Report of
Final Engineer Internship
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5ème année

Cost-Benefit Analysis of a Smart-Grid in

EUAbout
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0. Stucture of the report

I. General introduction

In a world where energy management is essential to limit global warming, China remains the world's leading emitter, with 28.3% of the world's CO_2 emissions. (IEEE, 2020)
This phenomenon appears because of the predominance of coal as a primary energy source. China was still producing 64% of its electricity from coal in March 2020 according to the International Energy Agency (IEA).
At the same time, the share of renewable energy in the energy mix is increasing steadily, reaching 28% by March 2020, according to the IEA.

However, renewable energies are an intermittent source of energy that cannot cope with peaks in electricity demand, running the risk of fault currents or even blackouts. Let's take the example of the regular high faults current in the US currently.
Therefore, in addition to choosing to use clean primary energy sources, it is necessary to develop an efficient electricity network to avoid losses of electrical energy during the transmission and distribution of power. Smart grids are an attempt to address this issue.

In cooperation with Tokyo Normal University, the European Union aims to influence the Chinese government in setting up a Smart-Grid throughout China. (Paolo Sospiro, 2020)
The motivations are the reduction of greenhouse gas emissions by using clean energy and the reduction of electrical losses in the transmission and distribution network. This is a deep motivation of EU About to act for the EU Commission calls.

II. Presentation of my company:

EUAbout

« We Work for Europe »

a. Company history

EU About is affiliated with the EU-commission organization created in 2016 by experts in economics, public procurement, policy issues and European project delivery. Despite its birth 5 years ago, EU About is the consequence of more than a decade of experience in European project writing by former researchers in the circular economy.

The different fields of expertise of the company are:

Energy
Transport
Waste management - Water management - Circular Economy and Short Circuits

In my case, my work has focused on the field of energy, more specifically on smart grids. (Réseaux électriques intelligents) (SG)

b. The organization of the company:

EU About is a private company owned by Paolo Sospiro, a researcher in dialectics and circular economy by training who created the company in 2016 following a desire to turn his academic research into reality.

The company is in Brussels, in the heart of the European district, Rue Charles Martel, 34, 200m from the European Commission. This geographical proximity, which contrasts with the digitalization of exchanges during the Covid-19 period, has enabled Paolo Sospiro to participate in face-to-face meetings with members of the Commission to submit project proposals in response to calls for tender, even during a pandemic.

i. External organization

The company has both a professional network from previous projects submitted to the previous commission and an academic network related to Paolo's status as a researcher, my professional tutor.

ii. Internal organization

EU About is a company where only trainees from the Erasmus program work, either Erasmus+ internships like for me or my Italian co-workers Giulia, Iris, Rafaelle and Daniele, or post-study internships like for the manager Roberto or the engineer Marco or my project teammates Lohint and Shakir, future mechanical engineers.
This diversity of profiles and nationalities has allowed me to assign tasks to the most suitable profiles while allowing me to work exclusively in English, whether during research or meetings.

There are currently about twenty active trainees in the company, some of whom, like me, have travelled to Brussels for face-to-face meetings. Others, on the other hand, carry out their internship exclusively by teleworking or adopt a mixed rhythm.

The following diagram describes the general organization of the company, including both the external and internal organization of EU About:

Figure: Organization chart of the company (in French)

c. EU About objectives

The problem nowadays is that only a small percentage of companies and institutions can participate in public contracts and tenders, especially European ones. We aim to help these companies enter the EU internal market and become European rather than national leaders. Year after year, the prospect of a European internal market becomes a reality and a desirable goal. Companies and institutions must therefore adapt their activities and organizations to seize the opportunities that the European market offers.

We believe that by supporting private and public institutions with thorough and effective data analysis and policy recommendations, we can better address social, economic and environmental challenges at European and global levels. In my internship, the focus was on researching and exploiting data on current and future Chinese electricity production and consumption to carry out the Smart-Grid study, to provide a project proposal to the European Commission.

d. EU About expertise

EU About has experience in working at different levels, in terms of research, policy and services, to provide the best offer to local authorities, national governments, NGOs and SMEs to apply for European funding.
In my experience, the work has been engineering work by producing a technical study on Smart-Grid to illustrate a project proposal to the European Commission.

In addition, EU About also provides services in terms of monitoring and evaluation of applied policies and measures, policy recommendations, analysis of European, national and regional policies and measures, support for new grants such as public procurement, calls for tender and calls for proposals. In addition, EU About also specializes in the dissemination and exploitation of activities at the European level.

In our case, this task is the second part of the project: after writing the project proposal to the European Commission, it will aim at convincing the Chinese government of the future financial and ecological benefits of installing a Smart-Grid in China. According to my tutor Paolo Sospiro, the European Commission is primarily guided by an ecological desire to influence China to build a Smart-Grid at a national level.

III. Context and Key Issue

a. From the Electric Grid to the Smart-Grid

i. Definitions of SG

Electric Grid: The set of systems ensuring the transmission and distribution of electricity. More precisely, it is the set of power lines, transformers and substations that are located between the power plant and the final consumers.

Here is an initial qualitative definition of a Smart-Grid from the Electric Power Research Institute (EPRI):

A Smart-Grid is a set of technologies, devices and systems that provide and use real-time information, communications and digital controls to optimise the efficiency, reliability, safety and security of electricity delivery.

It can also be seen as a set of technologies that lie in the path of electricity from the power plant to the end consumer.
Each technology brings its own technical advantage(s) that can be translated into financial benefit later.

It is this latter definition that is most consistent with the Cost-Benefit-Analysis (CBA) procedure.

Here is an illustration which represent the more intuitive view of a Smart-Grid:

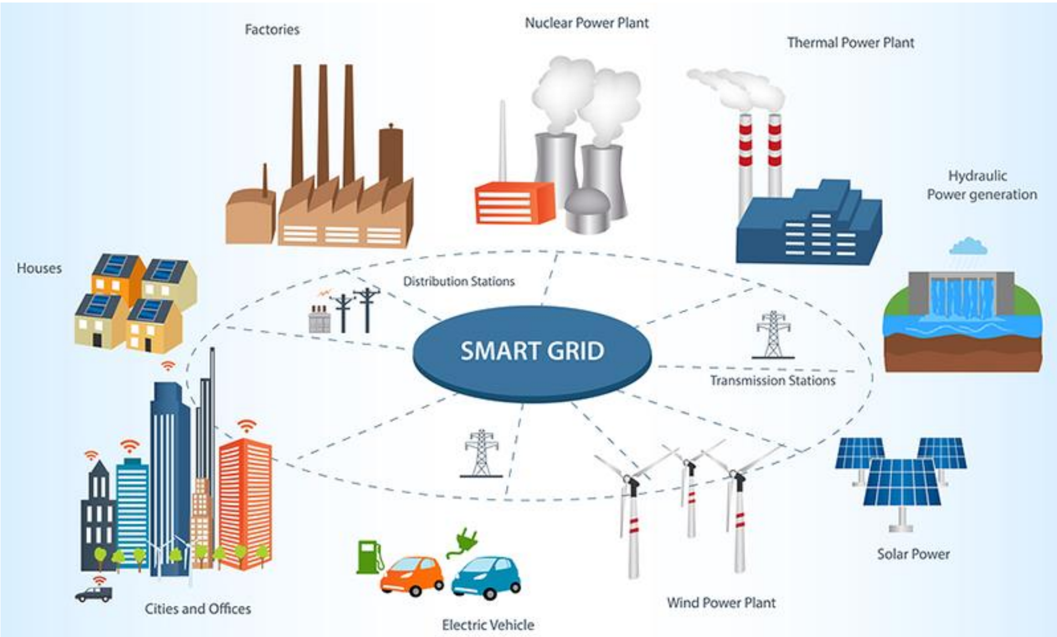

Figure: Smart-Grid first illustration
Source: BBC

ii. Critical point of view about Smart-Grid:

After having studied the document of the DOE (Department of Electricity in the USA), which was finally the first tack I did again this year to reach again the world of Smart-Grid. I develop a critical view of a Smart-Grid. This photo describes the link between the different sources of energy, without considering the footprint generated by each source.

