Implementing the Third Industrial Revolution: A Case Study of a French Example

By

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ABSTRACT

Economic growth is now stalling in Europe and at the same time unemployment has remained at high levels for a long time. On the other hand, the United-States are posting record growth rates and enjoy low unemployment, in great part thanks to their exploitation of shale oil and gas that has provided a surge of economic activity in the sector and has benefited to the whole economy through cheaper energy. Europe cannot rely on such natural resources to restart its economy and is facing difficult times since the financial crisis. However, this problematic situation might be in fact an opportunity to renew its economic system and impulse a new wave of healthy economic activity by choosing the path of an energy transition. The underlying assumption of this thesis is that, beyond any environmental considerations, the energy transition represents an unparalleled opportunity to restore economic activity and cope with the challenges of this century. However, as beneficial as a new energy system might appear to be upfront, it definitely implies ambitious and complex transformations. This thesis explores practical ways, best practices and shortfalls to avoid to implement the energy transition by focusing on the case study of the Third Industrial Revolution (TIR) Master Plan developed in collaboration with Jeremy Rifkin in the Nord Pas-de-Calais region in France. This region has decided to implement an energy transition plan for some obvious environmental motivations, but mostly for economic and employment-related ones. The thesis explains and reviews the concept of TIR, but it mostly spends time analyzing the NPDC Master Plan itself to explore the ways it has decided to implement its energy transition. The goal is to identify best practices and successes but also mistakes and failures on the path to making the TIR a reality. Hopefully, it will be useful for other projects of this kind, with the same ambitions for other regions of the world.

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Chapter 1: Introduction

In this introduction, I will explain what sparked my interest in the transition to clean energies and what led me to focus on the case study of a region in France to deep dive in this subject. I will present in more details the theories that led my interest in an energy transition, i.e. why it could be in theory a great economic opportunity. Following this, I will briefly review the concept of Third Industrial Revolution ("TIR"), forged by Jeremy Rifkin, that conceptualized an energy transition path. This will lead me to introduce the subject of my case study, i.e. the TIR project happening in the French region of Nord-Pas de Calais ("NPDC"), and explain why it is an interesting situation to study. I will eventually conclude by presenting the different parts of the thesis and giving details about my methodology.

1. From the Financial Crisis to the Green Revolution

I started my higher education in 2008, specializing in economics to prepare for the entrance exams of French business schools. With this timing, one can easily imagine that I have kept hearing about the financial crisis and its disastrous consequences; it has been at the center of many of my classes and I really developed a deep interest in the subject. Reading many books about the origins of the crisis, its impacts and consequences, and most importantly on what could be done after it, not only to make sure that it won't happen again any time soon, but also to restore economic growth, I stumbled upon different authors who were arguing that the classic remedies wouldn't be very useful this time and that it might be the opportunity to transition to a more sustainable economic system. This more sustainable system would rely a lot on the wide diffusion and generalized use of clean energies. One of most interesting book that I read on the subject and that really planted the seed of this idea in my head was *Illusion Financière* ("Financial Illusion") by Gaël Giraud; unfortunately, it has not yet been translated in other languages.

More than seven years now after the financial collapse, Europe, and France in particular, are still struggling to restore growth and fight high unemployment rates. As a citizen from this area, I am very concerned about the situation and I follow closely the solutions proposed and implemented there and what could be further done. In the meantime, I have become more involved with sustainability, as my year at MIT has proven me that this subject is not only urging and sometimes worrying, but also fascinating and exciting because it offers many challenges to rethink and reinvent many things and concepts we currently rely on, and as such, presents many business and economic opportunities. In particular, transitioning our energy system towards clean sources appears to be a necessity but more importantly it is an incredible challenge and could be a unique opportunity to take a sustainable – in every sense of word – and viable growth path, as I will explain further. However, this energy transition has to be a practical path, it must be possible to implement and have real impacts.

To find out more on this topic and follow what had started to be a real passion for me, I decided to do my Master thesis on it. Rather than conduct a theoretical study and try to estimate the economic impact of an energy transition in a specific area, I decided to look at real-life examples. Again, a solution has to be practical and possible to implement, so simulations and models would not bring much value, while looking at specific projects, studying their successes, weaknesses and failures, made a lot of sense. It happened as a coincidence that a French region had just decided to start a project of energy transition in 2013: it was a comprehensive and ambitious project, with the goal of becoming 100% reliant on renewable energies by 2050, and it had already started to implement the first actions. With its scale, vision and maturity, the plan of this region was the perfect case study.

2. Why an Energy Transition Could Be a Unique Economic Opportunity

Switching from fossil fuels to renewable energies would mean getting away from the negative economic impacts that fossil fuels may have, and also benefiting from the potential of new energy sources. In this section, I give a brief and high-level overview of the economic impacts of this change[1].

The first obvious thing that needs to be reminded about fossil fuels is that they are finite resources. As such, there might be a point where they block further economic growth. Going back to basic economic theory, it is known that the key to long term economic growth is increased productivity. But this notion of productivity is blurred and remains an enigma. It is also known as the "Solow residual", or *total-factor productivity,* and accounts for effects in total output not caused by traditionally measured inputs of labor and capital. This unexplained factor is in fact responsible for the major part of our historical economic growth. As many economists now agree, the reason behind Europe's "secular stagnation" – characterized by slow economic growth and high unemployment rates – is a stalling productivity. The key question is then: why has productivity been stalling? According to Robert Ayres and Benjamin Warr from INSEAD, energy is an important "engine of growth" and, in fact, it explains the vast majority of the "Solow residual" over long historical periods[2]. For a long time, we

[1] For a more detailed study on the subject, see for instance Chapter 5 of Environmental Protection Agency (2010)
[2] Ayres & Warr (2002 and 2006)

have benefited from energy sources becoming more efficient and cheaper, and this has driven growth since the First Industrial Revolution. However, our reliance on finite fossil fuels and lack of focus on improved energy efficiency have led us to a point where energy prices have stopped decreasing and productivity has stalled, creating a vicious relationship with economic growth. Indeed, as the economy fosters, demand for fossil fuels increases driving their prices up; as a consequence, costs increase throughout our heavily oil-dependent economic system, capping the economic growth in return. This view is linked to the peak-oil theory[3], which states that because oil reserves are finite, we will reach a point of maximum oil extraction after which it will then only decline. With similar or growing demand, the result of this decline in availability is of course sky-rocketing prices. This theory is very controversial and refuted by some with strong arguments; however it raises our awareness on the fact that oil reserves have become harder and more expensive to exploit and that this trend is set to continue, so even before a potential geological depletion, we will reach a point where it becomes too expensive to extract and use oil, at least compared to alternative energy sources. Currently, oil prices are "low"[4] – around $50-60 a barrel – simply because the world economy is still sluggish, in particular with countries that were driving economic growth and oil demand, such as China, currently experiencing much lower growth rates. A surge in economic activity will, in the longer run, drive prices up again. Based on this, it can be argued that we have actually reached the outer limits of how fare we can extend global economic growth within an economic system dependent on oil and other fossil fuels, and that it is time to switch to non-depletable resources before our economic growth potential becomes completely depleted.

The previous argument is not unanimous, as oil advocates argue that improvements in technology will help us reduce exploitation costs and maintain prices in a reasonable range[5]. Hence, other negative aspects of fossil fuels must be put forward to further support the idea of an economic opportunity in the transition to renewable energies. For instance, dependency on elite energy sources (elite meaning held only by a small minority of countries/regions) creates political tensions and costly conflicts. The USA for instance factor in as a cost of oil all the military expenses related to interventions for the protection of oil sources, particularly in the Middle-East. These elite sources also create strong inequalities, giving an unjustified economic power to the few countries/regions that have them at

[3] First introduced by M. King Hubbert in 1956

[4] Talking about low prices today is somehow exaggerated: it should be reminded that only in 2001, the price for a barrel was $24

[5] See for example: Gold (2014)

hand over others, who, on the other hand, are dependent on oil and gas and must sometimes rely heavily on imports that represent a financial burden at a national level. It also creates a national security issue for countries that depend on others for most of their energy supply. Furthermore, the volatility of fossil fuel prices creates uncertainty for importing countries and makes economic prediction and planning difficult. Lastly, fossil fuels require a concentrated energy production system, where energy is produced in big, centralized sites and then distributed to consumers through a grid. This architecture creates inefficiencies, energy losses, and supply/demand mismatches. It also results in regions being "off-grid" because of complicated access or costly grid connections.

Not only would renewable energies solve the problems listed above, but they would also bring additional benefits. Renewables are by definition unlimited energy sources that require no fuel, so once the infrastructure to exploit them is in place, their operating costs are much lower and more predictable than for fossil fuel generators, as these technologies have to incorporate the fuel costs in their operating costs. On the side of marginal costs, which should normally rank the generators to use in order of priority to satisfy demand, Solar PV systems for instance virtually have a null one with no fuel required and very little maintenance As a consequence, renewable sources would stop the upward pressure on energy prices and provide an unparalleled productivity boost in the long run. Prices would also become much more stable, giving more economic visibility. Furthermore, most renewables are evenly distributed (wind and sun are found everywhere), which solve the tensions, inequalities and dependency issues associated with elite energy sources. Additionally, renewables are more compatible with a distributed energy system, where energy production is close to final consumers, allowing more efficiency in the system. Finally, the transition in itself would be an important economic stimulus plan, driving investment and employment for the construction of new infrastructure required by these new energy sources.

From this high-level and theoretical review, one can easily see the economic impacts of switching from fossil fuels to renewables. At the same time, we already realize two broad sets of difficulties on this path. The first set is that an energy transition should be more than a list of benefits: it should be a comprehensive program with a vision and ambitions, to get adhesion of political leaders and of the population. What we really need is a global and coherent change of our economic system, a positive exit for a growing and sustainable economy. The second set of difficulties is on the implementation side, as it also appears as obvious that the switch would be a tremendous challenge in terms of financing the required investments and programming them with enough political will and power. A comprehensive program for an energy transition will have to bring answers to these difficulties to be a success.

3. Third Industrial Revolution 101

The expression "Industrial Revolution" was first used by French economist Jérôme-Adolphe Blanqui to describe the major technological changes occurring in France in the late nineteen century. It has since been used to refer to an earlier period of history when economies like Great Britain and France transitioned from traditional societies to a new era characterized by the factory system and new social relations. This First Industrial Revolution was followed by a Second one, more than a century later, when disruptive technologies provoked new social and economic changes. These two periods of great economic transformations were the result of a combination of various factors into complex processes that would deserve hours to study, but here I will simply remind that two obvious and very impactful factors were technology and new energy sources. The First Industrial Revolution really occurred thanks to the exploitation of coal and steam powered engines, allowing the creation of factories. For the Second one, the time of electricity, steel and the exploitation of oil and its derivatives had come.

The Third Industrial Revolution (TIR) is a concept forged and developed by the economist Jeremy Rifkin[6]. According to him, the TIR is the economic revolution that will happen thanks to the synergies between renewable energies and the new information and telecommunication (ICT) technologies. His concept gives a vision, a story and specific goals to the vague idea of an energy transition. However, it is still a purely theoretical work and his book sometimes lacks an anchor in reality and discussions on how to solve financial and political obstacles in order to implement the TIR. Still, since the publication of his book, he has been advising countries and companies on how they can progress on this path and he was the advisor and coordinator of the Master Plan established by the NPDC region.

