenge, both to avoid dramatic climate consequences and to secure future energy needs for societies. One of the key aspects to energy decarbonization, among increased efficiency and tamed consumption, is the need for fossil fuels to be phased out by renewable energy sources to drastically cut off greenhouse gas emissions. This constitutes the core of the EU Green Deal which aims at reducing European emissions by 50%-55% until 2030 and to be the first carbon-neutral region in 2050. One of the eight pillars of the Green Deal is therefore to supply clean, affordable, and secure energy. (European Commission, 2019)

To enable this arduous substitution, a solution put forward is to rely on a global electrical grid. Such a grid could contribute to substantially counter negative effects of renewable energy sources (e.g. inter-seasonal and intra-day supply-demand mismatch, need for storage due to intermittency, electricity price volatility…) while tapping into remote areas where wind and solar energy sources abound. Most experts expect regulatory, political, and financial aspects to be the main barriers to the materialization of the project. This master thesis aimed at depicting the main barriers to the participation of Europe in a global grid and extricate potential solutions to these barriers.

The first thing to note from the literature review is that Europe is a privileged counterpart to engage in this project. There is already a strong institutional push in Europe compared to the rest of the world as the EU has been emphasizing the need for a highly integrated and meshed Internal Energy Market to secure energy supply, generate competition and increase the share of renewables.

The main financial barrier identified in the literature review stems from the risky nature of the project. A global electrical grid involves strong risks and uncertainties at many levels which prevent the enormous investments needed. Among these risks are the long term nature of the project, the stochastic nature of renewables and their impact on the grid, the regulatory risk from changing tariff regulation, the uncertain price differential dynamics, the hazy CBA analyses, the regulatory risks arising from international cooperation, and the regulatory gaps that are difficult to bridge. Another key issue relates to public acceptance and the frequent opposition that goes with large infrastructure projects. Finally, some important issues must be solved to leverage intercontinental interconnections, such as the need for compensation mechanisms to indemnify losers from accrued electricity trade as well as national grids experiencing loop flows or being transited.

It was also clear in the literature review that the large amounts of money needed to proceed to building the needed infrastructure of a global grid would add up on other investment costs for grid security and renewable development at national level. Discussions regarding these additional costs are therefore expected to be very sensitive. On the other hand, putting the burden on end consumers through increased tariffs is expected to be politically very contentious. One therefore expects the need for strong institutional support to push the project through. Due to the project nature, it is also advised to strongly take stakeholders into account to have a large driving force and support towards project materialization. With regard to the different investment schemes, merchant investments were deemed to be compatible with regulated investments, though it appears clear that merchant investments cannot sustain in the long term in a global grid as prices converge and congestion rents vanish.

Among the solutions put forward in the literature, one notes the application of the Coase theorem, which consists in making beneficiaries of an interconnector support and financially contribute to a certain extent. Another solution brought up is to involve stakeholders in negotiations to ease implementation and avoid complaints and delays in later stages. Remaining advises include developing stronger trade and diplomatic ties, appointing an independent body with binding power and implementing compensation mechanisms, and adopting a regulatory framework with shared legal and regulatory provisions. The latter is especially important as experts expect the EU’s regulatory framework to be difficultly expandable to other regions. Finally, it should be noted that, no matter how TSOs collect additional funds, these incurred infrastructures would go with drastic tariff increases for end consumers.

Four main areas were identified to be problematic for the realization of a global grid apart from the pure financial aspects. First of all, technical and technological problems, mainly caused by sea depths, remain far from evident to solve at this stage. Regulatory issues are expected to be the most severe ones. As one sees how challenging these are at the European level, one can only expect them to be exacerbated on a worldwide basis. There are so many aspects to agree on and it remains to be seen which sacrifices the EU (and its level-playing field) and third countries are willing to make to have their markets merge. Political and geopolitical risks are mainly driven by political instability in some regions which could hold investors off to invest and the importance of energy sovereignty and independence for states. Finally, interviewees voiced their concerns towards the timing of the global grid as the IEM is not ready yet and it will be difficult to add a global grid on the plate at this time.

With regard to financial barriers, interviewees mentioned about the same issues as the ones which were found in the literature review. First, they noted the importance of positive CBAs and the problematic to see revenues decrease over time as prices converge. They also pointed out at the large amounts of money involved and the difficulty to add these up on top of existing national investments for grid security and renewables development. The large uncertainty such projects incur and the risk for assets to become stranded or the evolving regulatory uncertainty, particularly important for regulated investments were covered. The strong role of markets and their influence on prices, and therefore revenues, was highlighted. Finally, interviewees cited the issues stemming from local opposition, from the need to compensate losers from the introduced interconnector and from the financial pressure brought to the end consumer.

Investment schemes were also covered. Merchant investments were deemed too risky because they do not incur a guaranteed return and are not suited for the long term because of the price convergence incurred. Interviewees therefore voiced a preference for regulated investments. However, these also come with issues such as the need for political agreements and support and the importance of a supranational regulatory party, all difficult to implement on a worldwide basis. The importance of the recently developed cap-and-floor mechanism was praised by numerous interviewees. The mechanism enables compromises between both historical approaches. It brings an innovative dimension by financing itself while covering major risks and is therefore becoming the reference in Europe.

Several solutions were pushed forward by interviewees. First, there is an evident need for a common vision early on with regards to global energy outlook comprising a supervising body making funding available. This is what makes the current accomplishment of the IEM in Europe. PCIs were also stressed by most interviewees for their role in achieving the IEM and it was suggested to create a similar mechanism in a global context. Further, the importance of local grid development to leverage on intercontinental interconnections was indicated. Finally, the importance of a supranational regulatory entity was pointed out. ACER’s important role to bridge regulatory gap in Europe and making projects go ahead was pointed out and it was deemed wise to extrapolate on this to a global stage.

Overall, a lot of attention was given in the literature review to the merchant and regulated schemes to determine which one would be more suited as a backbone to the global electrical grid. Though interviewees have shown a light preference for regulated, it appeared the difference between both schemes is not that crucial in practice. One indeed noticed, once funding is made available, the scheme does not matter much. The relative importance given to the investment schemes in the literature probably stands from the lack of studies covering other financial aspects.

Further to the previous point, one of the key takeaways from this master thesis is that financial barriers identified can be considered much less important compared to other barriers. This was already present in the literature review and consistently highlighted by interviewees. Hoogstraaten (BritNed) mentioned there are already a lot of Chinese and Russian companies active in the electricity market in Europe. Gerkens (EGI) and Oliver Koch (DG Energy) also believe most investments to date are profitable because of the price differentials and therefore very easily funded. Additionally, Sanchis (ENTSOE) believes finding money is easy once you have investors and institutions on board.

The topic of a global electrical grid is one that divides minds and tears passions apart. Most interviewees expressed a clear opinion on the grid when asked whether they thought it would be desirable and realistic. They were either supporters and believers of the project or they were much more skeptical and did not think it would be the solution for the world's energy future. Bert Maes (Nemo Link), Isabelle Gerkens (EGI) and Maximilian Rinck (EPEX SPOT) were part of the former group. Jan Kostevc (ACER), Samson Hadush (ENGIE Impact) and Kristof Sleurs (Elia) were less enthusiastic. Importantly, they indicated other solutions than a global electrical grid must be considered, such as centralized energy communities or an energy transport through molecules (H_2 or any other gas) on a global level. The cheapest and optimal solution for society as a whole must be prioritized.

Nevertheless, a global electrical grid could play a major part in the EU Green Deal's objective to become carbon-neutral by 2050. The deal mentions the importance for the EU's energy supply to be secure and affordable for consumers and businesses through a fully integrated, interconnected and digitalized European energy market. This echoes with its former will to achieve an Internal Energy Market and inquires the TEN-E Regulation (which sets out guidelines on PCIs) to be reviewed "to foster the deployment of innovative technologies and infrastructure." (European Commission, 2019) A global electrical grid, while being a tailored fit for these ambitions, is in further adequacy with the EU's call for new, sustainable and disruptive innovation to achieve the Green Deal and supporting its immediate Eastern and

African neighbors through partnerships and support for clean energy development and trade. Ultimately, launching a global electrical grid could top the EU’s stand as environmental global leader and help further develop its “green deal diplomacy” globally. (European Commission, 2019)

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Appendices

A. SDG 7 Targets and indicators

TARGETS		INDICATORS	
7.1	By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.1	Proportion of population with access to electricity
		7.1.2	Proportion of population with primary reliance on clean fuels and technology
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1	Renewable energy share in the total final energy consumption
7.3	By 2030, double the global rate of improvement in energy efficiency	7.3.1	Energy intensity measured in terms of primary energy and GDP
7.A	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	7.A.1	International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
7.B	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	7.B.1	Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services

Source: retrieved on May 27th 2020 from https://sustainabledevelopment.un.org/sdg7

B. SDG 17 Targets and indicators

TARGETS		INDICATORS	
FINANCE			
17.1	Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection	17.1.1	Total government revenue as a proportion of GDP, by source
		17.1.2	Proportion of domestic budget funded by domestic taxes
17.2	Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries	17.2.1	Net official development assistance, total and to least developed countries, as a proportion of the Organization for Economic Cooperation and Development (OECD) Development Assistance Committee donors' gross national income (GNI)
17.3	Mobilize additional financial resources for developing countries from multiple sources	17.3.1	Foreign direct investments (FDI), official development assistance and South-South Cooperation as a proportion of total domestic budget
		17.3.2	Volume of remittances (in United States dollars) as a proportion of total GDP
17.4	Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress	17.4.1	Debt service as a proportion of exports of goods and services
17.5	Adopt and implement investment promotion regimes for least developed countries	17.5.1	Number of countries that adopt and implement investment promotion regimes for least developed countries
TECHNOLOGY			
17.6	Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	17.6.1	Number of science and/or technology cooperation agreements and programmes between countries, by type of cooperation
		17.6.2	Fixed Internet broadband subscriptions per 100 inhabitants, by speed
17.7	Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed	17.7.1	Total amount of approved funding for developing countries to promote the development, transfer, dissemination and diffusion of environmentally sound technologies
17.8	Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology	17.8.1	Proportion of individuals using the Internet
CAPACITY-BUILDING			
17.9	Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation	17.9.1	Dollar value of financial and technical assistance (including through North-South, South-South and triangular cooperation) committed to developing countries

TRADE

17.10	Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda	17.10.1	Worldwide weighted tariff-average
17.11	Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020	17.11.1	Developing countries' and least developed countries' share of global exports
17.12	Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access	17.12.1	Average tariffs faced by developing countries, least developed countries and small island developing States

SYSTEMIC ISSUES

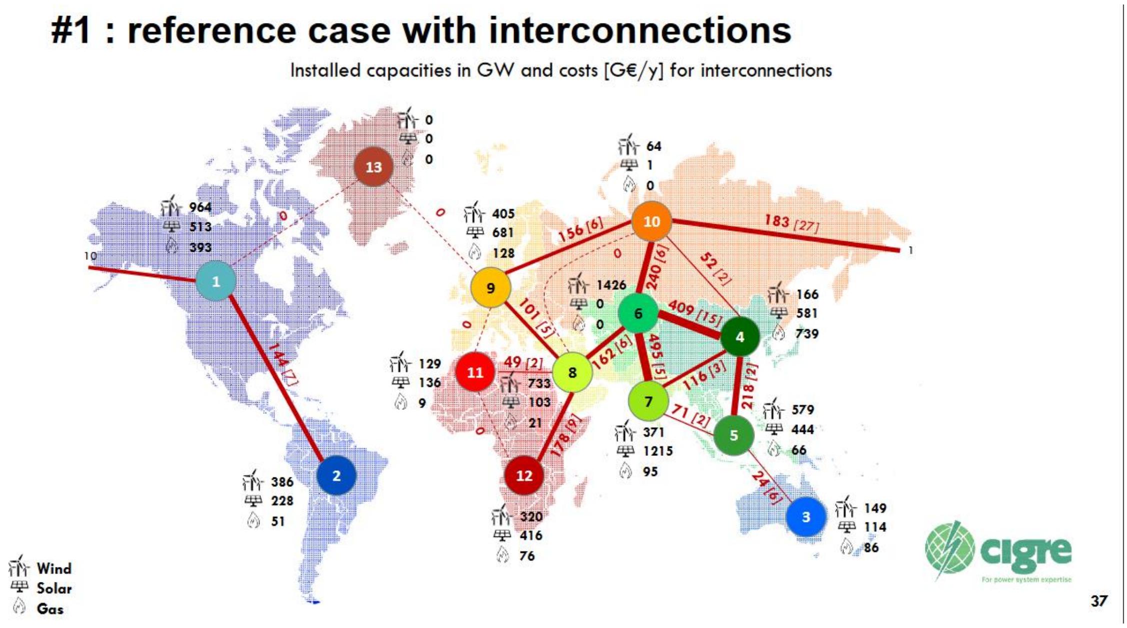
Policy and Institutional coherence

17.13	Enhance global macroeconomic stability, including through policy coordination and policy coherence	17.13.1	Macroeconomic Dashboard
17.14	Enhance policy coherence for sustainable development	17.14.1	Number of countries with mechanisms in place to enhance policy coherence of sustainable development
17.15	Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development *Multi-stakeholder partnerships*	17.15.1	Extent of use of country-owned results frameworks and planning tools by providers of development cooperation
17.16	Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries	17.16.1	Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the sustainable development goals
17.17	Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships *Data, monitoring and accountability*	17.17.1	Amount of United States dollars committed to public-private and civil society partnerships
17.18	By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts	17.18.1	Proportion of sustainable development indicators produced at the national level with full disaggregation when relevant to the target, in accordance with the Fundamental Principles of Official Statistics
		17.18.2	Number of countries that have national statistical legislation that complies with the Fundamental Principles of Official Statistics
		17.18.3	Number of countries with a national statistical plan that is fully funded and under implementation, by source of funding
17.19	By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries	17.19.1	Dollar value of all resources made available to strengthen statistical capacity in developing countries
		17.19.2	Proportion of countries that (a) have conducted at least one population and housing census in the last 10 years; and (b) have achieved 100 per cent birth registration and 80 per cent death registration

Source : retrieved on May 27th 2020 from https://sustainabledevelopment.un.org/sdg17

C. Illustrations of global grid examples

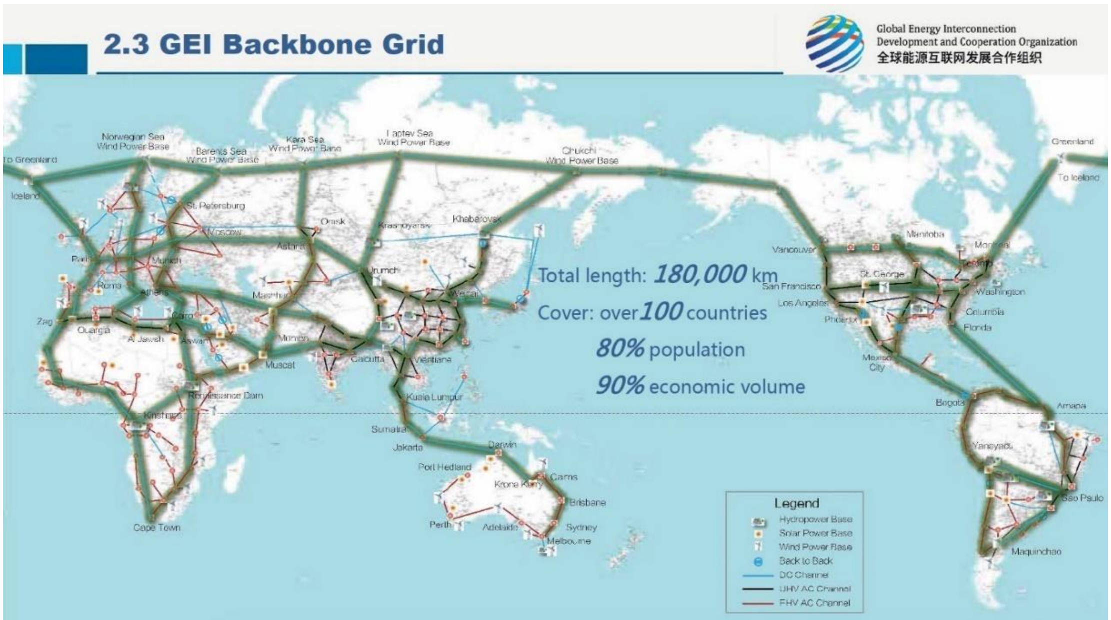
C.1. Conseil International des Grands Réseaux Electriques (CIGRE)



Source: CIGRE (2018). *Global Electricity Network Feasibility Study*. Retrieved on May 27th 2020 from