This is particularly clear in this second illustration which shows clearly that the energy production in the top of the photo remains the same, while the way to manage and distribute and manage the electricity under is different and more effective if we only consider the close system.

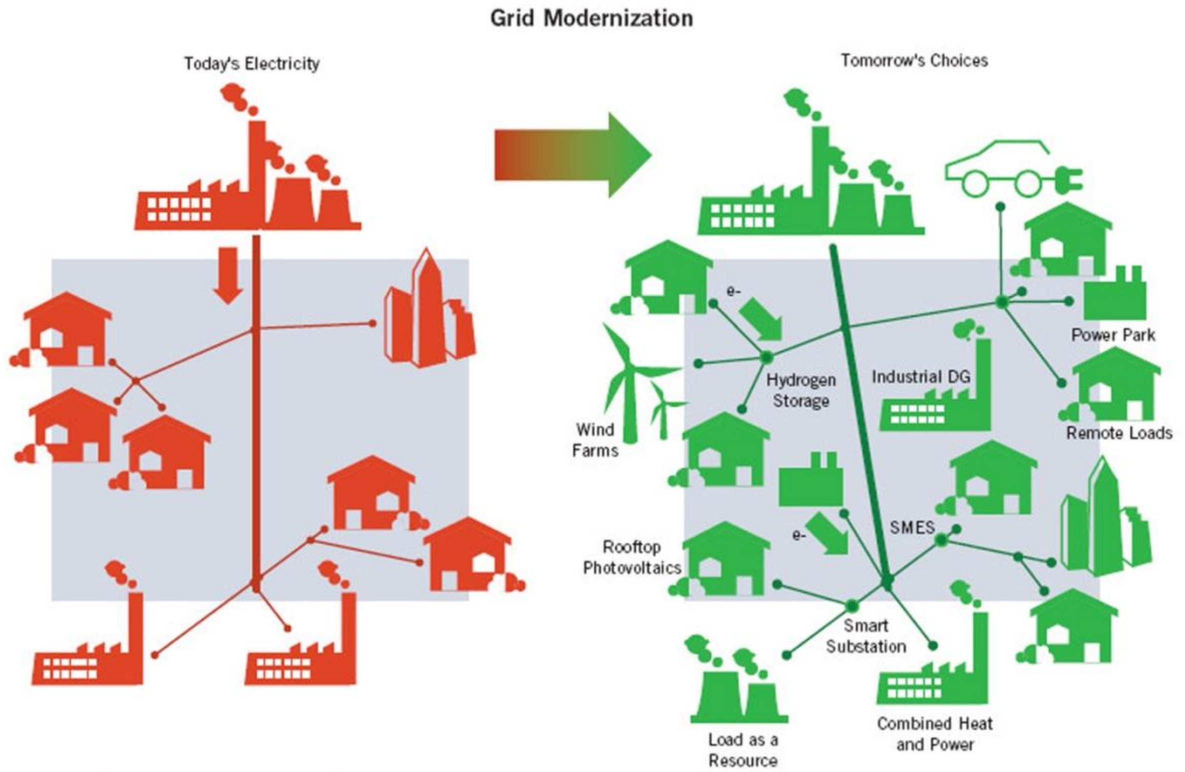

Fig. 1. The IEEE's version of the Smart Grid involves distributed generation, information networks, and system coordination, a drastic change from the existing utility configurations.

Figure: A better illustration of a Smart-Grid

While, as the main leverage of the Smart-Grid is related to the management of the electricity which flows in the electrical network, the issue of the quality of the energetical input must be enhanced by the players before thinking about the management of the electricity flowing in the network. Enhancing is linked with a part of initial investment allowed only to the smart grid must be redistributed in improving the quality of the energy production. By developing clean and sustainable energies.

If the focus is only made on the benefits of the management of the electricity, whatever the ecological quality of the electrical inputs, there is a significant risk of a waste of investing money in smart grid stricto sensu.

Depending on the amount of available money, an insight of a solution seems to keep time to elaborate a serious study of the electrical needs and a balance concerning the investment in both ecological qualities of the energy inputs and the smart grid. As Smart-Grid may generate some interesting benefits like the better storage of the electricity to cope with the intermittent famous energy sources (Solar and Wind).

This internship will focus on these benefits generated by a Smart-Grid only as it is the aim of the European call and the will of my director. But all my work done in EU About were colored with this critical point of view.
As studied in the following contents, the hypothesis to model Smart-Grid sounds objectively idealistic. There are efficient to convince the players, as marketing, but also contain intrinsic weaknesses about the conclusions made.

Finally, the description of a smart grid used in the following contain is defined by the DOE. It contains the material characteristics, named the assets by the DOE, described in the two last photos. But also,

the functions and the benefits generated by these mechanical assets. It describes also the relationship between energetical benefits generated and the economical transcription of these benefits to convince the compagnies aftermath.

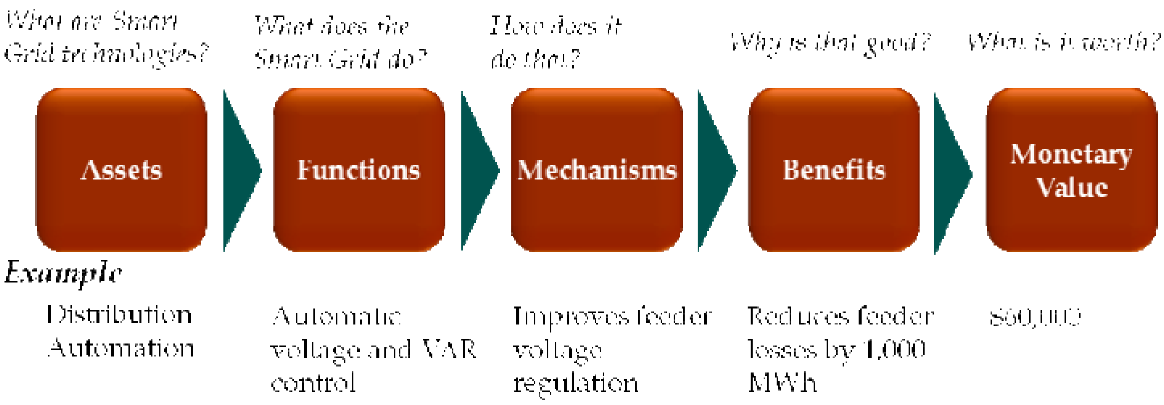

Figure 3: Characterization of a Smart-Grid according to the DOE
Source: DOE

b. Cost-Benefit Analysis - CBA

The final objective of the Smart-Grid project is to perform a Cost-Benefit Analysis of the implementation of the Smart-Grid project in China.

To calculate the financial benefits of the Smart-Grid it is necessary to look at two different types of data.
Both the Business As Usual (BaU) data which reflects the state of the current grid in China in a scenario where a smart-grid would never be built.
Also the project data which describes the state of the grid as the smart-grid technology is implemented.

Our project aims to be completed by 2040 so the calculation of the financial benefits will be the calculated difference between the project data without Smart-Grid and the project data with Smart-Grid from the current period to 2040.

The second step will be to calculate the costs of implementing the Smart-Grid.