4. Studying the French Revolution (but not the one you think about)

The focus of this thesis will be a case study of the TIR Master Plan decided in the NPDC region in France in 2013, and implemented since then. This plan has the ambition to revive economic activity in the region by making it 100% reliant on renewable energies by 2050. It was decided by local

[6] Rifkin (2011)

authorities, who called upon Rifkin's expertise, and coordinated the elaboration process among relevant stakeholders.

A case study is here particularly relevant because it is hard-to-impossible to evaluate the economic potential of an energy transition and the relevant questions are more: is it possible to implement it and how do we do it? An anchor in reality is needed as the goal is to identify best practices, evaluate answers to the obvious financing and political challenges and to other obstacles, and to give recommendations. A case study will allow me to confront theory to economic reality. The situation in the NPDC region is particularly interesting and relevant for this thesis as it is the first time that such a project is made at a regional scale - previous projects were for cities (Roma, San Antonio, and Utrecht) - and it is the most comprehensive energy transition program of this type so far. As a result, the project will be directly confronted with the financial and political realities that are absent from Rifkin's works. Finally, the NPDC region suffers from the bad economic situation in Europe and its dependency on fossil fuels industries, so the Master Plan has economic ambitions before environmental ones.

5. Thesis Summary

The global ambition of this thesis is to see how we can make the energy transition a reality. I have already identified the two main questions that a transition project needs to answer more specifically in order to achieve this practical goal: does it have a narrative and sells a vision that will foster public and political adhesion? How does it overcome the financing and political obstacles of the transition? In this vein, the first part will give some background information on Rifkin and his theories as they serve as a basis for the NPDC project. I will review and explain the ideas presented in his book published in 2011, *The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World.* It will show that he succeeded in crafting a vision and narrative for the energy transition. I will then tackle the more urging question of practical implementation with the case study, starting in the second part with the elaboration process and ambitions of the Master Plan established by the NPDC region in 2013. These elements are derived from the synthesis of the Master Plan[7], published by the leaders of the project to present it and communicate it to the public and interested parties. In the third part, I will review in details the Master Plan[8] and how the authors have planned its implementation. I will

[7] Region Nord-Pas de Calais (2013, October 25). *L'énergie renouvelée du Nord-Pas de Calais - synthèse réalisée à partir du master plan de Jeremy Rifkin*
[8] Region Nord-Pas de Calais (2013). *Nord-Pas de Calais, Troisième Révolution Industrielle Master Plan*

look into the specific projects and measures taken to realize the energy transition and how they articulate together. The fourth part will present an analysis of the projects to evaluate the strengths and successes of the Master Plan, but also its weaknesses and failures. The last part will conclude, wrapping-up what answers have been given, what points remain unclear and overall what has been learned through the case study.

Chapter 2: Background on the Concept of Third Industrial Revolution

In this part, I will review Rifkin's theories on the Third Industrial Revolution as they are the theoretical foundations supporting the Master Plan established by the NPDC region. I will go over the general concept, its content and ambitions. It will give the keys to understand how and why the Master Plan was crafted and show that Rifkin has managed to give a vision to the energy transition.

1. Background on Rifkin and the Concept of Third Industrial Revolution

The theoretical framework and inspiration for the NPDC Master Plan mainly comes from Jeremy Rifkin's research. He has, for a long time now, focused his teachings on the transition to a post-carbon economy and on the economic impacts of such a transition, and he is actually the special advisor and consultant of the NPDC region for the Master Plan.

Rifkin is one of the only economists that rethinks classical economic theory by taking into account the laws of thermodynamics and energy. In simple words, he considers the irreversibility of some human activities for the environment and the fact that the energy sources we rely on the most are available in limited quantities. In that respect, Rifkin can be seen as a long time heir of Thomas Robert Malthus! Malthus was the only classical economist to worry about the limited availability of subsistence means as population kept growing. His visionary thought that "the power of population is indefinitely greater than the power in the earth to produce subsistence for man"[9] was a thoughtful warning of the situation faced for instance by some regions with regards to water[10] or crops, or the issue of rising oil prices described earlier. Rifkin reminds us that our current economic system strongly relies on oil and all its derivative products (from plastics to fertilizers, through drugs and clothes) to work and grow. It is important to realize that oil is a finite resource that gets more and more expensive and that its exploitation and use have irreversible impacts on our environment.

As a solution to the preoccupying economic situation of the world, which he identifies as a consequence of a fossil fuels based system, Rifkin advocates for a new Industrial Revolution based on the interaction and synergies between renewable energies and new information and telecommunication (NITC) technologies. The latter are already widespread, but the former need a real

[9] Malthus (1976)
[10] See for example the 2014 and 2015 droughts in California

development boost to catch up with the process he envisions and reach their full potential and positive impact. Based on this, for the TIR to happen, there is a need to focus on making renewable energies available and used by the whole society, from individual households to businesses. To reach that goal, Rifkin proposes to rely on five pillars, which represent the foundations of his new system.

It should already be noted at this point that putting in place the five pillars implies massive transformations in our economic and energy system. The two previous Industrial Revolutions were also synonyms of massive transformations but happened "naturally" as new technologies imposed themselves by being better than previous ones. Here, we already have most of the necessary technology at hand for the TIR to happen, but we have not seen their massive distribution and implementation so far for several reasons. Among others, the two most important ones are the financial needs (even if renewables will be profitable in the long run, the upfront costs of a whole system change are huge) and the governance gap (politicians don't feel enough electoral support for such policies and at the same time, electors are waiting for politicians to take actions). It appears that these will be the main obstacles faced by any project in the vein of the NPDC Master Plan, and the most interesting lesson from the case study would be to find out whether the NPDC overcomes them, and if so, how.

2. The Five Pillars of the Third Industrial Revolution

Rifkin's Third Industrial Revolution is based on 5 inseparable pillars:

1. Shift to renewable energies
2. Transform buildings into micro-power plants to collect energy on site
3. Deploy storage capacities across the infrastructure to store intermittent energies
4. Upgrade the power grid into an "intergrid" where energy can easily be exchanged between users / producers
5. Transition our transport fleet to electric and fuel cell vehicles

The five pillars work logically together and form an interactive, integrated and seamless new system. They must be laid down simultaneously as they can only function in relationship to the others. Indeed, the power grid must be upgraded and made "smart" to handle the shift from centralized and steady energy sources to distributed and intermittent ones. At the same time, energy storage will become essential to allow a match between supply and demand of energy. Without that, we have renewable sources producing sometimes more energy than currently needed, or the opposite, less production than demand. Also, if the building stock is not progressively transformed to produce energy on-site and be more efficient, total supply might fell short of total demand. Finally, unless all these considerations are met, it will be hard to deploy the required infrastructure to power millions of electric cars.

Without going into too many technical details, the following paragraphs will give a brief overview of each pillars and the benefits they could bring.

2.1. Shift to Renewable Energies

Overview

The table below gives the list of renewable energies at hand for electricity generation and a brief description of each:

Energy Source	Description[11]	Capacity installed as of end 2013[12]
Onshore Wind	Turbines deployed in the mainland to extract kinetic energy from wind and convert it into electricity via an aerodynamic rotor connected to an electric generator.	312 GW (excluding offshore wind)
Offshore Wind	Turbines deployed in the sea take advantage of better wind resources than at land-based sites and achieve significantly more full-load hours.	7 GW
Solar Photovoltaic (PV)	A PV cell is a semiconductor device that converts solar energy into direct-current electricity. PV cells are interconnected to form a PV module, typically up to 50 to 200 Watts. PV modules, combined with a set of additional application-dependent system components (e.g. inverters, batteries, electrical components, mounting systems), form a PV system.	128 GW
Solar Thermal	Concentrating solar power (CSP) devices concentrate energy from the sun's rays to heat a receiver to high temperatures. This heat is then transformed into electricity.	330 GW
Hydroelectricity	Derives energy from turbines being spun by fresh flowing water. Mature and cost-competitive renewable energy source, it already contributes to more than 16% of electricity generation worldwide.	1,310 GW
Ocean Power	Encompasses 5 technologies: tidal rise and fall (barrages), tidal/ocean currents, waves, temperature gradients, and salinity gradients. Depend on conventional technology, but have not been deployed at large-scale yet	0.54 GW

[11] International Energy Agency (IEA) (2014)
[12] National Renewable Energy Laboratory (2014) and IEA (2014)

Biomass	Any organic, i.e. decomposable, matter derived from plants or animals available on a renewable basis and used directly as fuel, or processed into liquids and gases to produce energy	Accounts for 10% of energy world supply, mainly in developing countries for cooking and heating. Modern bioenergy is still small
Geothermal	Produce base-load power, heat and cooling from energy stored in trapped vapour and liquids (e.g. high-temperature hydrothermal resources, hot rock resources).	11.4 GW

All these energy sources (a part from offshore wind and hydroelectricity to a certain extend) have the ability to be deployed in a distributed manner, i.e. instead of centralized energy production and then distribution, energy can be produced on site. It is a major point to be noted as it has a significant impact when assessing efficiency of renewables and in the appreciation of their positive effects for the economy. In terms of cost-efficiency, it is hard to compare energy sources without context: many of them are heavily depend on the environment where they are deployed. However, geothermal, hydroelectric and wind are in general already cost-efficient compared to fossil fuel based energy sources[13]. Moreover, technology is moving very fast in solar PV and the cost per kilowatt-hour curve has been going down strongly[14].

Benefits

I will here give a brief overview of the benefits that can be expected from the deployment of renewable energies.

First of all, for economic activity and employment, the renewable energy industry is generally more labor intensive than fossil fuel technologies and can have positive economic ripple effects, particularly at a local level, since the money spent for energy imports is now used for local energy production. Producing energy locally fosters local companies that maintain and operate the production sites, local government can collect property and income taxes from renewable energy project owners, and land owners can get leases for the land where the projects are built.

Secondly, since renewable energies mainly require upfront costs and operate at very low marginal costs once in place, as the "fuel" they rely on is free and unlimited, they won't be impacted in the future by

[13] See US Energy Information Administration (2014)
[14] Shultz & Armstrong (2014)

fluctuating fuel prices of any kind. With increasing efficiencies and economies of scale, they will help lower energy prices, resulting in increased household income in the long term.

At a national level, public health benefits will represent massive savings, as air and water pollution resulting from coal and natural gas plants is linked to breathing problems, neurological damage, heart attacks, and cancer. These health impacts have high economic value: for instance, replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays. The result is reduced public healthcare costs[15].

For national security and energy independence, distributed and modular renewables offer a reliable energy system, less prone to large-scale failure. For example, in 2012, Hurricane Sandy damaged fossil fuel-dominated electric generation and distribution systems in New York and New Jersey and left millions of people without power. In contrast, renewable energy projects in the Northeast weathered Hurricane Sandy with minimal damage or disruption[16]. Power outages are extremely costly for an economy, thus a more reliable energy system will have important economic impacts. Finally, for many regions in the developing world, at the periphery of the grid, distributed energy sources are more relevant than a centralized production system. They can be the key to bring electricity access and allow economic development. There are already many examples of electrification programs in Asia and Africa thanks to small scale solar panels and wind turbines.

