Supporting the implementation by NRAs of renewable energy technologies in the road infrastructure

Deliverable 4.1

Overview of business model: general proposal and description

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TABLE OF CONTENTS

1. INTRODUCTION 6

2. BUSINESS MODELS 7

2.1 BUSINESS MODELS BASED ON RENEWABLE ENERGIES 9

2.2 BUSINESS MODEL BASED ON THE ENERGY DEMAND RESPONSE (DR) 10

3. RENEWABLE ENERGY SIMULATION (COSTING) SOFTWARE 12

3.1 HYBRID OPTMIZATION MODEL FOR ELECTRIC RENEWABLES (HOMER) 17

3.2 RETScreen 18

3.3 HYBRID2 20

3.4 iHOGA 20

4. GENERAL BUSINESS MODEL DESCRIPTION 21

5. BUSINESS MODEL: DESIGN AND APPLICATION 24

5.1 DEFINITION OF THE NRA LAND/ASSETS 27

5.2 RET ELECTRICITY PRODUCTION 27

5.2.1. Small- and large-scale wind energy 27

5.2.2. Solar photovoltaic energy 29

5.2.3. Mini-hydro energy 29

5.3 COST ESTIMATION MODEL 30

5.3.1. Intermittence in the production and non-used capacity 30

5.3.2 Tendencies in the generation costs of RE 30

5.3.3 Target costing, sunk costs and net margins 32

5.3.4 Classification of costs 36

5.4 CAPITAL EXPENDITURES (CAPEX) 37

5.5 OPERATIONS EXPENDITURES (OPEX) 38

5.6 DEVELOPMENT AND ENGINEERING COSTS (DEC) 39

5.7 COST ANALYSIS STRUCTURE, MARGINS AND THE LEVELIZED COST OF ENERGY 40

5.8 CASH BUDGET AND CASH-FLOW MANAGEMENT 41

5.9 RE INVESTMENT FINANCIAL ASSESSMENT 42

5.9.1 Payback Period 42

5.9.2 Accounting Rate of Return (ARR) 42

5.9.3 Net Present Value (NPV) 43

5.9.4 Internal Rate of Return (IRR) 43

6. FINAL COMMENTS 44

LIST OF REFERENCES 45

ANNEX 1: LIST OF CURRENT SIMULATION AND ANALYSIS TOOLS (CHAPTER 2) 51

LIST OF TABLES

Table 1. Software tools for renewable energy systems 13
Table 2. Comparison of wind energy technologies 28
Table 3. RE Target Costs and Countries' Net Margins for distribution 34
Table 4. CAPital EXpenditures 38
Table 5. OPerations EXpenditures 39
Table 6. Development and Engineering Costs (DEC) 39
Table 7. Cost analysis structure and margins (yearly) 40
Table 8. Cash budget (investment cycle in years) 41

LIST OF FIGURES

Figure 1. Elements of the business model design. Source: Teece (2010) adapted. 8
Figure 2. Business Model approaches 8
Figure 3. Two generic business models. Source: Ritcher (2012) 10
Figure 4. Model data flow for the decision making. Source: based on Aung (2011). 13
Figure 5. HOMER software. 18
Figure 6. Inputs and outputs generated in a HOMER analysis. Source: Ram et al. (2022) 18
Figure 7. RETScreen software 19
Figure 8. Inputs and outputs generated in a RETScreen analysis. Source: Ram et al. (2022) 19
Figure 9. Hybrid2 software. 20
Figure 10. Inputs and outputs generated in a Hybrid2 analysis. Source: Ram et al. (2022) 20
Figure 11. iHOGA software. 21
Figure 12. Inputs and outputs generated in an iHOGA analysis. Source: Ram et al. (2022). 21
Figure 13. Dimensions of the strategy in RE: quality, time, efficiency and innovation. 22
Figure 14. From the definition of the NRA land/assets to the performance assessment. 23
Figure 15. Steps in the design of the General Business Model 24
Figure 16. Business Model application 26
Figure 17. Distance between turbines in diameters of rotor. 28
Figure 18. Distance between PV panels. 29
Figure 19. Global weighted-average utility-scale LCOE by technology (2010-2020). Source: IRENA 31
Figure 20. USA estimated capacity-weighted levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2026 (2020 dollars per megawatthour). Source: U.S. Energy Information Administration. 32
Figure 21. Electricity prices for non-household consumers (€/kWh) (first half 2021). Source: Eurostat 33
Figure 22. European PPA Prices Dec 2020. Source: PexaQuote 34
Figure 23. Net margins based on target development and engineering costs. 35
Figure 24. Basic structure of the energy's cost accounting. Source: Bierer and Götze (2012) 36