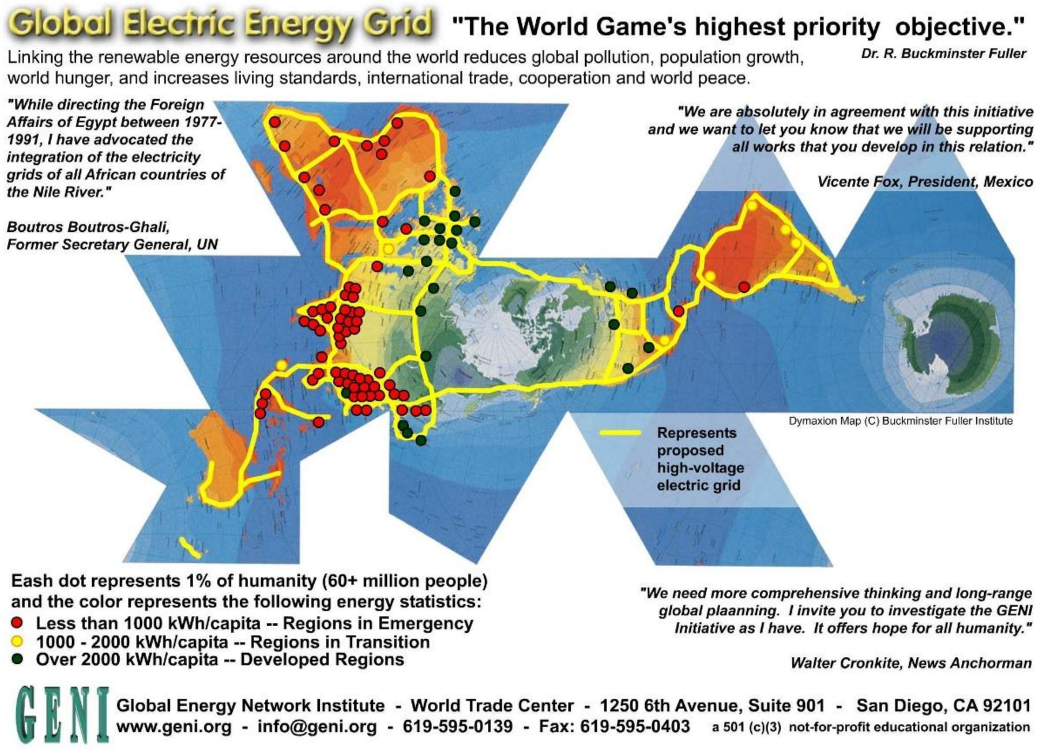
https://globalenergyinterconnection.com/wp-content/uploads/2019/02/2018-08-28-Cigre-WG-C1-35-Tutorial-Global-Electricity-Network-final-v4-1.pdf

C.2. Global Energy Interconnection Development and Cooperation Organization (GEIDCO)



Source: retrieved on May 27th 2020 from https://medium.com/fairbank-center/does-the-path-to-a-low-carbon-future-run-through-a-global-grid-ac8774d8556

C.3. Global Energy Network Institute (GENI)



Source: retrieved on May 27th 2020 from https://www.technocracy.news/china-promotes-global-smart-grid-intercontinental-energy-distribution/?print=print

D. Article 17(1) of Reg. 714/2009

Art. 17(1)'s Threshold Test: a project meeting the following conditions is eligible for an exemption from the provisions of the regulations identified above:

a) the investment must enhance competition in electricity supply;
b) the level of risk attached to the investment is such that the investment would not take place unless an exemption is granted;
c) the interconnector must be owned by a natural or legal person which is separate at least in terms of its legal form from the system operators in whose systems that the interconnector will be built;
d) charges are levied on users of that interconnector;
e) no part of the capital or the operating costs of the interconnector have been recovered from any component of charges made for the use of transmission or distribution systems linked by the interconnector; and
f) the exemption must not be to the detriment of competition or the effective functioning of the internal market in electricity, or the efficient functioning of the regulated system to which the interconnector is linked.

Source: Rubino, A., & Cuomo, M. (2015). A regulatory assessment of the Electricity Merchant Transmission Investment in EU. *Energy Policy*. p. 467.

E. Different regulated exemption types for merchant lines

As mentioned in the previous section, an interconnector that successfully applies for an exemption may be exempt in full or in part from one or more of the following:

i. Restrictions on the use of congestion management revenues (pursuant to Article 16(6) of the Regulation).
ii. Ownership unbundling for transmission and supply and generation interests (pursuant to Article 9 of the Directive).
iii. Third party access to interconnector capacity must be granted on an objective and non-discriminatory basis (pursuant to Article 32 of the Directive).
iv. Regulation of tariffs (pursuant to Article 37(6) and (10) of the Directive).

(Note: The Directive and the Regulation the text refers to are Dir. 2009/72 and Reg. 714/2009)

Source : Rubino, A., & Cuomo, M. (2015). A regulatory assessment of the Electricity Merchant Transmission Investment in EU. *Energy Policy*. p. 467.

F. List of interviewees

Interviewees are listed in chronological order.

Name	**Position**	**Entity**	**Type**
Brice Libert	Adviser	CREG (Commission de Régulation de l'Electricité et du Gaz)	Belgian regulator
Samson Hadush	Power system economics consultant	ENGIE Impact	Consultancy wing of electricity generator ENGIE
Bert Maes	CEO	Nemo Link	Regulated line
Kristof Sleurs	Head of Grid Development department	Elia	Belgian TSO
Jan Kostevc	Head of Electricity Infrastructure team	ACER (Agency for the Cooperation of Energy Regulators)	European regulator
Jan Hoogstraaten	Manager Regulatory Affairs	BritNed	Merchant line
Gérald Sanchis	Head of staff of the President	ENTSOE (European Network of Transmission System Operators for Electricity)	European TSOs association
Maximilian Rinck	Senior Business Analyst	EPEX SPOT	Power exchange

Oliver Koch	Head of Internal Energy Market unit	DG (Directory General) Energy	European Commission
Isabelle Gerkens	Head Regulatory and Market	EGI (Elia Grid International)	Consultancy for interconnector projects

G. Interview guide template

Introduction

The aim of this master thesis is to identify financial barriers to the participation of Europe to a global electrical grid (e.g. by connecting with Greenland, North America, or enhancing connections with Africa). This interview is intended to verify and confront theoretical insights gained from the literature review I have previously done on interconnector theory.

If it is ok for you, I will record our conversation in order to analyze the data and to write transcript as I have to include them as appendix to my master thesis.

1) Could you please introduce yourself, so I know a bit about your background and your work in your organization?

2) Do you think the participation of Europe to a global grid is realistic? Achievable? What do you see as the main barriers to its participation?

3) What can be, according to you, the main financial barriers to its participation and the materialization of subsequent interconnections (e.g. with Greenland, North America, Africa)?
   - What are the reasons behind the materialization of the barriers you just mentioned?
   - What are the consequences of these barriers?
   - How can the barriers be avoided, or their consequences mitigated?

4) Are there financial barriers intrinsic to the electricity market structure/characteristic (without going into specific regulation/investment schemes) with regard to the needed interconnection developments for the participation of Europe to a global grid?

   - What are the reasons behind the materialization of the barriers you just mentioned?
   - What are the consequences of these barriers?
   - How can the barriers be avoided or their consequences mitigated?

5) What do you think are the problems inherent to regulated and merchant investment schemes for interconnectors with regard to the needed interconnection developments for the participation of Europe to a global grid?
   - Do you think these two schemes are appropriate for a participation of Europe in a global grid and, if not, which potential problems do you see arising from such schemes?

- Do you see regulated investment and merchant investment as credible compatible solutions? What should be changed?

- What are the reasons behind the materialization of the barriers you just mentioned?
- What are the consequences of these barriers?
- How can the barriers be avoided, or their consequences mitigated?

6) What are the solutions? Are there good practices or examples that show international/intercontinental electricity interconnections could work in Europe or elsewhere in a large scale? What can/should we learn from them?

Thank you very much for your help and time. I sincerely appreciate it.
Maximilien

Note: questions in red were aimed to guide the interviewee’s thoughts response if he/she didn’t know what to cover but were not much used in practice.

H. Interviews

Organization: CREG (Belgian National regulating authority)

Interviewee: Brice Libert

Date: 31st of March 2020

Pourriez-vous vous présenter afin que je connaisse mieux votre travail et ce que vous faites à la CREG ?

J'ai une certaine expérience en développement de grands projets d'interconnexions. Je suis notamment un des architectes du mécanisme de « cap-and-floor » qui a été développé depuis 2010 avec le régulateur ofgem en vue de permettre le financement, la construction et opération de l'interconnexion Nemo qui a été mise en service en 2019 entre la Belgique et la Grande-Bretagne et qui traverse 3 eaux territoriales (UK, Belgique et France). J'ai une certaine expérience avec ça et puis, de manière générale, je travaille sur tout ce qui est processus de fixation des tarifs de transport du gestionnaire de réseau de transport Elia depuis 2008. On est dans ce cadre-là régulièrement confronté à des problématiques de réalisation d'un investissement dans le cadre duquel on a notamment mis en place toute une série d'incidents au cours des dernières années pour s'assurer que le gestionnaire de réseau de transport réalise les investissements prévus en Belgique, en tout cas ceux qui étaient annoncés.

Pensez-vous que la participation de l'Europe à un réseau mondial d'électricité est réalisable ? Quels seraient les plus grands freins à sa réalisation ?

Ce que je vais dire ici est mon point de vue personnel. Quand j'ai commencé à travailler à la CREG, il y avait un projet qui s'appelait Desertec donc on parlait tout le temps. Cela consistait à mettre des panneaux photovoltaïques au Maghreb un peu partout et de les relier via des interconnexions DC via la Méditerranée vers l'Europe. Depuis lors c'est un projet dont on ne parle plus du tout. Que s'est-il passé ? Le printemps arabe est passé par là et a déstabilisé cette région du Moyen-Orient. C'est pour moi un premier frein au développement de ce type d'infrastructure : l'évolution géopolitique dans les pays qui sont concernés par ce développement d'infrastructure. Très clairement, le Groenland est un pays qui est certainement beaucoup plus stable que le Moyen-Orient, mais c'est quand même quelque chose à garder en tête. Le 2e élément, c'est bien sûr la quantité de financement qui est nécessaire pour réaliser ces projets. On parle certainement de plusieurs milliards d'euros voir dizaines de milliards d'euros voir même centaines. Ce sont certainement des montants d'investissement qui sont très conséquents. Enfin, ce qui ne facilite pas la discussion, c'est certainement aussi le nombre de parties intervenantes. Si on parle de réseau maillé, inévitablement ça connecte plus de deux pays les uns avec les autres, ce qui veut dire qu'il y a beaucoup plus d'intervenants autour de la table pour se mettre d'accord, que ce soient les gouvernements ou les gestionnaires de réseau de transport qui sont probablement les acteurs économiques qui sont impliqués dans la réalisation de ce genre de projet. La question se pose aussi de qui va supporter les coûts, quels sont les revenus, qui va bénéficier des revenus ? Ce sont des discussions qui sont très compliquées et qui généralement ont tendance à ne pas se dérouler très rapidement. Pour moi ce sont à première vue les trois premières difficultés que je vois. D'abord le risque géopolitique (la stabilité des régions qui sont concernées par les projets où on va installer par exemple les éoliennes qui seront raccordées, in fine, au réseau européen). Ensuite les montants d'investissements très conséquents qui s'ajoutent déjà à des montants d'investissements conséquents qui sont investis dans les différents pays européens actuellement en vue de réaliser la transition énergétique. Et enfin le nombre de parties prenantes autour de la table qui devront décider de la manière suivant laquelle les coûts de ces investissements en capacité de transport sont répartis entre les différents pays et comment les éventuels revenus seront également répartis entre ces différents pays.

Voyez-vous d'autres freins à la réalisation d'interconnections intercontinentales ?

Non pas à première vue je pense que ce sont déjà des assez gros problèmes.

Quels sont les causes et les conséquences des problèmes que vous venez de mentionner ?

En ce qui concerne le risque géopolitique, il suffit de regarder ce qui s'est passé avec Desertec. C'est très bien de se dire qu'on va mettre des panneaux photovoltaïques dans une région du monde et qu'on va investir massivement pour les raccorder au réseau européen. Si pour une raison ou pour une autre, que ce soient des islamistes ou un général loufoque décide que finalement les capacités photovoltaïques soit ne viendront pas, soit sont nationalisées pour être utilisées à d'autres fins, on aurait investi des milliards d'euros en capacité de transport qui seront tout à fait « stranded », c'est-à-dire qui n'auront plus aucune utilité et dont la valeur comptable passe de plusieurs milliards d'euros à 0 en quelques heures ou quelques minutes. C'est déjà une conséquence assez importante. Au niveau des montants d'investissement, il y a déjà des pays qui doivent investir très massivement dans le réseau de transport ; je pense par exemple à l'Allemagne qui, historiquement, avait développé toute sa capacité de production dans le sud pour alimenter les industries de l'Allemagne de l'Ouest qui étaient justement situées dans cette région. Avec la transition écologique, l'idée est de développer massivement de l'éolien dans le Nord, d'où une grosse difficulté qui vient à devoir tirer des centaines et milliers de kilomètres de lignes à haute tension à travers le pays, ce qui a un coût très conséquent. Donc, en plus de cette forte augmentation des tarifs qui est liée à ce développement interne au réseau allemand, pour prendre un exemple facile et compréhensible, on viendrait rajouter encore une couche pour construire un réseau qui va être très coûteux en mer. Ça entraîne quand même pas mal de questions en termes d'acceptabilité. Aussi si on regarde, par exemple, les factures que les clients résidentiels où certaines industries paient en Allemagne, c'est déjà nettement supérieur à ce qu'on constate en Belgique. Parfois, on voit encore certaines catégories de clients qui paient 2 à 3 fois plus. C'est principalement lié à la composante transport d'électricité, mais également à la composante financement des énergies renouvelables. La question est : « est-ce que le consommateur allemand va être prêt à faire encore plus de sacrifices au niveau de sa facture d'électricité ? ». Pour une bonne cause, ce n'est pas ça le problème, mais ça pose quand même pas mal de questions sur la possibilité de réaliser ce genre d'investissement après l'échéance. Quand bien même, d'un point de vue technique, c'est certainement quelque chose de très séduisant de voir des éoliennes construites à des endroits où elles vont tourner en pourcentage du temps beaucoup plus que ce qu'on voit ici à la côte belge, c'est très attractif mais il faut voir qui sera prêt à supporter le coût d'un tel développement.

Et enfin le nombre de parties autour de la table. Puisqu'on voit que les montants d'investissements sont très conséquents, le fait de devoir payer même 1% en plus ou en moins de cet investissement ont des conséquences qui sont très importantes pour toutes les parties qui sont autour de la table. Ce ne seront pas des discussions qui vont être très faciles.

Y a-t-il des freins financiers liés à la structure et aux caractéristiques du marché électrique ?

Très clairement, supposons qu'on mettrait 40 000 mégawatts de capacité de production au Groenland en éolien. La question se pose de savoir combien de milliers de mégawatts de capacité de transport on va connecter entre le Groenland et l'Europe. Intuitivement, on pourrait se dire on va mettre 40 000 MW de capacité de transport ce qui aurait pour avantage qu'à aucun moment il n'y aurait de congestion sur la capacité de transport puisque même dans le cas où toutes les éoliennes tourneraient à plein régime, il y aurait suffisamment de capacité de transport. Cela peut paraître séduisant, mais c'est aussi l'option la plus coûteuse. Cela étant, on pourrait se dire qu'on ne va peut-être pas viser d'installer 40 000 MW de capacité de transport parce que peut-être qu'on se rend compte que ce n'est qu'une proportion du temps qui est relativement réduite. Donc, on pourrait envisager une capacité de transport sensiblement plus faible, ce qui permettrait d'injecter au niveau européen la plupart de l'énergie qui est produite au Groenland pour prendre un exemple. Dans ce cas-là, il y aura certains moments où, inévitablement, il y aura une congestion de la capacité de transport, c'est-à-dire qu'on ne sait pas transporter toute la capacité qui est produite au Groenland. Il y aurait vraisemblablement une différence de prix qui apparaîtrait entre le hub au niveau du Groenland et au niveau européen, ce qui générerait sur cette capacité de transport des rentes de congestion qui pourraient à un certain moment être utilisées pour financer cette capacité de transport. On voit que c'est une discussion qui n'est pas évidente. Intuitivement, on pourrait se dire qu'on aurait intérêt à mettre la capacité de transport maximale, de sorte qu'il n'y ait pas de mégawatt/heure de perdu. Mais d'un autre côté si on pense à comment on pourrait financer ou en tout cas limiter au maximum le coût qui serait supporté par la société, par le consommateur européen, pour développer cette infrastructure, on pourrait avoir la réflexion de se dire qu'il n'est probablement pas indispensable d'avoir toute cette capacité de transport qui est construite. On pourrait construire un petit peu moins, ce qui allège sensiblement le coût et, d'autre part donc, pourrait à un certain moment générer des rentes de congestion sur la capacité de transport et pourrait en partie financer le développement de l'interconnexion. C'est un mécanisme qu'on a utilisé avec le régulateur britannique pour financer l'interconnexion entre la Belgique et la Grande-Bretagne. On n'a pas eu la discussion de savoir concrètement « est-ce qu'on limite la capacité par rapport à ce qui est économiquement optimal ? ». Premièrement au sein du marché européen c'est un raisonnement qui est très peu accepté par les autorités européennes et on avait surtout un problème au niveau de la capacité de transport au niveau de la côte belge vers l'intérieur des terres qui est limitée à 1000 mégawatts. On a donc mis une interconnexion de 1000 mégawatts. Comment cela fonctionne : il y a des gros différentiels de prix qui apparaissent entre la Grande-Bretagne et la Belgique ; à ce moment-là, à chaque heure, la capacité de transport est valorisée au différentiel de prix entre les deux pays multiplié, par 1000 mégawatts puisque si elles sont congestionnées c'est qu'elle fonctionne à plein régime dans les 2 directions. Et donc, ces rentes de congestion, on accepte que ce soit l'opérateur de l'interconnexion qui les conserve jusqu'à un certain niveau, c'est-à-dire qu'on l'a plafonné. C'est le principe du cap : sur base annuelle ils peuvent conserver un maximum de rentes de congestion et, inversement, si l'interconnexion a rendu un certain critère de disponibilité, on leur garantit que si le différentiel de prix disparaît totalement, on leur assure une rémunération minimale par le biais d'un floor. Dans le cas où les rentes de conjonctions sont supérieures au cap où inférieures au floor, sachant qu'il y a quand même un espace assez conséquent entre le niveau du cap et du floor, c'est l'utilisateur du réseau belge qui, soit en bénéficie, soit doit intervenir financièrement pour contribuer au financement de cette interconnexion. Dans les simulations qui ont été faites ex ante, des résultats de la première année d'exploitation montrent qu'on est quelque part entre les deux, ce qui montre que si les choses continuent comme elles ont commencé et comme elles sont anticipées que le développement de l'interconnexion Nemo ne devrait pas coûter où rapporter 1€ à l'utilisateur du réseau de transport belge.