2.2. Transform buildings into micro-power plants to collect energy on site

Overview

Renewable energies like wind and solar can be found everywhere – in various proportions and frequencies though; we should then collect them not only in a few central points. Of course, big wind farms and solar parks will be needed, but making every building a *mini power-plant* is key to be able to fully rely on renewables. As awkward as the idea may sound, there are already many examples of industrial, commercial and residential buildings that are "net-zero" (energy produced = energy consumed) or even "positive power" (production excesses consumption and can be sold back to the grid). The first step would be to renovate the existing building stock to improve insulation and energy efficiency, and then install small scale energy production devices.

[15] Machol & Rizk (2012)
[16] Elisa Wood (2012)

Benefits

- Create a distributed energy system for more modularity and reliability
- Production on site reduces the risk of energy losses and improves overall efficiency
- Economic opportunity for the construction sector, a large contributor to GDP and industrial employer

2.3. Deploy Storage Capacities across the Power Infrastructure to Store Intermittent Energies

Overview

Fossil fuel energies have the advantage of being a fixed stock, whereas many renewable sources have a variable and intermittent energy production. Moreover, energy demand is far from being linear and there are recurring peak and low periods; hence, production needs to be responsive to these changes to avoid mismatches. Because we can't completely control production from renewables, there has to be a third element in the supply/demand equation: this is where grid-scale storage comes into play. It is really the missing link to allow a massive deployment of renewables.

There are nowadays different storage technologies at various development stages that can be split into the following categories[17]:

Physical Storage	
Technology	*Description*
Pumped hydroelectric	Water is pumped uphill in massive reservoirs with electricity produced; Water is released downhill to produce hydroelectric power
Compressed air	With extra electricity, ambient air is compressed and stored under pressure; when electricity is needed, the pressurized air is heated and expanded in a turbine driving a generator for energy production
Flywheels	Excess electricity is used to motion a rotor in a frictionless enclosure; when electricity is needed, the inertia of the rotor (kinetic energy) is able to produce energy
Chemical Storage	
Technology	*Description*
Fuel Cells	Excess electricity is used to "produce" hydrogen which is then stored; when electricity is needed, the fuel cell uses hydrogen and oxygen to create electricity by an electrochemical process
Solid State Batteries	Device consisting of electrochemical cells that convert stored chemical energy into electrical energy

[17] Energy Storage Association (2015)

Flow Batteries	Technology is akin to both battery and fuel cell: liquid energy sources are tapped to create electricity

Many of these technologies are still at a development stage and there won't be a "one-size fits all". Different technologies will be interesting for different uses depending on several factors: scale, frequency of charging/discharging cycles, energy conservation duration, environmental conditions, costs, etc. However, a common trait so far is a cost that is still too high. The US DOE has the ambitious research goal of reducing large-scale, battery-based electricity storage (and reconversion) to $100/kWh. The best technologies are still in the range of many hundreds of dollars per kWh. Important factors affecting cost include the bill of materials used, the cycle, the reliability and calendar life[18].*Benefits*

Grid scale storage is the missing link to fully integrate renewable energies as it solves the supply / demand equation caused by these intermittent energies. Adding to that, storage solutions would have many benefits.

For electricity suppliers, grid-scale storage would help stabilize production throughout the day and the seasons by smoothing peak-load and low-load periods. Energy can be stored when demand is low and used when it rises. As a result, it would reduce the need for extra supply capacity, or "peaker plants". Indeed, part of the system supply capacity is only used to meet periods of peak demand (only a few hundred hours a year).

For grid operators, storage would drastically improve energy system efficiency by reducing energy losses when there is production overcapacity and by improving Transmission and Distribution equipment performance. It would of course also solve electricity outage and backup power issues.

Finally, for end-users, storage allows electricity bill management and stabilizes prices by storing energy when prices are low and using it when they rise. It also means better electric service quality and reduces costs associated with outages.

2.4. Upgrade the Power Grid into an "Intergrid" Where Energy Can Easily Be Exchanged Between Users / Producers

A smart grid encompasses a wide array of hardware, software and telecommunication tools. The idea is get to new data through sensors across the grid and have the ability to make better decisions based

[18] Shultz & Armstrong (2014)

on these data, both for producers and consumers. In that respect, a smart grid will have multiple applications and benefits[19]:

- Manage consumer demand to reduce peak demand. For example, in a situation of peak energy use, a software could adjust the electricity used by some non-essential appliances such as a dishwasher or dryers (skip cycles or report their use)
- Manage utility bills for end-consumers: ability to monitor consumption and proactively modify it
- Identify energy efficiency sources proactively: a smart grid provides exact information about energy use that is useful to identify the most impactful ways to reduce energy consumption
- Improve operational efficiency: sensors and controls will help utilities identify and correct technical problems to improve reliability
- Cyber Security and protection: more visibility and control on the grid will make it more secure against potential attacks

Rifkin even envisions an "intergrid" that integrates distributed renewable energy sources and allows "energy sharing". With buildings collecting clean energy on site and energy storage across the grid, the ability to then share energy is key to harness the full potential of the system. Excess capacity from some producers/storage would be instantly directed to elements of the grid with peak demand. As such, the smart grid is critical to the growth of the other four pillars.

2.5. Transition the Transport Fleet into Electric and Fuel-Cell Vehicles

Transportation energy consumption accounted for 28% of all energy consumption in the US, reaching 13.8 million barrels per day oil equivalent[20]. It is key to find alternative energy sources for this sector to reduce consumption if we are to stop relying on fossil fuels. Electric vehicles (running on batteries or fuel cells) are a way to do it. They represent one of the "hottest" and most mediatized element of the green economy, and they seem very near at hand, but in fact they can only be massively deployed and scaled up once the other pillars are in place. Indeed, they will at first require extra production capacity from renewable technologies and the grid will need to be upgraded to welcome all the necessary power stations. These stations will need to be installed along motorways, in parking lots, garages, commercial and residential spaces.

[19] See Gridwise.org

[20] US Energy Information Administration (July 2014)

The whole electric vehicle value chain, from car manufacturers to electric power charging players, could represent a huge sector of the economy, fostering job creations, consumer demand, and public and private investments.

To conclude this part, I would say that Rifkin's concept of TIR really gives the vision of a comprehensive, coherent and seamless new system with multiple elements interacting together and supporting each other. It has a real narrative that can give hope and as such can gather the attention and commitment of the population. However, as I have started to outline, this vision is pure theory and says nothing about the practical challenges to overcome on its way. This review was then key to understand the context of the case study and realize these key challenges. I will now turn to the study of the NPDC project in itself. I will first go through its elaboration and rationale.

Chapter 3: Applying the TIR concept – The NPDC Master Plan Process and Ambitions

In this part, I will give some background information about the NPDC region that help understand why a Master Plan was decided in the first place. I will then explain how the project was elaborated and present its ambitions and expected impacts.

1. Background Information on the NPDC region

The NPDC region was a pioneer of the First Industrial Revolution thanks to massive extraction and exploitation of local coal resources, deployment of rail roads, and a boom in the textile and iron industries. It generated strong economic and demographic growth starting in the 19^{th} century, and the region became known as "the First Factory of France". During the Second Industrial Revolution, the economy of the region diversified in the food and agribusiness, retailing and automobile industries. Despite these new activities, the decline in the coal, textile and ironworks industries, lead the region to a strong and steady decline from the 1970s, after the Glorious Thirty era. Many factories were simply abandoned, and unemployment rose with hundreds of thousands of jobs destroyed in the three sectors. In that sense, the region experienced in advance the results of a fossil-fuel based economy coming to saturation.

Because of this difficult most recent history, the NPDC region implemented early-on different industrial reconversion programs and long term growth plans with public-private partnerships. It that sense, the region has a long history and good expertise of active public involvement in economic development. However, despite these efforts, in the early 2010s it still had one of the highest unemployment rates in France, and above national average poverty levels. Today, the region represents 6.5% of the total French population (4.02 million inhabitants and 1,607,528 households), but its PIB accounts for 5.2% of the French PIB (97 billion euros). Its leading economic sectors are the railroad, e-commerce, technical textiles, food processing, agro-biotech and nutrition, and retailing industries.

These different elements explain the attractiveness of an ambitious economic program at the scale of the region for the political and economic leaders of the region.

At the same time, the region has some noticeable strengths that leave open great opportunities for its future development: it is located at the earth of the active Northern Europe's economic area, it possesses three seaports open on the world's most active sea area (Boulogne, Calais, Dunkerque) and has railroad connections to 5 European capitals and major German cities (Paris, London, Bruxelles, Amsterdam, Luxembourg). Thanks to that, it is a very open region, accounting already for 10% of the total French exports.

2. Genesis of the NPDC Master Plan

The political leaders of the region, wanted to elaborate a development plan with the goal of restoring economic growth and better economic prospects in a region that had suffered in the past from harsh economic reconversion. Beyond that, they also had the desire to anticipate, and be at the forehead of the necessary economic transformations that will happen in this century, namely the probable changes in our economic model (a more circular economy), the reduction in energy consumption, the production of energy in a sustainable way to cope with the rising population and manufacturing production. At least at a local level, this setting already partially solves the "governance gap" evoked earlier, as there is a strong political will to act and change the situation in the region. To be completely solved, this gap will also require popular adhesion and commitment as I will discuss later.

The leaders' desire to call on Jeremy Rifkin for the elaboration of the plan revealed the high ambitions that they had. They wanted to bring to the table expertise, networks, and media coverage to have the ability to gather people around ideas and make the project a success.

3. Elaboration of the Master Plan and Leadership

It is important to give information on the elaboration process of the Master Plan as it is the starting point, and the first positive recommendation that the thesis give in the next part. Indeed, from the beginning the Master Plan has been anchored in reality by involving all relevant stakeholders to assess how the TIR pillars can be realistically applied. This process was key in coming up with the interesting elements detailed in the next part of this thesis.

It is also worth noting that from the beginning there was a desire of a *lateral decision process* instead of a centralized one, in order to avoid imposing a vertical frame and instead make the projects come from enterprises and local authorities. The main purpose of the Master Plan is to stimulate, coordinate, impulse and finance concrete actions that fall under the TIR. Authorities of the region will give a tool box and provide financial resources through a bold public-private contract policy to support innovative actions from local authorities and enterprises. It is a coordinated and collaborative project, completely different from a central planning.

