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FLExibilize combined cycle power plant through power-to-X solutions using non-CONventional Fuels

D8.8 – "Documentation of selected business model(s)"

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Contributing Author(s)	CNET (Tommaso Orlandini, Goncalo Calado, Paul Kessler, Nuno Lopes Filipe, João Maciel), TP (Alessandro Gaglione, Torelli Giorgio, Chiara Corti) ENLAB (Hannes Laget)		
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[1] PU = Public
CO = Confidential, only for members of the consortium (including Commission Services)

Executive Summary

The objective of the document: D8.8 " Documentation of selected business model(s)", is to develop suitable business models for the Flex'nConfu solution.
The main concept of FLEXnCONFU system is its operation as an active Balance of Plant (BoP) absorbing CC electricity production during low price period and reducing environmental impact of existing CC. Two solutions tested in two different pilot sites are planned: the first one is the P2A solution (TRL6) in Savona laboratory, the send one is the P2H solution (TRL7) in Ribatejo combined cycle (EDPP). The electricity produced during low electricity price periods is converted to hydrogen/ammonia, stored, and then converted back into electricity at appropriate times (e.g., peak loads). Therefore, the project's added value to the community regards economic benefits, improved quality of end consumer's electricity, increased resilience of the electrical system and, reduction of fossil fuels consumption in the electrical system. Moreover, these solutions have high potential for replicability as they can be implemented with due adjustments on other Combined Cycle sites.
FLEX'nCONFU's solution acts as a storage mechanism that benefits the entire electricity supply chain enabling the promotion of new business opportunities for diverse energy stakeholders. Several storage services can be provided through this solution to different subjects. Some of which are: black start (for generators), voltage and frequency management (for system operators), correction of forecasts inaccuracy (for market operator), peak shaving (for end users).
Business models of three categories of plant stakeholders have been analysed: end users, energy generators and technology manufacturers. Considering end-users, their aim is to obtain a secure and continuous electricity supply without interruptions and possibly to use electricity produced from green generation sources. In this context, the Flex'n Confu provides benefits in term of both flexibility and environmental impact. Considering Energy Generators their scope is to obtain revenues by supplying electricity to the grid. FLEX'NCONFU's solution allows these entities to supply low environmental impact electricity (more desired by consumers), while providing all the ancillary services usually required to a cogeneration plant. Considering technology manufacturers, their scope is to obtain a remuneration for the technology supply and achieve a validation of proper product functioning. Therefore also in this case the realization of the FLEX'nCONFU project will bring benefits as it will test and disseminate the correct functioning of such technologies.
As regards the state of the plant (new or retofit), the business model changes mainly in terms of cost: in one case all the plant construction costs must be considered, in the other only the renewal costs.
Finally, considering the applicability in Italy, Belgium and Portugal, in any State there are specific incentives for cogeneration using natural gas blended with renewable gases such as hydrogen and ammonia. However, various incentives and benefits regarding energy efficiency and emission costs savings can be considered as the FLEX'nCONFU solution determines significant reductions in terms of CO_2eq emissions and an increase in the level of efficiency of the plant.

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Abbreviations

Abbreviations	
Acronym	Definition
AAT	Very High Voltage
ACER	Agency for the Cooperation of Energy Regulators
AIA	Integrated Environmental Authorization
ARERA	Regulatory Authority for Energy, Networks and Environment
BSP	Balancing Service Providers
CA	Consortium Agreement
CBA	Cost Benefit Analysis
DMP	Data Management Plan
DSO	Distribution System Operators
ECB	European Central Bank
ENTSO-E	European Network of Transmission System Operators
ERSE	Energy Services Regulatory Authority
EU	European
FRNP	Non-programmable Renewable Sources
GA	Grant Agreement
GME	Gestore dei Mercati Energetici – Energy Market Manager
HV	High Voltage
IMF	International Monetary Fund
IPQ	Portuguese Quality Institute
LV	Low Voltage
MGP	Day ahead market
MI	Intraday Market
MIBEL	Iberian Electricity Market
MSD	Ancillary Services market
MV	Medium Voltage
NoBo	Notified Body
PE	Pressure Equipment
PS	Permissible pressure
REN	Redes Energéticas Nacionais – National Energy Grids
RIB	Recognized Inspection Body
SOGL	System Operation Guidelines
TIDE	Integrated Text of Electricity Dispatching
TIUC	Integrated Text of Accounting Unblinding
TIUF	Integrated Text of Functional Unblinding
TSO	Transmission System Operator

1. Introduction

This deliverable was prepared within the framework of Work Package 8 "Dissemination, communication and exploitation" and refers to activities carried out by RINA-C within Task 8.3 "Business model definition and Techno-Economic Roadmap towards TRL9".

The purpose of this document is to develop suitable business models for the Flex'nConfu solution. To achieve such result, the document provides:

- ✓ a description of the FLEX'nCONFU solution and its value proposition, specifying the benefits that determines on: grid stability, decarbonisation and development of renewables.
- ✓ an analysis of three categories of plant stakeholders (end-users, energy generators and technology manufacturer) and of their Business Models,
- ✓ an analysis of plant business models depending on the plant state (new or retrofit)
- ✓ an analysis of the FLEX'nCONFU solution applicability in each selected Member State (Belgium, Italy and Portugal).

The structure of the document is in line with the four performed activities just listed.

2. Business Opportunities and Value Proposition

The main concept of FLEXnCONFU system is its operation as an active Balance of Plant (BoP) absorbing CC electricity production during low price period and reducing environmental impact of existing CC. Two solutions tested in two different pilot sites are planned:

- ✓ **P2A solution** (TRL6) in Savona laboratory (UNIGE) where a modular and containerized solution will be connected to an existing mGT, installed within a smart grid, properly modified for ammonia combustion. The functioning scheme is represented in next figure

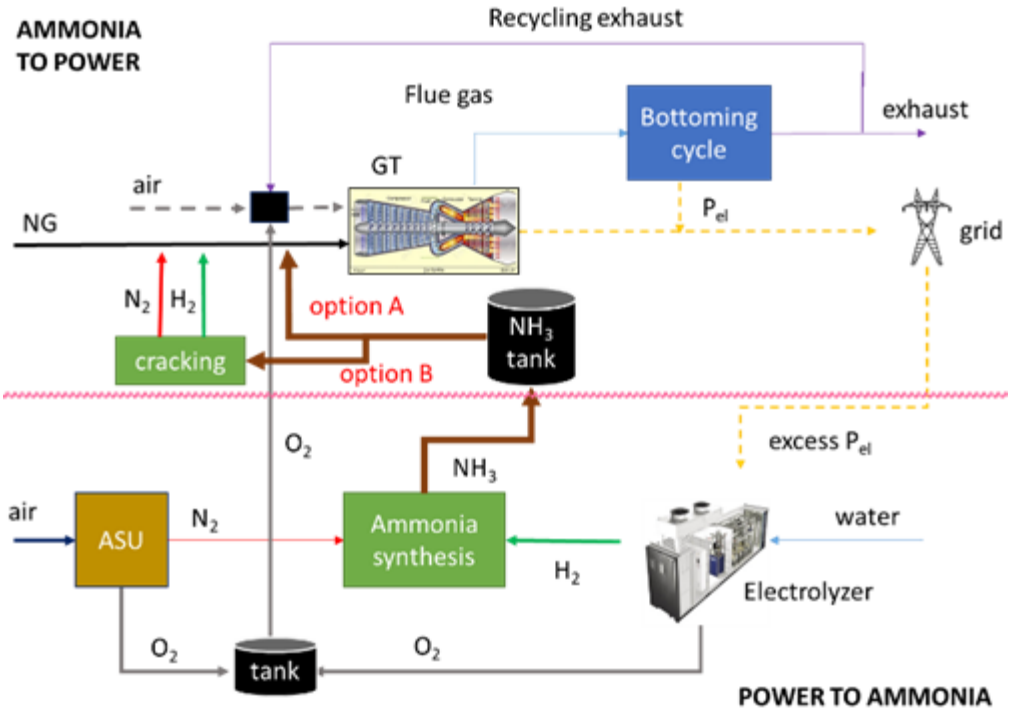


Figure 1: P2A layout

- ✓ **P2H solution** (TRL7) in Ribatejo combined cycle (EDPP) where a complete system composed by 1MW fast-cycling electrolyser, gas compressor and pressurized hydrogen storage (300bar) will be installed to demonstrate the potential of FLEXnCONFU concept in a real environment. The functioning scheme is represented in next figure