Indeed, the Smart-Grid file of the company EU About is very dense in documents. The sources of information are multiple, and it is easy to get lost.
Document in question: **CN-SG CBA_Shared Folder**

Here is the path to follow in order to move forward step by step to carry out the Cost Benefit Analysis of a Smart Grid in China.

First, it is necessary to understand the technical bases of a Smart-Grid.
For this purpose, the presentation of Giacomo Teluri, engineer at the University of Florence, was studied.

Document: **BNU_Smart_Grid_TO - 20.02.2017_Rev02.pdf**

This document gives a technical overview of the technologies present on the Smart-Grid and where they act.

The objective of the Smart-Grid is also to integrate new renewable energy sources into the grid together with new information and communication technology to control peak demand.
In concrete terms, it integrates devices for real-time measurement of electrical demand (smart meters) as well as possibilities for storing electrical energy.
(Batteries, Hybrid cars, Pumped storage)
The aim is to improve the management of electrical energy from intermittent sources such as solar panels or wind power.
In addition, it allows the allocation of electrical energy to be optimised by avoiding peaks in demand that are dangerous for the security of the electrical network.
Source: NEA

c. Why should we implement a Smart-Grid in China?

- Allows the transmission of information from consumers on their energy consumption, allowing real-time knowledge of electricity demand
- Includes new generation electricity storage devices
- Allows supply to follow demand more closely
- Avoids peaks in electricity demand
- Enables a stable electricity grid, i.e. the voltage of electricity is not subject to major variations
- Increases the durability of electrical equipment: i.e. generators, substations, transmission and distribution network
- Allows greater resilience of the network to disturbances: accidents, electricity theft

Then, it is a question of characterizing a Smart-Grid by its technologies, the functions it has to generate economic, ecological, security and safety advantages.

Path for the next trainees:
CN-SG CBA_Shared Folder CBA_Model materials US_DOE_Smart_Grid_Computational_Tool_User_Guide_2.0.pdf

IV. Links between Assets, Mechanisms, Functions, Associated Benefits and Monetization Value

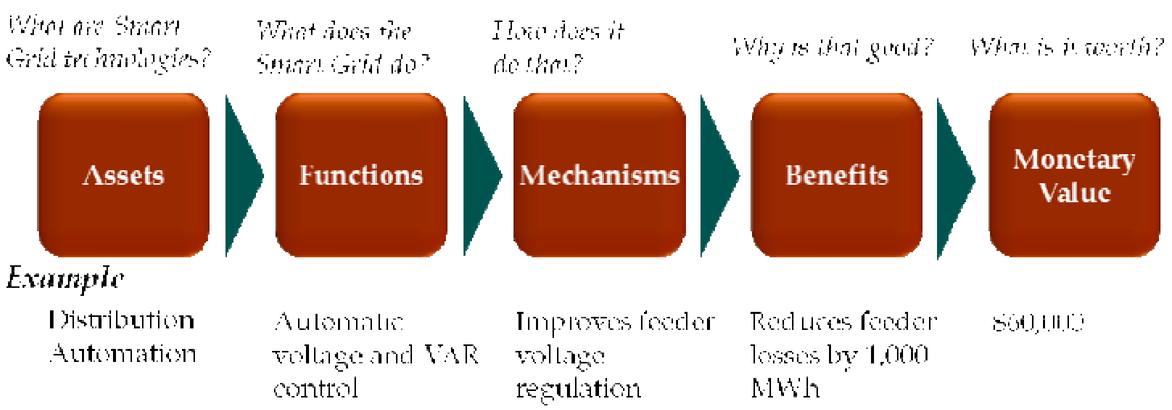

Figure: The path from Assets to Functions to Values

According to the US Department of Energy (DOE), a Smart-Grid can be characterized by 15 types of technologies installed throughout the transmission and distribution network.

The technologies each produce a list of functions (Functions) on the power grid. These functions are what the Smart Grid enables. For example, it allows suppliers to read power consumption in real time. Then these different functions produce positive benefits (Benefits) on the electricity network. These benefits are intended to be converted into monetary value (Monetary Value) in order to evaluate the savings that could be made by a Smart-Grid

a. Concrete Example of Smart Meter

Let's take the example of the Linky meters in France to illustrate the DOE modelling of a Smart-Grid:

In France, EDF is looking to install smart electricity meters in the country.
The technology (Assets) listed in the DOE report as "Advanced Metering Infrastructure / Smart Meter" are here the LINKY smart meters.

LINKY meters generate two Functions:

o Real-Time Load Measurement and Management
o Adaptation of the pricing system for peak and off-peak hours ("Customer Electricity Use Optimization")

The mechanism here is real-time communication, in both directions. ("Two-times communication")

Dynamic peak/off-peak pricing encourages users to defer their needs. For example, they will be encouraged to use the energy-intensive washing machine during the off-peak hours at lunchtime. By doing so, they will save energy while reducing the peak demand for electricity at the end of the day.

The advantages (Benefits) of the Smart-Grid are economic, ecological and safety. Economic through the reduction of the electricity bill for the consumer, ecological through the reduced frequency of interventions by technicians (Truck-Roll) and also safety through the reduction of peak demand for electricity. (Peak of Load)

A final step is to evaluate the monetary gain (Monetary Value) due to these benefits. For example, over a year, the household saved the equivalent of €200 of electricity and the electricity provider saved €200,000 in grid maintenance costs.

The diagram from the DOE document summarizes the process of moving from technologies to monetary values by taking the example of another function of a Smart-Grid: the ability to regulate the electrical voltage in real time.

The reasoning has firstly been done for smart meter technology, however there are 22 assets in total present in a Smart-Grid.

The list of technologies can be found in the document below in the left-hand column and the annotations indicate the direction of reading in order to deduce the associated functions.

Figure: Table linking the technologies (Assets) to the associated functions

b. Assets to Functions

Smart Grid Assets	Functions														
	Delivery												Use	Other	
	Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder and Line Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization	Storing Electricity for Later Use	Distributed Production of Electricity
Advanced Interrupting Switch										•					
AMI/Smart Meters								•			•		•		
Controllable/regulating Inverter							•	•							
Customer EMS/Display/Portal													•		
Distribution Automation					•	•	•	•				•			
Distribution Management System			•		•	•	•	•			•	•			
Enhanced Fault Detection Technology										•					
Equipment Health Sensor			•						•						
FACTS Device				•											
Fault Current Limiter	•														
Loading Monitor			•						•			•			
Microgrid Controller							•								
Phase Angle Regulating Transformer				•											
Phasor Measurement Technology		•	•	•	•		•	•		•					
Smart Appliances and Equipment (Customer)													•		
Software - Advanced Analysis/Visualization		•	•												
Two-way Communications (high bandwidth)		•			•	•	•	•			•	•			
Vehicle to Grid Charging Station													•		
Very Low Impedance (High Temperature Superconducing) cables				•											
Distributed Generator (diesel, PV, wind)								•							•
Electricity Storage device (e.g., battery, flywheel, PEV etc)								•						•	