More specifically, the elaboration process took 9 months of collaboration between 120 stakeholders (economic and political leaders, CEOs of local companies, scientific researchers, representatives of the education system, labor unions leaders, environmentalists) organized in working groups. The timeline detailed below shows that the elaboration process was definitely collegiate:

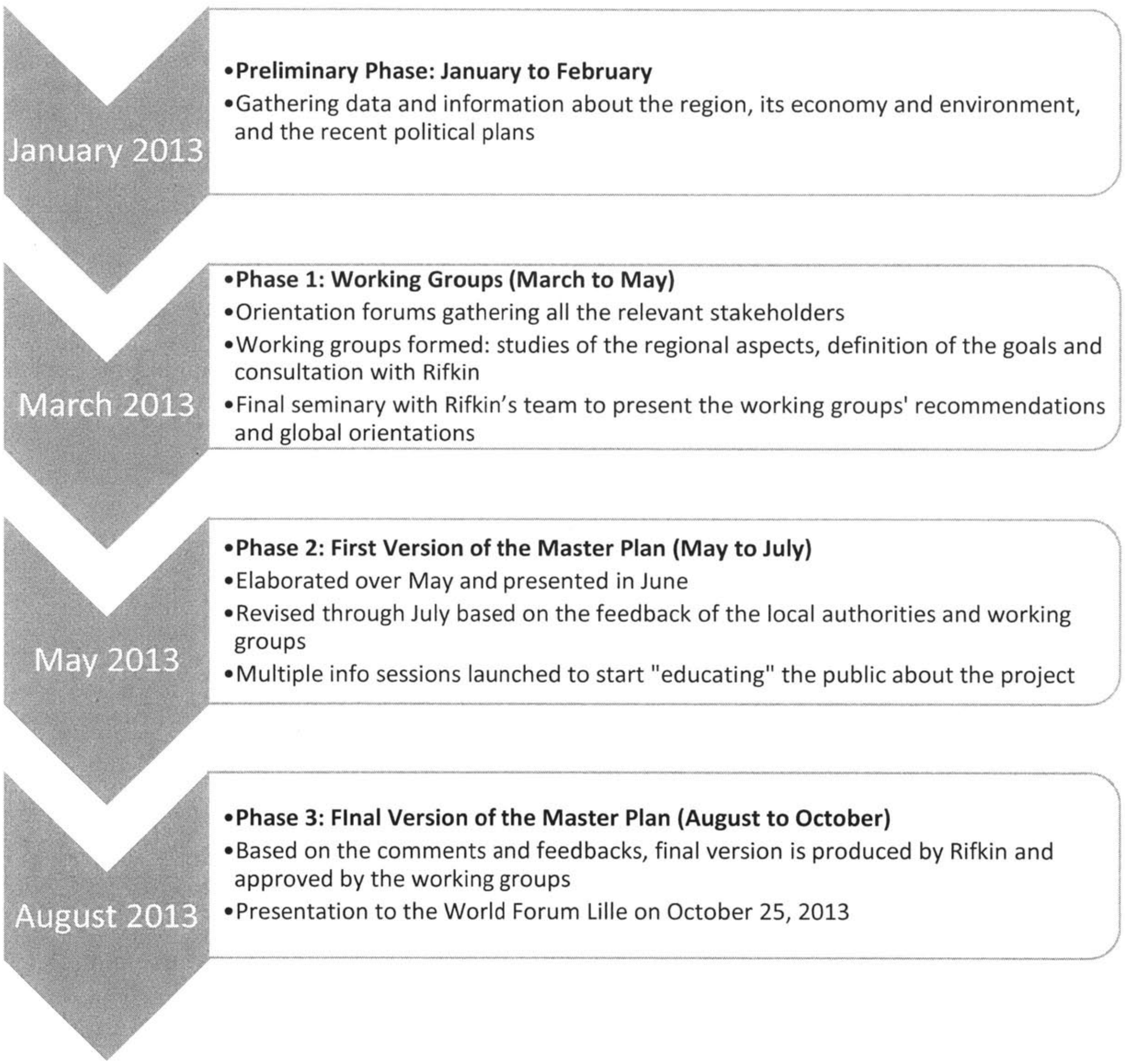


Figure 1: Timeline of the elaboration process of the Master Plan[21]

[21] Retrieved from the Synthesis of the Master Plan (p. 12)

The leadership structure decided to oversee the implementation of the Master Plan is also worth mentioning as it illustrates again the collaborative aspect of the project. It is composed of the three following elements and gathers representatives of the public and private sectors:

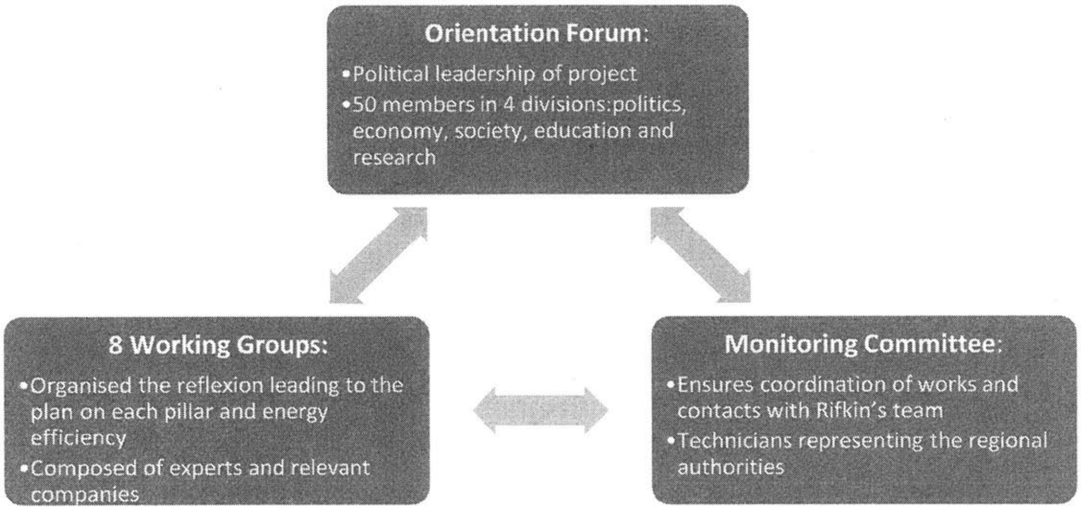


Figure 2: Leadership structure of the Master Plan[22]

The working groups are organized as follows: 5 groups for each pillar of the TIR, 1 group for the transversal subject of energy efficiency, and 2 groups to work on the economic models of the circular economy and the functional economy.

However, as I will emphasize it later in this thesis, it can already be noted that this elaboration process involved only local authorities and stakeholders, but had limited contacts with and involvement of national and supra-national authorities. With limited autonomy for French regions, it signals that some elements might be hard to implement.

22 From the Synthesis of the Master Plan (p. 12-13)

4. Ambitions of the NPDC Master Plan

The region leaders and Jeremy Rifkin have chosen to set ambitious goals early on to generate adhesion of the public and gather people around the project. The global objective of the Master Plan is to have 100% of the NPDC's energy needs covered by renewable energies by 2050. It means that the region will have reduced its energy consumption by 60% and divide by 4 its GHGs emissions. The NPDC region will then become one of the first post-carbon economy.

The graph below summarizes the objective of the Master Plan for the Region:

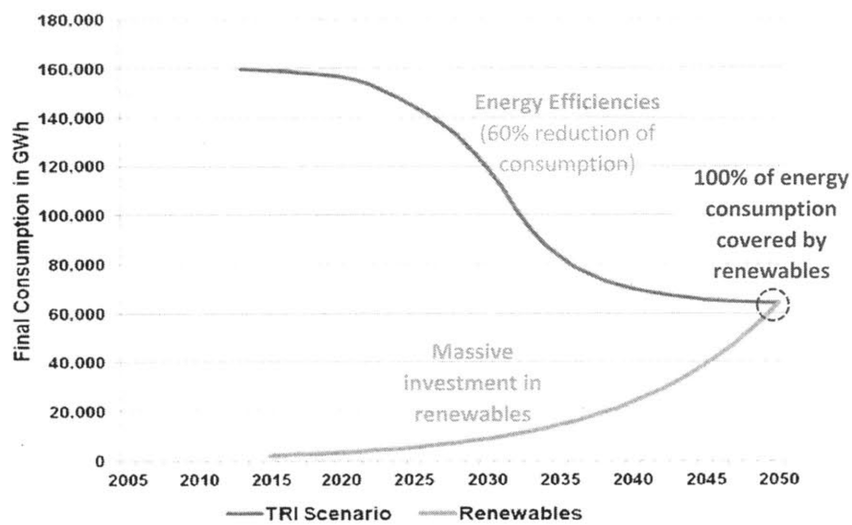


Figure 3: Scenario for energy production and consumption in the NPDC[23]

To achieve these ambitious goals, the NPDC Master Plan will rely on three levers that can be activated right now:

- Phase 0: Increase Energy Efficiency. This lever is really the starting point, the cornerstone of the project
- Pillar 1: Renewable Energies. Massive investments to reach a production level around 60,000 GWh by 2050
- Pillar 2: Building Stock. Renovate the residential and commercial stock to improve energy efficiency and create a network of distributed energy production sites ("Zen-e-ville" plan)

[23] Retrieved from the NDPC Master Plan (figure 52 – p. 78)

The combination of these three pillars should enable the region to almost cover 100% of its energy needs with renewable energies. They are based on already available technologies but imply an ambitious investment program that will require a strong financing plan. Meanwhile, the region will further promote the TIR project by committing in the longer run to its other pillars:

- Energy storage solutions: the region wants to become a leading cluster in the new storage technologies and will help innovative companies working on hydrogen, hydraulic pressure, and compressed air technologies
- Smartgrid: the region will promote the required regulative and legislative changes, and coordinate investments required to develop the infrastructure of a new grid
- Transportation: the region wants to promote electric vehicles, and also efficient fleet management and logistics solutions

On top of that, it was a specific desire of the leaders of the project to think about ways to implement the principles of functional and circular economy at the regional scale. They specifically want to promote the recycling of natural resources as this effort will reinforce the ambitions of the TIR.

5. Estimated Investment and Impact

Overall, it is estimated that all these projects will require 200 billion euros of investments, from both public and private sources, which represents in total a bit more than two times the current regional GDP, or 5 billion of investment per year across the 35-year period. This massive amount is justified in the Master Plan by the fact that the energy bill will be largely reduced over the period through efficiency gains and reliance on local energy sources. This energy gains will be even more impactful in an environment of rising energy prices. Also, thanks to the economic sectors created or stimulated, it is estimated that 165,000 jobs will be created in the region by 2050. Combining the reduction in the energy bill, the job creations and the overall economic stimulation, the region estimates that its GDP will be 10 billion higher than a business as usual case (which assumes a 0.8% annual growth rate over the period, starting with a GDP around 90 billion). However, as I will discuss later, these numbers are only rough estimations that should be considered with caution.

By reviewing the elaboration process of the Master Plan and its ambitions, we start grasping a more practical view of an energy transition and some rough numbers about its costs and impacts. Practical implementation appears to feature some variations from Rifkin's theories, such as a bigger focus on efficiency and consumption reduction, but the two main challenges anticipated earlier (financial needs and political will and power) are still very concerning and represent areas of doubts . I will now study the content of the Plan in more details to clarify these preliminary findings.

Chapter 4: From Theory to Practice – Implementation of the Master Plan

In this part, I will review the key measures and projects that the NPDC region has actually included in its Master Plan to apply the five pillars and start transitioning to a post-carbon economy. It shows the big jump from theory to practice, how the sometimes very abstract ideas of Rifkin could be applied but also how the anticipated difficulties are hard to tackle. As such, it provides some of the key learnings of this thesis, whose ambition is to study how an energy transition can be implemented, and the challenge it represents.

1. Energy Efficiency: Pillar 0 or the Cornerstone of an Energy Transition

The instigators of the Master Plan realized early on that for the NPDC region it would be impossible to rely on renewables as the only energy supply by 2050 if demand was not reduced first. This is the reason why the Master Plan has set the objective of reducing energy consumption by 60%, and why this lever will be the first to be activated and will remain central to many initiatives. This objective will partly be achieved through the five pillars which all indirectly or directly contribute to the energy consumption reduction, but a number of specific initiatives targeting energy efficiency will be put in place. I detail some of them in the sub-parts below.

Overall, it is interesting to note how promising this lever is, as the necessary technology is already available and a lot can be achieved in a profitable way or at very low costs, and at the same time to realize how challenging it will be to implement some initiatives because of the necessity to change behaviors or interfere with some economic activities.