Vous dites que les rentes de congestion seraient utilisées pour financer d'autres interconnexions ou la même interconnexion ?

Pour Nemo on a été assez innovant parce que la législation européenne limite fortement l'utilisation de rentes de congestion qui sont perçues sur les interconnexions et cette limitation a tendance à être de plus en plus strictes au fil des directives européennes. Donc les rentes de congestion initialement ne pouvaient être utilisées qu'à trois choses : développer les interconnexions, maintenir ou augmenter la capacité existante, et diminuer les tarifs. Cette troisième possibilité est devenue vraiment l'exception à la règle au fil des directives européennes à savoir qu'il faut démontrer qu'on ne peut plus augmenter la capacité ou qu'on n'a pas d'argent pour réduire les tarifs. Nous, en Belgique, on a toujours fait comme ça. On a très fortement interconnecté avec les pays voisins et c'est dû à une volonté, une politique volontariste, de développer les interconnexions qui ont été financées par les utilisateurs du réseau belge très tôt dans le cadre de l'ouverture du marché. Donc ça nous paraît tout à fait normal, puisque le consommateur belge a déjà fortement soutenu les investissements dans les capacités interconnexions aux frontières, et bien les rentes de congestion qui sont perçues sur ces capacités et qui, entre nous, ne sont pas spécialement liées à un problème de congestion en Belgique (cela pourrait être lié à une congestion ailleurs sur le réseau européen). On n'allait pas indéfiniment continuer à augmenter la capacité d'interconnexion aux frontières et c'était normal que cela revienne dans la poche du contribuable belge. Ça a été la politique historique en belgique. Aux Pays-Bas, ils ont capitalisé progressivement les rentes de congestion qu'ils percevaient sur leurs frontières en vue de financer le développement d'une future interconnexion notamment dans le cadre de Norned. On a un petit cochon, on le rempli et lorsqu'il est rempli, ils ont fait une interconnexion avec ça. Nous dans le cadre de Nemo on a été assez innovant dans la mesure où on s'est dit « pour le moment on n'a pas d'argent, notre petit cochon est vide. » Chaque année, on le vide pour le redistribuer aux utilisateurs du réseau. On est presque sûr que Nemo va générer beaucoup de rentes de congestion car la Grande-Bretagne est assez peu connectée au continent, le mix énergétique est très différent, ils n'utilisent pas la même devise, ils ont un décalage horaire d'une heure. Il y a plein de raisons qui font qu'il y a un différentiel de prix très conséquents entre la Grande-Bretagne et la Belgique. On s'est dit « on va tabler sur le fait qu'il y aura des rentes de congestion dans le futur et on va mettre en place un cadre régulatoire qui redistribue ses rentes de congestion en priorité pour le financement de l'interconnexion. » Mais on va mettre certaines limites tant à la hausse qu’à la baisse, sachant que la limite inférieure entre nous ils ne gagnent pas vraiment leur vie. Mais si on se trouve au niveau du cap, ils gagnent assez bien leur vie mais ils ont pris un risque additionnel par rapport aux investissements assez conséquent puisqu’ils ont pris le risque de ne pas bien gagner leur vie et dans certains cas s'ils ne gèrent pas bien le budget ils risquent de perdre de l'argent. Ce qui est assez innovant c'est qu'on a donc toujours respecté la directive européenne qui est de dire que les rentes de congestion servent à développer ou à maintenir en place les interconnexions. Mais le caractère innovant du mécanisme qu'on a développé avec les anglais et que les anglais ont après transposé à deux autres interconnexions avec le continent c'est que les rentes de congestion qui seront perçues sur l'interconnexion servent à financer le développement de cette même interconnexion.

Pour étendre la capacité ou plutôt pour repayer les dettes ?

Pour payer tout ce qui est lié à l'investissement initial, c'est-à-dire les amortissements, la rémunération du capital des investisseurs, les charges du personnel, les services et biens divers

Si j'avais bien lu, ce sont les opérateurs du réseau belge et britannique qui sont développeurs du projet. Est-ce exact ?

Du côté belge c'est effectivement le gestionnaire de réseau de transport qui détient 50%, du côté britannique c'est plus compliqué parce que le gestionnaire du réseau de transport National Grid ne peut historiquement pas développer d'interconnexion. En fait, National Grid est la filiale d'un holding qui a lui-même d'autres filiales, qui elles développent des interconnecteurs. C'est le cas par exemple de Britned. Ils ont à chaque fois des sociétés différentes qui développent une interconnexion. Ici on a Nemo Link qui est à 50% détenu par une filiale du holding qui détient le gestionnaire de réseau de transport anglais et à 50% par Elia du côté belge.

Que pensez-vous des régimes merchant et regulated ? Quels problèmes y voyez-vous pour une réseau mondial ?

L'exemple de Nemo est très intéressant parce qu’en fait, historiquement, les régulateurs belges et anglais ont une approche qui était tout à fait différente. Ce n’est pas spécialement la volonté du régulateur belge mais c'est qu'en Belgique, Elia a une position très confortable dans le sens où elle a un monopole légal. C'est acté dans la loi : seul Elia peut développer des capacités de transport en Belgique. Ça peut paraître anodin mais c'est loin de l'être et c'est assez exceptionnel au niveau européen ce qui fait que la Commission européenne est toujours en train d'instruire un dossier à ce propos-là pour supprimer ce monopole légal. Dans certains cas, le Gestionnaire de réseau de transport fait un peu l'enfant difficile et malheureusement cela arrive c'est-à-dire qu'il n'a pas envie de faire l'investissement soit parce qu'il a suffisamment d'autres choses à faire, soit il estime qu'il ne gagne pas assez bien sa vie. Eh bien dans ce cas-là, le régulateur n'a pas la possibilité de faire ce qui est tout à fait possible dans un pays comme l'Allemagne, c'est-à-dire de lancer un tender pour qu'un tiers puisse avoir la possibilité de réaliser l'investissement à charge ensuite, soit de continuer à l'exploiter, ou de transférer au gestionnaire de réseau de transport l'asset qui a été développé. Ça c'est une possibilité qui existe dans les pays voisins, maintenant quand on discute avec les régulateurs étrangers concernés ils nous disent que le fait que cette possibilité existe suffit pour qu'on ne doive pas l'utiliser, c'est-à-dire que le gestionnaire de réseau de transport est un peu comme un jardinier qui a un beau jardin et qui en prend soin. Il voit d'un très mauvais œil que quelqu'un d'autre vienne commencer à cultiver une petite parcelle sur son terrain. Donc cette possibilité suffit pour faire pression sur le gestionnaire de réseau de transport pour qu'il réalise cet investissement. En Belgique on n'a pas cette possibilité : exemple notre gestionnaire de réseau de transport était un peu récalcitrant à investir dans une interconnexion entre la Belgique et la Grande-Bretagne parce qu'il estimait qu'il ne gagnait pas suffisamment sa vie : il voulait une rémunération plus importante. Du côté anglais historiquement le gestionnaire de réseau de transport ne peut pas développer d’interconnexion. La raison derrière cela c'est parce qu'il y avait moins d'intérêt à se raccorder au continent (logique thatchérienne) et en tout cas il y avait la logique de se dire que si les gens sont convaincus qu'il faut se raccorder au continent, ils n'ont qu'à en supporter les risques et les avantages. Et donc ce qu'il s'est passé au cours des dernières décennies entre la Grande-Bretagne et l'Europe, c'était très peu de projets d'investissement et les projets d'investissement qui ont abouti juste avant Nemo qui est le projet Britned, ça ne s'est pas très bien passé pour les développeurs du projet puisque la Commission européenne est tout d'un coup intervenue et a décidé que c'était fort bien de développer une interconnexion sur base du modèle merchant entre la Grande-Bretagne et les Pays-Bas. Mais la Commission européenne avait certains doutes, elle suspectait que les rentes de congestion allaient être beaucoup plus importantes que ce qui était repris dans le dossier de demandes d'exemption. En toute fin de parcours, ils ont imposé un plafond à la rémunération sur base d'un modèle IRR. S'il dépasse 12% vous devez restituer tout ce qui est au-dessus de 12% aux utilisateurs du réseau de part et d'autre. Ça a échaudé le régulateur anglais, le groupe National Grid qui est un acteur privilégié pour développer des interconnexions avec le continent, puisqu'ils ont leurs profits qui est plafonné à la hausse mais aucune garantie de soutien à la baisse dans le cas où les rentes de congestion pour une raison ou une autre sont trop faibles. Et donc on s'est retrouvé en 2008 pour mettre en perspective le cheminement suivi dans le projet Nemo. Début de discussion en 2008 et mise en service en 2019, c'est un bon benchmark du rythme de réalisation ; ici on parle d'une interconnexion qui fait quelques centaines de kilomètres, alors que le projet qu'on mentionne avec le Groenland fait certainement des dizaines de milliers de kilomètres d'interconnexion. Ici on s'est retrouvé en 2008 avec le régulateur anglais et on s'est rendu compte qu'en faisant chacun un pas dans la direction de l'autre, on pourrait vraisemblablement trouver une solution qui arrange un peu tout le monde, c'est-à-dire d'une part, nous étions prêts à ce que la rémunération soit plus importante pour le gestionnaire de réseau de transport pour peu qu'on ait une interconnexion qui soit disponible, bien gérée et pour peu que les rentes de congestion soient importantes et qui augmentent la rémunération de l'opérateur dans le cas où il se comporte bien ne mènent pas à une augmentation des tarifs au niveau belge. Du côté anglais ils étaient intéressés parce que ça permettait de continuer à donner toute une série de stimulants qui sont présents dans l'approche merchant où le développeur a intérêt à gérer chaque euro qui est dans sa poche parce que sinon ce sont des euros qui vont directement en moins dans sa poche, ce qui n'est pas le cas dans le cadre de l'approche régulée, où, pour ce qui est des coûts, la charge de la preuve revient généralement sur les épaules du régulateur avec une asymétrie d'informations qui limite assez fort les possibilités d'intervention. Le régulateur anglais était intéressé par maintenir ce plafond à la régulation qui était imposée quoi qu'il arrive par la Commission européenne mais en contrepartie offrir une rémunération minimale basse à l'opérateur de telle sorte que, s'il est suffisamment disponible mais que les rentes de congestion sont faibles pour des raisons qui sont extérieures à l'activité d'opération de l'interconnexion à proprement parler, et bien dans ce cas on socialise une partie des pertes avec les utilisateurs du réseau. L'élaboration de ce cadre régulatoire a bien pris 4-5 ans. Ça s'est quand même étalé sur plusieurs années avec quand même des discussions qui ont été assez intenses. On était à un rythme à un certain moment d'une réunion par mois avec les opérateurs. Et puis la décision finale d'investissement a été prise en 2015 et puis il a encore fallu presque 4 ans pour réaliser les stations de conversion de part et d’autre et puis placer les câbles qui raccordent ces 2 stations de conversion ACDC. Cette expérience du projet Nemo permet d'illustrer la différence entre l'approche merchant et l'approche régulée et démontrer qu’entre les deux, il est possible d'avoir quelque chose, par exemple le mécanisme de cap-and-floor qu'on a développé avec les anglais et que les anglais ont transposé pour d'autres projets d'interconnexions en faisant presque un copier-coller puisque le projet Nemo était un peu leur projet pilote pour développer leur nouveau modèle de régulation des interconnexions. Je sais qu'en France ils ont développé quelque chose qui s'apparente assez vaguement, à la française, ça ressemble très fort à ce qu'on fait mais ça n'en porte pas le nom. Donc on voit qu'il y a toute une série de choses qui se sont développées de part et d'autre. D'une part pour éviter, au niveau du mécanisme régulé, les risques inévitables d'avoir une interconnexion qui potentiellement ne fonctionne pas où qui est mal géré d’un point de vue coûts. Mais d'autre part, pour lever certaines barrières qui sont liées au projet merchant (une certaine asymétrie au niveau des gains et des profits) qui étaient imposées par la Commission européenne, intervenue avec Britned en 2006 ou 2007

Est-ce que vous voyez un des deux modèles comme la solution ou plutôt un modèle entre les deux comme vous venez d'expliquer ?

Le fait que ce soit en dehors de l'Europe, on voit bien comme avec la Grande-Bretagne qui va bientôt sortir de l'Europe (qu'ils le veuillent ou non ils devront continuer à plus ou moins respecter ou au moins en partie les conditions qui sont imposées du côté européen pour pouvoir fonctionner on peut difficilement gérer). Une interconnexion DC c'est un peu un bouton qu'on tourne soit à gauche soit à droite pour diriger les flux dans un sens ou dans l'autre avec une certaine intensité. Si du côté européen, on impose certaines conditions en termes d'opérations et bien on est contraint de quand même suivre le Royaume-Uni, il n'est pas possible d'optimiser le fonctionnement d’une interconnexion en fonction de deux sets de contraintes qui sont différentes. Le fait que ce soit en dehors de l'Europe n'est pas un problème. La difficulté, ce sont plusieurs milliers de kilomètres de câbles jusqu’aux Etats-Unis, donc la question que je me pose est « quel est le différentiel de prix que l’on observe entre la zone PGN (qui couvre le Massachussets) et l'Europe ? ». Est-ce que ce différentiel de prix est à ce point suffisant que pour couvrir les coûts d'investissement de la pose d'un câble ? Alors j’ose imaginer que, si on arrive dans des zones très profondes en plus, outre le nombre de kilomètres de câbles, il y a aussi une complexité technique liée à la pose de ce câble. Est-ce que le différentiel de prix est vraiment suffisant que pour justifier tout simplement la réalisation de l'investissement ? C'est la première question. Si on se rend compte que les différentiels de prix sont très limités, et bien il est très fort probable qu’on puisse abandonner ce projet très rapidement. Vous pourriez faire l'exercice en prenant une hypothèse comprenant le coût par kilomètre de câbles, en prenant les mêmes hypothèses que le projet Nemo ou, peu importe. Vous pouvez trouver ces estimations sur Google : « que coûte la pose d'un câble 2000MW/km ? ». Cela vous donnera une idée très conservatrice de quel devrait être le différentiel de prix qu'on constate plus ou moins de manière constante, de telle sorte à ce que, si on opère le câble uniquement dans une direction, il peut au minimum, sur une durée de 20-25 ans, couvrir les coûts d'investissement. Cela pourrait être un « sanity check » très intéressant et très facilement réalisable avec les États-Unis. Il y a déjà les données de prix et mettre une 1000MW d'interconnexion ne va avoir aucun impact sur les prix des marchés de part et d'autre. Pour le Groenland, c'est plus compliqué : il n'y a pas grand-chose à ma connaissance. Je ne pense pas qu'il y ait beaucoup d'industries ou de consommation importante sur place. La difficulté c'est que probablement si la … c'est plus compliqué à analyser, si vous avez suffisamment de capacité de transport qui est construite entre le Groenland et l'Europe pour couvrir à tout moment la capacité de production éolienne, alors le différentiel de prix sera toujours nul entre l'Europe et le Groenland. Donc ce ne sont pas les rentes de congestion qui vont permettre de rentabiliser l'investissement en capacité de transport. Si par contre il n'y a pas suffisamment de capacité de transport qui sont construites parce qu'on se dit « au fond ça ne coûte rien de construire des éoliennes là-bas, personne ne se plaint et ça tourne un nombre de pourcentage d'heures très important, » et intuitivement si on met beaucoup plus de capacité éolienne que de capacité de transport, il va y avoir certains moments où l'interconnexion est congestionnée et les prix vont devenir négatif au niveau du Groenland. Puisque l'idée sera de se dire certaines heures de l'année on préfère avoir des prix négatifs et normalement ce qui va se passer c'est qu'on peut piloter les éoliennes pour équilibrer ce qu'il faudra bien équilibrer sur cette zone. Il y aura la possibilité de faire du réglage sur les éoliennes. A partir du moment où la capacité de transport est congestionnée, il n'y a plus vraiment de flexibilité. En tout cas la seule possibilité s'il y a trop de production au niveau du Groenland c'est de demander aux éoliennes d'arrêter leur production et la manière de le faire, si on réfléchit en termes de fonctionnement du marché, c'est d'avoir des prix qui deviennent négatifs à ce moment-là. S'ils n'ont pas de mesures de soutien (et je ne pense pas que ce soit le but de commencer à subsidier des éoliennes dans un pays fort éloigné en tout cas pas de la poche des consommateurs européens) et bien dans ce cas-là, il y aura des prix négatifs. Le prix négatif va faire que progressivement certaines éoliennes se coupent jusqu'au moment où on peut imaginer que le prix devient nul au niveau du Groenland et que la capacité de transport exporte le maximum possible à ce moment-là. D'où, dans ce cas-là, une rente de congestion qui apparaîtrait entre le Groenland ou le prix serait de 0€ et le prix européen qui serait vraisemblablement de plusieurs dizaines de euros du mégawattheure. Donc ça pourrait être une piste à creuser d'avoir une capacité de transport qui serait sous dimensionnée par rapport à la capacité éolienne qui est installée au Groenland.

Dans le cas où la capacité de transport serait égale à la capacité de production, vous dites que ce ne serait pas envisageable parce qu'il n'y aurait pas de rentes de congestion. Ne serait-il pas possible de se dire que c'est du coup le consommateur final qui paierait pour le transport de cette énergie-là ?