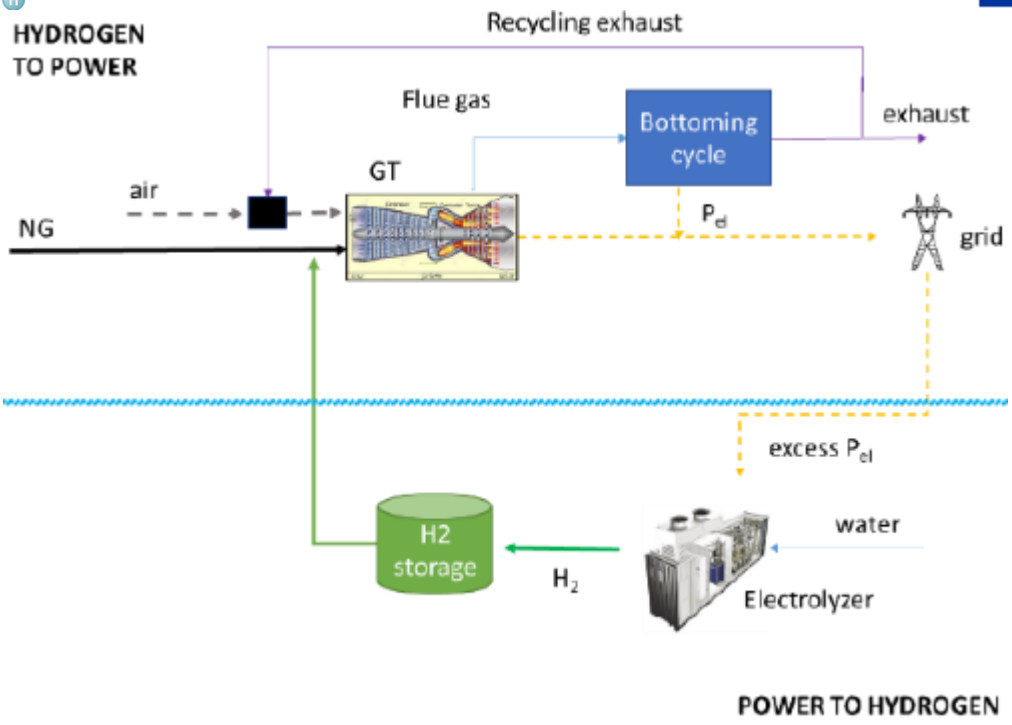


Figure 2: P2H layout

Therefore, the electricity produced during low electricity price periods is converted to hydrogen/ammonia, stored and then converted back into electricity at appropriate times (e.g., peak loads).

The **project's added value** to the community includes economic benefits, improved quality of end consumer's electricity, increased resilience of the electrical system and, reduction of fossil fuels consumption in the electrical system. In fact, the use of natural gas (NG) in combined cycle with the combustion of nonconventional fuels (H_2/NH_3) as well as the energy efficiency increase measures from the enhanced storage integration, are expected to result to significant savings in the fossil fuel consumption and GHG emissions of the electricity system.

The qualitative value that will be added to the local electricity grid can be summarised to the following points:

- Improvement of Combined Cycle (CC) flexibility allowing higher RES generation share
- Enhancement of the grid's resilience
- Provision of spinning reserve capacity

The project's value proposition can be summarised to the following:

- Increase of the operational efficiency of the Combined Cycle units
- Support of the energy transition towards a more environmentally friendly generation system
- Increase of the RES share in the electrical system
- Support of the generation adequacy during peak demand hours

The project has high potential for replicability as it can be implemented with due adjustments on other Combined Cycle sites. Indeed, once the environmental, operational and economic benefits of the proposed solution have been demonstrated, the future objective will be to replicate it in other CC sites. Therefore, ease of replicability is a crucial aspect for the success of the project. So, this project is expected to be the first step to prove the P2X2P as an important piece in the future decarbonized Europe.

In this context increased environmental concerns in the EU dictate its climate strategy which is reflected in the European Climate Law (June 2021), establishing the aim of reaching net zero greenhouse gas emissions (GHG) in the EU by 2050. In addition, the Climate Law sets an intermediate target of reducing GHG by at least 55% by 2030 compared to 1990 levels. In this respect, the decarbonization of the energy sector, as the major pollutant factor, is a necessity in order to achieve the EU energy transition targets. Indicatively, the "Fit for 55' package, which is a set of policy proposals by the European Commission to achieve this 55% reduction target, proposes an increase of the target for renewable energy production to 40% by 2030. However, the intermittent production of the RES, caused by the probabilistic variations of the wind speed and solar radiation, introduce high stochasticity and challenges in the operation and management of the whole electricity grid. High RES shares in the production mix will impose larger imbalances from the supply-demand equilibrium. Maintaining the balance between supply and demand will become a challenging task and the need for alternatives to deal with renewables in the energy system will emerge in the short/mid-term. This implies that sufficient backup capacity must be available to restore the balance in a fast and cost-efficient way.
Therefore, the energy transition requires the integration of energy storage capacities/mechanisms along the entire energy value chain to provide flexibility to the electricity system in order to balance and mitigate intermittent RES production more efficiently. The storage needs are diverse depending on the time frame they are requested at the grid level. The resulting storage capacity will be introduced to the markets, thus enabling the promotion of new business opportunities for diverse energy stakeholders[2]. Figure below portrays an approach of the portfolio of energy storage services that can be offered at various time durations to the potential users.

[2] Roland Berger, Business Models in Energy Storage, 2017

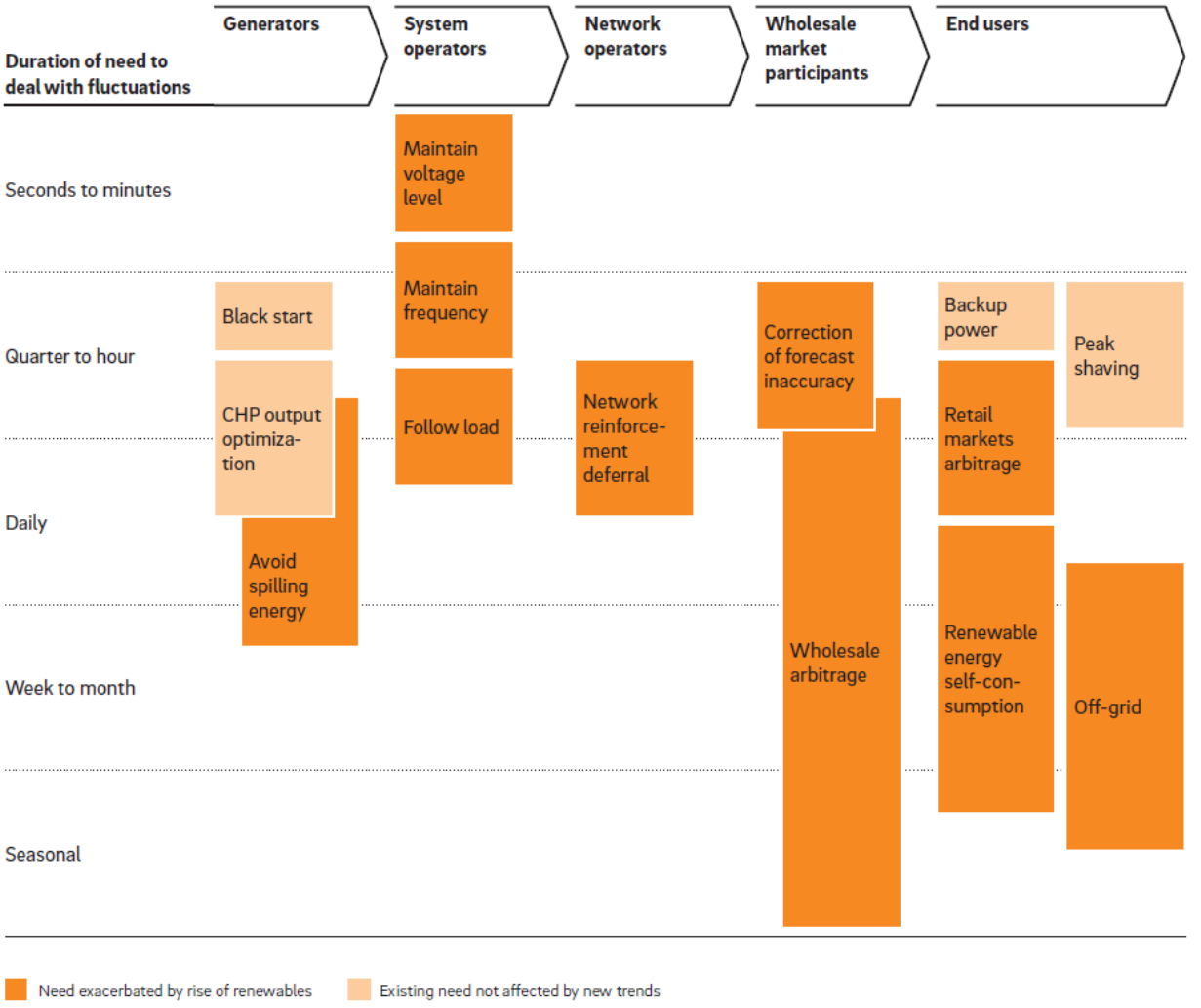


Figure 3: Storage needs along the value chain
Source: Roland Berger, 2017

At the **electricity generation level,** electricity storage can support the generation adequacy and contribute to a more cost-efficient production. Black start, CC optimisation and management of excess RES production are the most common business application for the storage capacities at the highest level of the electricity grid. Such applications demand a storage duration ranging from a quarter to an hour up to a week at most. At network level, system operators have short duration storage needs. Operating the grid and maintaining balance between intermittency may lead to frequency deviations and voltage excursions. On a slightly longer time frame, load following is also becoming more important, where sudden changes in energy output from renewables cannot be matched as quickly by scaling up or down conventional generation output. For system operators, the increase in decentralized energy generation attached to the local distribution grid may cause the power flows to go in different directions than initially foreseen with the outlay of the grid. Energy storage may prevent or defer some refurbishment and network reinforcement investments. On wholesale market level, trading and fulfilling the portfolio management function of utilities entails the exploitation of storage capacities to reduce the trading risks.