1. INTRODUCTION

This document responds to the development of Task 4.1 of the Project, overview of the business model general proposal and description. The Business Model (BM) is inserted in the conceptual stage and their outputs, the economic and financial feasibility study, will be inserted into the GIS-based Multi-Criteria Decision Model analysis (MCDM). There are some prior considerations and limitations in terms of the analysis and selection of the renewable energy generation technologies for application in NRA's assets and topologies (WP2) and as result of the assessment of the applicable legislative and regulatory frameworks (WP3). These previous analyses are oriented towards the design of a simulation and analysis tool of the financial and economic issues of renewable energy (RE) projects. As the RE industry is increasing, the state-of-the-art review has been carried out for a sample of different available software, to establish their functioning basis, strengths and limitations, with the aim of enhancing the value of this project proposal.

Considering that the general business model supports the decisions for the provision of renewable energy at a cost-competitive price, WP4 proposes the preliminary estimation of revenue streams, costs, savings, and margins for the selected RE technologies within the facilities of the National Road Authorities. This would support their energy efficiency and decarbonization targets. The model flow starts from the present NRA's energy demand for one or more locations, and considers the self-consumption as a first approach to the RE production. Other approaches might be considered by the NRAs as well, like offering and selling part or all the energy generated.

The importance of an accurate estimation of the quantity of energy sold and the prices are shown in the literature since expectations were not covered (Conversation, 2018; GCR, 2019). While the RE production depends on several variables and contextual factors, the ENROAD's MCDM analysis is based on economic criteria from the BM including the cost of installation, cost of maintenance and the life cycle cost, both individually and as a whole. Undoubtedly, the selection of the technologies and their CAPEX are directly connected to the operations and maintenance costs (and other OPEX), and if they are underestimated, this eventually results in negative margins (SH Final, 2020).

Furthermore, the results from the ENROAD Survey based on the opinions of 21 representatives from 16 different countries (see D 2.1) show that the economic barriers are the most important ones (71%), rather than the regulatory (62%) and technical (48%) barriers. The fact that the economic (or financial) barriers rank most highly in studies by a significant margin is somehow common (Brown & Sherriff 2014). Some of the reported economic (financial) barriers are: the cost of the investments; the asynchronous production-consumption of energy (NRAs use a lot of energy at night); the lack of funds due to cuts on public budgets; small scale RE solutions, which are not always profitable; the high cost of the technologies against the relatively low rate of return; and the fact that business cases are needed to understand the cost-benefit ratio. In addition, the development of installations like PV Noise Barriers depends on the financial viability.

In brief, the implementation of the BM in the GIS is a multistage process based on alternative scenarios that starts with the selection of location and area for the renewable energy generation by the NRAs (this selection does not have to be necessarily associated with a specific energy demand), and is followed by the collection of energy market prices, the selection of feasible locations in terms of electricity production by technology, the CAPEX and OPEX estimation, the revenues and saving estimation, and the economic performance and financial assessment. It is important to remark that this Deliverable 4.1 presents a design of the BM that shows a balance between the accuracy of the results and its ease of use within the GIS. As a result, it may occur that during its developement this has to be conditioned either by the scarcity of disaggregated RE data or because, despite the availability of such data, their incorporation to the tool is not advisable as this would cause an overload of work and information for the NRAs. If this happens, modifications would be proposed, always under the premise that the MCDM GIS-based tool is still useful and easy to use.

In addition, in Deliverable 4.2 we will provide NRAs with several business cases that can be applied to the different technologies, assets, and regulatory conditions, based on an analysis of the electricity market prices. With the information provided in this Deliverable, the GIS-based tool will allow the selection of the best possible RE technologies and provide a list of possible business models, with their related CAPEX, OPEX and revenue streams.