1.1. Avoiding the Rebound Effect

The authors of the plan have carefully considered the risk of "rebound effect" in the longer run. This effect is characterized by a rebound in consumption due to less careful behaviors when individuals start seeing a decrease in their energy bills. While technologies will be useful to counter this effect, the most important solution comes from the education of the population to deeply root the changes in behavior. The region will create educational programs in high schools, launch tracking systems to measure the positive impacts of energy efficiency in residential buildings and communicate them to the public, favor communication on social networks to share experiences, etc. The goal is really to give an immediate visibility to the results and their positive impacts in order to further stimulate and educate the public. While the Master Plan authors' awareness of the difficulty to change individual behaviors and these initiatives designed at educating the population are positive elements, they do not represent a guarantee that individuals and companies will actually make the required changes to achieve the consumption reduction goal.

1.2. Reform the legal and fiscal environment

The political leaders behind the initiative of the Master Plan have promised major evolutions on this aspect. The goal is to create subsidizes and fiscal incentives at a regional level for initiatives around the TIR, but more importantly to change the rules and the fiscal policies that refrain or slow down the investments and set new norms that will favor their development. For instance, a very important aspect is to simplify the regulations and administrative requirements that still make grid connections of distributed energy sources, such as Solar PV on a building roof, a long and complicated process. This, however, must be done through a collaboration between the French Government and local authorities, as some elements are beyond the scope and sovereignty of the region alone. A point of concern also arises on that topic, as very little is said on the willingness and ability to implement rules and regulations to limit the consumption of highly impactful industries for the total region energy consumption, such as ironworks. It is hard to envision how consumption can be reduced by 60% if these major consumers are not actively targeted by reduction measures and incentives.

2. Distributed Renewable Energies: the Basis of a Post-Carbon Economy

The deployment of renewables depends on the geographic and climatic particularities of a defined region; in NPDC, the focus will be on solar, wind and biomass. The main challenge of the Master Plan here is to find solutions to finance the upfront deployment costs of the new technologies and the shutting down costs of past generators.

2.1. Distributed Solar Energy

The main issue refraining the deployment of this energy source comes from its high upfront costs due to the fragmentation of production and installation. As a solution, the Master Plan proposes the creation of *cooperatives* to organize and gather building owners ready to install solar panels on their roofs in order to increase and make visible installation capacities and thus reduce costs through bulk orders and programs. In the same logic, the region will create a *solar land register* to register and classify all buildings in favor of solar installation but that may lack the investment capacity. This land register will be an information resource for large scale investors and cooperatives in order to easily identify usable spaces. The region will also coordinate Solar PV installations with the building stock upgrade program run to improve energy efficiency to further reduce costs by doing some operations in common, e.g. intervention on the roof for isolation works coordinated with a solar PV installation. Finally, the legal environment will evolved to make it easier and faster to connect local production capacities to the grid and be able to exchange energy between users. It is the condition to allow consumer-producers to emerge because as of now the legal and administrative requirements make it almost impossible.

2.2. Wind power

This energy source has a huge potential in the region, estimated at 3,000 MWh/year, and it will be its first renewable source. An important challenge to its deployment is local opposition based on arguments of visual and sound pollution. Overcoming this will require education in the first place, but the NPDC region will also rely on the reconversion of former industrial sites which are away for inhabitations, and allow a reduction in construction costs thanks to their easy road access and grid connection. Finally, off-shore wind power has a huge potential in the North Sea and the Channel Sea (this area has seen 18GW of projects for 2013-2014 from other countries). The NPDC has so far been away from such projects but has a great capacity to launch some as it will be able to use its harbors and great sea logistics network. The region will take part in the next national request for proposal for offshore wind development in France (3,000MW to be attributed). Two potential sites have been identified so far, one away from Dunkerque and the other away from Berck-sur-Mer.

2.3. Biomass

This other source also has a great potential in the region: in the scenario of reduced energy consumption, biomass could cover 40% of the region natural gas needs by 2050. In particular, natural gas produced from this source would be used in case of excess energy demand, which will be especially useful as long as there is a lack of a cost-effective grid-scale energy storage technology. The great potential of this technology comes from the strong agricultural and agribusiness sectors of the region: it is easy to produce biogas through the methanisation of waste at farms and factories. Adding to energy production, there are other uses of biomass such as natural fertilizers and construction (isolation components).

It should be noted that very little is in fact said about a proper transition from one energy system to the other, in particular about how to move away from and dismantle previous generating plants. Indeed, the Master Plan details implementation of the new technologies but not what happens to the old ones, while there disappearance will actually imply stranded costs and raises the question of the reconversion of former industrial sites.

3. Renovating the building stock with a new vision of urban planning

The Master Plan emphasizes the idea that retrofitting the existing building stock and applying specific technologies to new ones is key to achieve the energy consumption reduction goals and benefit the most from renewable energies.

3.1. Project Zen-e-Ville

This project is a *large-scale "laboratory"* of 600 buildings, both commercial and residential, that will be built to gather all relevant stakeholders (local authorities, users, construction businesses etc.), and to experiment and evaluate new urban planning policies. It will allow stakeholders to work together in real conditions and will integrate and test various elements: use of local construction materials, energy efficient buildings, on-site energy production and storage capacities, smart grid and local energy exchanges, smart logistics and transportation... It will be the opportunity to learn about the social and economic evolutions required by these new urban planning, and also about some efficient education and involvement programs for the general public. The learnings form this experiment, hopefully gathered by 2020, will then be used and deployed on a large scale through a retrofitting program, coordinated by the Regional Counsel, of half of the residential buildings by 2050. In particular, this project will be a good opportunity to evaluate the quality of the interactions between the different stakeholders and see what are the missing inputs or external interventions required, especially on the legal and regulatory side.

3.2. Transform and reintegrate former industrial sites

It is an important aspect for the region as many of its industrial sites were abandoned with the decline of the First Industrial Revolution sectors. Some of the spaces will be depolluted to favor preserved spaces for biodiversity, others will be used for biomass and wind energy production.

3.3. Creation of a Regional Office for Energy Services

This regional office will act as a third-party investor, i.e. it will act as an operator and will finance the building works required by an energy efficiency and distributed energy production project for a building. This third-party investor steps-in when the owner of the building does not have the financial ability to fund the project. The third-party investor then get reimbursed and paid by receiving the cost savings realized by the investment.

3.4. Clarify the fiscal and regulatory environment

Energy efficiency renovation projects are still lagging behind because of a lack of visibility and quality standards, and of weak fiscal incentives. The Region will set quantitative objectives and put in place clear norms and quality labels to certify companies and products active in energy efficiency projects. It will also make the fiscal incentives clearer and more efficient by linking them to projects run by these certified companies.

3.5. Lead by the example with public and semi-public buildings

The "zero-carbon university" project has the goal to make the seven universities of the region completely carbon neutral by retrofitting the buildings and installing production capacities on site. In the same vein, several social housing projects across the region imply the renovation or building of energy neutral houses, with the combination of high energy efficiency and on-site clean production.

4. Energy Storage: Implementing already available solutions and offering experimentations for emerging ones

Although grid-scale storage capacity is mandatory to compensate for intermittent production of renewable energies and demand/supply mismatches, there is no available technology with the ability to scale up today. Adopting a pragmatic approach, the NPDC will rely in the short to mid run on alternative solutions to provide a storage "bridge" found in extra production capacities from "cleaner" and on-demand energy sources (such as natural gas produced through biomass), and will try to be at the forefront of the promising storage sector and will implement the first technologies as soon as they become available. However, there is clearly a big uncertainty here that does not depend on the region itself but on technology availability, and that affects the rest of the new system, as the success of other elements directly depends on the introduction of storage capacities.

4.1. Hydraulic storage

As of now, it is the only available and cost competitive technology. The Master Plan will take advantage of the former coal mines that can be exploited as huge reservoirs. Another option for this technology is the use of giant reservoirs under the Channel Sea, in some areas where depth is limited. These projects will provide some storage capacity but are by definition hard to scale up and will be only of marginal help.

4.2. Finding the Storage Bridge with cleaner extra-production capacities

In the short/mid run, the NPDC will find extra capacities to support renewables in peak load periods or replace them when the production is intermittently interrupted. The first kind of these extra capacities comes from biogas derived from biomass production through methanization of wastes. Another solution is a hydrogen/natural gas mix that could be used for both public transportation fleets and central heating systems of residential buildings. There is already a project piloted by GDF-Suez (project GRHYD) based on this "Power-to-Gas" technology and implemented in the city of Dunkerque since the beginning of the year. Another technology that will be explored by the region consist in combining hydrogen to CO2 to produce methane: it is a great opportunity to recapture and recycle CO2 released when burning fossil fuels, offering a second life to CO2 emissions.

5. Smart grid: Preparing the infrastructure

The goal of the Master Plan is to deploy smart energy meters with analysis and communication capacities, and connected to supply/demand regulation platforms, in order to establish energy equilibrium at local scales (neighborhoods, cities) through direct exchanges between consumer-producers. Here, the technologies are already quite mature, e.g. readily available smart meters, so the main issue is more to anticipate the needs and coordinate the different stakeholders (consumer-producer, distributors, regulators-managers) to frame and adapt the grid in a coherent and suitable way. Transforming the whole grid of the region is also a costly and complex project. Again, the ability to overcome the financial and political challenges will be deterministic in the success of this pillar. In the long run, the region will also try to impulse an international grid across Europe to further guarantee equilibrium and security through energy exchanges at a national or regional level.

5.1. Gathering information in a secured way: creating a central data platform

The first step to ensure a comprehensive view of the needs and to facilitate the coordination will be to share information on energy consumption while protecting the privacy of users. These data are essential to control consumption and identify the most promising investment projects. In order to gather the data in a secured way, the NPDC will negotiate with the different stakeholders to create a platform that will gather all relevant data and offer building owners, local leaders, energy utilities, and investors the resources and analysis essential to them.

5.2. Deploying smart meters

Smart meters are the cornerstone of the "intergrid" project to allow interconnection between consumer-producers. These devices are already being tested and implemented by ERDF for electricity (Linky) and by GRDF for natural gas (Gaspar). Their deployment at the level of the whole grid will however be a more complex and costly process, and represents only the first condition towards the achievement of a complete "intergrid".

6. Changing the transportation networks and systems

Finding solutions to reduce energy consumption in transportation has been identified as a key element of the Master Plan as this sector represents 20% of the energy consumption in the NPDC and relies mainly on fossil fuels. The goal is to reduce energy demand for the sector by 10% before 2020 and by 25% before 2030.

6.1. Improving logistics for the transportation of goods and people

In the same way as energy efficiency is the first step towards deploying and relying on renewable energies, logistics efficiency is the first step towards changing the transportation system with cleaner solutions. The idea of the Master Plan is to think about transportation networks in the same way we think about communication networks: transportation flux can be rationalized through common traceability, transportation and storage modes, and with cooperative networks or under the supervision of supra-operators. In order to achieve this optimization and coordination, the region will create a *governance organism dedicated to transportation* that will prioritize investments, coordinate transportation modes, and define proper regulations to facilitate and incentivize collaboration between different actors. This organism will be helped and advised by a counsel gathering the different stakeholders of the sector (local authorities, experts, companies, researchers etc.) with the aim of studying and evaluating new innovations, and of organizing their potential implementation. One of the first ideas is to create a *transportation exchange* to optimize the utilization rate of trucks in the region. Truck space availability will be gathered and freely "traded" on this exchange.