Tout est toujours envisageable, bien sûr, mais comme j'ai donné l'exemple de l'Allemagne où ils paient déjà excessivement cher rien que pour renforcer leur ligne en interne. Va-t-on demander à nos voisins allemands de payer encore potentiellement (ça dépend de la taille du projet) mais si on part dans l'idée de construire des dizaines de milliers de mégawatts d'éoliennes au Groenland, ça va coûter des montants qui sont assez conséquents et qui se chiffreront encore une fois sur la facture des consommateurs. C'est une réflexion tout à fait personnelle que je mets sur la table mais peut-être une possibilité serait de se dire « on sous-dimensionne un petit peu la capacité de transport par rapport aux éoliennes qui sont installés » ça permet déjà de réduire les coûts d'investissement qui sont quand même assez conséquents pour chaque câble que vous allez tirer vers le Groenland. Deuxièmement, l'intérêt serait de permettre à certains moments de générer des rentes de congestion. Il faut un petit peu voir comment cette capacité de transport est proportionné par rapport aux éoliennes mais, grosso modo, si la capacité de transport n'est pas congestionnée parce que le vent n'est pas à son maximum au Groenland et que donc la capacité de production en MWh est inférieure à ce qu'on peut transporter sur le câble, mécaniquement le prix au niveau du hub Groenland serait au niveau du prix du marché européen. C'est à ce moment-là que les éoliennes gagneraient de l'argent. Par contre, dès qu'il y a un peu trop de production par rapport à la capacité de l'interconnexion et bien là on peut s'attendre à ce qu'il y ait des prix qui chutent vers 0€ ou quelque chose comme ça. A ce moment-là, les différentiels de prix pourraient générer des rentes de congestion qui, en fonction d'une part, de la taille de la capacité installée du parc éolien au Groenland, et d'autre part, de la taille de la capacité de transport, pourraient peut-être en partie contribuer à financer cette capacité de transport. Donc pour résumer, il y a deux intérêts à sous-dimensionner : il y a très clairement la réduction du coût d'investissement et puis d'autre part l'apparition potentiellement d'une certaine source de revenus qui serait des rentes de congestion et les deux permettent, s'il faut quand même faire contribuer les consommateurs européens, sensiblement de diminuer la taille de la contribution. C'est une réflexion tout à fait personnelle je raisonne ici avec toi.

Y a-t-il des solutions ? Des bonnes pratiques ou des exemples qui montrent que des interconnections intercontinentales pourraient fonctionner en Europe ou ailleurs ?

Non, des projets vraiment de hub en mer qui raccordent différents pays je n'en connais pas. Il y a quelques petits exemples d'interconnexions de mémoire entre le Danemark et l'Allemagne, mais à chaque fois ce sont deux pays qui sont raccordés via plus ou moins un parc éolien ou quelque chose comme ça. Ce n'est pas la même chose mais c'est peut-être ce qui se rapproche le plus. On trouve ça généralement autour du Danemark. Il y a quelques projets, de mémoire, qui ont été mis en place et qui existent déjà. Parce que c'est bien d'avoir des projets comme on a parlé de Desertec (on aurait pu en parler pendant des journées mais in fine on voit ce que ça a donné, il n'y a rien de concret qui était sorti). Donc des projets vraiment réalisés, à première vue je regarderai dans cette zone-là, autour du Danemark. Mais c'est assez réduit en termes de taille et l'objectif était de tirer profit d'une infrastructure qui était déjà existante pour raccorder un pays à un parc éolien en se disant qu'on va raccorder un autre pays via ce parc éolien. Cela étant, je ne sais pas vraiment comment ça fonctionne concrètement. Je n'ai pas l'impression qu'ils ont développé une zone de prix spécialement pour le parc éolien qui est situé dans la Baltique de mémoire. Je ne sais pas par exemple qui a raccordé en premier : est-ce que le Danemark contribue à juste payer son raccordement au parc éolien, ou est-ce qu'il intervient dans l'infrastructure, dans l'investissement allemand pour accorder le parc éolien ? Je ne sais pas répondre, mais c'est peut-être là où on peut trouver des pistes de réflexion additionnelles, soit pour confirmer, soit pour infirmer ce que je viens de présenter ici.

Une des idées serait justement de raccorder en ayant été raccordé au Groenland de raccordé par après le Groenland aux États-Unis ce qui permettrait d'importer de l'électricité des Etats-Unis en Europe.

Encore une fois, il suffit de calculer un câble de 1000 MW, ça a un certain coût, de regarder la distance à vol d'oiseau (sachant que ce n'est jamais à vol d'oiseau parce qu'il faut éviter des récifs). Mais en prenant un vol d'oiseau, sur base de données qui sont des données de pose de câbles en eaux qui sont relativement peu profondes, je pense que ma première impression (je serais ravi d'entendre le contraire) c'est que ça va être impossible de rentabiliser ça par un quelconque spread entre les États-Unis et la Belgique. Donc voilà, après si le but c'est aussi de développer au Groenland de l'éolien pour faire bénéficier les États-Unis alors c'est une autre idée, un autre objectif et quelque part, qu'on soit directement raccordé aux États-Unis, ça ce n'était pas l'objectif principal. C'est bien à avoir mais ce n'est pas un objectif qui justifie le développement du projet.

Le projet du global grid en tant que tel, ce serait de se dire qu'il y aura toujours une capacité restante qui pourrait être alloué à l'échange entre les États-Unis et l'Europe et que donc il y aurait aussi des rentes de congestion qui seraient générées en plus de toute la capacité qui va être réservée pour le transfert de l'éolien du Groenland dans les deux sens.

Ça nécessite certainement des simulations qui vaudront ce qu'elles valent. Ce sont des simulations qui ont été faites dans le cadre de Nemo : il y avait des consultants qui ont fait des modèles qui simulaient les parcs de production à différentes échéances (2020, 2025, 2030) de part et d'autre et aussi les pays qui étaient les pays voisins et qui calculaient heure par heure des prix. Sur base de ça, ils regardaient dans une deuxième étape quel serait le flux qui pourrait être généré sur l'interconnexion et quels sont les rentes de congestion qui pourraient être obtenues sur cette base donc c'est certainement un premier exercice pour confirmer ou infirmer le raisonnement. Maintenant, je le dis un bon « sanity check » serait simplement de contrôler quel est le prix moyen d'un côté et de l'autre et de mettre ça en relation par rapport au cout de l'investissement de l'interconnexion. Si cette analyse n'est pas prometteuse, il y a un problème.

Le prix moyen n'est qu'une partie des sources de rente de congestion, il y a aussi la volatilité de part et d'autre à analyser : on pourrait avoir 2 pays qui ont un prix moyen identique mais qui ont des prix totalement décorrélés. Dans ce cas-là, il pourrait y avoir des grandes rentes de congestion. La première étape est quand même de regarder au niveau du prix moyen « est-ce qu'il y a un écart qui est déjà conséquent ? ». Si tel n'est pas le cas, c'est déjà un élément qui doit appeler certaines questions avant de se lancer.

Organization: Engie Impact

Interviewee: Samson Hadush

Date: 7th of April 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

My name is Samson Hadush. I did my studies at KU Leuven in the engineering department. My PhD was actually on transnational electricity transmission projects with a European focus and the so-called Projects of Common Interests (PCIs). I was looking at how investments between two neighboring European countries could impact welfare and how this welfare would be redistributed between different countries and looking at the costs for these interconnectors and how they would be allocated. So, I used this concept called beneficiary-based principle because the way it works now doesn't really reflect the way countries benefit. For example, an interconnection between two neighboring countries could benefit a third country but countries each pay for the part of the interconnectors that is in their country.

So it's just to see how the economics of interconnectors and their physical laws apply in framing these benefits and how we can use that to allocate the costs of transportation.

After that, I mainly dealt with regulatory topics (e.g. how regulation affects investments at distribution level, how to coordinate transmission and generation investments through incentive design). I am currently working as a consultant at Engie Impact mainly looking at power systems economic topics. Engie Impact is the consultancy wing of the parent company Engie. They do projects for Engie and other clients.

Do you think the participation of Europe to a global grid is realistic? Achievable? What do you see as the main barriers to its realization?

Coming back to the Projects of Common Interests (different scale but same kind of vision) which are aiming at interconnecting Europe, creating a single electricity market and integrating more renewables (with lots of offshore wind farms being developed in the North Sea). For those to happen, you need some large investments in cross border transmission. For that, one of the key barriers was financing because it was happening during the financial crisis but, apart from this, regulation was also an issue because it's a regulated business not a free business like any other kind of business. So, the regulation of different countries was different basically: some countries apply a totex approach. What happens is the TSO invests on a line and the costs are recovered through tariffs (i.e. the remuneration) which depends on the regulator. For example, you could have a price cap where you cannot charge more than a certain level which brings a risk as you might not recover all your cost. So, the regulatory uncertainty is one difficulty. Today at European level they decided that they would create these very crucial investment projects that would be supported by EU funds so that's why they called some of these projects as "PCIs". So, one of the issues was to facilitate the financing of the projects. The second issue was actually the public acceptance because people were resisting that transmission lines are put next to their homes (NIMBY), so people became more conscious about the visual impact. The need to get a permit is not to underestimate, you have to make sure that that the community is on board and all these kinds of things needed when you roll out such investments.

What can be, according to you, the main financial barriers to the materialization of such interconnections?

For me the financing. It's a critical infrastructure, so lots of investors would be interested. But then, there would be many risks involved: public acceptance/resistance that may harm the project materialization, regulation (i.e. the regulatory risk) if regulators are changing the regulatory frameworks from time to time, this adds risk to the investment, which has a negative impact on the financing . A third one is related to a debate going on: "do we really need these large infrastructures?". The system is more and more going towards decentralization; people are starting to put rooftop solar panels and to trade electricity among neighbors. There's this mentality of local energy communities being created. With this trend happening, what is the relevance of having these huge transmission investments, large scale investments? It could go against this trend. I am not saying we don't need them, but what could happen is that we would have a mix between centralized and decentralized large investments. So the trend towards decentralization of the electricity system can also have a negative effect. We don't know how the system will look like in the future: will it be distributed that we will all be decentralized with small units everywhere, or will it be with large units and we would have to transport energy with large cables from China? We don't know about all this, but we need to take it into account. There is uncertainty and risk associated with it that potential investors have to take into account. So, I would say it's because of how you manage these risks that will determine the financing. At a global scale if you think about it, you need some kind of agreement. Some countries would have to invest in renewables: maybe they are more expensive and the ones benefiting from these renewables would be some other countries that are transporting it so we need to have some kind of… I don't know. There is a political dimension involved. More and more countries might want to be independent and have sufficient electricity supply on their own without taking imports into account because it could be more efficient, economically speaking, that you import from another country and build a transmission line than building generation plants in your country. Although it might be more efficient for them to import, if the line is cut there's no electricity for your population. So, it's a more nationalistic thoughts the way to advocate your energy independence, it could also be another risk. In Europe, it's getting less and less as we go for integration but what about importing from China? We need some understanding; it could be a big barrier.

Are there financial barriers that are intrinsic to the electricity market structure or characteristic (without going into specific regulation or investment schemes)?

It depends on the type of projects that we are talking about. For me the electricity prices could be a big issue for merchant lines. You could have transmission lines which depend on their profits (congestion rents) so for these ones you could definitely see a high risk but at the same time, for lines recovered through regulated tariffs you have less of an issue. So, the impact of the price fluctuations directly on transmission lines would be less and, if in most cases they are regulated, I don't think there's an issue with that. Because the wholesale electricity markets are mainly for the energy profit not the transmission. The costs or investment from the regulated transmission line is recovered from regulated tariff. So, in that case the fluctuations that you have in the electricity market might not have an impact on the transmission line. However, for merchant lines, profits and revenues depends on price differences and you would have an issue.

What do you think are the problems inherent to regulated and merchant investment schemes?

For regulated investments you would need to have a lot of support from the public sphere. You need a lot of political agreement so you need agreements as well in this case; merchant lines will be hard to realize in a global context: in Europe we tried it a bit, we had a few merchant lines. Many of them were planned but never happened. Taking this to a global scale is tricky because you have different regulations, different market designs, the way the electricity market works is totally different in the US, Europe, Asia, Australia, China. As you are trying to connect these countries, the question is, if you want to create a market around these infrastructures, there's a lot of harmonization needed. Otherwise, if it has just about evacuating some power from China on the network that could be just done. So, it depends on the aim of the network: create a global electricity market or separate markets that are connected together. So, the scale is a bit different in each case.

Do you think these differences in market structures between continents are a problem for both regulated and merchant lines?

For the merchant, where does the revenue come from? Because normally for the merchant lines you will have revenues coming from price differences. But if you have different market designs... I don't see that clearly how this would go in a global contact but it would definitely have an impact especially for merchant lines.

Do you think they are credible compatible solutions?

You have to put them in a context. They could be compatible and work together. At the end of the day they're just physical lines. It's just the commercial arrangements that would be different. So, physically, yes, they would be compatible. But if you look at it from the perspective of the investor, you might have competition. It could create competition, additional risk. It should be put in a context, but in a physical sense I don't see any incompatibility.

What do you think about alternatives such as cap and floor regimes? Could they be a solution?

Probably one of the ways to deal with the risks associated with merchant lines is by putting caps & floors. Any kind of commercial arrangements is possible between these two, but then you need to decide on what kind of regulatory frameworks you have to put. How is this investment going to be? How will the cost be recovered? Who will pay for it? Does the government pay first and is it then recovered from citizens? How is it going to be arranged? These questions must be answered first, which makes the investment quite complex and difficult to realize sometimes.

Do you think it's a good idea to have these investment schemes in between to counter the disadvantages of the pure merchants or pure regulated investments?

Yes, it's a possible solution. It's about managing the risks, so, yes, it could work but you have to put it in the context which is quite important in this case when this kind of investment happens. It's not like there is one solution for every line; you need to treat them case by case. Which political borders are these lines crossing? What are the laws and regulations from these countries? What are the possible risks? All these things need to be taken into account so you cannot give one solution, you have to put it in the context and see if it works. That must be treated case by case because we are not really talking about a single country, but rather about multiple countries with their own political systems, market designs and regulatory frameworks.

What are the solutions? Are there good practices or examples that show international or intercontinental electricity interconnections could work in Europe or elsewhere in a large scale?

I think Europe has good experiences, especially in dealing with the risks as I told you. ACER also plays an important role in bridging the gap between differences in regulatory frameworks in countries and making sure these projects go ahead, so, for me, this is an interesting example. You could also have a look at this vision of Road and Belt from China. I'm not a strong believer of these transnational big networks as such; some people think that's the vision for the future but others, like me, don't see that as a vision for the electricity system we want to create in the future. And these are not easy projects to realize as such. For best experiences especially in dealing with risks, I would point out the PCIs. They are nice examples to take into account. Because it's a different scale: you have at the European Union level kind of a political agreement, the EC DG Energy is pushing for these kinds of projects, you have a European regulatory body which is trying to facilitate all this. So basically, if you want to have it at the global level you have to replicate that at another level.

I think you need to emphasize what's the vision and put it in the context of the trends that we have especially the decentralization trends and digitalization of the electricity system. How does this fit into this? Because building big infrastructure transmission lines and generation plants was the conditional way of thinking about the future of the electricity sector, but now things have changed. So, you need to put it in that context because the uncertainty related to that is also quite important whether we can make it happen or not.

Organization: NEMO Link

Interviewee: Bert Maes

Date: 9th of April 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

My name is Bert Maes. I studied applied economics. I started my career with 6 years in the audit world and 7 years the banking world and I only started at Elia in 2005. I was working for the CFO doing a lot of things on regulatory work, investment relations, and business development. In this role, we acquired 50 Hertz in 2010, which is one of the four TSOs Elia has in Germany and since 2015 I'm spending half of my time on Nemo Link. It's also the day that we started constructing Nemo Link between Belgium and the UK and it was finalized in 2019 as we started operation. I'm still working half of my time for Nemo Link as a business director for Elia as Nemo Link is a Joint Venture between National Grid and ELIA (each having 50%)

I'm also supporting EGI (Elia Grid International) which is the consulting firm of ELIA group and which is active around the world and advising possible interconnectors between Europe and other regions and continents.

Do you think the participation of Europe to a global grid is realistic? Achievable? What do you see as the main barriers to its realization?

I do believe it's achievable and I do believe it will be realized one day the question is “how long will it take?”. So, I really support that case and I think we have to evolve in this direction but as for everything it will go step-by-step. So, I do believe that the focus today should be more on interconnecting all the European countries including England and Eastern Europe and this should be further optimized. I do believe that we already do a lot of things with flow based market mechanisms, we are building lots of interconnectors and instead of AC we are making them HVDC which allows to transport more energy; so I do believe the Commission is taking right actions and is supporting further cases going forward. You are probably aware of the Project of Common Interests where they make subsidies available to invest in these projects. Personally, I believe some projects should be more subsidized than other ones; some shouldn't honestly be subsidized with public money but of course that's a political debate and it's all about lobbyists being better than other ones.
The next step is interconnecting Europe with other continents but I don't know if you heard about the Euroasia project? It is one of the PCIs and it was meant to connect Europe with Israel but there was another angle (maybe not mentioned in the PCI): it would also connect Europe with Africa through Egypt. So the PCI would be between

Greece and Crete which would then go on to Cyprus and then to Israel but there is another angle that would connect Cyprus to Egypt.

There's lots of renewables available in the Middle East and investments are foreseen In Saudi Arabia to increase that and you already have HVDC lines between Saudi Arabia and Egypt, so the connection on the African side is already there. So, if we could connect Europe with Egypt that would then be the first line between two continents.