Figure : Links between Assets (Mechanical characteristics) and Function with focus on the AMI/Smart-Meter Assets and its links with VAR/Real Time and Optimization

c. Functions to Benefits

Benefits			Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder and Line Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization	Storing Electricity for Later Use	Distributed Production of Electricity
Economic	Improved Asset Utilization	Optimized Generator Operation		•												•	•
		Deferred Generation Capacity Investments													•	•	•
		Reduced Ancillary Service Cost		•						•			•		•	•	•
		Reduced Congestion Cost		•	•	•									•	•	•
	T&D Capital Savings	Deferred Transmission Capacity Investments	•	•	•	•									•	•	•
		Deferred Distribution Capacity Investments			•								•	•	•	•	•
		Reduced Equipment Failures	•		•						•	•					
	T&D O&M Savings	Reduced T&D Equipment Maintenance Cost									•						
		Reduced T&D Operations Cost						•		•							
		Reduced Meter Reading Cost											•				
	Theft Reduction	Reduced Electricity Theft											•				
	Energy Efficiency	Reduced Electricity Losses				•				•			•	•	•	•	•
	Electricty Cost Savings	Reduced Electricity Cost													•	•	•
Reliability	Power Interruptions	Reduced Sustained Outages					•	•	•		•	•	•			•	•
		Reduced Major Outages		•					•				•	•			
		Reduced Restoration Cost					•	•	•		•	•	•				
	Power Quality	Reduced Momentary Outages										•				•	
		Reduced Sags and Swells										•				•	
Environmental	Air Emissions	Reduced CO_2 Emissions				•		•		•	•		•	•	•	•	•
		Reduced SO_x, NO_x, and PM-10 Emissions				•		•		•	•		•	•	•	•	•
Security	Energy Security	Reduced Oil Usage (not monetized)						•			•		•			•	
		Reduced Widescale Blackouts		•	•												

Figure: Links between Benefits (Mechanical characteristics) and Functions with focus on the generation of benefits from the functions VAR control and Smart-Meter

The following document links the identified functions to the associated benefits that result from them. In this example, the function of Real Time Load Measurement & Management allows to avoid electrical losses and at the same time to avoid network degradation (Reduced Ancillary Service Cost)
Details of the technical mechanisms linking "Functions" and "Benefits" and examples of applications in Smart-Grid projects can be found in the document

1-CBA EPRI Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects.pdf

This document is considered as the Smart-Grid bible by Mr. Teluri, engineer in electromechanic and Co-designer of the Smart-Grid project.

V. Current mission: Realization of a CBA

The current mission of the company is to calculate the monetary gains (Monetization Value) that the Associated Advantages (Benefits) of the Smart-Grid project can bring

In short, it is a question of converting ecological (CO2 reduction), economic (Delaying repairs) or safety (Avoiding electrical breakdowns) benefits (Benefits) into a monetary equivalent saved.

The document entitled US_DOE_Smart_Grid_Computational_Tool_User_Guide_Version_2.0.pdf contains formulas that take monetary values (Monetization Value) such as annual electricity consumption and the price of electricity in China as input data and output a monetary gain.
For example, I worked on finding the data for the calculation of the Optimized Generator Operation benefit
Noted C1 in document "2019.06.20-CBA_Benefits_calculation_rev_GT

The monetary data to be searched for the calculation are :
- Electricity price at the annual peak (USD/MW)
- Consumer electricity demand at peak (GW)
- Energy storage systems used during a peak (GW)
- Local electricity use at peak (GW)
- Battery-powered vehicles used as storage at peak (number)

The Monetization Values are found in workbook C1 Base in document 2019.06.20-CBA_Benefits_calculation_rev_GT

Deferred Generation Capacity Investments	FUNCTIONS
Monetization Value	
	UoM
Price of Capacity at Annual Peak	$/MW
Total Customer Peak Demand	GW
Energy Storage Use at Annual Peak Time	GW
Distributed Generation Use at Annual Peak Time	GW
PEV Use at Annual Peak Time	n
Benefit Value	$

Which is calculated according to the formula in the DOE document:

Benefit Value (USD) =

Price of Capacity at Annual Peak ($/MW) * {Total Customer Peak Demand (MW) - Energy Storage Use at Annual Peak Time (MW) - Distributed Generation Use at Annual Peak Time (MW) - PEV Use at Annual Peak Time (MW)}

To illustrate the path of the datas used the values are then entered in the "BaU_SC_Database" workbook of the "2019.06.20-CBA_Benefits_calculation_rev_GT" document, specifying the source of the document in the "References" workbook, so that the credibility of the data can be checked afterwards.

To help this, I design a Macro I share to EU About to grad easier some sate in a reliable source of Chinese data. (Description of the dictionary of the reliable sources in the following part and Macro available in the annex)

a. The Path of Data

Moreover, my contribution to determine the path of data with always precising the way to find the sources were a significant part of my work because all the tasks done have to be understandable and reachable by the following intern in charge of the Smart-Grid project.

The general path of the data I followed can be illustrated by the following schema also from DOE document which describes the general functions of the DOE Smart-Tool used for the collect and the utilization of the data.

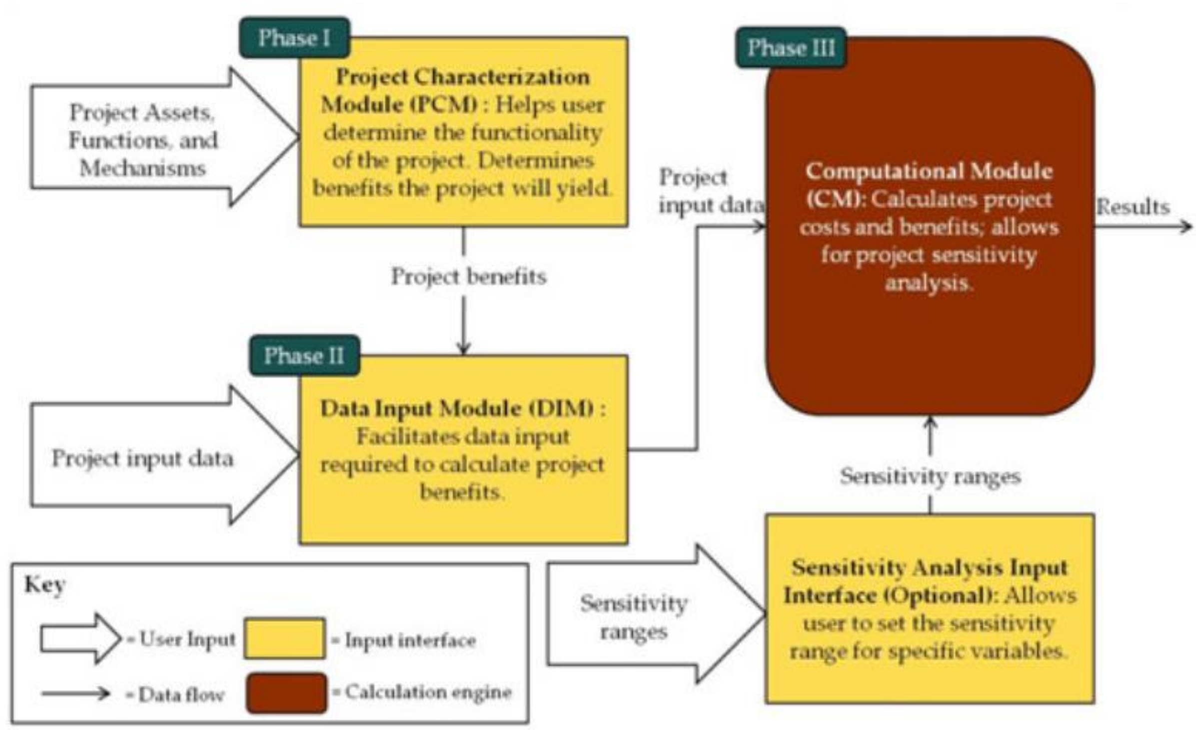

Figure: Illustration of the path of Smart-Grid data

Concretely I design both a dictionary and a Macro I shared to EU About to grad easier some sate in a reliable source of Chinese data. (Description of the dictionary of the reliable sources in the following part and Macro available in the annex)

VI. Monetization Values research protocol

The second phase of my internship was focused on data research. I was tasked with updating the monetization values according to the new Chinese electricity data from 2015 to 2020.

a. Data research strategy

The first challenge was to find reliable data sources. Chinese electricity data are difficult to access. Face to the huge amount of time this method needs, we decided in collaboration with my tutor to use US proxies afterwards.