For the transportation of people, the same idea of a logistics internet will be put in place with the goal of having complementary transportation modes, interconnections between them, clear and unique prices, emphasis on bikes access and safety, promotion of innovative solutions like car-sharing, and optimized infrastructures. The efforts towards this will be coordinated by a *Mobility Agency*.

6.2. Promote Clean Vehicles

The region will promote the installation of 2,500 electric stations for vehicles through public-private partnerships that will start the process of economies of scale to then make them more accessible to the public and to private companies. It will also develop distribution networks for hydrogen and biogas by converting public vehicles (bus fleets and others); it would be the first mandatory step to guarantee access to compressing stations and then allow private fuel cell vehicles.

7. Applying the principles of circular economy and functional economy to further increase economic and social welfare

It is the first time that these two new economic models are integrated to a Master Plan designed by Rifkin. It was the desire of the NPDC instigators to integrate them to the roadmap as their application can enhance the goals of economic and social welfare of the TIR. Indeed, both of these concepts have the aim of creating value and welfare while favoring a quick decrease in the use of non-renewable natural resources that are depleting (water issues and depletion of precious metals like silver, copper, zinc etc.). To do so, they always ask the question of the resources consumption with regards to their final use, which reinforces the idea of social and environmental efficiency. These principles will be applied to every projects and aspects of the Master Plan by developing evaluations tools and labels, encouraging short distribution networks, eco-conception of products and services, the use of renewable inputs, and by financing enterprises to help them deploy the best available technologies.

7.1. Functional economy

This concept has the aim replace the sale of a good or service by an integrated solution, potentially shared, and focused on the usage value and the satisfaction of a specific need rather than on the material ownership.

7.2. Circular economy

This concept has the aim to replace the linear life cycle of raw materials by an optimal reuse of wastes, considered as new resources, in closed circles with only renewables inputs. It covers the principles of eco-conception, reuse and recycling of products.

8. Financing the required investments

Here comes one of the most challenging aspects of the implementation process of the TIR. On this topic, the leaders of the Master Plan have made it clear that the energy transition has the goal to foster a better economic situation in the long run, and as such it has to find its own economic equilibrium. Thus, the region won't be financing non-profitable projects. Nevertheless, many projects will require important upfront investments, take time to prove their model and payback only after some years. As a result, the investment horizon is unusually long and the overall financing need is massive: we are talking about 200 billion euros over a 35-year period. Such a program should clearly identifies its funding needs and potential sources; it will eventually require mobilization of all already available sources and of dedicated new ones, and will combine public and private sources.

8.1. Existing public sources

At a European level, funds can be obtained from the European Regional Development Fund (ERDF) that has a program over 2014-2020 with an important part reserved for projects in the vein of the TIR. The European Investment Bank will also be solicited. At a national level, funds can be obtained from the "*Programme des Investissements d'Avenir*" (Investment program of 47 billion euros launched by the French government in 2010 with a focus on research and new technologies in energy, transportations and buildings and urbanism) and from several specialized entities such as the CDC (Deposits and Consignments Fund), the BPI (Public Investment Bank) and ADEME (French Agency for Environment and Energy Management). There is also a couple of entities and funds at a regional level. The NPDC Master Plan lists those potential sources in details but does not provide much insights on its ability to tapper specific amounts from the different entities.

8.2. Mobilizing private sources through new mechanisms

It will be necessary to complement public funds with private ones in order to generate enough leverage. The leaders of the Master Plan want to access every kind of audience and use innovative financing forms while collaborating with the banking system. For Institutional Investors, a *Common Securitization Fund* will be created and dedicated to the TIR. Any bank lending to a TIR project will have the opportunity to sell some amount of the loan to the Fund to refinance and enhance its ability to lend to other projects. For private individual savings, a specific saving accounts has been created: it works as a traditional saving account in France, where you can freely deposit and withdraw funds, the only difference is that the funds are used only to finance TIR projects. Another source is to use a small portion of the life insurance premiums deposited in evergreen funds (without any specific termination date). Finally, the region will innovate by putting in place a crowdfunding platform where internet users will have the opportunity to donate funds, lend money with or without interests or invest in bonds or stocks in TIR projects. This source will be mostly used for start-ups and SMEs and will also provide an education and enrollment lever for the public.

By describing and quickly analyzing the details of the Master Plan, this part has shown that the TIR can be translated into real projects. It has given a first hint of some of the innovative and well-thought directives of the Plan to make the transition happen and overcome some practical difficulties. At the same time, it showed that the Master Plan has left unclear the answers to the financing and governance gap challenges, and has also revealed new difficulties, not anticipated before. I will now further analyze these elements to identify the lessons that can be taken from of the NPDC project.

Chapter 5: Putting it all together – Challenges, lessons learned and recommendations

In the previous part, the thesis has presented the elaboration process of the NPDC Master Plan, its content and some of the practical ways the Region plans to start implementing the TIR pillars. This review was already the opportunity to bring some answering elements to the key question of the TIR implementation challenges, especially the financial and political ones. I will now adopt a more analytical view of this plan and focus on these answers by clarifying the previous findings and bringing new elements. I will start by showing some of the innovative and promising ideas of the Master Plan, I will then study in more details the "challenging opportunity" of consumption reduction, and finally, I will look at weaknesses and challenges that the Master Plan will have to come over along the way.

1. Positive aspects of the Master Plan and innovative solutions

1.1. Maximizing public adoption early-on, starting with the elaboration process

Two important positive things are to be noted about the elaboration process of the Master Plan. The first one is that it has been a very collaborative process, involving all relevant stakeholders from different horizons and with varied interests. There was no intent to impose things to some parties, but rather to collaborate and compromise in order to have as many parties "on board" as possible. It was as much an education process as a working process: the goal was to present the opportunity of such a plan to all the parties involved and then get their input, needs, concerns and requirements to build it. The second point is related to the first one: the elaboration of the plan was really a bottom-up process. It started by considering local needs and inputs from initiatives already taken by local authorities, and companies active in related sectors through the 8 working groups. The intervention of Rifkin and his team only occurred at the end to coordinate everything and give the global vision and goals. No ready-made plan was imposed, it was rather tailored to the situation and needs of the region. By doing so, the Master Plan simply gave a common framework, narrative and direction, in order to gather and coordinate a multiplicity of smaller initiatives and actors already in the field.

Those two aspects of the elaboration process explain the positive reaction of the public and the early adoption of the project. It cannot forecast the success but it is surely a positive sign as the outcome of this project depends a lot on private initiatives and behavioral changes.

1.2. Communication: it is about what you say and how you say it

The leaders of the Master Plan have done a really good job at communicating it and this stands out directly when one reads the different marketing materials that they provide to present the project.

First, they focus on the economic impacts and opportunities of the plan rather than on its supposed "environmental necessity". In other words, they talk about economic development in priority, and the environmental impacts are positive side effects but not the main rationale. Why does this matter? Because climate change should not be the main issue and people can get tired of this subject. It should not be the main issue because it is in fact still a very controversial topic among the scientific community, and some scientists[24] argue on the impact of human-driven CO2 emissions on CO2 concentration levels in the atmosphere and on the link between CO2 concentration in the atmosphere and global warming. More importantly, the public sometimes gets tired of this subject as we are all aware of it now and we keep hearing about it. In fact, most of the current communication on climate change makes it appear as a burden, a bill that we need to pay for. Moreover, some people consider that other concerns need to be addressed in priority, such as an unemployment, starvation, or poverty, and for them climate change is not the priority. Hence, presenting the Master Plan as an economic opportunity rather than as an environmental necessity results in a much more powerful message.

Second, they make sure they send a positive and rational message. Indeed, the success of their communication is in great part dependent on the ability to show that the TIR investments will yield to results superior to the ones of a business-as-usual scenario. They also insist on the fact that projects should find their economic model and equilibrium and that funds will not subsidize unprofitable ventures. By doing so, they try to show that the TIR is a rational and profitable choice that will yield to a higher GDP and more jobs in the region, relying on scenario analysis. The table below presents the numbers they provide in their communication:

	2020	2030	2050
GDP – Base Case (0.8% growth per year)	97	105	123
GDP – Downside Case (energy price increase of 40% by 2050)	95	100	112
GDP – TIR Case	99	112	133
Net Jobs Creations	+37,000	+109,000	+165,000

[24] See for instance Gian Paolo Beretta, professor of fluid and thermal sciences at MIT (2015)

I will discuss more about these results later, but for now it is important to note that the communication really tried to show positive economic impacts and sell the project as a great opportunity.

Third, they set clear and ambitious goals, which is primordial for such a plan. Indeed, Jeffrey D. Sachs[25], drawing on what has been achieved over the last decade in the fight against poverty thanks to the Millennium Development Goals, shows that fixing objectives is primordial:

- It is essential for social mobilization: objectives orient actions in a coherent manner, avoid distractions and allow consensus so that everyone knows what to focus on
- It creates peer pressure: organizations committing to specific objectives can be asked about the concrete measures they took to serve them and become accountable for the results they achieve
- It generates epistemic communities (group of experts with specific knowledge) and uses them towards action: these communities will meet, often for the first time, and propose concrete ideas to solve the problem. In the case of the Master Plan, the orientation forums and working groups are a great illustration of that
- It commits networks of diverse stakeholders (politicians, scientists, NGOs, international institutions etc.). This diversity is essential as such objectives often require a multiplicity of skills and action levers

With the clear goal of reducing energy consumption by 60% before 2050 and being 100% reliant on renewable energies, the Master Plan goes beyond any European or international agreements and is clearly ambitious. It generated hope and faith and so far has received a great commitment from various stakeholders and important public adhesion.

Finally, the assistance and presence of Jeremy Rifkin has a strong impact on the overall marketing of the project. He is seen as a credible, respected and inspiring figure, and as such he has helped attract a lot of attention and media coverage on the region and its project. It helps "sell" the Master Plan at a national and international level and also creates credibility in the region to further enhance public adhesion.

Overall, through different mechanisms, the idea was to communicate a holistic and positive message, and maybe more than that: hope. The Master Plan is not imposed as a cost or a necessity to mitigate

[25] Jeffrey D. Sachs (2015, March 30)

climate change, fight unemployment or other plagues; it has the positive vision of making the NPDC a dynamic economy and the leader of the energy transition in Europe, and as such it "sells" a great opportunity for the region.

1.3. Solving technology bottlenecks in a pragmatic way

By reading the theories of Jeremy Rifkin on the TIR, one can cast serious doubts on the ability to make some of them a reality as many rely on innovations yet-to-be discovered or commercialized on a large scale, e.g. energy storage and hydrogen production. The authors of the Master Plan have managed to overcome this obstacle pretty well by being pragmatic, focusing on technologies available today and making sure the region will be ready to adopt other useful innovations as they become available along the way.

This pragmatism is expressed in the sense that the Master Plan starts with what can already be done today and that the bulk of its projections relies on already available technologies. For instance, as developed through the McKinsey curve shown later, measures to improve drastically energy efficiency in the system and technologies to build energy-neutral or -positive buildings are currently sufficient to reach the 60% reduction in energy consumption. As figure 3 of this thesis shows, it is mostly this reduction that will allow the region to reach a high percentage of renewables in its energy mix. The rest of the effort will come from increased production capacity for renewables.