The accuracy of the predictions of the renewable energy output is very important for the trading process. Any deviations from the predictions would require on the-spot sourcing of more electricity or selling of additional volumes. In long-term, energy storage enables more arbitrage. Major fluctuations in generation output will lead to larger price differences. Storage provides the means to take advantage of those differences. Finally, at the lowest grid level, end users have storage needs in order to improve their energy profile in terms of costs or environmental footprint, to maximize their self-consumption in case of prosumers and to shave demand peaks.

A Business Model for a storage project can be characterised by three parameters: the application of a storage facility, the market role of a potential investor, and the revenue streams obtained from its operation. Figure below depicts 28 distinct business modes for energy storage applications and their revenue streams, depending on the end users of the electricity system (trading, production, transmission & distribution, consumption). Each individual business model is indicated within a box and applies storage to serve a particular need and to generate a distinct revenue steam for a specific market role[3].

[3] iScience, Business Models and Profitability of Energy Storage, 2020

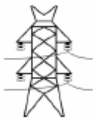
	Cost Avoidance	Investment Deferral	Price Arbitrage
Trading			
	**Frequency containment** Provide frequency containment *Avoid cost of ramping portfolio* **Short-term frequency restoration** Provide short-term frequency restoration *Avoid cost of ramping portfolio* **Long-term frequency restoration** Provide long-term frequency restoration *Avoid cost of ramping portfolio* **Trading forecast** Meet buying / selling forecast *Avoid penalties for deviations*		**Trading arbitrage** Buy at low / sell at high prices *Exploit volatility in electricity market prices*
Production			
	**Frequency containment** Provide frequency containment *Avoid cost of ramping production* **Short-term frequency restoration** Provide short-term frequency restoration *Avoid cost of ramping production* **Long-term frequency restoration** Provide long-term frequency restoration *Avoid cost of ramping production* **Schedule flexibility** Meet selling forecast *Avoid cost for ramping up* **Production forecast** Meet selling forecast *Avoid penalties for deviations*	**Voltage control** Provide voltage control *Save investment in voltage regulators* **Black start energy** Provide black start energy *Save investment in black start generator* **Backup energy** Provide backup energy *Save investment in backup generator* **Peak shaving** Shave demand peaks *Save investment in capacity expansion*	
Transmission & Distribution			
	**Frequency containment** Provide frequency containment *Avoid cost of control services* **Short-term frequency restoration** Provide short-term frequency restoration *Avoid cost of restoration services* **Long-term frequency restoration** Provide long-term frequency restoration *Avoid cost of restoration services* **Black start energy** Provide black start energy *Avoid cost of black start service*	**Voltage control** Provide voltage control *Save investment in voltage regulators* **Peak shaving** Shave supply / demand peaks *Save investment in capacity expansion*	
Consumption			
	**Frequency containment** Provide frequency containment *Avoid cost of ramping consumption* **Short-term frequency restoration** Provide short-term frequency restoration *Avoid cost of ramping consumption* **Long-term frequency restoration** Provide long-term frequency restoration *Avoid cost of ramping consumption* **Peak shaving** Shave demand peaks *Avoid demand charges*	**Voltage control** Provide voltage control *Save investment in voltage regulators* **Backup energy** Provide backup energy *Save investment in backup generator*	**Consumption arbitrage** Buy at low prices *Exploit volatility in consumer prices* **Self-sufficiency** Buy at low prices *Exploit gap in buying and selling prices* Business model Application *Revenue stream*

Figure 4: Business Models for the Energy Storage
Source: iScience, 2020

3. Business Actors

In this section, the different project stakeholders are considered by analysing their business model. Plant stakeholders can be grouped into three categories according to their role:

- ✓ end-users: the final consumers of the electricity produced in the plant,
- ✓ energy generator: plant owner that produce electricity and supplies the electricity wholesale market (that has different features according to the Country considered),
- ✓ technology manufacturer: manufacturers and developers of innovative technologies installed in the power plant for electricity production

For each of these stakeholders, the activities performed, the objectives, the costs and revenues and in general the entire business model could differ. Therefore, following each stakeholder category is described and, if possible (only "energy generator" and "technology manufacturer"), represented through a Business Model Canvas. This model summarizes important aspects of the business under consideration on one single scheme, allowing an immediate understanding of the key features of the business. BM Canvas sections are represented and described in next figure:

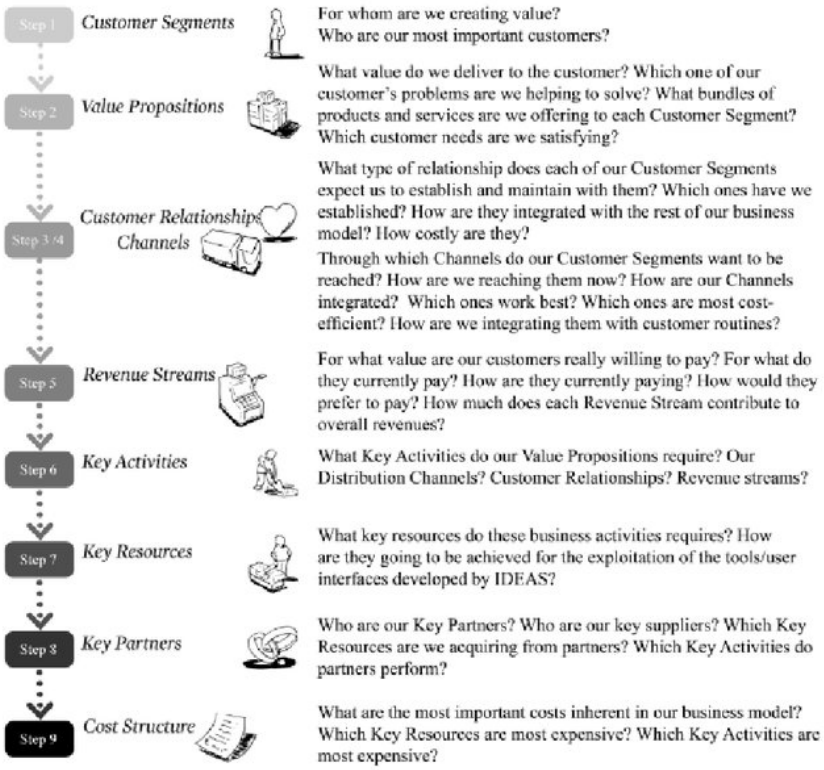


Figure 5: BM Canvas sections
Source: Research Gate, 2014

As figure shows, such Business Model (BM) is useful to define how organizations can create, deliver and capture value. In BM implementation, it is necessary to describe the logic behind a business operation,

to describe how an entity allocate their activities and resources (investments) to reach their objectives, and to identify monetary and physical flows in the Business mechanism.

4.1 End-users

Starting with the End-users, these subjects under consideration are the final consumers of the electricity produced in the power plant. End-users are the last stage of the electricity supply chain (as shown in the next figure) and therefore do not represent an entity having a Business Model, but only consumers who have certain preferences in their purchasing choices. Therefore, this category of actors cannot be represented through the BM Canvas as most of BM sections are not relevant.

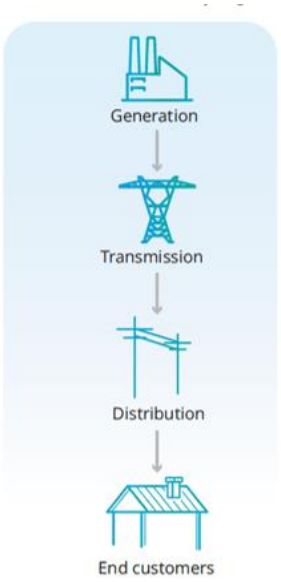


Figure 6: Electricity supply chain
Source: Deloitte, 2020

Considering the purchasing choices of end consumers, it should be specified that the main condition that has to be fulfilled is continuity and security of electricity supply. In this context, Flex'n Confu's solution, by providing a high level of flexibility in electricity generation, is well suited to fulfil this supply condition. The second aspect that is of increasing importance in the choices of end consumers concerns the climate impact of energy consumption. Again, Flex'n Confu's green hydrogen/ammonia turbine solution would significantly reduce the level of emissions associated with electricity generation in a power plant also eliminating the problem of variability and intermittency that usually characterize renewable generation sources.