I know there are projects between Spain and Morocco or France and Morocco through the Mediterranean Sea. So, I know there are other projects but I do believe the Euroasia might be the fastest one. I don't know if you heard about the Desertec project but it was never built, so Euroasia could be another option. That's why I'm saying it will be step by step. We will see these kinds of projects more and more towards the future and at the end I believe the whole world can be connected indeed but that will take probably many decades before it will be realized.

What can be, according to you, the main financial barriers to the materialization of such interconnections?

Couple of months ago I would have answered you that there is plenty of money so there would be no real financial burdens to make these investments. Coming back now on the Euroasia case, I think they are really relevant for these kinds of questions of course. The business case of connecting Greece and Crete and Cyprus is not positive, let's be honest. The generation of energy from these small islands is too low and the investment is too big because we speak about couple of billion euros of investments. You will never get that back based on the spreads between electricity prices between the islands and Greece. However, if you can connect it to Egypt and the Middle East, the business case becomes extremely positive as you can make use of the tremendous amount of renewables from the Middle East. So, from that perspective if there can be a guarantee given by the local authorities that the connection can be built, I don't think finding money for it will be a big hurdle. It's more about the complexity of the construction itself because you have to lay cables deep into the sea; how would the cables be replaced if something happens?

Another hurdle is whether governments will support this and make land available for the conversion stations. You probably need subsidies from Europe so you would need subsidies to build the project between Greece and Cyprus as the business case of this is not positive, but it overall depends on the business case. But the spreads between continents will be rather huge and so the business case would be large, especially at the beginning and you will find money. For the moment, there's plenty of money for these kinds of investments, rather stable, certainly when you make it regulated.

What then currently holds countries in the EU back from investing and doing it?

Good question. I have always heard there's 500 billion or 1 tn € available for this type of investments projects but it was never spent. But if you see how they are spent now subsidizing interconnections between Spain and France or France and Ireland, in my opinion this should not be the place where you should put these subsidies.

Private investors are also allowed to make business cases, but in Europe it seems like the more you get interconnected the less positive your business case is because for private investors the business case is only based on the spreads between the electricity prices of both countries. The more you go to a European integrated electricity system and markets, the lower the spreads become in the future. This is different, however, for transmissions system operators that build a regulated transmission because then, not only the spreads are important, but the full social welfare is important. It is not only about the spreads but also about the producer surplus and the consumer surplus that are generated by these interconnectors. From that perspective, I do believe that the regulated interconnection has future as there will be positive cases for social welfare but the business case as such might be negative purely based on the spreads and therefore you won't find any private money anymore between European countries. So that probably needs to shift again completely to transmission system operators and then again, I'm not saying they're not eager to build it fast, but you have for example the 10 year development plans approved by governments and that's the reason why it takes much more time to make these interconnectors.

A last important element as well if you want to build overhead lines is that it is still difficult because of the local opposition (NIMBY).

Are there financial barriers that are intrinsic to the electricity market structure or characteristics (without going into specific regulation or investment schemes)?

It might be. If you look at the offshore wind farm industry today, you see that there is a strong appetite to build a lot of offshore wind farms in the future. But for one or another reason, there's a lot of delay in building these kinds of things. You can always wonder what's the reason. One of the reasons is probably that not all of them can find a connection to the onshore. The second reason might be that the onshore grid is not able to absorb so much offshore winds in the near future so this onshore grid must be strengthened, must be changed, things like that. And of course, there is the fact that all European countries do have their own subsidy systems for offshore wind farms. Today, we are trying to set up or to convince wind farms that they should accept that they cannot only put wind on the onshore grid that they are connected to or on countries they got subsidies from, but they should be open to put their wind farm on an interconnector so that you can build hybrid interconnectors. So you build an interconnector between two countries but on that interconnector you also connect some offshore wind farms. Then, of course, these offshore wind farms can always sell wind in both directions depending on the price. For that, you need to create what we call offshore bidding zones. That could be a solution but it's very difficult and not so easy to convince the European Commission, wind farms and national regulators of the interest for the society in order to do it that way. Wind farms want to maximize their wind output and their revenues, local authorities only want to pay subsidies for wind farms that bring offshore wind to their country and local TSOs are always afraid to have too much wind because their grid is not ready to absorb this much wind. There are many difficult discussions to tackle before a massive rollout of offshore wind can get done.

I do believe that we try to find always new market mechanisms to solve these issues but it takes time and today I don’t think that market mechanisms are real barriers for these kinds of investments. But of course, regulation always plays a role. I don't know if you followed energy package climate change package that was recently approved where interconnectors always have to guarantee that 70% of the capacity must be given to the market. That, for instance, was very negative for hybrid interconnector because then, if a windfarm is connected to an interconnector, you cannot guarantee 70% anymore because the wind farm always needs to have a priority on its output.

So it's a lot of discussions but I don't think you can say that market mechanisms make it more difficult for these assets to be built.

The local interests are for countries more important than the European interests

What do you think about the power exchange markets, the way they auction the electricity and capacity? Do you think that's also a problem for future interconnectors?

This plays a very important role, and everything goes very well. EPEX SPOT and Nord Pool spots are doing a very good job. You've got JAO (Joint Allocation Office) which is selling the capacity on the long-term basis and intraday basis. They're doing fine, they're very helpful in getting our European dream having all the same wholesale electricity price over Europe.

What do you think are the problems inherent to regulated and merchant investment schemes?

My personal preference is regulated. Then the question is of course “who's going to pay for it: only the country where the interconnector arrives or the EU?”. You will also have to integrate in the market mechanisms that exist and, therefore, it's better to let exploit it by regulated but on the other hand, when starting interconnecting continents, as the spreads would be rather huge I do believe you will find positive business cases. As I told you, if you connect Egypt with Cyprus or Spain with Morocco you can make a positive business case purely on the spreads between these countries. But of course, the more you will interconnect continents the lesser the spreads will be. On the other hand you speak about continents, so if they are not that keen to build a wholesale electricity price as we have it in Europe that will take time.

So, you will find private as well as public regulated investors at the beginning, but I don't know if you are aware of China State Grid? I think they already made a study five years ago and their aim is really to interconnect the world. So, they already have plans to connect Berlin with Beijing with underground cables; if it is not possible with overhead lines. So, their dream to realize exists. The push comes again from China and that might be a hurdle for European countries, but the longer we wait, in the end, they will build it anyways. And they will start building over Russia and Eastern Europe. So, it is not a dream so far away, it's feasible. So, to come back to your question: private as well as regulated investors would be interested to build these interconnectors between continents.

You said the business case would be attractive for private investors, so do you know what could be the reasons why they are not doing it yet?

One of the reasons is the depth of the sea; companies are still analyzing and it will take time before they get answers. Secondly, the focus is more on creating the European dream, to have an integrated electricity market before we start interconnecting with other continents.

What are the solutions? Are there good practices or examples that show international or intercontinental electricity interconnections could work in Europe or elsewhere in a large scale?

Interconnectors between the UK and the Continent, Britned, Nemo link, IFA, NSL, Viking are all very good examples, I believe. Between two continents, I would have to refer you to the websites of Euroasia and Euro Africa where would you see the PCIs of these projects. Of course they're not built yet, it's still a dream, but it's a realistic one, so it's something that could be built if all authorities and national regulators and investors can come to an agreement on all the aspects that we discussed.

An interconnector between the UK and Iceland is yet to be built. I don't think there is already a project between France and Morocco or Tunisia. So a lot of potential projects are there but nothing real for.

Organization: ELIA

Interviewee: Kristof Sleurs

Date: 20th of April 2020

Could you please introduce yourself so I know a bit about your background and your work in your organization?

I am an engineer from the KU Leuven. I did a PhD as electrical engineer in telecom. I started at Elia first at the national control centre in 2010 (which corresponds to the operations), then for a few years I was in the grid development department. I am now the head of the grid development department. This department is responsible to define the future vision, collecting future needs and solutions of the Belgian system. On the collecting need side, I am speaking with clients, with the customer relations department and with distribution grid operators to determine where we need new connections and reinforce connections, what do we expect in the future with the changing circumstances (more RES, other generations and load patterns, where will we expect congestion) and therefore where do we need to reinforce or restructure, where do we need additional interconnectors with other countries from a market perspective? Collecting all these needs for grid development and then, together with other departments, work on a solution and launch the infrastructure projects to realize the projects in the grids. The department is not into project realization but more into design and defining projects that need to be realized.

Do you think the participation of Europe to a global electrical grid is realistic? Achievable? What do you see as the main barriers to its realization?

The global electrical grid might be one of the solutions to the problems that you just stated (intermittency and local shortage of RES). But I am not convinced yet and I don't think it's clear yet that it will be “the” solution because there are also other solutions. You could also have a transport of molecules, for example gas (H2 or any other gas) on the global level so it's not the only solution. Secondly, I don't think it's the first step in the global decarbonization. These global interconnections might serve to further integrate renewable energy that is all over the world, but I think you should first build renewable energy production on a massive scale before you start building these interconnectors. This is also true for Europe. In Europe, it is probably true that we don't have sufficient potential in renewable energy to meet our consumption but there is still a lot of untapped RES potential in Europe. We will first have to find solutions to tap into the European potential before we start thinking of going further to a global grid because the further you go the more expensive it gets. There are also quite a lot of technical questions when you speak of a global grid. What level of transport capacity do we speak about? How many megawatts? What is the investment costs, operational costs? It’s not only about building a big block interconnector between two continents, you will also have to connect it to existing grids at both ends, which is also not that straightforward. So, I think there is still a lot of questions to be answered before you are able to say whether or not it's realistic, feasible and desirable. We first have to know whether it's desirable to move to such a grid.

Why would it not be desirable? Please explain.

There are different solutions towards the future. For example, you could have molecule-based transport. Are we sure that an electrical global grid is the most efficient, energy efficient, cost efficient solution? If it's not the best one, then it's probably not desirable to build. We should look for the solution that is the cheapest or the best one for society as a whole. This is what I meant by desirable. But apart from that, another aspect of this is our desirability; something that goes further than efficiency and costs. One of the main differences between building interconnections and the transport of energy through other carriers (natural gas or H2) is as follows. By the electrical transport, you want to solve the problem of intermittency but by doing this by, building electricity interconnectors, you should look into a more political question because today we are in Europe already dependent on imports of energy from other countries which might not be politically desirable. If you replace fossil fuel dependency by electrical dependency, it worsens the situation because you are immediately dependent as you can store fossil fuel, but you cannot store electricity. In addition to the cost question, there is also a political question.

What can be, according to you, the main financial barriers to the materialization of such interconnections?

It's a lot of billions of euros you have to put on the table. In general such things don't happen as a Big Bang. We should try to realize things stepwise where you have to invest a smaller amount of money producing the risk and then take one step ahead and invest more money to increase the profit afterwards and see the benefits. Of course, if we talk about intercontinental interconnector it is very difficult and it will be a big lump sum you have to put on the table. What's key here is, given it's a lot of money, you want to be sure that your investment will bring benefits as soon as possible and not end up as a stranded investment which comes back to the point that you will first need to develop massive RES generation before building an interconnection.
Another point: the business case of electrical interconnectors, given that electricity cannot be stored in large quantities, depends also a lot on the market set up at both ends. Changes in these market setups can have big impacts on the profitability of the interconnector. So, let's say, stability of market setup, of regulatory schemes are required before any party will decide on such investments. Interconnectors between continents or simply between countries can either be built as merchant or regulated investment. For intercontinental interconnectors we see that today, more and more for shorter-distance interconnectors, it is more and more difficult to do it as a merchant

interconnector because you have to rely on congestion rents and differences between market prices in the two countries to build your business case. This is in general very volatile as it depends on regulatory setup at both ends, is also very dependent on generation mixes at both ends, very dependent on parallel paths.
For example, between the UK and the continent, the more interconnectors you build, the less profitable the existing interconnectors become. So you might be able to build a business case as first mover, but as soon as there's a second one coming, this divides your profit by two. This makes it very difficult and I think this will be especially true for intercontinental interconnectors because it makes all these challenges bigger, very difficult to build as a merchant. If it's built, I believe it would be built as a regulatory setup where you have for the party investing security or certainty of the return on investment and so indeed the upside potential will be more limited but it will also reduce the risk by recovering for example the cost through tariffs.

You said you do not believe merchant lines can be a solution. Do you not think sufficient profit can be driven from potential large price differences from the connected continents?

From a gut feeling, I think this will be too risky. We will have to see how it evolves in the future but even if we have not sufficient renewables to cover every consumption in Europe, we will have an enormous amount of RES on both sides and market prices will become more volatile. It will depend a lot on specific mechanisms in the different countries. If you have capacity mechanisms, capacity payments, other income, these all affect the market price and therefore also affect the revenue and business case for the merchant line which I think will be very risky considering the amount of money that you have to put into it.

What do you think are the problems inherent to regulated and merchant investment schemes?

If you build a merchant line, in the end, this means that the party investing in it will have to build its business case on congestion rents. But the interconnector's overall benefits for society have additional factors; it's not only the congestion rents but you can also have consumer and producer surpluses on both sides which means that from a societal point of view the value of the interconnector might be bigger than if you look at it from an investor's point of view. This might come to the point that, for a merchant investor, the investment might not be interesting while, from a societal point of view, it might be interesting but then you would need some regulatory setup or party.

So what could be a problem or a barrier in the regulatory setup is that you need to set something up regulatory wise, and for such an interconnector you will have lots of parties around the table (multiple countries with multiple tariff schemes or principles). You will need to find an agreement that fits them all.

Another thing, on the short term, nowadays for the grid infrastructure we already face large investments (billions of euros) to be invested by the companies in the infrastructure, so there's the question "is there a place left on the short term?" Is there room left financially to add such very expensive investments to the portfolio in the short term? Is it possible to put money on the table? This depends also on, if you speak about TSOs for example, the structure behind the TSOs which is not the same for all TSOs: you have fully state-owned TSOs which might have more limited access to financing compared to TSOs which are fully able to go to the Stock Exchange.

Does this mean that, for the short term, TSOs already spent all their money on current short-term grid infrastructure and there is no funding left?

I'm not sure this is the case for all TSOs, there might be money left, but it is at least something to look into. There will be differences: there will be TSOs, also depending on the historical grid they have of course, that will have to combine with renewable investments with investment in new interconnectors for example; so it all depends between TSOs I guess but it might be a challenge to find the euros. Because depending on the business structure of the TSO, if you have a state-owned TSO, the means and potential to find euros to invest in such really expensive intercontinental interconnectors will be different between TSOs and might pose difficult challenges for some of the TSOs.

These amounts of money can never be financed by a single TSO or a single country. It should be a European project, which adds difficulty to the realization of the project. I don't see Elia investing 1000 000 000 000€ in one interconnector.

Are there financial barriers that are intrinsic to the electricity market structure or characteristics (without going into specific regulation or investment schemes)?

I'm not an expert in this field but, indeed, you have the volatility of the prices, the dependence on market set up. If, for example, bidding zones structure changes, this might severely impact your revenues. You have the point that in the market you have forward prices up to three years ahead but that's it, not longer. So I think you cannot really have a long-term hedging of your risk, so indeed there is quite some particularities in the electricity market that are challenging. But I'm not sure these are barriers - there might be solutions to these - but these are challenges. For example, the fact that you cannot store your electricity. This means you have to have some financial hedging of your position or you have to sell it immediately which means that you are fully exposed to these short-term prices which are very volatile. This will probably also be very difficult for a small market player to have in his portfolio.

What are the solutions? Are there good practices or examples that show international or intercontinental electricity interconnections could work in Europe or elsewhere in a large scale?

I don't know about intercontinental. The scope of a global grid that is more about between Europe and Greenland, that doesn't exist yet. In a smaller scale, indeed interconnectors between countries in Europe or even outside of Europe, exist in different setups. You have merchant ones, regulated ones, and hybrid interconnectors. These are interconnectors that are directly connected to offshore wind parks. That will come up more in the near future. There are working examples of all these and they all have benefits and drawbacks

Is there anything you think we can learn from them or something that is good practice that can be reproduced ?

I am not sure. The difference between these projects and the global grid is the distance and so the amount of money you need. What is the same (and much greater for the intercontinental case) is the risk in revenue from the volatility, so you should look for solutions and practices to mitigate the volatility of revenues. That's something that would be very useful for intercontinental interconnectors. Apart from that, I'm not sure. I really doubt that you can have the business case around intercontinental interconnectors by only looking at prices maybe it will be possible in the future but the market setup would have to change.

What do you mean by only looking at prices? Which other things should be considered?

Either the price structure needs to change, or the average consumer price will more or less stay the same this will not make a big difference… I'm just not convinced yet that the future way to go is to build a global electrical grid, given the money it will cost and the challenges that it poses. Maybe we have other and better solutions. The financing is not the only barrier.

Organization: Agency for the Cooperation of Energy Regulators (ACER)

Interviewee: Britned

Date: 28th of April 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

My name is Jan Kostevc. I am a team leader of the Electricity Infrastructure team at ACER, where I have been working for the past 5 years. Before, I worked for the Slovenian TSO as head of the Operational support team for 8 years.

The Electricity Infrastructure team is dealing with aspects of pan-European network development, such as TYNDP (e.g. in terms of CBA, scenarios) and PCIs (opinion on selection of PCIs and PCI monitoring report), also tariffs, R&I, etc.

Do you think the participation of Europe to a global electrical grid is realistic? Achievable? What do you see as the main barriers to its participation?

Difficult to judge. There have been many ideas on connecting other systems to the continental Europe, but not many survived to become real project, yet alone to be implemented. There are many barriers, one is financial, the other operational and the third political.