For these new production capacities, the Master Plan adopts again a practical approach and focuses on the most promising sources, as not all of them are at grid parity, i.e. they produce electricity at a higher cost than traditional technologies. A conventional measure of the cost of an energy source is the Levelized Cost of Electricity (LCOE), which "represents the per-kilowatthour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle."[26] This key measure is used in comparative studies and integrates various variables from building the plant to operating and maintenance costs. The results on LCOE from the latest Energy Outlook of the US Energy Information Agency are presented in the table below:

[26] US Energy Information Agency (April 17, 2014)

Plant type	Total system LCOE
Dispatchable Technologies	
Conventional Coal	95.6
Integrated Coal-Gasification Combined Cycle (IGCC)	115.9
IGCC with Carbon-Capture System (CCS)	147.4
Natural Gas-fired	
Conventional Combined Cycle	66.3
Advanced Combined Cycle	64.4
Advanced CC with CCS	91.3
Conventional Combustion Turbine	128.4
Advanced Combustion Turbine	103.8
Advanced Nuclear	96.1
Geothermal	47.9
Biomass	102.6
Non-Dispatchable Technologies	
Wind	80.3
Wind-Offshore	204.1
Solar PV	130
Solar Thermal	243.1
Hydro	84.5

Table 1: U.S. average levelized costs (2012 $/MWh) for plants entering service in 2019[27]

As one can see, even if these numbers are specific to the USA, the comparison holds true almost everywhere (in fact, natural gas is more expensive in Europe so the LCOE for Natural Gas-Fired plants may even be higher), and some of the renewable sources designated as priorities in the Master Plan such as wind and biomass are already at grid-parity. Also, the other technologies are evolving at a fast pace and grid parity will be achieved in many regions shortly. For instance, in its 2015 Solar Outlook[28], Deutsche Bank says that Solar PV will be at grid parity in up to 80 per cent of the global market by the end of 2017, and this holds true even with the drop in oil prices. So here again for energy production, the Master Plan focuses first on technologies available and cost competitive as of today, and opens the door for improvements in others.

The last missing piece that still lack the sufficient and competitive technology is storage. Without it, it will be impossible to achieve 100% reliance on sources like wind and solar as they are intermittent sources and the load varies strongly throughout the day and over a year. Instead of staying trapped by this technology bottleneck, the Master Plan will first rely on cleaner "*peaker* plants" – plants used only

[27] US Energy Information Agency (April 17, 2014)
[28] Deutsche Bank (2015)

to respond to extra demand in peak hours – such as natural gas fired ones, with gas produced in biomass plants in the region. These *peaker* plants are the bridge solution while storage is being improved, and the region will at the same time continue its experiments with hydrogen and hydro-storage to make sure it can integrate these technologies once they become competitive.

1.4. Innovative financing solutions

I can't emphasize enough that one of the biggest challenges of such an ambitious program is obviously the financing part. The Master Plan has come up with some innovative and interesting ideas on this topic.

First, it has carefully considered the investment models for different types of projects. For instance, investments at the level of a building – for energy efficiency and/or on-site energy production – will be greatly facilitated by the Regional Office for Energy Services that will act as an *Energy Services Company* (ESCO), which is a third-party investor that can finance the project and gets paid back through the economies realized. Indeed, an owner financed model is suboptimal and cannot reach the expected level of investments, especially when there is a large number of rented buildings, where the owner of the building would not be the beneficiary of the energy gains. For investments of a larger scale, the region will put in place the *Sustainable Energy Utility* (SEU) model, where a utility is overviewed by the local authorities of the places where it operates. This control and centralization at a local level allows an easier aggregation of public and private funds, notably through the issuance of bonds, to finance infrastructure investments. The gains of the investments are then used to pay back investors.

Second, in terms of sources of financing, the use of crowdfunding seems particularly innovative and really adapted to the TIR. It will allow the financing of smaller scale and local projects, mainly individual building renovations and on-site energy production, and as such it will be another efficient alternative to the owner financed model. It also has the benefit to further implicate individuals, as they can learn about different projects and their impacts. Finally, it provides households with an additional way to benefit from the economic gains realized thanks to the TIR, as they will be rewarded financially for their investments. The same can be said about the specific savings account created earlier this year. It is a more traditional banking product, targeting less tech savvy households, but it has same working principles and benefits, i.e. involving the public and making it contribute to and benefit from the projects.

While very interesting and potentially impactful, these initiatives are far from completely solving the financing challenge of the TIR and are only signaled as good ideas but not as complete and sufficient solutions.

2. Building a more efficient system: a challenging opportunity

It is not obvious in Rifkin's books and theories that the mandatory first step to an energy transition is to reduce energy consumption, probably because it sounds less like an economic opportunity at first. But the practical hard fact for the NPDC, and for any other place, is that it will be impossible to rely only on renewable energies if energy consumption is not reduced in the first place. It also makes a lot of sense to rethink some consumption patterns and inefficiencies to generate immediate savings, and take the most accessible path towards the reliance on more renewable energies. On the other hand, consumption reduction is a big challenge as it relies for a great part on the changes in individual behaviors and on the commitment of high-consuming industries and companies.

The Master Plan demonstrates a good understanding of the priority of consumption reduction as one of its objectives is to reduce it in the region by 60%. The reference consumption level (in electricity equivalent) was of 160,000 GWh in 2005; it should be brought down to 64,000 GWh by 2050. Such an ambitious goal is explained by the fact that there is huge room for improvement, as the region is currently one of the least efficient of the country. Indeed, looking at the energy efficiency of the region in two different ways, its low level is blatant:

- Per capita: in 2009, the annual average energy consumption for an inhabitant of the region was 35,700kWh, when the French national average was 27,800kWh
- Contribution to economic activity: in 2009, each GWh of energy consumed resulted in 600,000 euros of GDP. In France, each GWh generated 58% more economic activity, i.e. 948,000 euros of GDP on average

This low level of efficiency is explained by various elements:

- The region is still very industrialized and this sector accounts for 50% of the total consumption, with ironworks alone accounting already for 23%. The question being: how will the Master Plan have an impact on this part of the total consumption?

- Buildings represent 31% of the total consumption and are particularly old (80% of houses were built before 1990) and inefficient (68% of the building stock is considered having a low thermic quality)
- Transportation by car is very high in the region as 65% of travels are done by car, showing low logistics efficiency

Hence, the strong emphasis of the Master Plan on energy consumption reduction is particularly adapted to the region profile and is also supported by research on the subject. Amory Lovins for instance, mainly in his book *Reinventing Fire*[29], shows that reducing consumption through more efficiency is the first step towards a bigger, more productive, and more independent US economy. Implementing renewable energies is only the second step. This, of course, also holds true outside the US, in other countries and regions.

Very adequately, the Master Plan also considers transportation logistics in a similar way as the energy system: the first step towards transforming it, is improving its efficiency. Here again, even without massive technological breakthrough, consumption can be drastically reduced without damaging economic activity.

However, as previously mentioned, one of the biggest challenges for the region will be its ability to taper this energy efficiency potential. In order to do so, it has to communicate that the consumption reduction will not rely mainly on personal restrictions (some popular shortcuts give a bad publicity to this concept, making it look restrictive and regressive: using your electronic devices less, reducing central heating, walking instead of driving, or using less lighting in buildings etc.), but will mostly be driven by more efficiency in the energy system. Moreover, it should strongly remind that a reduction of energy consumption will in fact translate in lower energy bills for both households and companies, resulting in overall economic gains. The now famous McKinsey GHG abatement cost curve[30] reproduced below shows that many energy reduction initiatives actually have a negative cost (the investment they require is more than paid back by the savings) and, as a result, energy efficiency can be improved while making significant economic gains:

[29] Amory Lovins (2011)
[30] Enkvist, Dinkel & Lin (2010)

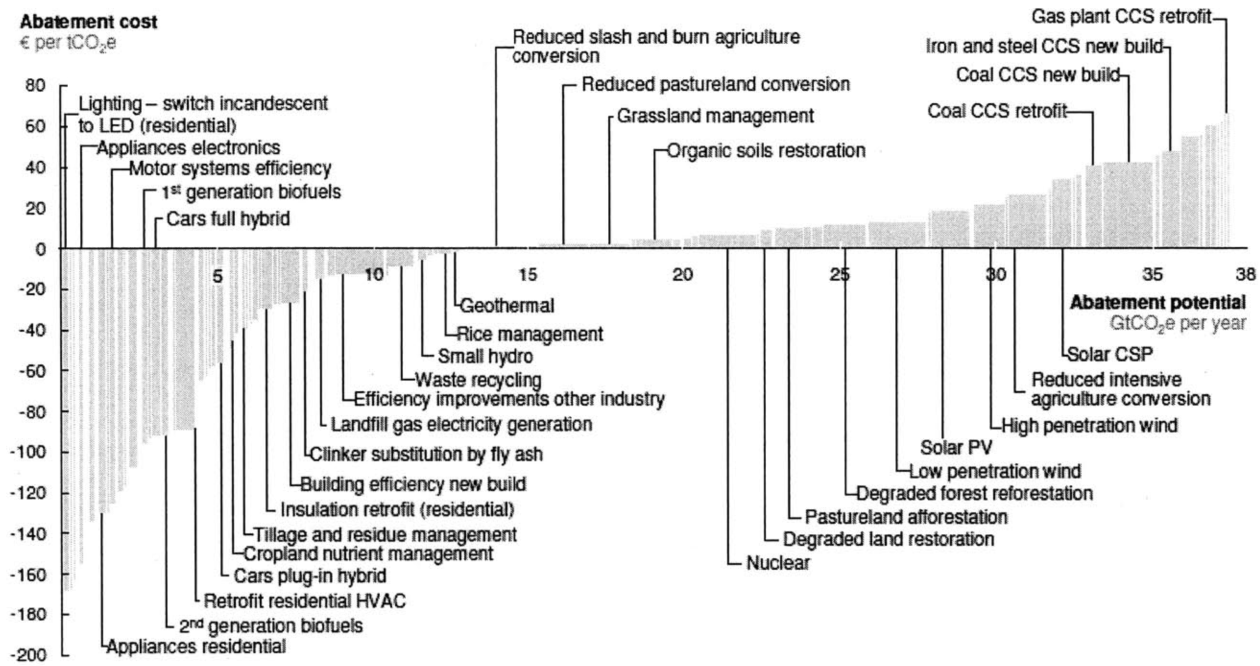


Figure 4: Version 2.1 of the Global GHG Abatement Cost Curve[31]

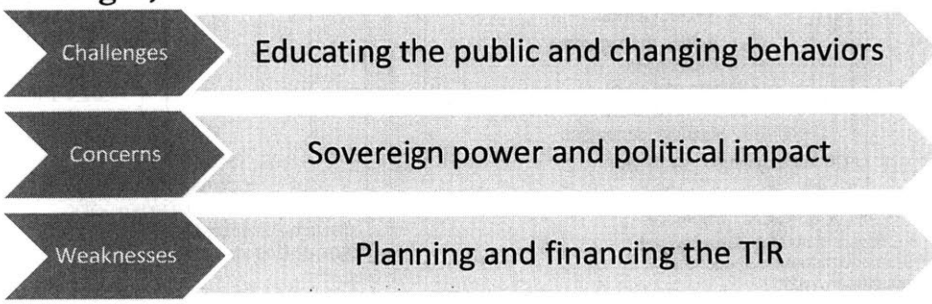
At the same, time, the McKinsey curve also shows that reaching the 60% reduction goal will surely imply going beyond the first initiatives where the gains exceed the costs,. The further we go on the path to consumption reduction, the less profitable the initiatives are and the lower the total return becomes. At any given state, any incremental initiative to further reduce consumption will be less profitable or more costly than the previous ones, so setting intermediary goals is dangerous as the temptation to stay where we stand will be important.