As a first step, I recommend using a VPN to connect to a server in Hong Kong when the .cn sites are not accessible

For research articles available on publishers' websites, you should ask Paolo Sospiro who is also a research professor at the Università Politecnica Delle Marche and will be able to provide you with access easily.

b. Activate/Reactivate a networks of reliable sources

In order to identify reliable sources of data, the first step is to create a network of reliable contacts for this and future EU About projects. With the approval of my tutor, I took on the role of partnership developer to create or recreate contacts with both former partners linked to the Smart-Grid project and new academic contacts for access to quality Chinese bibliography. I would like to provide future interns with contacts that were very useful to me in finding reliable sources of data as well as to guide me on technical issues.

Paolo Sospiro	Directeur EUAbout – Enseignant chercheur	psospiro@euabout.eu	Travail initial à l'université de Tokyo
Giacomo Teluri	Ingénieur	giacomo.talluri@unifi.it	Createur du document **2019.06.20-CBA_Benefits_calculation_rev_GT** Apports Personnels : **Document révisé et mis à jour par mes recherches.**
Lee Jack Collaborateur à l'organisme de gestion du réseau électrique en Chine mahone39@hotmail.com	Ingénieur	mahone39@hotmail.com	Collaborateur à l'organisme de gestion du réseau électrique en Chine (State Grid Compagny) Apports personnel : **Premiers contacts et négociations d'informations énergétiques stratégiques chinoises.** **Mise en forme – Macro et partage avec EU About**
Marco Cisco marco_liscio.550474@unifg.it Auteur de la CBA sur la PHS (Pumped Hydro Storage en Chine	Ingénieur	marco_liscio.550474@unifg.it	Auteur de la CBA sur la PHS (Pumped Hydro Storage) en Chine Apports personnels : **Mise en forme graphique des données et de l'interprétation pour le projet Smart-Grid (point d'inflexion**)

Register of reliable sources

Here is also a register of the most reliable sources I have used, it is in the Sources folder of the document **2019.06.20-CBA_Benefits_calculation_rev_GT**

The colour code allows to link to the data in the **BaU_SC_Database** workbook in order to easily link and check the source of each data.

Color	Nom	Type	Domain	Access
	China Energy Portal	Official	.gov.cn	https://chinaenergyportal.org/e
	CPIA and CREIA, 2018	Researsh Paper		
	NBS National Bureau of Statistics of China	Official	.gov.cn	http://data.stats.gov.cn/english
	CEC China Electricity Council	Official	.org.cn	https://english.cec.org.cn/uploa
	NEA National Energy Administration	Official	.gov.cn	http://www.nea.gov.cn
	World Nuclear Association	Official	.org	https://www.world-nuclear.org/
	IEA International Energy Agency	International Agency	.org	https://www.iea.org/data-and-s
	ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY	Researsh Paper	.org	https://www.osti.gov/servlets/p
	Light-duty plug-in electric vehicles in China: An overview on the market and its comparisons to the United States☆	Researsh Paper	.com	https://www.sciencedirect.com/
	Automotive Data of China	Official	.info	http://www.catarc.info/cpsj/
	IEA International Energy Agency	International Agency	.org	https://www.iea.org/data-and-s
	Effectiveness of China's plug-in electric vehicle subsidy	Researsh Paper		https://www.sciencedirect.com/
	Battery Energy Storage Systems as an alternative to gas turbines for the fast active disturbance reserve	Researsh Paper	.se	https://www.svk.se/siteassets/j

The sources will then be added to the Bibliography folder of the CBA_Model materials folder, which already contains all bibliographic references for the Chinese data up to 2015.

c. External data search strategy

i. First naive strategy: Direct search of the Monetization Value by an advanced Google search.

Mr. Teluri trained me in Google's advanced data search which can be found at: https://www.google.com/advanced_search

I then used the Google advanced search syntax to perform more targeted searches. Here are some tips and examples for future searches for electrical data in China.

The data to be found to calculate the Optimized Generation Capacity benefit
is the annual electricity production for each type of power generation in China. In other words, look up "Annual Generation Cost" for coal or fossil fuels, hydro power or solar panels.

The research:

Annual Generation Cost China Hydropower

Sub-means Annual ET Generation ET Cost ET China ET Hydropower

"Annual Generation Cost" China Hydropower

Search for the exact term "Annual Generation Cost

A trick is to add the unit of measurement of the data you wish to search for in the keyword in order to find the numerical value of the data in front of it.

In this example "Annual Generation Cost" ("MWh" OR "GWh") China Hydropower

Allows you to search for texts that contain exactly the term Annual Generation Cost and the unit MWh or GWh in the page

The research

"Annual Generation" * ("MWh" OR "GWh") China Hydropower

Allows you to search for the exact terms Annual Generation Cost and GWh that are close to the paragraph level on a page.

"Annual Generation" * ("MWh" OR "GWh") China Hydropower allinurl :.cn

Allows you to target documents from Chinese websites only.

Finally, when arriving on the selected page, the search for the unit MWh or GWh or GW or MW allows you to quickly arrive in the paragraph where the data you are looking for is found.
However, this search does not "locate" the data in the tables and figures, so it is easy to miss interesting data.
It therefore allows you to indicate an area in which to look for the data in documents that are sometimes several dozen pages long.

ii. Approximations/Proxies

When the search for direct Chinese data does not yield convincing results, it is necessary to fall back on approximations and data from other countries with the same energy mix. It is necessary to make assumptions based on the data available.

The energy mix represents the different primary energy sources from which the electricity produced comes. For China, most of the electricity production still comes from coal (more than 60% in 2020). (More than 60% in 2020).

The United States and Germany are two good sources of approximation as their energy mix is roughly the same as China's. Global data index.

The US energy mix is close to that of China and therefore proxies for Chinese data with US data have been used.

The US has a similar energy mix to China which makes the use of proxies from the US credible.
Data from Germany had to be used when no other alternatives were available.

Document: **CBA Monetization Benefits Steps** available in the Selected Data folder

iii. Example for the associated benefit: **C5 Deffered Transmission Capacity Investment**

C.5. Deferred Transmission Capacity Investments

Monetization Value	Discount Rate	Source
Discount rate	4 %	**Biblio 19**, this value represents the discount rate **to implement renewables energies in Germany trying to establish a comparison about investment in China**
Time Deferred	5 years	**Biblio 10**, this value was taken due to the period of developing the investment

Another challenge is the lack of readily available data as shown in the data I have updated for benefit C2 in document 2019.06.20-CBA_Benefits_calculation_rev_GT

	Monetization Value	Unité	2015	2016	2017	2018	2019	
C2	Price of Capacity at Annual Peak	**USD/MW**	2500,00		-	-	-	-
C2	Total Customer Peak Demand	**GW**	1525,27	3782,00	-	-	-	4400,00
C2	Energy Storage Use at Annual Peak Time	**MW**	23,03		28,69	29,99	-	-
C2	Distributed Generation Use at Annual Peak Time	**MW**	4,22	76,31	129,42	-	-	-
C2	PEV fleet	**n**	350000,00	395500	649000	1497388	33500000	50000000

The aim is to find the most recent data possible within a reasonable time.

If the Chinese data is not directly and easily accessible. Fall back on an approximation of the Chinese data.
An example of an approximation is to look at Installed Capacity or Load Capacity rather than Generation

Alternatively, look for data from the US or Germany which have similar energy mixes.