Given the above, the main characteristics of electricity end-users are outlined below:

- ✓ **End-users' activity:** consumption of electricity according to their requirements. Considering the typical consumption pattern of end-users and given the increasing production share of electricity through renewables, the typical load curve of dispachable plants is the so-called "Duck Curve" shown in the figure below. This curve clearly indicates the level of flexibility and variability

required to meet electricity demand, which can only be achieved with programmable generation sources.

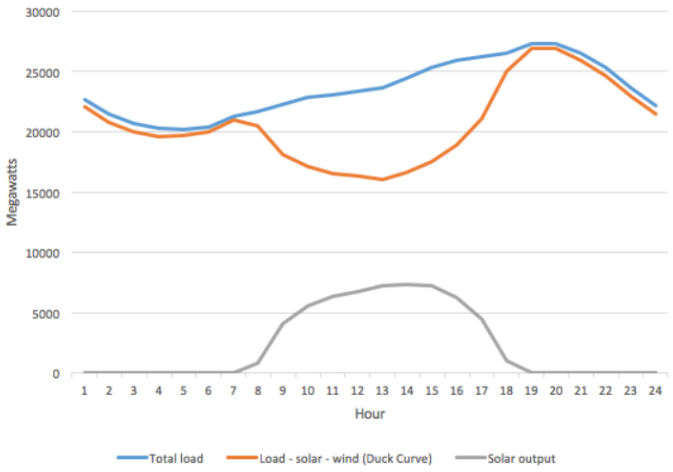


Figure 7: Duck Curve
Source: California ISO, 2016

- ✓ **End-users scope:** the aim of end-users is to obtain a secure and continuous electricity supply without interruptions. In addition, an increasingly popular goal for end-users is to use electricity produced from green generation sources or from generation path resulting in significant emission savings compared to traditional methods.
- ✓ **End-users relationships:** as far as the end-users' business relationships are concerned, typically these are with Electricity Retailers. The selection of the supplier depends mainly on the purchase price. Therefore, as already described in deliverable D1.4 - "Electrical market assessment for enhanced FLEXnCONFU concept in DC", there is no direct relationship between the electricity generator and the end-users.
- ✓ **End-users cost:** the costs that end-users incur is related to the purchase of electricity from the grid and depend on the supply contract signed with the Electricity Retailer in terms of €/kWh. The supply of electricity produced solely from renewable generation sources may lead some consumers to incur slightly higher costs.

End-users therefore represent the existing electricity demand to which generation must adapt to keep the grid always in balance. The increase in the share of renewables requires, as already stated, increasing flexibility of programmable generation sources. In this context, the Flex'n Confu solution acts on two sides that are difficult to achieve at the same time: flexibility and low environmental impact.

4.2 Energy Generator

Energy Generator is considered as plant owner that generate electricity and supply it to the wholesale market or use it for other in-house production processes. In this case, the stakeholders are mainly power generation companies, chemical companies, oil and gas companies and in general all entities that operate a turbine for the production of electricity. For these entities, it is important to ensure an uninterrupted and flexible supply of electricity to the grid or to a production process. In addition, a

decrease in emission levels would result in significant economic benefits in terms of CO2eq Savings and related costs.

Energy Generator Business Model can be schematically represented and described through the BM Canvas methodology.
Following each BM Canvas section is described:

- ✓ **Customer segment:** in the case of electricity production with the aim of injecting it into the grid, the 'costumer' is the Electricity Market, where electricity producers sell the electricity produced at wholesale or on request. The counterpart is the national Market Manager. In the case of using the energy produced within the company for a specific in-house production process, there is no customer as the electricity is planned to be used inside the company. Considering the ancillary services supply, the "customers" are represented by the national Transmission System Operator (TSO) and the local Distribution System Operator (DSO), that manage the electricity grid at a national level with high voltage (TSO) or local level with medium-low voltage (DSO). These Operators aim to maintain the grid stable and balanced for guarantee its proper functioning.

- ✓ The **Value proposition** of this Business Model is to favor the integration between RES and dispatchable sources generations. Since Combined Cycle Gas Turbine (CCGT) plant will be for the next years the best flexibility sources for compensating the intermittency of the RES, the conversion of renewable electricity into alternative fuels like green hydrogen or ammonia (that don't produce emissions) that are going to be injected in a innovative turbine, will determine a programmable electricity production with no carbon emissions. This solution make electricity generation from renewables adaptable to electricity demand trends by reducing its variability. Moreover, this solution make RES derived electricity suitable for providing all the ancillary services usually provided by a CCGT plant. In fact, following the installation of a turbine powered by hydrogen or ammonia, excess electricity from renewables is converted into hydrogen or ammonia and, during peak load, this hydrogen/ammonia is used to power the turbine, which, among other things, is able to provide the grid with all those ancillary services that guarantee the security and reliability of supply.

- ✓ Considering the sale of electricity, the only **Channel** used to reach customer is the participation in wholesale or/and on request electricity markets. Otherwise, considering the provision of ancillary services the channel used is the participation in Balancing Energy Markets, Balancing Capacity Markets and Transmission-redispatch Markets.

- ✓ **Revenues** derives mainly from the sale of electricity in the national Electricity Market and from the supply of all the ancillary services that are requested by the Transmission System Operator or by the Distribution System Operator to maintain the stability and security of the grid. In case of using the energy produced within the company for a specific production process, the Revenues are represented by Cost Savings related to the production of such electricity.

- The **Key activity** of the Energy Generator is the generation of electricity through the innovative turbine fueled by hydrogen or ammonia. Other activity to be considered is the production or purchase of the alternative green fuels: in case of production, a renewable production plant has to be installed and operated along with all those components needed to convert electricity into hydrogen/ammonia (for example the electrolyser).

- As **Key Resources** hydrogen or ammonia are certainly two components that must be produced or purchased. It is important to highlight that only green hydrogen/ammonia determines the economic benefits of the Flex'nConfu solution in terms of emission avoiding. Therefore, as already stated, in the case of green hydrogen/ammonia self-production, the presence of a renewable plant is necessary. Other resource that has to be purchased is the Natural Gas that usually is injected into the turbine by blending it with the alternative fuels. Considering the necessary equipment, the main components are the turbine powered by hydrogen/ammonia and in the case of in-house production of alternative fuels, the installation of renewable generation plants and the installation of the equipment for the conversion of the electricity produced into hydrogen/ammonia.

- **Key partners**, in energy generation, the producing company mainly establishes supply relationships with technology manufacturers (turbine, other equipment), Natural Gas Retailer, Hydrogen/Ammonia supplier (in case it is not directly produced within the company).

- **Cost** derives mainly from the purchasing of the turbine, and the purchase/production of its fuel (natural gas, hydrogen or ammonia). Moreover, these types of green fuels need a special equipment to be transported and stored, that have to be purchased and installed. Other costs are related to the cost of CO_2 emission that each plant have to pay based on the amount of emission it produces. FLEX'nCONFU solution in this context could result in a significant cost saving for the plant owner.