This document is structured in six chapters. The first chapter introduces the methodologies for the cost estimation and the determination of margins considered in the ENROAD project. The second presents the business models and explains their application as methodology of management in the launching of green energy companies. The third chapter reviews the software programmes useful in the preparation of the business model, giving special attention to the most important. Chapters 4 and 5 describe the business model and explain the cost model. Finally, some relevant issues are discussed in chapter 6.

2. BUSINESS MODELS

In essence, a business model (BM) is a conceptual model of a business. According to Teece (2010), it sets out the logic and provides data and other evidence to prove how a company creates and delivers value to customers. In addition, it describes the architecture of the income, costs and profits associated to that company. In the context of a technology innovation approach, the elements of the business model form a virtuous circle that makes it possible to identify the utility for the consumer and the most suitable market segments, confirm the possibility to obtain a revenue stream, design the mechanisms for achieving them in the future and turn the value into liquid funds (cash) and benefits with which to face the following innovation cycle (Figure 1).

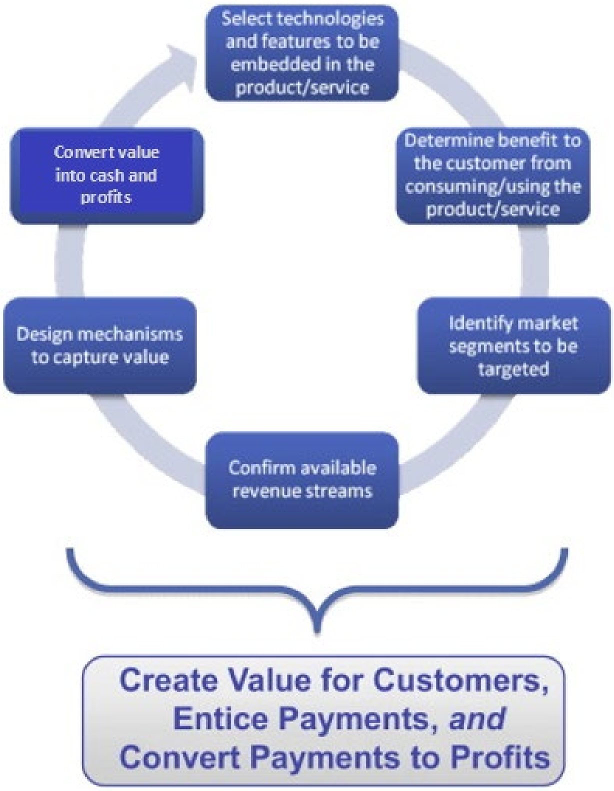

Figure 1. Elements of the business model design. Source: Teece (2010) adapted.

Business models have varying approaches and diverse definitions. In fact, the academia offers different meanings in a wide literature with scarce consensus on the interpretation and the relationship with the strategy (Massa et al. 2017). The main four refer to the creation of value, implementation of the strategy, monetization processes and the organization (Figure 2). There is an all-embracing approach that combines the strategy, the monetization plans as well as the implementation of the strategy to generate economic benefits creating value for the customers (Bigelow and Barney 2021).