The financial is often the easiest to solve, as it simply means that the project requires a positive CBA (benefits outweighing costs), but there is also an issue of affordability; if one imagines an extra-long-distance interconnector, this would bring extremely high costs, which are difficult to put on the shoulders of either a merchant investor (how would they get a loan for e.g. 10 billion €) or on the shoulder of tariff payers, as the increase of tariffs such an investment would bring could be unbearable.

Operational barrier pertains to the issue on how connecting two (large) systems would affect both of them in terms of stability and overall operational security. This was the case e.g. with the connection of Turkey to continental Europe, which caused a lot of power oscillations. In part, these problems are solvable through the usage of HVDC technology, but this further increases the already high costs.

Lastly, the political aspect; some countries would like to connect to others, while others feel they would lose sovereignty by doing that.

One would first require strong political support to achieve such interconnections, which should be backed up by a CBA and further backed up by reassurance that such connection is not bad for operational security.

What can be, according to you, the main financial barriers to its participation and the materialization of subsequent interconnections (e.g. with Greenland, North America, Africa)?

As mentioned, one barrier is the overall cost of building such a project. Even EU projects often cost in excess of 1 billion €. One can easily imagine where the costs would end up with such long-distance projects, if they are even technologically feasible.
The other financial problem is the CBA. If costs are extremely high, the benefits need to be even higher. The monetized benefit can be approximated by the price difference between the markets you are connecting. If the price in Europe is X €/MWh and in North America it is Y €/MWh, the benefit are (X-Y) x transmitted energy in MWh. If a cable of 1000MW is constructed, a price difference of 10€/MWh brings us to the benefit of 10.000€ per h (assuming line is always in use). Economic lifetime is 25 years, which brings us to 25x8760hx10.000 = 2.2 billion €, which is not even close to cover the investment costs (CAPEX), yet alone maintenance, which would be very costly to perform in the middle of the Atlantic.

How to avoid such barriers? Either the benefit would need to be there to exceed costs, or there should be a strong political momentum to help push such an investment through.

Are there financial barriers intrinsic to the electricity market structure or characteristics (without going into specific regulation or investment schemes) with regard to the needed interconnection developments for the participation of Europe to a global grid?

I wouldn't say I can identify any barriers directly linked to the structure of the market.

What do you think are the problems inherent to regulated and merchant investment schemes for interconnectors? Do you think these two schemes are appropriate for a participation of Europe in a global grid and, if not, which potential problems do you see arising from such schemes?

Difficult to judge since I do not have any knowledge of a different scheme. Both are based on a CBA, one is putting the burden on all consumers, the other on the merchant project promoter. But given the high financial burden of such projects, other incentives would be required to push these projects through, as the CBA would most likely not be favorable.

What are the solutions? Are there good practices or examples that show international or intercontinental electricity interconnections could work in Europe or elsewhere in a large scale? What can we learn from them?

We need to first ask ourselves “do we need such solutions?”. Do these solutions make (economic, operational or political) sense? If the economic sense exists, there are different options on how to overcome high costs, e.g. through loans, grants, etc. If the CBA is not positive, why would you push such projects forward?

Organization: Jan Hoogstraten

Interviewee: Britned

Date: 28th of April 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

I am responsible for the regulatory, compliance, capacity trading and legal matters of Britned, which is the interconnector between the Netherlands and the UK. Britned is a 50-50 Joint Venture between Tennet and National Grid.

Do you think the participation of Europe to a global grid is realistic? Achievable? What do you see as the main barriers to its realization?

On a technical note, the losses along the way are a first barrier. Imagine you transport power from South Africa to the Nordics, this would incur huge losses. For example, there is a 3% loss on the Britned interconnector which is only a few hundred kilometers long between the Netherlands and Great Britain. It might be worse between continents as you have to get deep into the ocean.

You also need to agree on frequency. If all the continents across the world are connected you need to agree on frequency, and I think that's a challenge. I'm not saying it can't be done but the question is "who will take the lead on that?".

What can be, according to you, the main financial barriers to the materialization of such interconnections?

I don't really see financial barriers. I think there is already a lot of both Chinese and Russian companies active in the electricity market in Europe. Lots of electricity generation companies were sold to Russians or Asians. For example, there is a lot of Asian companies importing ACDC cables that connect the continent to offshore wind parks in Europe. So, I don't really see financial barriers.

Are there financial barriers that are intrinsic to the electricity market structure or characteristics (without going into specific regulation or investment schemes)?

You could answer that question twofold.

First, mainly in Europe, the electricity market has a lot of restrictions and requirements and you don't change them overnight. So basically, as a participant you have to adapt to that in order to play the game. And this would be the same in Asia and in the US for example. So as long as you play according to the rules of the game, I don't see barriers, but integrating all these different markets will be the main difficulty. However, I don't see the value of that. Also you could argue a global electrical grid is already there because we're already connected to Africa and to Russia and to the UK. European land borders are already connected.

On the other hand you would need to build more sub-sea cables. This brings more difficulties as they won't always be fit to operate and there has to be a reason why you want to build that interconnector. The main purpose of the interconnector is to equalize the price difference between different markets, otherwise there is no purpose to build it. So, for example if the power in Africa is much lower, then you could import power for a very cheap price and that's why you want to build an interconnector. With the global grid, the price convergence will be stimulated, but, in the end, if there's a full price convergence, then the interconnectors will become quite expensive overtime. So that could be a barrier, maybe just not in the beginning. Interconnectors will become more expensive. Who will pay for that?

Could this be solved by regulatory mechanisms?

You can socialize the cost of interconnectors but there is still the point of the energy price and I think the goal is in the end to have affordable energy. This includes the production cost but also the transportation costs and currently we're investing a lot in interconnectors and this part of the price is quite low for the moment but would become substantial in the future and that's something you need to take into account. The overall electricity price will rise. Who will pay for this? The benefits must outweigh the costs of building the grid.

What do you think are the problems inherent to regulated and merchant investment schemes?

I think there are so many different setups. Europe, for example, is mainly regulated. I don't think there is either one that would be the solution, but it would be more of a hybrid scheme depending on the electricity market where you are. Europe is fully socialized but it is not the case in the US, nor in the UK. In Asia they also have different incentives; they also look into merchant options there. So, I think it depends who you're dealing with. So, the solution for a global grid would be more of a hybrid model. You could argue if you want to build a subsea cable from Europe to Greenland, it would be very costly, so the risk profile would be very high given the distance; you don't want to socialize these costs. But if you say a merchant party can take that risk with according earnings, that might be an option. There are many different ways to regulate TSOs if you look at the regulatory landscape; some are very investment-driven due to the regulatory incentives. If you look at Germany or the Netherlands for example, they are very investment-ready, they make money for that; but maintenance is not an attractive option, as opposed with Italy. So, even within the European landscape, there is many options so if you want to have a global grid, you need to make sure the regulatory incentives are the same. Otherwise for Italy there's something else, etc. In Europe we are working together with all the TSOs so there are many different parties and they all need to work together for a common regulation. If you see how much time this takes to form agreements, that's tremendous. I don't think it's an appropriate setup because a lot of time, cost and energy are wasted in this process. We would need to do this worldwide, but we will end up in a debate with people having different vision of the energy landscape with different regulatory incentives. Asia, Europe and US would disagree. I don't think they could compromise.

Specifically, regulatory incentives are different; if it's socialized you can get a remuneration and cost back on the public. Then it's always a regulator that is going to say "I'm going to regulate you in this and this way, if this is your output you get this, if that is your output you get that". None of these incentives are the same so we don't have one regulatory regime for TSOs Europe-wide that gives incentives to expand or maintain the grid. It's all different. So even in Europe, we can't do that but if you want to have a global grid and the global market that would actually work, you need to have that at an even larger level.

What are the solutions? Are there good practices or examples that show international or intercontinental electricity interconnections could work in Europe or elsewhere in a large scale?

There is an interconnector between Spain and Morocco, interconnectors to Turkey already exist too. There is no real regulatory framework around it. More would be built in the future.

They are good examples in the way that they work also technically and are always ready to operate. You can also increase your home market and help each other. The main goal in the end is to maintain your electricity grid. You don't want your grid to go down, you want to avoid this, and this is why you might want an interconnector. Belgium's grid's demand was secured by the Netherlands for example. Whether it's a sub-sea cable or just cross-border interconnector, it doesn't really matter.

Could we learn something from these examples?

It's more about governance; for example, some Asian countries were thinking to build a grid between China, Korea and other countries. This has to do with trust if you don't really know the other parties well. You also need to trust that they keep up with the promises. For example, where do you establish the control room of that interconnector? Who's in charge of that? There's a lot of practical questions. How do you go with the converting stations? What kind of entity runs the interconnector?

Organization: Gérald Sanchis

Interviewee: ENTSOE

Date: 6th of May, 2020

Pourriez-vous vous présenter afin que je connaisse mieux votre travail et ce que vous faites au sein d'ENTSOE ?

Je travaille d'abord chez le gestionnaire de réseau de transport français qui s'appelle RTE mais plus précisément mes tâches sont orientées vers l'association pérenne ENTSOE. Je peux aussi vous parler du projet e-highway2050 et du CIGRE qui est une instance scientifique internationale spécialiste des grands réseaux qui constituent un club de scientifiques et par lequel j'ai piloté une étude visant à étudier la pertinence d'un réseau mondial électrique.

ENTSOE : l'étude e-highway2050 a été financée par la Commission européenne pour identifier quel serait le réseau de transport d'électricité à l'horizon 2050 qui permettrait une meilleure intégration des énergies renouvelables, c'est-à-dire en respectant les accords de la COP 21 avec une énergie décarbonée. Ce projet visait à identifier quel serait le réseau à l'horizon 2050 en Europe pour assurer cette intégration forte du renouvelable. Et donc, on a identifié différents scénarios pour décrire 2050. A la fin on finit par identifier les réseaux qui pourraient répondre aux enjeux décrits par chacun des 5 scénarios. Nous avons un des réseaux les plus maillés au monde ; nous sommes dans une situation favorable d'échange d'électricité entre pays. On ne peut pas vraiment dire qu'il y a des freins mais plutôt une incitation forte de la Commission européenne à interconnecter le plus possible les pays européens également via le mécanisme des PCIs qui sont une aide financière pour aider au développement des interconnexions qui pourraient ne pas s'avérer suffisamment rentables dans un premier temps et donc difficiles à être supportées financièrement par les pays impliqués. Le mécanisme des PCIs permet d'obtenir en quelque sorte une subvention européenne pour faciliter la création de ces réseaux qui s'ils ne sont pas rentables à court terme et ne pourraient pas bénéficier d'un financement national du fait de ce manque de rentabilité à court terme. Ce mécanisme de PCI permet d'avoir un financement et de passer le cap court terme à plus long terme. C'est bien un outil ou un mécanisme assez innovant et qui n'existe pas ailleurs dans le monde parce qu'en fait, si on regarde les interconnexions entre continent, il y en a très, très peu. C'est surtout l'Europe qui est très maillée. Et donc ce mécanisme de financement est novateur et on pourrait imaginer le transposer à d'autres régions pour développer les interconnexions.

Mon rôle est Directeur de cabinet du président d'ENTSOE qui préside l'association. Nous sommes 42 gestionnaires de réseau de transport, donc à peu près un par pays (pays de l'Union européenne et certains pays périphériques tels que UK, Norvège, Suisse). Cette association des 42 TSOs fut créée en 2009 à la demande de l'Union européenne en vue de faciliter la création d'un marché de l'électricité en Europe. Il y a eu l'équivalent du côté gaz (ENTSO-G). Dans les obligations que cette association a, il y a entre autres la création d'un schéma directeur, c'est-à-dire l'unification du réseau électrique pour justement fixer un cap, une cohérence européenne qui permet d'indiquer quels seront les couloirs électriques à créer pour consolider ce réseau électrique européen. Il y a même des incitations avec des objectifs quantifiés visant à augmenter les capacités d'interconnexion entre pays. D'ici 2030, on vise 15% de capacité de transmission par rapport à la capacité de production du pays pour amplifier les échanges et avoir un libre-échange électrique au niveau européen sans trop de limitation. Aujourd'hui il y a des limitations physiques du fait de l'absence de suffisamment de lignes électriques qui fait qu'on ne peut pas échanger les quantités, on est limité en quantité d'échange entre pays par les capacités de ces lignes. Les objectifs visent justement à augmenter ces capacités, d'avoir la plus grande capacité possible entre pays pour que les clients européens puissent bénéficier du meilleur prix en faisant jouer la concurrence entre les différents fournisseurs électriques qui sont répartis sur l'ensemble du territoire. On a donc aussi comme objectif de donner cette visibilité sur le développement du réseau pour que la Commission européenne puisse orienter en quelque sorte ses actions vis-à-vis des pays pour les inciter à amplifier si besoin les capacités de transport électrique entre ces pays. Ça, c'est une des fonctions de l'association : donner une visibilité sur les besoins de développement de réseau, mais également d'établir les règles pour que l'accès au réseau électrique en Europe soit le même, qu'il n'y ait pas de distorsion d'accès au réseau d'un pays à l'autre, sachant que l'objectif est d'avoir un marché unique au moins dans les 27 pays. On regarde aussi les interconnexions avec les autres continents (Afrique, Russie, etc). Notre association a pour but, grâce à sa représentation élargie de l'ensemble des acteurs du transport d'électricité européen, de donner une visibilité à l'Union européenne et de mettre en œuvre des règles qui visent à faciliter l'intégration de ce marché électrique.

Regardez-vous également vers le Groenland et plus vers l'ouest ?

Je vais vous référer à une étude que nous avons faite dans le cadre du CIGRE. Cette étude vise à étudier la pertinence d'un tel réseau global sachant que les premiers à avoir exploré ce concept sont les chinois (route de la soie aussi bien du côté du transport de marchandises que du réseau électrique). Le CIGRE a décidé à la demande du comité chinois d'étudier la pertinence d'un tel schéma au-delà d'un concept imaginé dans la tête de certaines personnes pour voir si cela était pertinent d'aller au-delà. On a donc entamé ces travaux et comme la spécialité du CIGRE sont les réseaux électriques et que nous avons mené ces travaux sur une période limitée de deux ans, on s'est donc d'abord alimenté des études faites par d'autres et notamment la WEC (World Energy Council) qui a produit une étude en 2013 et 2016 visant à décrire en quelque sorte quel serait le mix énergétique dans le monde à l'horizon 2050. Nous avons utilisé ces données/estimations de 2050 et à partir de ce moment-là, regarder quel serait le réseau maillé mondial répondant le mieux à ces objectifs. Aujourd'hui le réseau est très peu maillé dans le monde. Il n'y a pas vraiment de connexion dans le monde entre continents aujourd'hui. Le Groenland y est identifié comme une région et on a regardé s'il était intéressant de connecter les régions. La demande électrique en Europe est plus forte en hiver qu'en été, ce qui est l'inverse des autres continents (mis à part la Russie). Les autres pays de l'hémisphère nord sont dans une logique où c'est la climatisation qui tire la consommation électrique ; le chauffage électrique est très peu employé. Il y a également un effet saison avec l'hémisphère sud. On a donc inspecté s'il était intéressant de connecter les continents pour profiter d'un décalage de saison électrique. Dans un scénario de continents isolés, le coût serait de 54€ par mégawattheure et le pourcentage d'énergie renouvelable serait de 53% ; dans un scénario connecté, le coût serait de 48€ par mégawattheure et le pourcentage d'énergie renouvelable serait de 76%. On peut toujours discuter sur l'estimation mais l'important est de voir qu'il y aurait une réduction du coût. Le réseau serait particulièrement développé en Asie du fait de la forte consommation en Asie et en Chine. Sous ce scénario de vision globale, une interconnexion avec le Groenland serait par contre trop chère par rapport à ses bénéfices. Cela ne veut pas dire qu'il faut l'enterrer car elle a tout de même un intérêt pour le scénario européen s'il n'y a pas de vision globale.

Quels freins voyez-vous à la participation de l'Europe à un réseau mondial d'électricité ? Est-ce réalisable ?

D'une façon générale, peu importe l'emplacement, les freins qu'on a au développement du réseau ce n'est pas que le financement. C'est l'acceptation environnementale. Les riverains, les citoyens ne sont pas favorables au développement de ses infrastructures. Les plus grands freins sont liés à cela : à convaincre que l'ouvrage doit être construit. Les infrastructures ne plaisent pas beaucoup aux riverains. La Commission européenne a cherché à faciliter cela. Le statut PCI impose aux pays de faciliter la construction de ces ouvrages. Les pays sont censés faciliter et convaincre les riverains que l'ouvrage a un intérêt général et ainsi faciliter la construction. On a donc heureusement aussi ce soutien en quelque sorte des pays lorsque l'ouvrage est considéré d'intérêt général européen. C'est important d'avoir le soutien de la Commission européenne et des pays pour faciliter la construction. ENTSOE est favorable car plus un réseau est maillé plus il permet cette fluidité. Nous sommes favorables à l'élargissement aux autres pays à l'est et au sud. Les pays concernés ont parfois d'autres visions de par les aspect politiques. Plus le réseau est petit, plus le réseau est fragile. Le TSO doit veiller à ce que le réseau soit en équilibre. S'il y a une défaillance de la production ou de la consommation, la mission du transporteur est de trouver une solution le plus rapidement possible pour pallier à la défaillance. On se couvre par l'achat ou la production de réserves. Plus le réseau est fort, moins cher ça me coûte de couvrir ces réserves. Plus le réseau est étendu plus bas est le risque d'une défaillance de production.
Au niveau du financement, il faut chercher à soutenir des projets rentables. S'ils sont rentables à court terme, ils n'ont pas besoin de soutien financier. Si la rentabilité est seulement sur le long terme, il est soutenu par le projet d'intérêt commun. La Commission est donc favorable à l'extension du réseau.