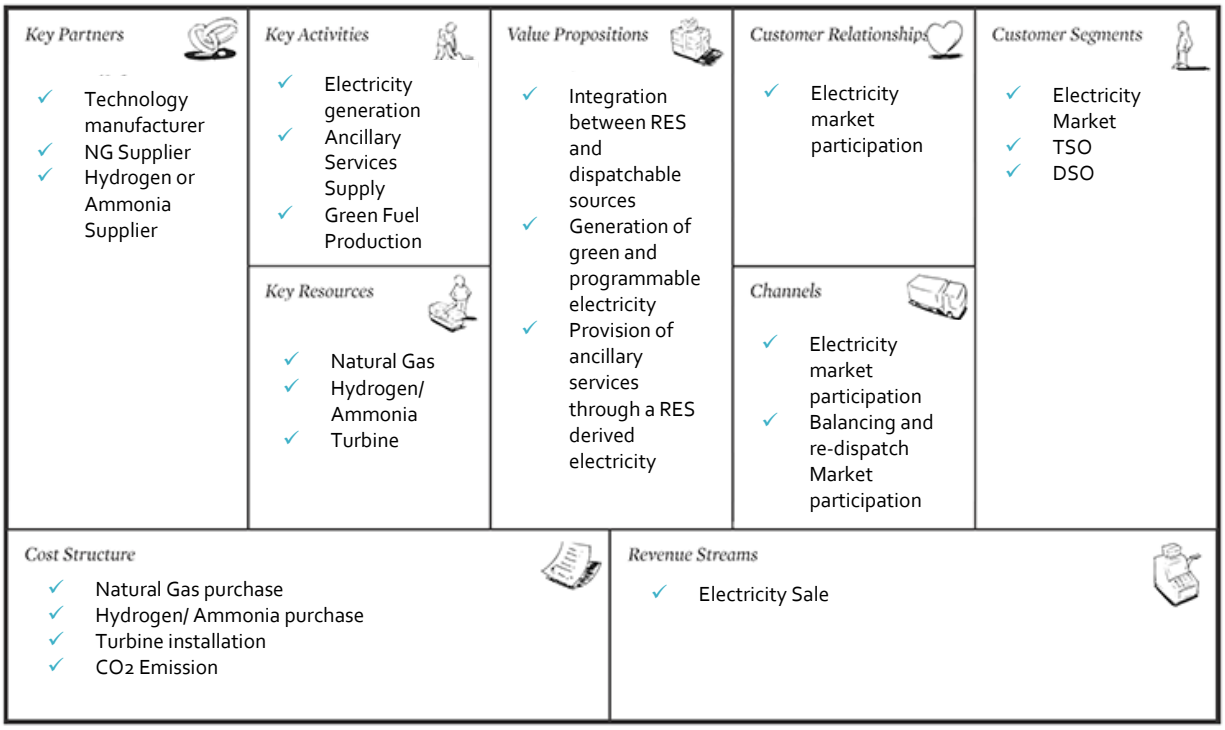


Figure 8: Energy Generator BM Canvas
Source: Rina elaboration

4.3 Technology Manufacturer

Considering the Technology Manufacturers, these are the plant suppliers of the technologies used to implement the Flex'n Confu solution. Among these are certainly the manufacturers of the green hydrogen/ammonia-powered turbine. However, other supplier stakeholders can be considered as: ammonia reactor supplier, electroliser supplier etc. The aim of these stakeholders is mainly to obtain a remuneration for the technology supply and achieve a validation of proper product functioning.

Again, Technology Manufacturer Business Model can be schematically represented and described through the BM Canvas methodology. Following each BM Canvas section is described:

- **Customer segment:** in this case the 'costumers' are mainly CCGT plants, but outside Flex'n Confu project other power generation companies, chemical companies, oil and gas companies and in general all entities that operate a turbine for the production of electricity can be considered. For these entities, it is important to ensure an uninterrupted supply of electricity to the grid or to a in-house production process. In addition, considering the use of non-conventional fuels, it is appropriate to highlight that a decrease in emission levels would result in clear economic benefits in terms of CO2eq Cost Savings.

- The **Value proposition** of this BM is to provide a product/technology that can be used to generate electricity through Flex'n Confu project's process. The products provided have to replace the common natural gas-powered turbine process in the electricity generation, guaranteeing all

ancillary services useful to maintain the security of the grid but also guaranteeing an important emission savings to the power plant.

- ✓ Considering the sale of the technology, the main **Channels** used to reach customer are sales agents, fair events, company website. Moreover, given the high level of innovation that characterize the products under consideration, participation in R&D projects could be useful to validate and develop the functioning of the product itself and, above all to disseminate the results and increase the products commercial reputation.

- ✓ **Revenues** derives mainly from the sale of the products. In some cases, public subsidies could be obtained due to the high level of innovation of the products.

- ✓ The **Key activity** is the manufacture and provision of the innovative products suitable to be inserted in the electricity production process according to the Flex'n Confu solution. A secondary activity is the execution of all the tests and validation needed to confirm the correct functioning of the technology.

- ✓ As **Key Resources** all the materials and technologies necessary for the physical construction of the product must be considered. Furthermore, considering the level of innovation of the technologies needed for the implementation of the Flex'n Confu solution, the knowledge achieved during the development, validation and production phases can be considered as a key resource. The same regards the availability of high qualified personnel with a high level of knowledge on the specific topic.

- ✓ **Key partners**, all the materials and technologies suppliers necessary for the realization of these technologies must be considered as key partners. Even the owners of the application site can be considered partners in some cases since they allow a sort of "validation" of the functioning of the product.

- ✓ **Cost** derives mainly from the purchase of all the materials and technologies needed for the turbine production. Moreover, cost of personnel (highly qualified due to the level of innovation of the product) have to be considered. Finally, the cost of execute all the tests and validation in laboratory, in order to assure the correct functioning of the technology, is another significant component.

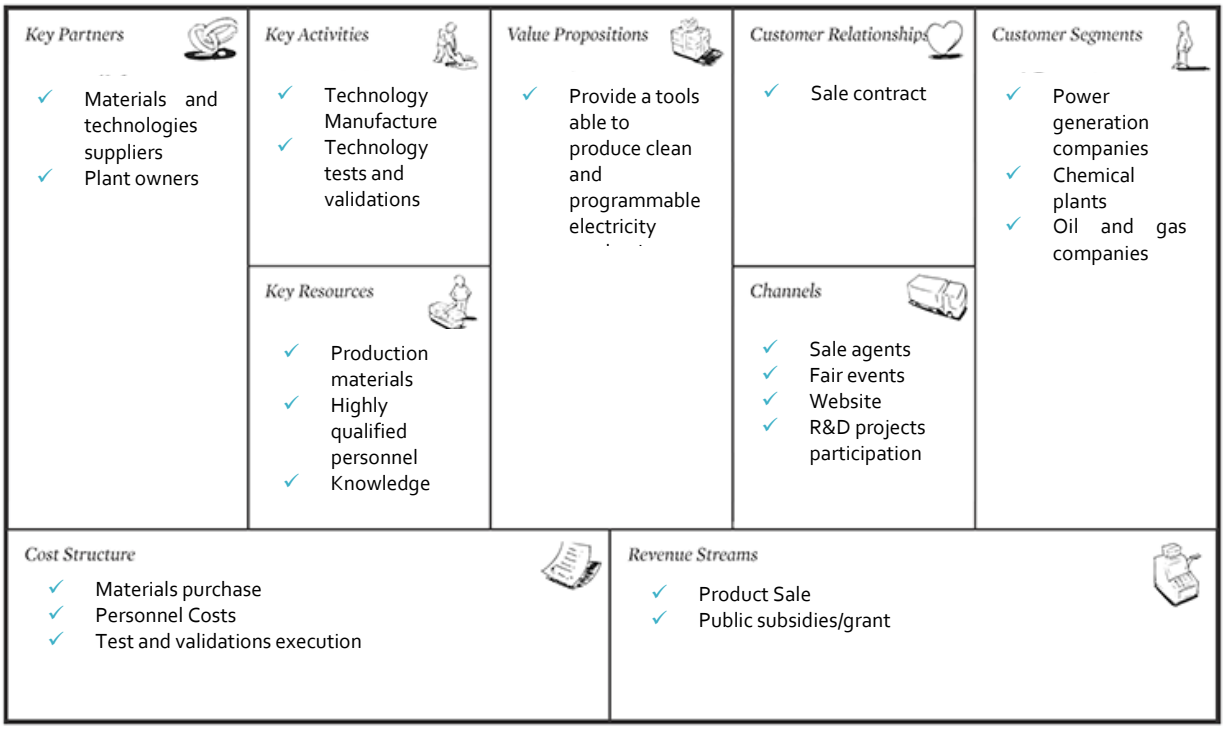


Figure 9: Technology Manufacturer BM Canvas
Source: Rina elaboration

4. Plant Condition

The plant's business model may change depending on the state of the facility. The two options under consideration are the implementation of the Flex'n Confu solution in an existing plant and therefore requiring appropriate modifications, and the installation of this solution in a new plant. These options differ mainly in terms of implementation costs. Below, the business model is described for each option, highlighting the main differences.

5.1 New Plant

In the case of the construction of a new CCGT electricity generation plant, the plant owner's Business Model differs from the situation where a plant is already in place, especially in terms of cost.

The sections of the BM Canvas from the plant owner point of view of a new CCGT plant with the Flex'n Confu solution are described below. However, many Canvas sections do not differ between the two type of plant (new or retrofit) and are similar to the Business Model already described in paragraph 4.2 regarding the Energy Generator.

- ✓ **Customer segment:** the only 'costumer' in electricity sale is the Electricity Market, where electricity producers sell the electricity produced at wholesale or on request. The counterpart is the national Market Manager. Considering the ancillary services supply, the "customers" are represented by the national Transmission System Operator (TSO) and the local Distribution System Operator (DSO), that manage the electricity grid at a national level with high voltage (TSO) or local level with medium-low voltage (DSO). These Operators aim to maintain the grid stable and balanced for guarantee its proper functioning.

- ✓ The **Value proposition** of this Business Model is the implementation of a new plant able to favor the integration between RES and dispatchable sources generations. The conversion of renewable electricity into alternative fuels like green hydrogen or ammonia (that don't produce emissions) that are going to be injected in a innovative turbine, will determine a programmable electricity production with no carbon emissions. This solution make electricity generation from renewables adaptable to electricity demand trends by reducing its variability. Moreover, this solution make RES derived electricity suitable for providing all the ancillary services usually provided by a CCGT plant. In fact, following the installation of a turbine powered by hydrogen or ammonia, excess electricity from renewables is converted into hydrogen or ammonia and, during peak load, this hydrogen/ammonia is used to power the turbine, which, among other things, is able to provide the grid with all those ancillary services that guarantee the security and reliability of supply.