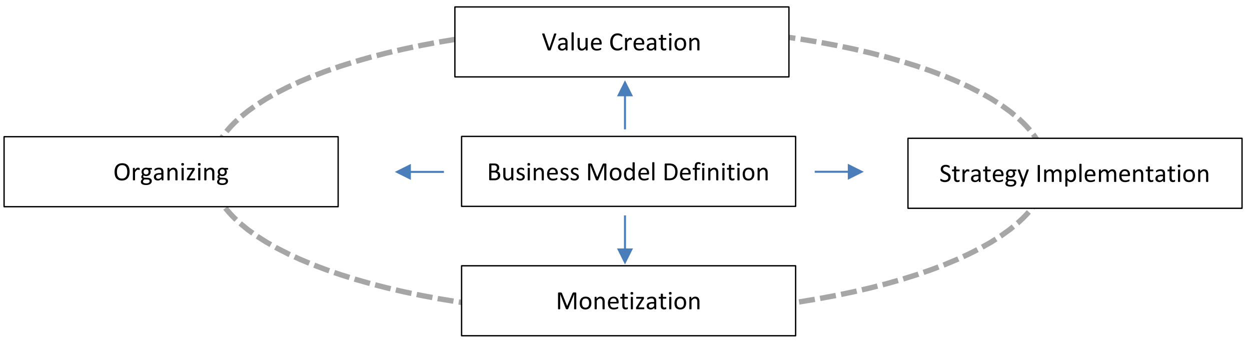

Figure 2. Business Model approaches

Practically for this case, the most suitable meaning is the one considering the creation of value from the demand perspective (i.e., the customer), which is based on the idea that a businessman or entrepreneur generates and retains the economic value generated. The value creation analysis can be carried out in terms of the following important elements involving the process:

- A value proposal for the customers.
- The formula for the determination of benefits and margins.
- The list of resources.
- The processes that are necessary to implement the proposal in an economically viable way.

These elements must line up and equilibrate in order to get an arrangement logical with the achievement of a competitive advantage fitting with the economic, social and environmental scenario (Lanzolla and Markides, 2020). Nevertheless, since the project deals with the generation of energy based on renewable technologies, the business model is bound to assume conditions that are not observed in the traditional sources, like the imbalances between the demand and the offer due to variations in the meteorological conditions and the response of the demand (Demand Response – DR). The DR is defined in the EU directive 2019/944 of the electricity market as the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market, whether alone or through aggregation (Directive, 2019/944). In light of this Directive, the need to adjust the demand to the availability of energy can also be perceived as a singularity in the market, thus resulting in the creation of a new market by segmentation through a new product or service, in this case through making energy available at different prices depending on the supply at the time (Klarin, 2019).

2.1 BUSINESS MODELS BASED ON RENEWABLE ENERGIES

The business model is seen as an essential tool to support the energy transition to the renewable energies (Ritcher, 2012 and 2013, Rochlin 2016, Herbes et al. 2017, Bryant et al. 2018, Karami and Madlener 2021) and the policies that make this transition possible (Andersen et al. 2009, Provance et al. 2011, San Roman et al. 2011, Wüstenhagen and Menichetti 2012, Annunziata et al. 2013, Huijben and Verbong 2013, Gauthier and Gilomen 2016). There are different examples of applications, including PV technologies (Tayal et al. 2017, Poe et al. 2017, Rigo et al. 2022, Nguyen et al. 2021, Cielo et al. 2021), wind turbines (Mohsin et al. 2019, Nguyen et al. 2021), small hydraulic (Holguín and Chacón 2019), the implications of electric vehicles (Costa et al. 2022), the design of projects and applied studies in different countries (Huijben and Verbong 2013, Steinbach 2013, Goh et al. 2014, Tayal et al. 2017, Zhang 2017, Al Gami et al. 2021, Chaurasia et al. 2021, Ruggiero et al. 2021), the design optimisation of the renewable energy system

(Mohamed et al. 2015, Behrangrad 2015, Liu and Hao 2021, Ogunmodede et al. 2021; Hirwa et al. 2022), the estimation of the costs of production (Short et al. 1995, Bahramara et al. 2016, Al Garni et al. 2021), their effect on the reduction of greenhouse effect gases (GHG) (Wagh and Kulkarni 2018), and the use of software of support (Sen and Bhattacharyya 2014, Ramli et al. 2017, Aggarwal et al. 2021).

In particular, Ritcher (2012) highlights the generation and consumption of energy in the transition to green energies. On the one hand, the generation must evolve from the traditional sources to the green energies and on the other, the consumers can become producers. This means that now the production is also located on the point of consumption. Based on this distinction, he proposes two generic business models in the value chain of the energy generation and consumption: a model of renewable energy business from the perspective of the client, and a model of renewable energy business from the perspective of the producer (Figure 3).