Y a-t-il des interconnexions PCI avec des pays tiers à l'UE ?

Oui, par exemple il y a un PCI entre le Maroc et le Portugal. D'autres sont en développement. Med-TSO est le pendant d'ENTSOE, il regroupe tous les TSOs du bassin méditerranéen. Cette association vise à faire un peu la même chose, c'est à dire établir une ligne directrice d'interconnexions. Elle vise à identifier quels couloirs pour des liaisons sous-marines seraient rentables. Les projets fourmillent entre l'Europe et l'Afrique. Les motivations des uns et des autres sont un peu différentes. Désertec, imaginé en 2009 par des acteurs allemands, avait pour but de substituer le nucléaire allemand par des énergies renouvelables en Afrique du Nord. Il ne voyait qu'un aspect des choses : couvrir les besoins allemands. Il a été mis aux oubliettes mais il sort maintenant car ces régions préparent l'après-pétrole. Les pays fortement producteurs de pétrole commencent à s'intéresser à une autre source d'énergie dont ils sont très riches, à savoir le solaire. Ils sont donc intéressés par des connexions électriques pour exporter leur énergie solaire. Les pays qui n'étaient pas motivés par des connexions électriques le deviennent, en se projetant sur une période où on ne pourra plus bénéficier de la manne du pétrole. Maintenant, il y a un intérêt partagé. Les chinois sont aussi très motivés par le développement de lignes électriques entre L'Afrique et l'Europe parce qu'ils ont entrepris des études qui viseraient à permettre un développement des énergies renouvelables en Afrique avec des fonds chinois pour exploiter l'exportation d'énergie solaire. Les chinois sont intéressés par une rentabilité.

Y a-t-il des projets transfrontaliers avec des pays tiers qui bénéficient du mécanisme de projets d'intérêt commun ?

La règle n'est valable que s'il y a un intérêt général européen. Par exemple, une ligne entre la France et l'Irlande n'est pas aussi simple que ça à rentabiliser. La Commission européenne a tout intérêt à soutenir les membres à rester en Europe suite au Brexit, particulièrement l'Irlande. Ce projet-là a donc bénéficié du statut et du financement pour compléter le soutien financier, sachant que la rentabilité n'est pas garantie sans ce soutien économique. Quand il s'agit d'un pays européen comme la Tunisie et l'Italie, les règles européennes sont telles que si le projet ne bénéficie qu'à l'Italie, le mécanisme ne peut pas être actionné car il faut qu'il profite à plus qu'un seul pays européen. S'il profite à au moins deux pays, il peut bénéficier d'un soutien de l'Europe. Ces règles sont amenées à évoluer. Le mécanisme est en cours de révision, entre autres de par le Green deal. Il y aura également des montants qui seront alloués à l'Afrique parce qu'elle s'est rendue compte que la production d'énergie décarbonée doit être mondiale, que le changement climatique ne doit pas être combattu par l'Europe uniquement. Elle compte ainsi aider le continent africain à atteindre ses objectifs de diminution des émissions de CO 2 et le réchauffement de la planète. Peut-être que les projets associant des pays non-exclusivement européens pourraient bénéficier du mécanisme révisé de projets d'intérêt général. Pour résumer, avec les règles actuelles non, mais demain peut-être que oui.

Imaginons une interconnexion avec l'Italie et la Tunisie. Comment définit-on si elle bénéficie à d'autres pays européens que l'Italie ?

Pour répondre à ces questions techniques et économiques, ENTSOE fait tourner ses modèles qui vérifient la rentabilité et la plus-value sociétale de l'interconnexion. Elle utilise des analyses CBA qui sont consultables sur son site internet.

Pensez-vous que toutes les interconnexions vers des pays tiers pourraient être couvertes par de l'argent public ou plutôt par de l'argent privé en complément ?

Tout est possible et la Commission européenne fera tout pour favoriser aussi l'argent privé. Les projets d'intérêt communs sont également applicables aux acteurs privés. Il y a un projet qui vise à relier Chypre avec le reste de l'Europe et est entrepris par un promoteur privé. Ce projet est très cher et donc difficile à rentabiliser par les bénéfices attendus et les coûts estimés. Il a obtenu le statut. En théorie, ce mécanisme s'applique donc ainsi aussi aux projets privés, même si ce sont souvent des entités nationales. Ces projets d’interconnexions peuvent très bien être portés par des intérêts privés et ce sont quelquefois même des mécanismes avec des capitaux privés et publics qui permettent d'assurer un meilleur financement. Toutes les solutions et tous les mécanismes sont ainsi possibles. On voit que les capitaux privés cherchent quand même à avoir de la visibilité sur la rentabilité. Les régulateurs sont là pour donner cette visibilité mais il est vrai qu'on n'a pas beaucoup de projets privés. Il y a bien des promoteurs privés qui visent aussi à construire des interconnexions mais ils ne peuvent obtenir le feu vert du régulateur que dans la mesure où l'intérêt financier ou général est démontré. Ils n'obtiendront pas d’autorisations si les études montrent que ce ne sont pas des projets rentables.

Vous avez parlé de rentabilité à court terme et long terme et de l’éligibilité des projets d'intérêt commun. Qu'en est-il de la baisse des rentes de congestion vis-à-vis de la rentabilité à long terme ?

Il y a une limite à la création d’interconnexion : si à un moment donné il n'y a plus suffisamment de transit sur ces lignes, à ce moment-là, on casse la valeur sur les ouvrages existants et futurs. Il y a un optimum à trouver. Si on fait trop d’interconnexions entre deux pays, on va réduire l'intérêt des transits. Ça ne sert à rien de développer à l'infini. Si vous regardez les écarts de prix d’électricité, le marché de la bourse, les prix les plus élevés sont sur les pays les plus éloignés du centre européen : le Royaume-Uni, L'Espagne et l'Italie. À l'inverse, le centre européen bénéficie des plus bas prix. Les interconnexions ont un certain coût (par exemple entre l'Espagne et de la France) ce qui fait qu'on peut arriver à ne plus rentabiliser une interconnexion et qu'il vaut mieux construire une centrale dans le pays concerné.

Au niveau de la régulation qui existe, les 2 moyens principaux pour financer l'interconnexion sont l'interconnexion régulée et marchande. Que pensez-vous de ces 2 régimes et pensez-vous qu'ils sont appropriés en vue le développement de interconnexions vers les autres continents ? Que devrait changer ?

C'est une question à poser au régulateur. En tant que gestionnaire de réseau électrique, d'activités régulées, nous avons une vision partiale. Nous préférons évidemment plutôt la vision régulée. C'est ce vers quoi on va tendre plus facilement. Si on regarde ce qui se passe en France le régulateur à plutôt une logique de privilégier les lignes régulées. En Angleterre le régulateur privilégie plutôt les lignes marchandes. C'est vraiment le régulateur qui définit cette approche.

Pensez-vous que ces interconnexions vont pouvoir être subsidiées par l'Union européenne ou pensez-vous que l'argent de l'Union européenne ne pourra pas couvrir toutes ces liaisons, qu'il faudra l'intervention d'argent privé dans une certaine mesure ?

Tout n'est pas toujours possible, il y a toujours des contraintes techniques. Lorsque les sous-marins sont très profonds c'est très compliqué. Les mers Baltique et du Nord ne sont pas très profondes mais cela devient compliqué en Méditerranée où dans l'Atlantique où les profondeurs sont beaucoup plus importantes. Cela dépasse la technologie actuelle de créer ces ouvrages-là. Il y a bien sûr l'aspect financier mais il y a aussi l'aspect technique qu'il faut prendre en compte. Même pour les câbles sous-marins, il y a des problèmes d'opposition locale par des associations de pêcheurs. Est-ce qu'on arrivera à trouver l'argent ? Si on arrive à prouver la rentabilité c'est déjà un grand pas, mais je pense que ce sera un processus assez long. Pour avoir de l'ancienneté dans le domaine, on a mis du temps à accepter de devoir dépendre de son pays voisin pour son énergie car on n'est pas sûr que le voisin soit fiable et que chacun voudrait être autonome. Il y a une évolution dans la mentalité des politiques. Aujourd'hui les femmes et les hommes politiques en Europe sont beaucoup plus ouverts à cette mutualisation des ressources et à dépendre du voisin mais c'est un processus assez lent. Si on élargit le cercle, il faudrait aussi ce cheminement en tête, un peu comme Desertec. Ce n'est qu'avec le temps et l'évolution de la situation que l'intérêt est devenu partagé ; il faut que ce soit un jeu gagnant-gagnant. Les étapes à franchir ; d'abord convaincre tout le monde que les interconnexions sont bénéfiques à tous, avec un intérêt compris. Une fois qu'on aura franchi cette étape-là, il y aura moins de soucis pour trouver les financements parce qu'on aura le soutien politique, social, etc. C'est peut-être ça qui peut faire peur aux investisseurs : des projets politiquement/socialement sensibles avec une potentielle opposition sociale ou de référence. La première étape, c'est donc cette acceptation sociale. Une fois qu'on a passé cette étape-là, on peut rentrer dans un processus financier avec une visibilité sur le long terme pour investir. Il faut que les parties concernées et que les citoyens soient d'abord convaincus.

Organization: EPEX Spot

Interviewee: Maximilian Rinck

Date: 8th of May, 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

I'm a physicist. I've done a PhD in quantum transport theory and so I have a completely different background from the people who typically work at power exchanges. I joined the European Energy Exchange group (EEX, of which EPEX Spot is part) 9 years ago. I started in the risk management department, so that was very close to the financial regulation department. Six years ago, I joined the actual EEX company in product development for derivatives market, mainly developing products to ease the integration of renewables into the power markets because the kind of derivatives you usually buy on exchanges are base or peak load, constant production and consumption of electricity. Renewables don't fit into that scheme so we were looking at products that could mimic the generation profile of wind farms or solar PV panels. Three years ago I joined EPEX in a similar role, however more focused on spot markets and markets where you actually procure and sell electricity. My task is hybrid. I'm working on market design questions: bidding zones reviews, integration of flexibility into the grid, everything that concerns renewables in the end, and I'm working very closely with our regulatory team to bridge that gap between the product and market designers and the political department, to feed them with ideas and factual knowledge from the commercial part of the company.

Do you think the participation of Europe to a global grid is realistic? Achievable? What do you see as the main barriers to its realization? Etc

Not sure where to start.
The main idea of the global electrical grid will be to connect areas that have a lot renewable generation to major load centers so that is to bridge the gap between consumption and generation which is due to the renewable age. In the conventional energy markets, we didn't have that because power plants were built really close to consumption centers. You only had to transfer the fuel (coal, gas, etc) which in the renewable case you cannot do, it is the opposite: you build power plants close to the 'fuel' (wind, solar). This is why you need a well interconnected grid. We got a similar situation in Germany because major load centers are in the Southern part (Bavaria, etc) while most of the wind generation happens in northern Germany and there is congestion in the grid. When there is a lot of wind generation in the North, we have to curtail wind production and run conventional generation in the South because connections are not well built. Which puts financial strain on all the actors because you are not producing renewables, or you are producing but throwing away; you have to

pay for that renewable and conventional energy. It is inefficient due to the technical inability to connect the grid so in this sense having a grid that is as big as possible is very important but the challenge is to have grid connections that are actually capable of transporting the electricity. In Europe we are actually quite blessed with a well-functioning transmission grid. You can nowadays transport electricity from Spain to Poland at a reasonable capacity. Sometimes it is tough when there's a lot of renewables and not enough consumption, but most of the time it works out. This is from the grid perspective, to have a grid as big as possible to integrate the renewables and to equilibrate simultaneity of consumption and production is very important. We see that in Europe all the time because the peak load in European countries occurs at different times. We can use excess production in Germany and use it in France, so having a well-interconnected grid is very important.

From the market side, if you want to manage a well-interconnected grid, you need market mechanisms that actually span this. In Europe we have got two mechanisms (zonal markets & market coupling) that work for that and they are always challenged by regulators, politicians, but also market parties.

One is the zonal market model where you have huge market areas that usually coincide with national borders so you have one electricity price for each country and this assumes that the electricity grid is free of congestion so you can transport electricity within that zone without any disruption (which is not true in the grid operational sense, you always have to do adjustments) but from a market perspective that is very good. You have different model in the US where there is more like a market area per transmission system node. So more or less for every major city you have one market price which gives you a much better integration of the grid states into the market so you see where the congestions and constrictions are in the grid as they are reflected in the price. But you have quite a lot of small market places, which is difficult to manage from a trader's point of view. So, there are those two challenges (proper market design (i.e. zonal markets) and coupling of these markets by market-coupling mechanisms like we have in Europe). First you need to have a proper market design, which means you are able to have the money to build and manage the grid. In a system like the U.S. you have a good reflection of the grid situation, but the market efficiency is low in the sense that liquidity is very low. In Europe you have the opposite, the market is more efficient because it is more of a commodity market, but it doesn't reflect the grid situation. So, when you want to gather revenue from the market (price differentials between two countries) and you want to use that between two different zones and you want to use that congestion rent to put it into grid re-enforcement. The US nodal market is much more suited because in the European market you don't see the grid situation reflected in the market. But nonetheless if you want to establish a transparent global grid, then you need to have proper interconnections so you would have to reflect the bottom of the grid in the market somehow. I think this is one of the biggest challenges. We do this already in Europe when you have interconnections between different member states like from France to Germany, since these are two different market areas, they have two different prices. The one who operates this interconnector is taking the price differentials to finance the grid. It's a bit confusing. In Europe, what we've also done is trying to make this more efficient: if you want to export electricity from one country to another which for global grid means that so you have huge solar PV in northern Africa you want to bring this back to Europe, there's the technological challenge to have the grid line then you also have the commercial challenge to export it somehow. And what we used to do in the European markets was to buy it in one market, sell it in another and then you would have to buy the transmission capacity of these interconnectors: it's like buying a train ticket in the end. So you would have to manage the interconnection and the transport of electricity on the interconnector as well which means that you would need to have a good forecast of the national prices to know how much the value of the interconnector is. The value of the interconnector is always the price differential, so you would have to have a very good estimate of power market clears. What we've done in Europe is called market coupling: i.e. integrate the import export constraint into the overall European market clearing mechanisms. You don't have to manage an interconnector in Austria, you just buy the electricity here and the rest is done by TSOs. Market coupling is a concept that power exchanges have now spanned over all Europe. What we do is establishing connected markets on top of the grid that is already physically connected. For a global electricity grid, this is one of the challenges that you have so not just extend physical lines but also put the markets on top of that in order to ease transmission but commercial flows because the more complicated the commercial exchange, the higher the transaction cost and the less efficient that market is.

The problem with that then is that you are spanning a lot of jurisdictions for example in Europe there's political friction between Switzerland and the European Union is reflected in the efficiency of the market. The European Commission uses participation in the market coupling as a leverage or a bargaining tool to get commitments from the Swiss government in other areas like the Schengen contract. The further you span a grid and you put a market on top of that, the more you also see the regulatory or political frictions appear. So, there is a need for harmonization or at least finding basic competences between the regulators regarding electricity not just within the member states, or at the EU, ASEAN, NAFTA but also spanning continents. If we want to establish a global electricity grid, we completely aim at a completely new realm of commercial agreements that are necessary, so not just in North America or Europe, you would have to take into account Russia, Africa or Asia. This is not just technological globalization but also with harmonization requirements regarding regulation or at least finding minimum consensus that allows people to put market and commercial exchange on top.

Do you think market coupling can be extended to outside countries?

I hope so. If it is worth establishing a global grid, this is something we have to do. From what I see within Europe, I realize this is very difficult to harmonize and obtain consensus between different jurisdictions make the French talk to the Italians or Germans and to agree on a market foundation. Within the European Union there is an overarching framework that helps to organize that and we try to expand this to the Baltics countries and Russia. That becomes more difficult but nonetheless important. I would say this is the challenge, it's something that regulators and market designers and economists should aim at but I don't know if it can be achieved. To integrate the grid into the commercial exchange and if that is possible then I think a global electrical grid would make a lot of sense.

Are there financial barriers that are intrinsic to the electricity market structure/characteristic (without going into specific regulation/investment schemes)?

Depending on the distances that you have to bridge for example to North America, there's a question of whether it's feasible and what the cost would be, for example we are currently seeing it with the gas pipes with Nordstream costing billions. In the electricity trade, I could imagine that there would be other forms of transporting electricity for example through gas technology (liquifying gas and shipping over the ocean and re-electrify). Of course, this would be no longer an electrical grid, but it could be a financial barrier to find out what is the cheapest way. If you want to transport electric energy from one place to another, what do we use? Do we use copper cables? Do we use gas or hydrogen? There might be a mix in the forms of how we will transport electricity.

The fundamental question for any type of grid extension is who's going to pay for the infrastructure we see something like that in Germany as well because as I told you there's this North-South congestion so we have to build a lot of transmission lines somebody has to pay for it and in the end it will be the end consumer. In Germany it's easy because it will be the German end consumer but if you build an interconnection between Germany and Austria, it's more difficult: who's going to pay for that: Germans or Austrians? Whatever you do in managing that interconnector there's also a question; that's actually a political question in Germany: who's going to pay anything that goes over the border connection: Austrians or Germans? And the more we go to global perspective, the more complicated these questions will become in particular two countries or economic areas that are not as close as member states of the European Union. Cost-sharing between Austria and Germany is something you can negotiate. Between the European Union and Morocco that could be more difficult or if you get to the Arabic countries and want to bridge and do some sort of cost distribution over there.