- ✓ Considering the sale of electricity, the **Channel** used to reach customer is the participation in wholesale or/and on request electricity markets. Otherwise, considering the provision of ancillary services the channel used is the participation in Balancing Energy Markets, Balancing Capacity Markets and Transmission-redispatch Markets.

- **Revenues** derives mainly from the sale of electricity in the national Electricity Market and from the supply of all the ancillary services that are requested by the Transmission System Operator or by the Distribution System Operator to maintain the stability and security of the grid.

- The **key activity** is the generation of electricity as a result of the new plant implementation, using the innovative hydrogen or ammonia-fuelled turbine. Another activity to be considered is the production or purchase of alternative green fuels: in the case of production, the installation and operation of a renewable production plant and all the necessary components to convert the electricity into hydrogen/ammonia (e.g. electrolyser) is required.

- As **key resources**, hydrogen or ammonia are two necessary components for electricity production. It is important to emphasise that only green hydrogen/ammoniaca determines the economic benefits of the Flex'nConfu solution in terms of emission reduction. Therefore, in the case of in-house production of green hydrogen/ammonia, a renewable electricity production plant is required. Another resource that must be purchased is natural gas, which is injected into the turbine by mixing it with alternative fuels. Considering the necessary equipment, the main components are the hydrogen/ammoniaca-fuelled turbine and, in the case of in-house production of alternative fuels, the installation of renewable generation plants and the installation of equipment to convert the electricity produced into hydrogen/ammoniaca.

- **Key Partners** to consider are the plant constructors, the technology manufacturer (of turbines, other equipment), the natural gas and hydrogen/ammonia suppliers (in case it is not produced in-house).

- **Costs** derived mainly from the construction of the new plant, including the installation of the technologies necessary for the production of electricity through the Flex'nConfu solution (including the hydrogen/ammonia powered turbine). Moreover, the purchase/production of fuels (natural gas, hydrogen or ammonia) have to be considered. Considering green fuels, they need a special equipment to be transported and stored, that have to be purchased and installed. Other costs are related to the cost of CO_2 emission that each plant have to pay based on the amount of emission it produces. FLEX'nCONFU solution in this context could result in a significant cost saving for the plant owner.

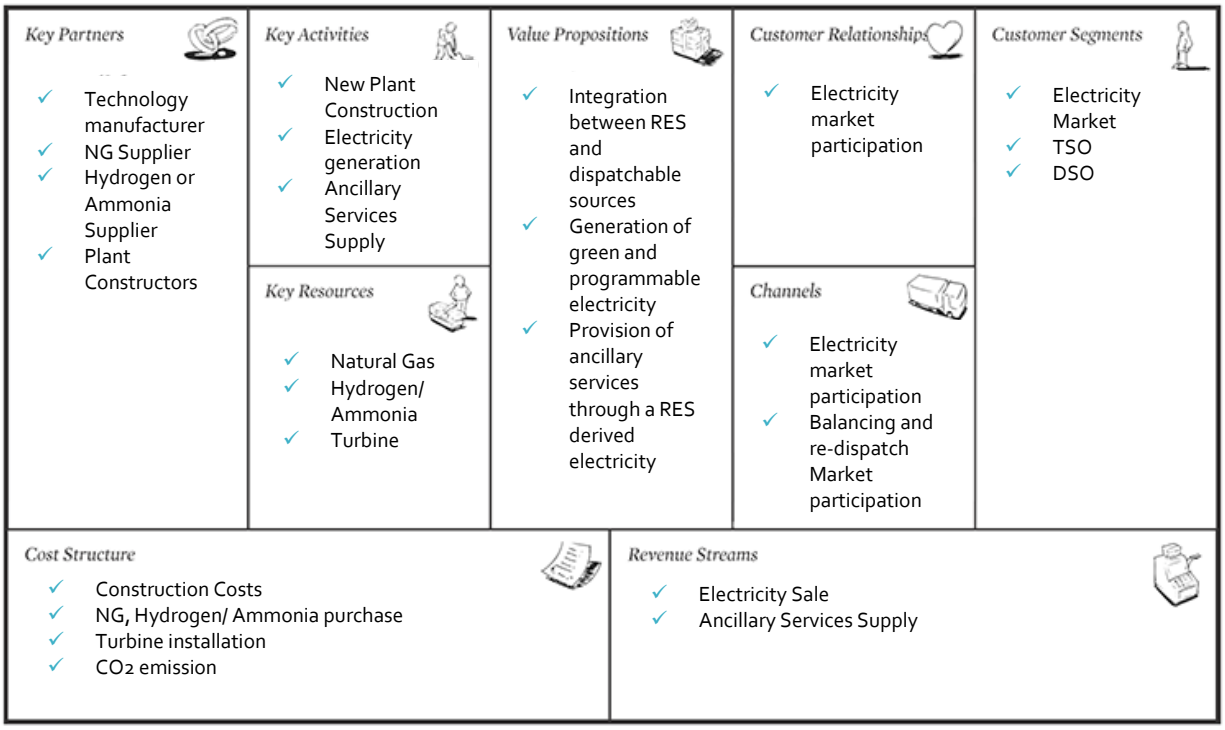


Figure 10: New Plant BM Canvas
Source: Rina elaboration

5.2 Retrofit Plant

In the case of renovating an existing CCGT plant, the business model differs in some sections from the case of a new plant construction. These sections are described and highlighted in the BM Canvas below.

- The **Value proposition** of this Business Model consists in the reduction of the CO_2 emissions of an existing CCGT plant, by replacing the turbine with one capable of being powered by green fuels. Moreover, as in the case of new plant, such solution favor the integration between RES and dispatchable sources generations. The conversion of renewable electricity into alternative fuels like green hydrogen or ammonia (that don't produce emissions) that are going to be injected in a innovative turbine, will determine a programmable electricity production with no carbon emissions. This solution make electricity generation from renewables adaptable to electricity demand trends by reducing its variability. Moreover, this solution make RES derived electricity suitable for providing all the ancillary services usually provided by a CCGT plant. In fact, following the installation of a turbine powered by hydrogen or ammonia, excess electricity from renewables is converted into hydrogen or ammonia and, during peak load, this hydrogen/ammonia is used to power the turbine, which, among other things, is able to provide the grid with all those ancillary services that guarantee the security and reliability of supply.

- ✓ the **Key activities** concern the restructuring of the plant, including the replacement of the existing turbine with an innovative one capable of being powered by hydrogen/ammonia. Another activity to be considered is the production or purchase of alternative green fuels: in the case of production, the installation and operation of a renewable production plant and all the necessary components to convert the electricity into hydrogen/ammonia (e.g. electrolyser) is required.

- ✓ **Costs** derived mainly from the renovation of the plant, including the installation of the technologies necessary for the production of electricity through the Flex'nConfu solution (hydrogen/ammonia powered turbine, and all equipment accompanying the turbine installation). Moreover, the purchase/production of fuels (natural gas, hydrogen or ammonia) have to be considered. Considering green fuels, they need a special equipment to be transported and stored, that have to be purchased and installed. Other costs are related to the cost of CO_2 emission that each plant have to pay based on the amount of emission it produces. FLEX'nCONFU solution in this context could result in a significant cost saving for the plant owner.