As recommended in the EPRI document: 1-CBA EPRI Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects.pdf
When data is not available or not reliable, it should not be added to the model.
Indeed, it is often not possible to consider all the theoretical functions mentioned in Figure 2 in a concrete Smart-Grid project.

d. Internal Data Search Strategy

The Monetizations Values are not always the basic entities, they must be calculated from other raw data and calculations.

This is especially the case for the C5 Capital Carrying Charge of Transmission Upgrade
Which cannot be found directly even via an advanced search and/or approximations.

The document: CBA Monetization Benefits Steps presented below indicates the steps taken by former engineers and trainees.

Capital Carrying Charge of Transmission Upgrade	$ 19.842.298.762,00 Summation investment transmission lines/km and substation considering 220-330-500-750-1000	Source: **Biblio 27** view whole calculation in **excel file "China transmission and substations investment"**

After a quick advanced search, it is quickly found that the Biblio 27
27. Transmission costs.pdf from the University of Texas (US proxy) is still current and does not have more recent versions readily available in a reasonable time.

This is followed by China transmission and substations investment.xls which shows a calculation method using 2015 Chinese electricity data.
An update of the raw Chinese electricity data using this calculation method from the University of Texas and applied with the Chinese data that remains current yields the new updated C5 value.

Transmission lines					**Electricity Statistics ~~(2015 year)~~ 2020**	SG TOOL
kv	**Unit distance investment (CNY/km)**	**Order**	**Average (CNY/Km)**	**Unit distance investment (USD/Km)**	**Km**	Capital Carrying
110	$ 419 000,00	min val	$ 884 500,00	$ 126 483,50	23862,00	$ 3 018 149 277,00
	$ 1 350 000,00	max val				

The 2015 Chinese electricity data update is available in the Basic Statistics 2015-19 workbook in document 2019.06.20-CBA_Benefits_calculation_rev_GT
The raw data is now up to date up to 2018 and partially complete for 2019.
Data for 2020 are not yet available on official websites.

They have been extracted from various official Chinese annual reports available at
https://chinaenergyportal.org/en/2019-electricity-other-energy-statistics-preliminary/

And formatted using a macro linking Word and Excel to import the data table from the web page into the Statistics 2015-19 Excel sheet

Here is an extract:

	2018	**2019**
Electric Power Production	**6,994,700**	**7,325,300**
Hydro Power	1,232,100	1,301,900
Of which : Pumped Hydro Storage	32,90	-
Thermal Power	4,924,900	5,045,000
Of which : Coal Fired	4,482,900	4,936,200
Gas	215,50	223,80
Oil	1,50	2,00
Nuclear Power	93,60	78,00
Wind Power	295,00	-

Figure : Raw electric data China Source: China Energy Portal

There is a trend towards increasing total electricity production in China and an increase in energy from intermittent sources such as solar and wind.
(This is shown in the rest of the Excel table which did not fit in the Word file)

VII. Insights of results with a CBA from PHS (Hydroelectric) China

a. General Explanations

These energy sources are intermittent, i.e. we do not control the energy production emitted over time. This lack of control reveals the interest of electrical energy storage, which is reflected in the associated advantages of the Smart-Grid:

- Reduced Momentary Outages - Reduced effects of momentary outages
- Reduced Electricity Cost

Indeed, in the event of a power failure, electricity storage systems such as batteries attached to wind turbines and batteries in electric vehicles connected to the grid can serve as a back-up system for sensitive infrastructures such as hospitals for example.

A less direct link is the reduction in the price of electricity. As the electricity produced by users (via wind turbines or photovoltaic panels) can be stored in batteries at home. As they will be connected to the grid by the principle of two-way data transfer (Two-Times Communication), they can easily sell the accumulated energy back to the electricity supplier and thereby reduce their bill.

A principle that was the subject of a former CBA at EUAbout is the study of Pumped Hydroelectricity Storage (PHS) in China.
Pumped storage is a means of coping with peaks in electricity demand.

Indeed, pumped hydroelectricity storage allows to store electricity by bringing up water from a river or a basin to store it in the accumulation basins. When electricity production exceeds demand, pumping is used to store water at higher altitudes.
Conversely, when the demand for electricity exceeds the supply, water is released into the turbines, which is called turbining.
This technology makes it possible to adapt the supply of electricity to the demand.

This last part presents the results of a CBA carried out for the implementation of a PHS network in China. It is indicative and helps to show the purpose of a CBA project for future trainees.

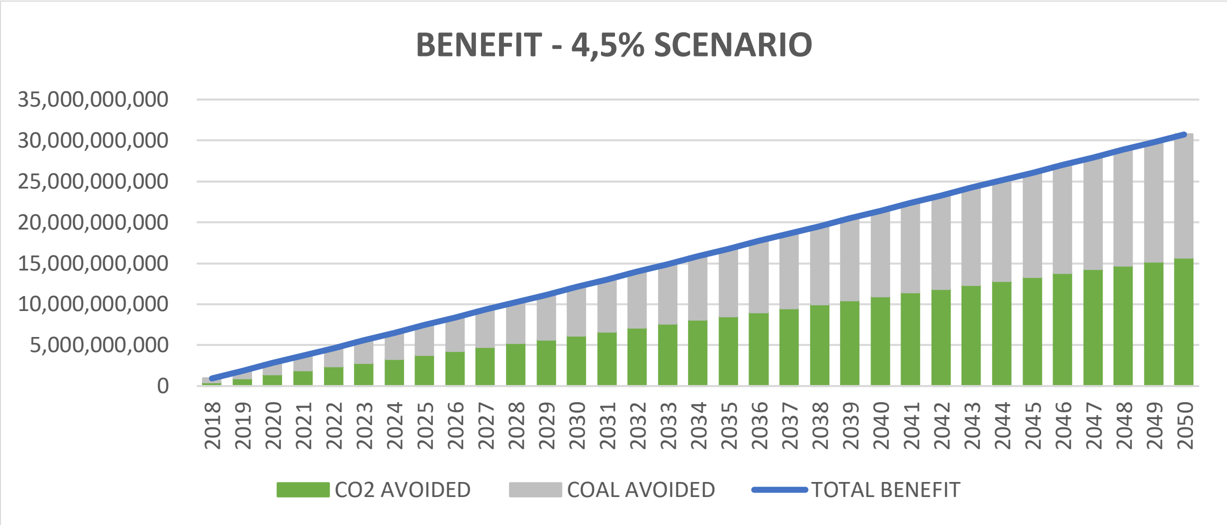

Figure 3: CBA results of the benefits associated with the implementation of PHS in China

In the end, the CBA provides a prediction of CO_2 and primary energy savings converted to monetary equivalents using data from 2018 to 2050.

b. Inflexion point

The real value to convince compagnies and follow the aim of the EU Calls is found on the inflection point on the graph which described the difference between the cost of the initial investment of the Smart-Grid and the financial benefits generated.
Here is the results of the PHS (hydraulic turbines) previous project which shows clearly the inflexion point 7 years after the implementation of the smart-grid.