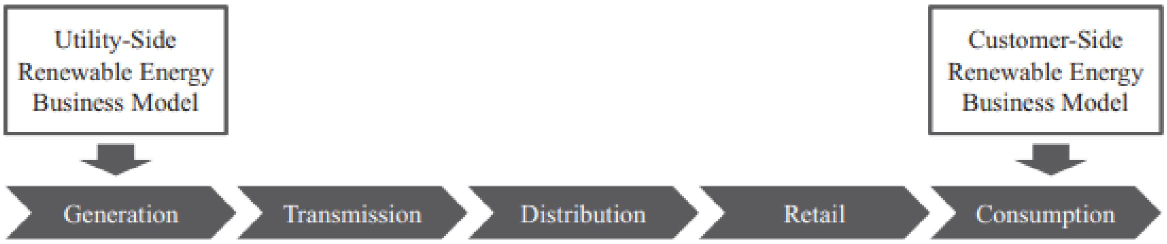

Figure 3. Two generic business models. Source: Ritcher (2012)

2.2 BUSINESS MODEL BASED ON THE ENERGY DEMAND RESPONSE (DR)

The benefits of the Demand Response (DR) in the electric sector have been widely discussed by O'Connell et al. (2014), who proposed to balance the fluctuations in the renewable generation and, in consequence, to facilitate a higher use of the renewable resources in the electrical system, as well as an increase of the economic efficiency by the application of the fee in real time (dynamic rates) and the reduction of the requirements of generation capacity (Kessels et al. 2016). According to Siano (2014), it promotes the interaction and response capacity of the customers and determines short-term impacts on the electricity markets, which in turn generates economic benefits for both customers and the public service company. In addition, by improving the energy system reliability and reducing the long-term peak demand, general investments of the plant and capital costs are reduced and the need to upgrade the network is postponed. In the technical literature, reference is made to three possible ways through which residential customers in DR can change their energy use:

- Reduce their energy consumption by means of load reduction strategies.
- Move the energy consumption to a different time interval.
- Use the energy generated on site, thus limiting its dependence on the main grid.

The proposal of DR has gained attention since then with applications to the heating systems, helping to reschedule the time of switching on and off, or modify their configuration (Guelpa et al., 2019). However, also Meuris et al. (2019) warn about its limitations, due to it being based on the flexibility of the demands as general requirement when this is difficult to achieve in circumstances of non-automated consumption; that is to say, that part of the consumption may be adjusted, but to a point from which elevated rewards are needed or a substantial reduction of the fee to the consumer, what for example would remove part of the profitability in markets such as the residential. In this market, as the project AlpEnergy emphasised, the problem stood out that in case it is assumed that the final users must react manually to the rate signals, the load change or the energy savings, then it is first needed that the user is at home and second, there is the will to consciously consider the options of response to the demand, what in both cases demands time (Kressels et al. 2016).

The maximisation of the potential of direct consumption of energy generated by renewable sources requires consideration of how to store energy without damaging profitability. The benefits of this option would be immediate, by the reschedule of the productions of high energy consumption in the industry.

In conclusion, regarding the business model, the value proposition is based on the supply in bulk of energy efficiently and sustainably produced, with the effect of reduction of the energy not used. Three groups of DR programmes can be considered (Siano 2014):

1) Based on fees or rates: The price of electricity may differ in determined schedules or may dynamically vary according to the day, week and year and the existing reserve margin. The customers would pay the highest fees during the peak hours and the lowest in the hours out of them. The fees can be established one day ahead on a daily basis, a certain schedule or in real time and the customer would react to the fluctuations in the rates of electricity. The possible fees are the fees of time of use (Time of Use), Critical Peak Pricing, and prices in real time (Real Time Prices).

2) Based on incentives: Customers are rewarded for reducing their electric charges when they request it or by giving the administrator of the programme certain amount of control on the equipment that uses the client´s electricity.

3) Propositions to the demand reduction: The clients send offers of reduction of the demand of the fee requested. This programme mainly encourages the big clients to offer reductions of charge in exchange for reductions in the prices, or to recognise the amount of charge they would be willing to reduce at the fee offered.

Due to the increasing complexity that the design and the use of the BM and the relevance this entails the following chapter will be focused on the tools based on support software.