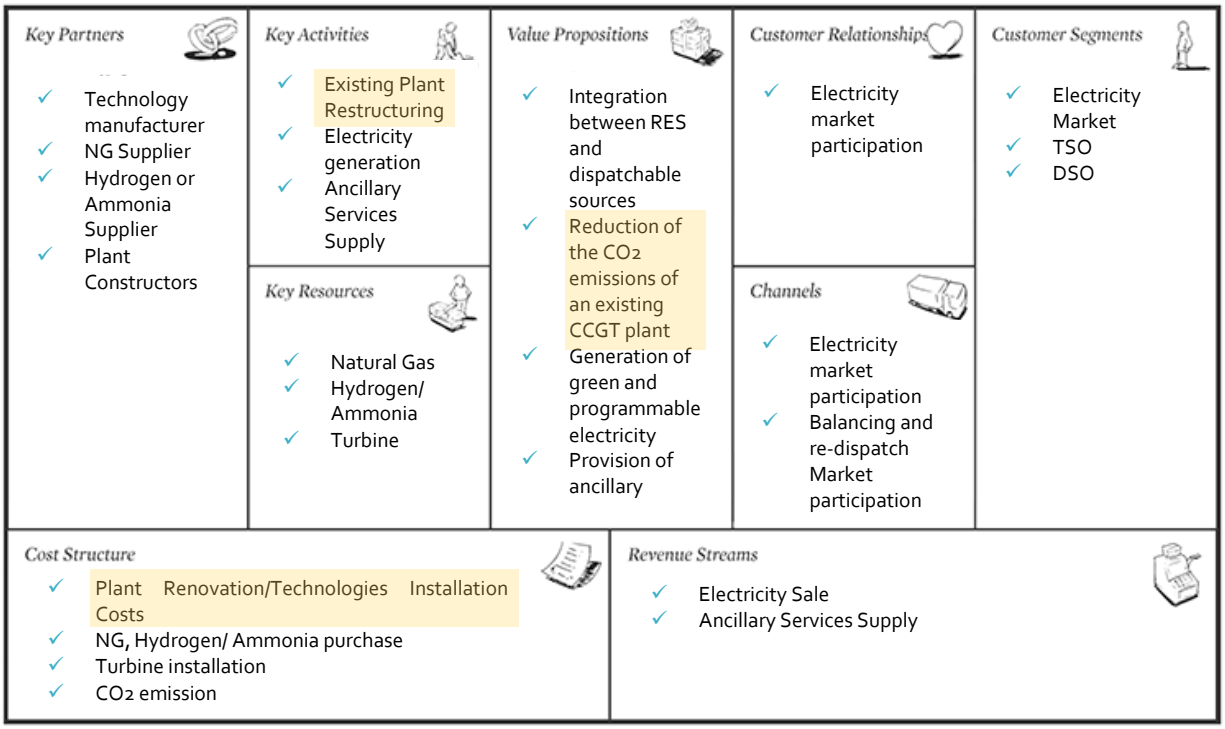


Figure 11: Retrofit Plant BM Canvas
Source: Rina elaboration

5. Applicability in Selected Member States

This paragraph analyzes the main regulations and characteristics related to the electricity market of the three representative countries: Italy, Belgium and Portugal. In particular, the analysis focus on:

- ✓ the incentives associated to the efficiency of cogeneration plants and to CO_2 emission savings
- ✓ electrical market pricing and penalization of unbalances.

6.1 Italy

The Italian government has established the wholesale electricity market through the Bersani Decree (1999) in order to increase the efficiency and the level of competition of the electricity market. The Italian electricity market is managed by the Gestore dei Mercati Energetici (GME). This market was established to promote competition (in generation, sale, and purchase) ensuring transparency and neutrality, and to ensure the availability of ancillary services. Concerning transmission and distribution activities, these are carried out under a national or zonal monopoly. In particular, the activity of electricity transmission is the exclusive responsibility of the transmission system operator, that is Terna[4]. As defined by ARERA (Regulatory Authority for Energy, Networks and Environment) through the TIUC and TIUF (concerning, respectively, accounting unbundling and functional unbundling), companies or groups of companies that operate in the infrastructure sectors (e.g., transmission) of electricity and in the liberal sectors (e.g., sale) are required to meet the obligations of functional unbundling. Considering accounting unbundling, the activities impacted are production, transmission, distribution, and sales[5][6].

Considering the incentives associated with the efficiency of cogeneration production plants, an important form of incentive is the Energy Efficiency Certificates (TEE), also known as White Certificates, that are released by the GME. They are negotiable securities based on the savings achieved in terms of energy efficiency[7]. One certificate is equivalent to saving 1 ton of oil equivalent (toe)[8]. **High Efficiency Cogeneration** solutions capable of guaranteeing significant primary energy savings can also benefit from TEE. As specified by the European Directive 2004/8/CE, the primary energy saving value achieved by the cogeneration plant must be at least 10%. The GSE specifies that for each ton of oil equivalent (toe) of savings obtained thanks to the implementation of the energy efficiency intervention, a Certificate is recognized which can be exchanged on the market platform managed by GME.
TEEs are divided into three types:

- ✓ Type I: certifying the achievement of primary energy savings through interventions to reduce final electricity consumption;
- ✓ Type II: certifying the achievement of primary energy savings through interventions to reduce natural gas consumption;

[4] Ministero dello Sviluppo Economico, Mercato elettrico, 2022, https://www.mise.gov.it/index.php/it/energia/energia-elettrica/mercato-elettrico
[5] Arera, TIUC, 2016, https://www.arera.it/allegati/docs/16/137-16all_ti.pdf
[6] Arera, TIUF, 2015, https://www.arera.it/allegati/docs/15/296-15tiuf.pdf
[7] GME, Titoli Efficienza Energetica, https://www.mercatoelettrico.org/It/Mercati/TEE/CosaSonoTee.aspx
[8] Arera, Cosa sono i certificati bianchi, https://www.autorita.energia.it/allegati/com_stampa/08/certificatibianchi.pdf

- ✓ Type III and IV: certifying the achievement of savings of forms of primary energy other than electricity and natural gas not achieved in the transport sector (Type III) and achieved in the transport sector (Type IV).

There are several other benefits recognized by law to High Efficiency Cogeneration:

- ✓ exemption from the obligation to purchase Green Certificates
- ✓ exemption from payment of the variable component (€/kWh) of the system fees
- ✓ precedence in the dispatching of electricity
- ✓ tax breaks on methane gas
- ✓ simplified technical-economic conditions for connection to the electricity grid
- ✓ simplified administrative procedures
- ✓ possibility of requesting the Guarantee of Origin (GO) from the GSE, an electronic certification that certifies the renewable origin of the sources used[9][10].

Considering the pricing in the electricity market, it is appropriate to make a distinction based on the type of market:

- ✓ Wholesale Market: the wholesale electricity market can be divided in the **Day-Ahead Market** and the **Intra-day Market**. The Day-Ahead Market consists of an auction that takes place at midday and covers the next day's 24 hours. All accepted bids are paid at the marginal offer price as next figure shows.

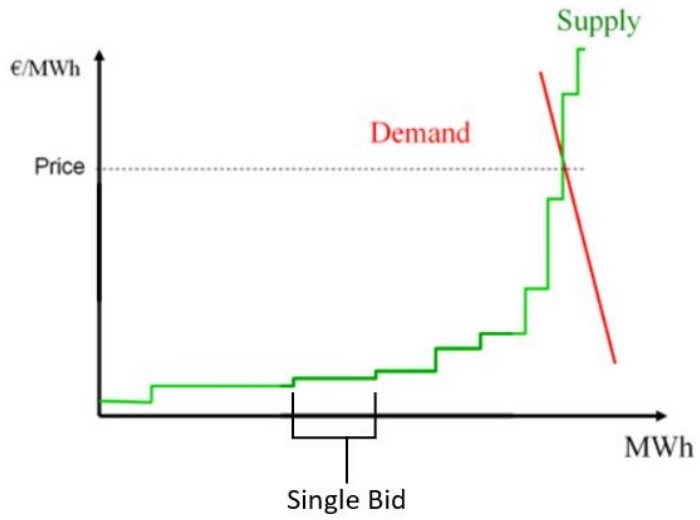


Figure 12: Price definition in the day-ahead market

[9] Lumi4Innovation, Certificati bianchi: cosa sono e come funzionano, 2019, https://www.lumi4innovation.it/certificati-bianchi-cosa-sono-e-come-funzionano/

[10] Intergen, Cogenerazione ad alto rendimento: cosa significa e come ottenere gli incentivi previsti, https://www.intergen.it/cogenerazione-ad-alto-rendimento/#:~:text=Una%20forma%20di%20incentivo%20importante,interventi%20di%20incremento%20dell'efficienza.

After the day-ahead market is executed, the intraday market starts. The intraday market is an important element that allow to adjust the quantity of energy exchanged in the day-ahead market, according to expected needs in real-time from the market agents. As Day-Ahead market, Intra-day market is structured via auctions[11].

- ✓ Balancing Market: The Market for Dispatching Service (Mercato per il Servizio di Dispacciamento - MSD) is the instrument through which the Transmission Operator (Terna) procures the resources needed to manage and control the system (intra-zonal congestion resolution, creation of energy reserves, real-time balancing). On the MSD, Transmission Operator acts as the central counterparty and accepted offers are remunerated at the price presented (pay-as-bid). The MSD is divided into the planning phase (ex-ante MSD) and the Balancing Market (MB) (consisting of the continuous submission of offers)[12].

6.2 Belgium

Since the beginning of the 21st century, the Belgian electricity market has been fully liberalized for the generation and supply of electricity. In accordance with EU electricity regulation, the objective is to:

- ✓ Improve competition in electricity market
- ✓ Enable final customers to select their energy providers
- ✓ Achieve a higher quality of service standards
- ✓ Ensure security of supply and sustainability.

In contrary, transmission and distribution activities are subject to a monopoly, either national (TSO) or zonal (DSO).