And this is one important thing if you have a global mesh grid, we go back to the situation in Europe and this is also a cost barrier. If you try to connect South and North Germany, electricity might go through loop flows through Poland, Austria or Netherlands, Belgium and France. This flow of electricity is not commercially substantiated. Since that's one market area you don't see any commercial exchange between Southern and Northern Germany and there is a strain on other local grids. So, for example Poland is having all the impacts of the renewable electricity flow due to congestion in Germany. In turn, they cannot transport their own electricity. This means that the Germans are sort of free riding on the electrical infrastructure of Poland and Czech Republic without paying for that. The more you interconnect different countries or routes, the more you have to make sure that if there's a commercial exchange between country A and B but the electrical flows go through country C, you don't put a disadvantage on the infrastructure of that country. So again, there is a question of cost and cost distribution that you have to make sure it works. In Europe, this is already quite difficult to achieve so if we expand this to Russia or other countries, this would be a more important question and would give rise to negotiation and confrontation/frictions.

Do you see explicit and implicit auctions as a solution to the potential problems?

Market auctions or to integrate markets. Explicit auctions are easier because you have to care about the export of electricity by yourself so you have to book transport capacity. So, this is the old-school market that we used to have in Europe for market coupling. Implicit auction means that you have to integrate that automatically which is market coupling more or less. So, by establishing a global electric grid I think it's going to be stepwise or graduate approach, first of all you need to get the infrastructure done and there are a lot of grids that are already connected in that sense that are synchronized or that there are already some sort of exchange happening even if it's not commercial. If you have the European part of the grid, a Russian part, the interface between the two, the first thing to have would be an explicit auction so that you have a market on each side of the interface which will manage the interconnector or the exchange of electricity between these two areas manually. And once that is working and proven it's been a success then the next step is to internalize these auctions it's a bit like what you do with your Excel sheet you automate stuff. This step would be first build line, establish some sort of basic naive simple commercial exchange and then the market coupling step. And even within the implicit function there are different levels of integration: the highest integration is what we have in central Europe, and there is variance of those implicit couplings, for example the way southern eastern part of Europe is coupled to Central Europe.

Implicit auction is market coupling: when the market is coupled, the auction is implicit.

Do you think it is a problem that you can only buy electricity three years in advance and therefore risky not to be able to hedge long term?

Difficult question. If you look at the market, with EEX you can buy up to six years ahead technically, but the contracts are usually only liquid for the coming three years; thus the price is only known up to three years ahead. It is a difficult question because as a consumer or investor you want to have financial security as long as possible. If you look at PPA contracts ("Power Purchase Agreement", usually a bilateral long-time contract for electricity), you have 15-20-30 years price stability. From the market's perspective

It's very difficult to look into the future because nobody has got that magic first of all.

Covid19 and Fukushima have been externalities that the market had no chance to foresee. So even if you hedge your risk using extrapolations of the status quo market situation, externalities can break your back and render any risk mitigation strategy void.

Enormous risk premium -- the longer you want to hedge price risk into the future, the higher a risk-premium you will have to pay. At a certain cost one will have to decide whether the cost of risk management is higher than the cost of risk itself.

Liquidity -- The further out into the future you want to secure your prices, the less liquid contracts become, which is due to the price uncertainty. Liquidity is a measure of getting the price you need for your own strategy to work. So low-liquidity means high transaction cost and high costs for risk management.

Risk of not getting the price right is so huge that it more than offsets any investment risk

In the case of grid investments, at least what happens in Germany is that it is a highly regulated business. If you are a grid operator your profit margin is determined by the regulator. So given your cost, the regulator defines your maximum income and you can charge your client accordingly so you kind of have a long term hedging contract with your own clients and clients are not rational market actors because they are forced to use your connection so you're a monopolist in that sense. I think for long term investments is the only way you can do this because there is no market price to interconnect the value of electricity 10 years in the future and I doubt there is a reasonable economic argument to have one. It is a classical question of how you finance infrastructure investments.

Organization: DG Energy, European Commission

Interviewee: Oliver Koch

Date: 14th of May 2020

Could you please introduce yourself, so I know a bit about your background and your work in your organization?

I'm the head of the internal energy market unit of the Directorate General (DG) Energy. We are tasked to realize an interconnected and competitive internal market. Regarding your topic, our main task is to deal with the regulatory aspects of the European electricity grid (which is the largest grid worldwide with above 30 countries). You could ask yourself why other regions don't have such a large and integrated grid and market coupling system. We are responsible for the legislation, the EU electricity directives and regulation, the redaction of the network codes which are above 1000 pages of rules on how to exchange energy, how to deal with it across borders (how much MS are entitled to block electricity flows from neighbors, etc).
In a nutshell, my unit's task is about working on network and regulatory issues in electricity.

What can be, according to you, the main financial barriers to the materialization of such interconnections?

I think we need to distinguish carefully what we are talking about and so there are different layers. There are many countries outside Europe we are connected to: Switzerland (one of the most interconnected countries), Norway, Morocco, Russia, Ukraine, UK. So, we do have these connections. The question if we start from the center of Europe is "why is it not going further?". Usually there are two barriers. First you need to transport electricity and so you need to have rules on how electricity is traded. There is a very highly sophisticated system. In the EU we have market coupling so if you want to trade electricity, you do it in the day-ahead or intraday market coupling system. That is a European-wide system with its own legislation. You need to be an unbundled TSO to take part, you need to have an independent regulator. So, there are standards; it's like the banking union. So we have close cooperation with a high degree of integration with majority decisions: EU TSOs can be outvoted by the majority of other grid operators when deciding about certain rules and deciding about resource allocation. And electricity transport is about a lot of money. So, we have been integrating a system in the EU which makes it complex from a regulatory angle. So, it's not a financial problem, as the financial problem comes down to "is it profitable?", and it usually is because usually you have a certain price differential which makes it profitable because you can import cheaper energy from abroad and building the interconnector is cheaper than staying not connected. It's a very easy economic question. It's not a question about "do we have the money available?" but rather about "what is the economic incentive?".

Countries must have an interest in doing so. Take a high price country like Iceland that has a lot of green energy, no fossil fuels. We could interconnect Iceland. This will influence Iceland. Prices are very low in Iceland; if it would connect to the EU maybe its electricity prices will slightly go up because the price in the EU are much higher. Maybe consumers in Iceland will not be happy to be interconnected. There's a multitude of reasons that play into the question of why does an interconnector happen or not: regulatory questions, economic questions, … Also often from a competitors point of view, if you're not connected you are a monopolist in your country. If you [the TSO] are integrated to an energy producer, you can exploit whatever you want. You dictate the prices. If you connect to neighboring countries, you suddenly get competition in your country. Many don't want this. And you could ask yourself why the US grid is so fragmented. They don't even have a common electricity grid, isn't this strange? This shows that, even within a single country, the competitive forces might be so big that there is little appetite to integrate. So, the real question is "what speaks for building interconnections?" and not "what prevents interconnections". This gets worse with the distance, but it is already true for direct neighbors. Direct neighbors don't want to connect. In the EU we call this underinvestment. We have a string of competition cases on strategic underinvestment. Because competitors who have a leading role in one country are seeing competition by connecting to neighbors. That's something that not everybody likes and that's why we need strong regulation to sometimes even force connection and force opening the borders. So that's already true for a highly interconnected grid like the EU and you can imagine how this goes for neighbors. Think about Russia or Belarus in the Baltics area where the Baltics are fighting against letting energy from Belarus in because it's a nuclear power plant that is supposed to be rationally not very safe. Spaniards don't want much Moroccan energy because of the energy produced from coal in Morocco that is cheaper and who don't have ETS or any boundaries. So, also this may play in the game of not wanting an interconnection. At the end, interconnection is not a question of financial investment. I would even say it is relatively cheap compared to the price of the energy that gets traded on it. What matters is "what is the impact on competition?" When trading electricity, that prevents in most cases interconnections. And again, the wider you go, of course if you talk about the world connected grid that's nice, but for 20 years it was not possible to build an interconnection between Northern and Southern Germany and that's 400 km apart. So, this illustrates the challenges of having an interconnection of 4000km or 10000km. So, it is worlds apart from the problems we have. We struggle even to connect EU countries properly among each other and with third countries. In most cases, it's not a matter of missing money but a problem about missing incentives and motivation to connect with neighbors.

Are there financial barriers that are intrinsic to the electricity market structure/characteristic (without going into specific regulation/investment schemes)?

Yes, we need an agreement. We are for instance negotiating an electricity agreement with Switzerland which ensures a level playing field, that they also have an independent regulator. We need level playing field rules so that others don't have an unfair advantage. Because they could exploit things to cheaply copy our companies in an anticompetitive manner. They could have monopolies, they don't have rules, they don't have legal control while our companies are state of rules and legal control. It cannot be that you participate in something, but you're not bound by the same legal rules. So, what we need to build an interconnector is financing, yes, but in most cases, it is not a problem. The main problem is the need of a regulatory framework and that is an intergovernmental agreement and that is something we've been trying to do with Switzerland since 2006 and it’s still not there because it's politically very contentious. With Russia and the UK we are just negotiating, it’s very complex.

Organization: Elia Grid International

Interviewee: Isabelle Gerkens

Date: May 20th, 2020

Pouvez-vous vous présenter afin que j'en connaisse un peu plus sur vous et votre organisation ?

Je suis responsable Regulatory & Markets chez Elia Grid International (EGI). EGI est la filiale de consultance internationale de deux TSOs : Elia en Belgique et 50 Hertz en Allemagne. On n'a jamais travaillé sur un réseau mondial ; ce qu'on fait le plus, c'est au niveau européen et des réseaux interconnectés en Europe plutôt sur des aspects techniques : comment gérer les flux (prévisions de flux), capacités/mises à disposition du marché, besoins d'investissement du réseau électrique.

Pensez-vous qu'un réseau mondial d'électricité soit réalisable ? Quelles les principales barrières à sa réalisation selon vous ?

Je crois que ça n'a jamais été étudié au-delà de certaines idées. Cette espèce de grid mondial, on n'y est pas du tout encore. Je crois que ces aspects n'ont jamais été mentionnés. Je pense que trouver de la documentation doit être assez ardu. Il y a la partie financement, mais du financement on en trouve toujours. Derrière, il y a la manière de faire fonctionner les choses. Si on veut vraiment avoir des réseaux interconnectés planétaires, on pourrait se baser sur l'histoire de ce qu'on a connu en Europe où on est parti de réseaux nationaux et on a progressivement construit une vision européenne. Un des gros défis, c'est d'être aligné en termes d'approche. Ce qui a beaucoup fait changer les choses c'est quand on a commencé à avoir une vision européenne, un point focal, centralisé qui pouvait donner une ligne directrice qui après était implémentée au niveau national. Si on n'a pas ça dès le départ, ça ne peut pas fonctionner parce que chacun développe sa propre vision avec ses propres intérêts nationaux et après il n'y a que les interfaces d'échange d'énergie qui sont développés. Quand on part avec des approches différentes c'est difficile de les réconcilier. Si on veut interconnecter les continents, ce qui me paraît pourquoi pas une bonne idée, il faut avoir une vision globale relativement rapidement et une entité qui pilote les choses. On a la même chose en Afrique avec des pools régionaux. Ils ne sont pas très loin mais ils essaient de faire la même chose qu'en Europe : avoir une vision régionale pour pouvoir lancer ces initiatives. Pour la zone méditerranéenne, l'idée est de connecter l'Europe avec la zone MENA, c'est-à-dire l'Afrique du Nord et Le Moyen-Orient. Il faut voir comment on arrive à connecter 3 zones avec des approches totalement différentes. Ce sont Med-tso et Medreg qui s'en occupent. Med-tso est supporté par la Commission européenne où les TSOs du Nord et du Sud de la Méditerranée s'associent pour réfléchir à cette vision à plus long terme. C'est intéressant parce que c'est focalisé sur les aspects techniques, de gestion de réseau et investissements. Med-reg s'occupent de tout ce qui est régulatoire et soutien en termes de législation. Ils ont beaucoup de documents très bien faits qui peuvent être une source d'inspiration des thématiques abordées et pistes de solutions car elles combinent des approches de quinzaine de pays. J'imagine que les problèmes mondiaux seraient similaires à ceux identifiés dans cette région. A part ça, je pense que c'est un problème qui n'a pas été étudié. Il y a aussi énormément de défis techniques et technologiques.

Peut-être un problème vient du fait que l'Europe adopte une position euro-centrique : elle ne s'intéresse pas aux interconnections qui peuvent exister en Asie, ou entre l'Afrique et l'Amérique, etc. Elle est surtout intéressée de réaliser le marché interne européen, résoudre les problèmes de connexion, développer le renouvelable en Europe, entre autres via ENTSOE. ENTSOE est principalement composée de techniciens. L'ensemble de problèmes technique, la gestion de réseau, d'ouverture de marché, sont progressivement régulés au niveau de l'Europe et en parallèle par zone spécifique (Baltiques, Europe continentale, etc). L'approche européenne est d'avoir une vision long-terme solidaire pour tout le monde en étant unifié et de travailler par cluster thématiques et géographiques. Il y a aussi des aspects financiers importants : promotion du renouvelable, investissement des réseaux, … tout cela est répercuté au niveau national et répercuté dans les tarifs d'électricité. Il y a des mécanismes de soutien européen mais c'est plutôt pour la recherche ou pour des projets pilotes. L'Europe soutient des projets de développement dans les pays périphériques à l'Europe : Europe de l'Est, Afrique du Nord, … Il y a là des fonds européens pour développer ces pays, que ce soit en termes de production d'énergies renouvelables, de renforcement réseau et d'interconnections entre eux, de mise en œuvre des modèles européen en termes de marché d'électricité. À terme, on pourrait imaginer que la zone complètement unie du réseau européen d'électricité avec une production à 100% renouvelable s'étend géographiquement avec l'est de l'Europe, le sud de la Méditerranée. Mais je pense que chacune de ces zones a sa propre législation mais elles ont leurs propres accords bilatéraux avec l'Union européenne. Ces pays s'engagent quelque part à développer une législation et une approche marché, de réponse technique, qui est soit complètement alignée, soit compatible avec le principe européen. C'est ce que je vois de plus proche à cette extension vers le réseau mondial.

Quels sont les problèmes liés aux régimes d'investissements régulé et marchand pour les interconnexions ?

Vous pourriez faire une comparaison entre les 3 régimes : merchant, regulated et de plus en plus au niveau européen, le modèle hybrid. Ce dernier est la combinaison des deux autres modèles. Le modèle merchant, c'est « perds tes profits », l'investisseur fait payer la réservation de capacité long terme ou court terme aux utilisateurs et se débrouille pour que ce soit rentable. Le modèle regulated, pour être très simpliste, c'est que cette interconnexion fait partie des réseaux nationaux et le coût et la rentabilité de cette interconnexion disparaissent dans les tarifs nationaux et sont considérés comme un tronçon national. En très, très simplifié. L'hybride est la combinaison des 2 modèles. Il y a toujours des investisseurs. On sécurise quelque part les investissements avec des régimes cap-and-floor. Par exemple, en Belgique, il y a Nemo Link. Ça a été le précurseur en Europe. Ofgem, le régulateur anglais était vraiment sur des modèles merchant. La CREG en Belgique était plutôt sur des modèles régulés. À force de négocier, ils sont arrivés sur le modèle hybride qui est vraiment devenus la référence au niveau européen. Ce modèle hybride permet de garder une rentabilité pour les investisseurs, qui peuvent être les TSOs eux même, mais également de limiter les risques de l'investissement totalement privé. En créant un mécanisme de cap-and-floor, vous avez droit à une rémunération minimale mais seulement jusqu'à un certain niveau, au-delà ce serait abuser et profiter du consommateur : la rémunération est donc plafonnée. On va donc de plus en plus vers ces modèles-là. Je vois aussi qu'en Asie et au Moyen-Orient il a aussi de grands projets interconnecteur. Ce modèle hybride est vraiment regardé avec grand intérêt. Après, derrière, il y a aussi tous les paramètres qui peuvent être adaptés : la rémunération, etc. Alors derrière, quelle difficulté il y a ? Il y a l'aspect financier : où trouver le financement ? Mais dès qu'on est dans un modèle hybride où régulé, particulièrement hybride parce qu'il y a une rémunération garantie, les risques sont couverts. Il y a tout l'aspect régulatoire car ces mécanismes doivent être acceptés par les systèmes législatifs nationaux. Que le ou les régulateurs soient capables de gérer ce genre d'interconnecteur, qu'il y ait déjà eu des interconnecteurs. Tout l'aspect des questions régulatoire démarre souvent à 0 car on parle de pays qui commencent des interconnexions. La plupart du temps, il y en a quand même quelques-unes pour assurer la sécurité des réseaux et éviter les black-out. Si on peut faire des interconnecteurs pour des flux marchands d'électricité, on rentre dans une autre dynamique. Là, il y a beaucoup de choses à mettre en place d'un point de vue régulatoire, que ce soit des législations, que ce soit la gestion contractuelle de l'accès à ces interconnexions par les acteurs de marché, puis quels acteurs de marché ? Parfois c'est géré par des entités verticalement intégrées. Est-ce qu'on crée des enchères ? Comment met-on ces capacités à disposition et par qui et à quel prix ? Ce sont tous les aspect régulatoires et de mode de fonctionnement de l'interconnexion. Ce sont parfois des mondes entiers complètement inexplorés. Quel contrat ? Qui gère ça ? Une TSO ? Une entité régionale ? Le dernier aspect c'est l'aspect technique : il faut tirer le câble et le faire fonctionner au quotidien. C'est non-évident. On a tendance à dire : « il n'y a qu'à… » Mais ce n'est pas si simple que cela. Il y a d'énormes défis techniques. Ce sont les 3 axes qui posent des problèmes et pour chacun, il y a des solutions adaptées.