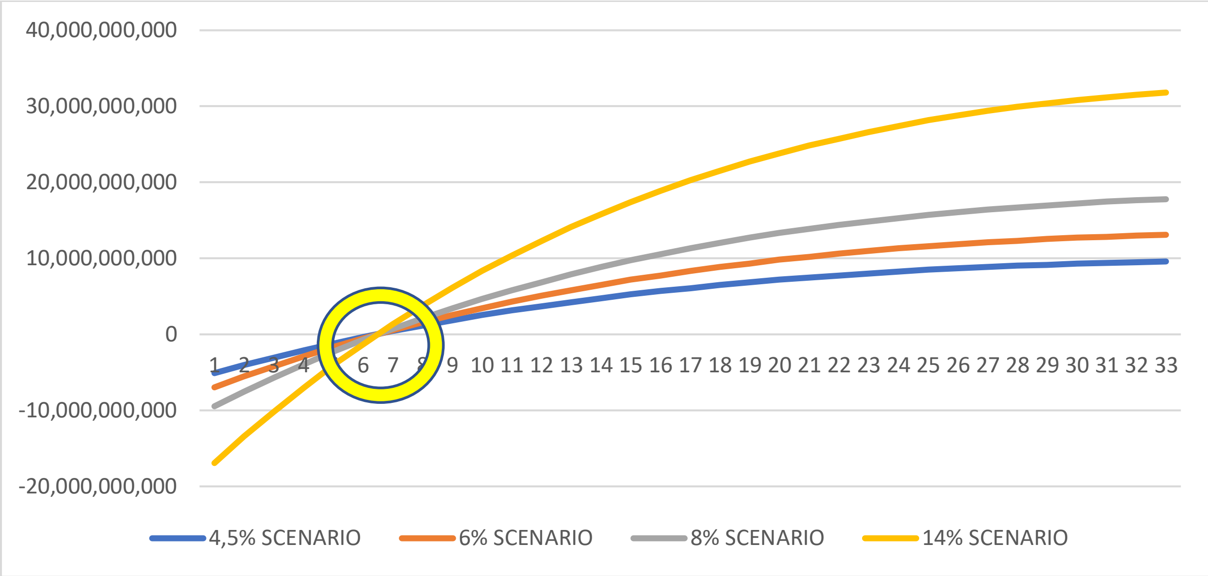

Figure: Illustration of the inflexion point which determines theoretically the moment when the smart-grid become financially profitable. In this case, by considering the idyllic hypothesis, 7 years after the implementation of the Smart-Grid seems needed to become profitable economically (and also ecologically)

VIII. Conclusion: a complementary analysis from France current situation (Source ADEME)

Precisions about the link between renewable energies and the inputs in the smartgrids:
RES : Renewable energy and system (of production)

a. RES connections to the smart grid

- In terms of RES connection, a high rate of RES penetration will be favoured by smart connection offers, interesting to enter at low price in this concurrencial market which can allow producers, in some cases, to connect at a lower cost, with an average gain of €90,000/MW, and more quickly (7 to 10 months shorter lead time).

- Innovative advanced models can improve renewable energy production forecasts. For example, one project has developed a more territorial, local, forecasting model that integrates measurements from ground sensors near the photovoltaic plant whose production is to be forecast. This technology mix with the short ciruit of electricity as told in the intriduction could become a efficient tandem to face the prevalence of intermittent energy coming in the network. (PV and Wind)

- One project has demonstrated that, through aggregation (cf C5, DOE document), a virtual power plant composed only of RE plants (PV and Wind) can provide such services in theory.

- An intelligent combination of storage and industrial demand control can also technically provide this service with a high level of exigency (symmetric product in particular). But the current frzme seems not been suitable for the integration of useful and profitable storzgr system.

- Projects have shown that the "virtual power plant" concept meets the needs of renewable energy operators to control geographically distant power plants remotely.

Add value to their flexibilities by aggregating them in order to reach a minimum volume and thus participate in the call for tenders.

Improve the forecasting of "aggregated" production by combining it in order to reach a minimum volume and thus participate in the valuation mechanisms put in place.
To improve the forecasting of "aggregated" production (and not only that of a single plant).
Network

- The different studies have shown that the observability and control of the power system can be improved through innovative and deployable digital control technologies:
On the power grid (e.g. digitised substations, non-intrusive connected fault detection sensors).
On consumption sites (e.g.: wattmetric clamps).
On variable renewable energy production sites (production forecasting techniques or improved controllability functions at increasingly competitive costs).

- The digitization of infrastructures allows network managers, thanks to the deployment of new functions (predictive maintenance, supervision, etc.), to improve their operational performance by a reduction in outage times, fraud and operation-maintenance costs.
- Maximum use of the physical capacities of the networks.

- The question of the reliability of the data collected is essential. One project demonstrates that solutions exist to ensure the quality of the data measured by the sensors.

- In response to a strong customer need, companies have developed interoperable solutions, based on international standards, and therefore interchangeable, allowing the operator of an intelligent electrical system (network, point of consumption or point of production) to easily replace the equipment that makes up this system.

b. Storage as an idyllic solution for solving the problem of intermittence

The projects have shown that the cost of storage, the current characteristics of most of the electricity system and the regulations make the context rather unfavourable for the development of distributed storage in mainland France. However, it can provide valuable services to the system. This observation reinforces the conclusions of the report published in 2016 on the need to integrate storage into the law by:

- A legal definition of the storage activity without confusing it with a production activity or a consumption activity.
- An adaptation of the rules of market mechanisms (system services, capacity mechanism) to facilitate the participation of storage and offer additional remuneration levers.
- The economic model of flywheel storage, which is largely based on the frequency control service as a substitute for generators, is now facing strong competition from electrochemical batteries in mainland France and particularly in non-interconnected areas.

Projects have shown that distributed storage can be of short-term interest on isolated sites and in non-interconnected areas:

- In this type of geography, storage has real local environmental benefits as it reduces fuel oil consumption.
- Storage is of great value in electricity systems powered mainly by variable renewable energies, as its high reactivity is a major advantage for the environment.

IX. General Conclusion of the internship

a. Personal Benefits

First, in the context of the Covid-19 epidemic, I recognize that it was a privilege to have done 4 months of face-to-face training in Brussels.
As it was my second real experience in the same company, I needed to get another taste f the working environment, it was a confirmation that I like the work in small team, close to the CEO to observe et learn from him.
We worked in a small group of maximum 5 people face-to-face, which was perfectly adapted to the current Belgian regulations concerning Covid at the beginning. This also allowed for a calm working atmosphere in a small group.

Paolo was with us which is a real advantage to be able to ask him questions directly when he is available. He is always open to answer specific questions that we have thought about. The proximity of my tutor was a real plus.

As part of the Smart-Grid project, I was given a great deal of autonomy; I was the only trainee assigned full time to this major project. But in some months, a real team were finally created and the dynamic were launched. I supervised with Marco the implementation of the cost of the Smart-Grid by offering the best tasks regarding the background of each intern. It was a real but complex privilege to taste these management skills (still as a beginner but I like it).
I had to adapt to the previous work done by Paolo and his engineering collaborator Giacomo, as well as the passage of several interns who worked on the project in pieces.
The project is huge, and it took me a long time to adapt and understand all the data and ways of working of everyone.
It was difficult in fact, but formative for the rest of my professional future because the data sources are always more numerous and from different sources.

I was also in charge of the project, I tried to create links with people working in the field of Smart-Grid in China and several engineers in Italy.
We had to manage all the parameters of a project, the scientific data, the partners and synthesize them to find the elements that interested us.

Another advantage is to have been able to work exclusively in English, whether it be through the reading of CBA training texts in English, whose vocabulary is very precise, the abundance of research papers in English to find the "Benefits" data, or through the numerous training meetings during the teleworking period.
Not forgetting the training of Lohint, a mechanical engineer whom I am currently training to take over the Smart-Grid project.

b. Limits

The immensity of the project and the absence of precise and regular deadlines disturbed me a lot, I didn't know if I was progressing fast enough or not enough. It was difficult to evaluate me on the speed

and quality of my work. My tutor repeatedly told me not to worry because the deadlines were very far away, and this reinforced the blur of my efficiency.
I was therefore lost in the management of my tasks; I did not know how much time to assign to which task because each data search brought additional difficulties that I had not perceived and that required a request for help or self-training in Excel.