In Belgium, the regional governments of Flanders, Wallonia and Brussels Capital are principally responsible for designing and implementing policies for energy efficiency, renewables, non-nuclear energy research and development and market regulation. Considering the incentives associated with the efficiency of cogeneration production plants, in Belgium, renewable sources and highly efficient cogeneration systems are promoted through CHP and green certificate schemes[13]. Under the green certificates scheme, renewable electricity producers receive one green certificate for each MWh they generate, while under the combined heat and power (CHP) certificates scheme, high-efficiency cogeneration installations receive one certificate for each MWh of energy saving they realise. In particular, the cogeneration certificate (CHP) scheme promotes primary energy savings using quality cogeneration plants for the generation of electricity and heat. In this context, producers can sell CHP certificates to electricity suppliers who have to satisfy their certificate obligation (they must guarantee a minimum quota of electricity from high-efficiency cogeneration). If the CHP producer is also an electricity supplier, it can use its own certificates to satisfy the certification obligation[14]. So renewable electricity

[11] GME, Mercato elettrico a pronti, https://www.mercatoelettrico.org/It/Mercati/MercatoElettrico/MPE.aspx
[12] GME, Mercato elettrico a pronti, https://www.mercatoelettrico.org/It/Mercati/MercatoElettrico/MPE.aspx
[13] Econotec, Analysis of Energy Efficiency trends and policies in BELGIUM, 2018, https://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-belgium.pdf
[14] VREG, Support system: CHP certificates, https://www.vreg.be/en/support-system-chp-certificates

producers and high-efficiency cogeneration installations can then sell their certificates (green or CHP) on the market and thereby obtain additional revenues on top of the electricity market price[15].

Considering the pricing in the electricity market, again a distinction has to be made based on the type of market:

- ✓ Wholesale Market: as in the case of Italy, the Belgian wholesale electricity market is composed by Day-Ahead Market and Intra-Day Market. The Day-ahead market is operated through a blind auction which takes place once a day, all year round. All hours of the following day are traded in this auction. Based on the buy-orders, the Power Exchange establishes a demand curve, based on the sell-orders it establishes a supply curve, referred to as aggregated curves, both for each hour of the following day. The market clearing price (MCP), which reflects supply and demand, lies at the intersection of both curves[16]. On the Intraday market, market participants trade continuously, 24 hours a day, with delivery on the same day. As soon as a buy- and sell-order match, the trade is executed. Electricity can be traded up to 5 minutes before delivery and through hourly, half-hourly or quarter-hourly contracts. As this allows for a high level of flexibility, members use the Intraday market to make last minute adjustments and to balance their positions closer to real time.
- ✓ Balancing Market: the Belgian TSO is Elia and is responsible for maintaining the balance between production and consumption of its transmission grid which covers the entire country. Since Elia has no production plants, it assigns responsibility of ensuring the balance to the Balance Responsible Parties (BRPs). A BRP is a legal entity that supervises the balance of one or more grid connection points. The purpose of the BRP is to create a balanced portfolio through a combination of injection, withdrawals, and exchange with other BRPs. Each generator and purchaser in the network must have a signed contract with a BRP. Elia imposes a penalty on all BRPs that are in imbalance, to encourage BRPs to keep their portfolio in balance. On the other hand, if BRPs reduce the net system imbalance they will be rewarded. Elia also buys capacity reserves to maintain the stability of the grid. The different types of reserves are used when different imbalance events happen. These include: primary reserve for frequency containment, that reacts within 500 milliseconds when a tension on the grid occurs; secondary reserve that is a bigger automatic frequency restoration reserves; and tertiary reserve that is a manual frequency restoration reserves, and is useful for larger and long-lasting imbalances. The balancing energy is remunerated in two ways: "capacity or availability remuneration" is the fee to keep capacity available, and "energy or activation remuneration" that is the compensation for the effective balancing service supply to Elia (the Belgian TSO). Both remunerations are based on the merit order principle and are established in the balancing market[17].

[15] European Commision, State aid: Commission approves Belgian certificates schemes for renewable electricity and high-efficiency cogeneration in Flanders, 2018, https://ec.europa.eu/commission/presscorner/detail/en/IP_18_821

[16] EpexSpot, Day-Ahead and Intraday – the backbone of the European spot market, https://www.epexspot.com/en/basicspowermarket#day-ahead-and-intraday-the-backbone-of-the-european-spot-market

[17] Next, What are Balancing Energy Markets?, https://www.next-kraftwerke.be/en/knowledge-hub/balancing-markets

6.3 Portugal

The energy sector in Portugal has been almost completely liberalized as a result of the application of European directives (Electricity Directive 2009/72/EC) and of the privatization process which was stimulated by the financial assistance plan imposed by the International Monetary Fund (IMF), European Central Bank (ECB) and European Commission. To date, anyone who has obtained a license can become a generator or a supplier of electricity. In fact, generation, distribution, and supply must be unbundled in terms of legal and accountability separation while transmission must also have an unbundled ownership. Regarding transmission and distribution, they are allocated through service concession agreements signed with the Portuguese government, granting concessionaires the exclusive right to manage the networks for periods of 50 and 35 years, respectively.

Considering the the incentives associated with the efficiency of cogeneration production plants, the promotion of the decarbonization of the electricity generation sector, is one of the main decarbonization target of the Portuguese NECP(National Energy and Climate Plan). In this context, the application of the ETS system, encourages the reduction of CO_2 emissions from the interested plants. The ETS System operates according to the "Cap and Trade" principle. An emission limit is set, which establishes the maximum quantity that can be emitted by the plants that are part of the system (including all cogeneration plants with a power greater than 20 MW). Within this limit, companies can buy or sell emission shares according to their needs. Each share enables to emit one ton of CO_2 or the equivalent amount of another GHG. Once a year, all companies participating in the ETS System must provide an emission allowance for every tons of CO_2eq emitted. A limited number of emission allowances are freely allocated to some companies on the basis of European regulations. Companies that do not receive free allowances or in which the allowances received are not sufficient to cover the emissions produced have to buy the allowances at ETS auction or from other companies. Conversely, those who have excess emissions quotas compared to the emissions produced can sell the allowances in excess.[18]
Moreover, it should be pointed out that, within the NECP decarbonization objectives and in particular regarding the development of renewables, one of the main goal is to promote renewable cogeneration and gradually reduce incentives for fossil fuel cogeneration.

Considering the Portuguese electricity market, the Iberian Electricity Market (MIBEL) covers both Spain and Portugal, with the aim of promoting the integration of the electricity systems of both countries. In this market, if a subject obtains the status of producer or supplier from one Country, it is automatically recognized by the other one, and therefore it has equal rights and duties. The management of the Iberian spot electricity market is the responsibility of OMEL.
In the spot electricity market, the participants operate on the day-ahead and intraday markets which aggregate the Spanish and Portuguese areas. Negotiation on the daily market is based on a daily auction, with energy settlement at every hour of the following day.
Following intraday sessions are scheduled, in which operators can adjust the quantities sold/purchased of electricity for the different hours of the day. Again, this negotiation takes place through auction.[19]

[18] Portugal NECP, 2019, https://energy.ec.europa.eu/system/files/2020-06/pt_final_necp_main_en_0.pdf
[19] Lexology, Energy Market in Portugal, 2021, https://www.lexology.com/library/detail.aspx?g=53596f69-d27f-47ba-9f38-2362078b1018

Following the intraday market, the Portuguese Transmission System Operator (REN), which is also the Ancillary Services Market Operator, purchase at "pay as bid" the needed electricity in order to guarantee the balance between electricity production and demand.

6. Conclusions

In FLEXnCONFU system the electricity produced during low electricity price periods is converted to hydrogen/ammonia, stored, and then converted back into electricity at appropriate times (e.g., peak loads). Therefore, the project's added value to the community regards economic benefits, improved quality of end consumer's electricity, increased resilience of the electrical system and, reduction of fossil fuels consumption in the electrical system. Moreover, these solutions have high potential for replicability as they can be implemented with due adjustments on other Combined Cycle sites. Therefore, FLEX'nCONFU's solution acts as a storage mechanism that benefits the entire electricity supply chain enabling the promotion of new business opportunities for diverse energy stakeholders. Several storage services can be provided through this solution to different subjects. Some of which are: black start (for generators), voltage and frequency management (for system operators), correction of forecasts inaccuracy (for market operator), peak shaving (for end users).

Business models of three categories of plant stakeholders have been analysed: end users, energy generators and technology manufacturers. Considering end-users, their aim is to obtain a secure and continuous electricity supply without interruptions and possibly to use electricity produced from green generation sources. In this context, the Flex'n Confu provides benefits in term of both flexibility and environmental impact. Considering Energy Generators their scope is to obtain revenues by supplying electricity to the grid. FLEX'NCONFU's solution allows these entities to supply low environmental impact electricity (more desired by consumers), while providing all the ancillary services usually required to a cogeneration plant. Considering technology manufacturers, their scope is to obtain a remuneration for the technology supply and achieve a validation of proper product functioning. Therefore, also in this case the realization of the FLEX'nCONFU project will bring benefits as it will test and disseminate the correct functioning of such technologies.

Finally, considering the applicability in Italy, Belgium and Portugal, in any State there are specific incentives for cogeneration using natural gas blended with renewable gases such as hydrogen and ammonia. However, various incentives and benefits regarding energy efficiency and emission costs savings can be considered as the FLEX'nCONFU solution determines significant reductions in terms of CO_2eq emissions and an increase in the level of efficiency of the plant.