The position adopted by the Master Plan and its authors to cope with this challenge is to set ambitious and long term goals from the beginning for the reduction in energy consumption and to really focus on improving efficiency with dedicated working groups and controlling entities. By doing so, they show that important results can be achieved and that the global economic impact is greatly positive over the 35 years period, even if it implies massive investments (200 billion euros over 35 years). This focus on efficiency is wise and pragmatic, as many initiatives in that sense can be taken today, and the communication around it is finely tailored to really change the perspective on energy consumption reduction and sparks the interest of the population by presenting a promising future.

[31] McKinsey, *Impact of the financial crisis on carbon economics – version 2.1 of the Global Greenhouse Gas Abatement Cost Curve* (p. 8)

However, as positive as this focus on efficiency is, its results are highly uncertain as their main transmission channels will be the behaviors of the population and of corporations. As I will show in the next part, having them adopt the right behavior will be a tough process.

3. Challenges, concerns and weaknesses of the Master Plan



3.1. Disruption, educating people and changing behaviors

The issue with ambitious plans around energy consumption such as the NPDC Master Plan is that they rely for some part on changing people's behaviors. Indeed, an important chunk of the energy consumption objective will rely on people changing their habits and behaviors, by reducing their own consumption or improving the efficiency of their energy system and isolation of their house for instance. However, changing behaviors is a very uncertain and sensitive thing; it is often more efficient to find ways to compensate or cancel the negative effects of problematic behaviors. In this situation, there is no shortcut like this, and people will have to be aware of the changes needed and actually implement them for the objectives to be reached.

Moreover, the new system will be highly disruptive and, as such, it will require important economic, material and technical transformations. It will force some sectors and industries to reinvent their business models and might put some of them out of their main revenue sources. For instance, the ironworks industry represent 23% of the energy consumption of the region, with notably two big ArcelorMittal plants among others implanted here, but there is no specific explanations on how the Master Plan will make sure that its consumption is reduced. It is impossible to reach a 60% reduction with actions only targeting the remaining 77% of the total consumption, and on the other hand, reducing the consumption of this 23% chunk will require either huge efficiency investments or a plain and simple decrease in production. Overall, there is no details in the communication of the Master Plan about the elaboration of the plan on the level of consensus reached among key stakeholders, and there might be protests and various blocking groups of interests that will impede part of the process.

On the solution side of these issues, there is only two ways to foster the transformations required from both corporations and the public: intensive education and communication about the topic, and financial incentives or penalties. The education and communication must be comprehensive, credible, adapted to different kind of people, deliver a positive and encouraging, yet persuasive, message. Most importantly it must deliver a vision based on values that echo the culture and history of the region to gather the population around the objectives. The region has a specific culture and history that to some extend make it stand apart from other French regions, but regional identities are not that strong in France, compared to the States in the US or the "Communidades Autonomas" in Spain. As a consequence, a powerful and effective communication is a real challenge and even if, as discussed earlier, the Master Plan seems to have framed a positive and convincing message, it has to deliver it in the launching years and maintain interest over the long time period. It is hard to judge it now and only the years will tell how effective it was. The second tool, financial incentives and penalties, means new laws and regulations, tax code reforms, new standards and labels, and of course it also means enforcing these measures. The process required can be long and fastidious to go through all the legal and administrative requirements, particularly in France, a country not known to be easy to reform.

In the end, the success of the Master Plan will depend largely on the uncertain adoption rate of the project and the long-term commitment of the population.

3.2. Limited political and administrative power for a region

Partly related to the previous point, it can be argued that the region will lack authority and decision power and might not be able to pass some of the required new measures. France still has a very centralized political system and local authorities only have a limited sovereign power. At best, the region will only be able to argue for some key measures and hope for support and a larger agreement to get a decision at a national level. Below is a list of some important topics that could have a material impact on the success of the Master Plan but that can only be decided at a national or supranational level:

- Distributed energy production: make access to the grid as a consumer/producer to exchange energy a quick and easy process. There are many hurdles to be removed in this area and it will require negotiations with French utilities and compliance with the European Union rules. As of now, it is a very long and complicated process to become an energy producer and it is almost impossible to sell back your excess energy to the grid as a household

- Subsidizes to fossil fuel related industries/products: many products derived from fossil fuels still benefit from subsidizes that artificially lower their prices. Eliminating these subsidizes would make cleaner substitutes more competitive
- Carbon tax: it would be a powerful tool to factor in all the social costs of fossil fuels and give to the market their real price to society. As a result, renewable energies would become even more competitive and their adoption would certainly increase significantly

As a result, the region might only be able to implement some projects but it will have to convince the French authorities to support them, and adhere to the Master Plan, to ensure that essential measures outside its sovereignty are passed. In that sense, the political challenge, i.e. the governance gap, is only locally solved and the question at a national and supra-national level remains unanswered.

3.3. The planning of all the transformations is not clearly defined

As previously explained in the concept of TIR, the five pillars work together and are essential to each other, so they need to be deployed simultaneously in a given region. Moreover, these deployments need to be ambitious and comprehensive in order to achieve economies of scale, foster network effects and ensure customer adoption. For instance, electric vehicles widespread use cannot be achieved without easy access to multiple power stations and an adapted electric grid. Pilot projects don't work in this context as they wouldn't have the ability to capture the impact of economies of scale and network effects. Hence, there will be a need of planning simultaneous global transformations of the region: it will be a highly complex task, particularly in the coordination of different public entities and private companies from various sectors that will need to interact with each other.

However, the Master Plan answers weakly to this challenge as it does not provide much details on the planning. It simply acknowledges some difficulties, especially to change the electric grid, but brings no specific answer to them. More precisely, it lacks a *detailed action plan,* with specific steps and important milestones along the way with key parties in charge that any investor would require when evaluating such a project. Without specific, measurable and timely goals along the 35-year period, with parties in charge of each of them, there is less accountability and progress tracking. As a result, it seems like the Master Plan has the ambition of being a coordinator of the many initiatives going in the direction of an energy transition, but without a properly defined planning it will be hard to achieve.

Directly linked to the previous weakness, this one in fact also has to do with the limited action power of the region that does not the ability to plan some transformations. Its authorities will need the French

State and the European Union to come up with this detailed planning. However, at these levels, the governance gap is still blatant.

3.4. Unproven economic projections and unclear financing plan

The Master Plan comes up with economic projections that estimate the potential impact of the TIR for the region by doing scenario analysis. It compares a base-case, with fairly simple assumptions (0.8% annual growth), and the TIR case that brings a higher GDP in 2050 and important job creations over the period. However, looking deeper at the TIR-case projections, the authors acknowledge the lack of reliable data and solid estimations to build upon. As a result, these projections are to be considered carefully: they show that there might be a material positive impact over the period, but no precise answer should be assumed and the advertised numbers should be no more than benchmarks. It is a tricky issue that seriously alter the credibility of the message and again it is a communication challenge.

Moreover, this technical inability to forecast the economic impact of the transition means that it is also impossible to get a good estimation of the costs of the program and the required investments. As a result, the financing section of the Master Plan is more than vague and elusive. Perhaps more important, the section shows more wishful thinking than a demonstrated financing plan with the different fund sources listed. Indeed, the financing section is just a list of the financing sources available at a regional, national and European level: it shows that these entities have funds to be invested in some sectors related to the TIR but it has no details or specific amounts that could be obtained from each. Again, it alters the credibility of the message and casts doubts on the ability for the region to really put in place some projects.

As a result of a more analytical reading of the Master Plan, some lessons emerge. Being able to communicate positively such a project and framing a vision based on strong values is essential and has been done successfully by the NPDC region. Adopting a pragmatic position to solve some technical issues and translate concepts into real projects is also a great achievement. However, it appears that the Master Plan still lacks some anchoring to reality, and a clear agenda over the time horizon of the project would be particularly needed. The leaders of the TIR project in NPDC have to come up with it once they have a bit more visibility on what they will be able to do in order to make this project more than a collection of great ideas and good intentions.

Chapter 6: Conclusion

The goal of this thesis was to find out how an energy transition can be implemented by studying a real project. I identified from the beginning that such a project would need a vision to gather people around it, and it would have to overcome two main challenges: organizing the necessary funding of the underlying investment program, and solving the governance gap that explains the general lack of political actions in the field of sustainability. To do that, I went over the first large-scale example of an energy transition applying Jeremy Rifkin's concept of Third Industrial Revolution. This case study allowed me to discover great insights and ideas on how to go with such an ambitious program. It showed that the TIR concept transmits the kind of vision able to spark public and political interest, and gather key stakeholders around its goals, and it reminded how important communication is, especially around critical issues such as climate change and sustainable economic development. People need to hear a positive message that carries a vision and hope, instead of being constantly reminded that if they don't act now the earth and human life are at peril. The NPDC Master Plan also proves that despite some important technological gaps, a lot can already be done today and with material expected gains. For instance, energy efficiency is something we, as a society, haven't care enough about, but that has a huge potential in terms of economic and environmental impacts.

On the other hand, the case study also reminds us that an energy transition is a complex and uncertain process. We don't really have the capabilities to plan precisely a transition and estimate accurately the costs and potential benefits. As a result, there is no "magic" answer to the financing challenge. Some innovative solutions are brought by the NPDC region, but it is completely unclear that it will have enough resources to finance all of its projects. Moreover, being a regional initiative only, the NPDC project only partially solves the governance gap. It shows a strong willingness to change at a regional level but it will need national and European support to actually succeed. Only early positive results and proofs of strong popular concern and commitment will decide those upper political levels to act.

Overall, one of the key lesson for me is that transitioning our energy system is no different to previous massive transformations that occurred in our History, such as the first two Industrial Revolutions. It represents a long and complex process with multiple factors interacting, and it is extremely hard to predict and plan, but it is certainly not just a dream. We are now forced to admit that many initiatives on this path already make economic sense (e.g. efficiency measures and some renewable energies), and that many others rely on technologies improving at a fast pace that will make them rational economic choices soon. Given that, I am optimistic because the economic argument is the strongest, it is the one that drove previous Industrial Revolutions: new technologies and processes imposed themselves because they proved more efficient and profitable that previous ones. We no longer need to rely only on the fear of climate change; we can now argue that a cleaner economy is also a more profitable and viable one in the long term. This optimism is reinforced by the fact that we progressively come to realize all the hidden costs associated with fossil fuels, what economists call negative externalities, and that make them less and less competitive compared to renewables. However, a carbon-tax that would capture these costs and reflect the real prices is yet to be adopted by a major economy, and a lot of education still needs to be done. This education should really focus on this cost aspect because, again, it fosters the economic arguments that are the only audible and acceptable ones for many political and business leaders. Once these new economics are widely accepted, the energy transition will go by itself progressively. A project like the NPDC's self-proclaimed Third Industrial Revolution has the merit of putting it to action without further due; and like any innovator would do, it will surely experience difficulties, failures and drawbacks along the way, especially in the first years because of the lack of experience, but the economics are on its side, and by the time others realize it, the region will probably have taken some advance.

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