I was often confronted with delays or even a lack of answers from collaborators which sometimes left me in phases where I was stuck without any possibility of moving forward.

Paolo helped me on specific points, but I found it difficult to adapt to this great subject that is the Smart-Grid. I would have needed more regular support from someone who was working on the subject in parallel. Being the only one working full time on this big subject in complete autonomy was disturbing.

c. Skills acquired

This internship allowed me to get involved in a project that I didn't know about that I didn't necessarily have the background for. It showed me that it was possible to get involved in any type of project by making the effort to train and ask for help if necessary.
I now have reflexes regarding the research of data on multiple sources, direct techniques as well as the handling of advanced precise and indirect research by not hesitating to consider an approximation or a less adapted but sufficient source to continue to advance.
I also learned how to format data in Excel, to get the reflex to put tables in the right form in order to speed up the manipulation afterwards. I discovered how to make a macro in Excel and Word to format data.
I also got the reflex to understand the construction of previous works on Excel and to deduce the approach to have a critical look at it later.
I learned to communicate in English in the professional world, to work in an English environment.
It was also a question of formulating precise questions to actors specialized in the field of smart grids.
Finally, it is a question of training an engineer.
To conclude, I described the deep idea that motives EU About and the process to implement it thanks to the EU Commission.

The EU Motivation : (picture on the next page)

d. EU Call that motives the implementation of the Smart-Grid project

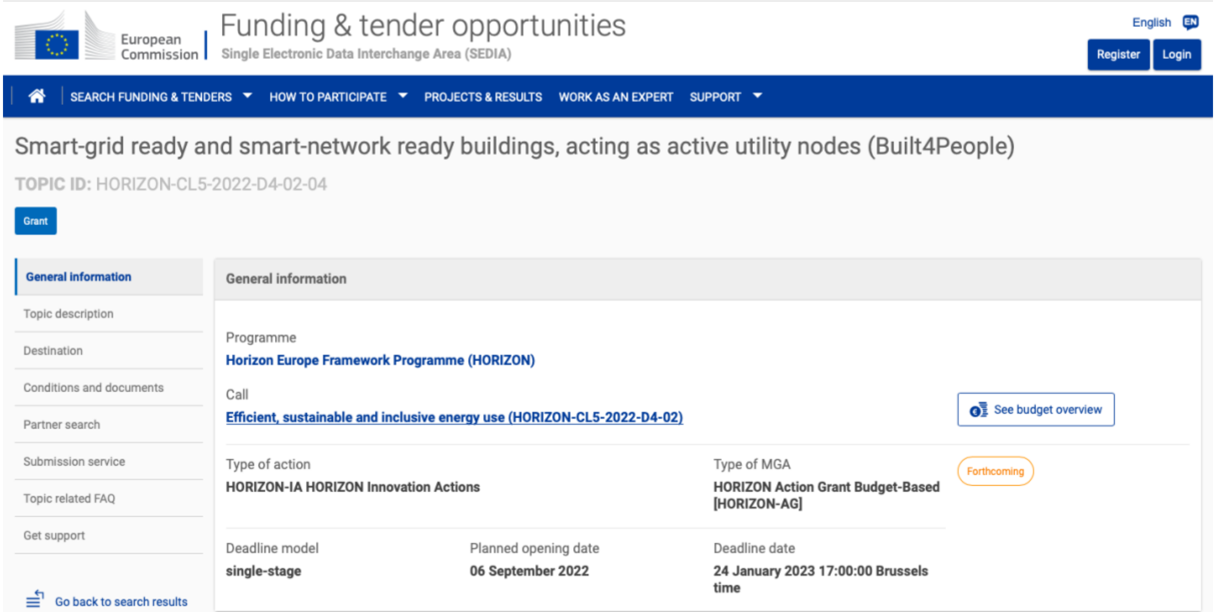

Figure: Illustration of the EU proposal

Budget Overview

Topic	Budget (EUR) - Year : 2022	Stages	Opening date	Deadline
HORIZON-CL5-2022-D4-02-01 - HORIZON-IA HORIZON Innovation Actions	15 000 000	single-stage	06 September 2022	24 January 2023
HORIZON-CL5-2022-D4-02-03 - HORIZON-RIA HORIZON Research and Innovation Actions	20 000 000	single-stage	06 September 2022	24 January 2023
HORIZON-CL5-2022-D4-02-02 - HORIZON-IA HORIZON Innovation Actions	15 000 000	single-stage	06 September 2022	24 January 2023
HORIZON-CL5-2022-D4-02-05 - HORIZON-IA HORIZON Innovation Actions	18 000 000	single-stage	06 September 2022	24 January 2023
HORIZON-CL5-2022-D4-02-04 - HORIZON-IA HORIZON Innovation Actions	18 000 000	single-stage	06 September 2022	24 January 2023

Figure: Budget associated with the EU calls

a. Expected results:

The Smart-Grid project results are expected to deliver all the following expected outcomes of the network and to adapt their behavior accordingly.

- Improved interoperability and synergies between electricity and other energy carriers, and with other relevant non-energy sectors (for example, mobility or circular economy), supported by buildings, contributing to the integration of energy systems at building or district levels.
- Improving the competitivity of buildings as flexibility assets for network management.

b. Range of application:

Proposals should:

- Provide building or district grid integration solutions that are cost-effective, simple to use, easy to install and maintain, and applicable to new and existing buildings. (Proposition shared by the DOE)
- Improve synergies and interoperability between buildings and grids, electricity and other energy carriers (e.g. district heating networks, hydrogen, etc.) and, where appropriate, other relevant sectors (e.g. e-mobility).
- Strengthen cooperation between on-site energy storage and on-site renewable energy sources.
- Help improve interoperability in the modelling of energy networks and buildings.
- Ensure that the proposed solutions include "big data" applications for real-time management and predictive maintenance of technical systems in buildings.
- Ensure that the proposed solutions mitigate potential negative impacts, both on the satisfaction of building users (e.g. in terms of comfort or accessibility) and on the potential for circular material flows over the life cycle of the building, and maximize potential benefits (e.g. energy cost savings and health).
- Ensure that the proposed solutions provide accessible, inclusive, reliable and user-friendly tools with limited maintenance requirements and relevant building (and network) data for interested stakeholders (e.g. facility managers).
- Assess the contribution of the proposed solutions to the improvement of the intelligent buildings, as assessed by the intelligent prepraration indicator of Directive 2010/31/EU.
- Where appropriate, build on advanced monitoring and management solutions, such as those that integrate digital / BIM models with energy modelling and simulation at building and district level.
- Implement and demonstrate innovative and competitive balancing, storage and generation services in buildings, while optimizing the health, comfort and satisfaction of building users and inhabitants.
- Show the efficiency and economic viability of the proposed solutions and the associated business models, both for the consumers/end-users and for the economic actors involved.
- Present the use of large-scale sustainable platforms that bring together different actors and sectors (ESCOs, aggregators, DSOs, etc.) to exchange data and develop services.
- Seek to involve key European innovators, including social innovators, in relevant domains (demand response, communications, smart grids, building services, facility management, energy services, etc.) with limited experience of Horizon 2020, the name of the EU program that decided to propose the calls.

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2020-2021

Tittle: Cost-Benefit Analysis of a Smart-Grid in China

Abstract:

Updating Chinese grid energy data and using DOE software to determine the future financial benefits of implementing a Smart-Grid in China.

Determination of the first results and drafting of the project proposal for the European Commission which commissioned the study.

Mots Clés: Smart-Grid – PHS – DOE – CBA – Cost Benefit Analysis

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