3. RENEWABLE ENERGY SIMULATION (COSTING) SOFTWARE

In this chapter, we explore the available computing tools for renewable energy simulation, in particular, those focused on cost analysis and financial reporting. In project phases, these tools are very useful, especially for the concept and development phases of a renewable energy project. Given their business nature, they are a special typology of tools related to the energy management within the Project Management tools. Taking into consideration budget function and duration, they are divided into two categories: static tools whose aim is to configure a project in the first steps of design and final decision (conception, initiation, design, and development based on a fixed budget); and dynamic tools that allow the management of the project as a whole including implementation, commissioning and handover. This is until the installation starts functioning, or even more, along with the firm's life (with the evaluation of cost deviations and flexible budget corrections). There are different RE simulation and analysis tools with a variety of features (Aung 2011):

- Technology databases.
- Meteorology databases.
- Energy modelling: solar, geothermal, wind, hydro, etc.
- Cost Analysis: levellized cost of energy (LCOE), life cycle cost, target costing.
- Financial Summaries.
- Sensitivity and Risk Analysis.
- Environmental issues.
- Planning, budgeting and control cycles (dynamic models)
- Customized reports.

Actually, the project team in the concept phase will gather the data (databases) and then will choose the tool in the consideration of the potential constraints of these features, what should limit the whole performance of the model. For instance, as it is shown in Figure 4, the decision-making accuracy depends on the location selected, the granularity (or detail) of the energy modeling will affect both the accuracy of the environmental-related estimations and the cost estimation for the cost-benefit analysis; and later, the quality of the financial summaries and the sensitive and risk analyses.

Table 1 lists some current RE simulations software and analysis tools with their descriptions, applications, and the free or open-source typology of the software ("yes" when it is free or open-source; "not" if it is fee-based) (Jafarinejad et al. 2021).

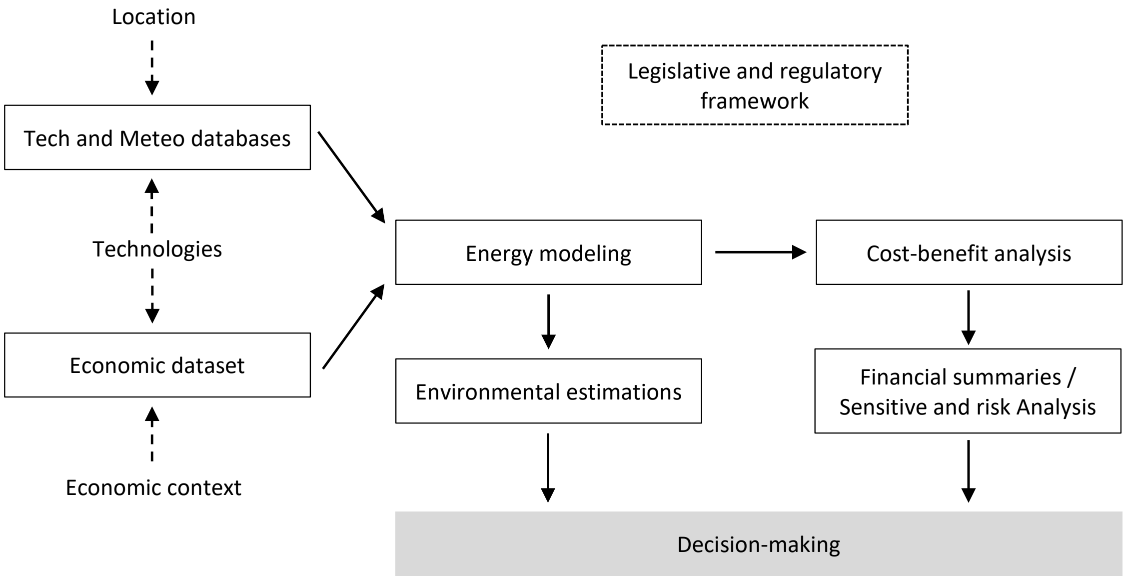

Figure 4. Model data flow for the decision making. Source: based on Aung (2011).

There is a wide diversity of this type of software depending on the purpose. For instance, some are PV specific (System Advisory Model – SAM -; Solar Advisory Model; pvDesing; PVcase; PVsyst; and so on), others are for wind farms (windPRO; ReSoft WindFarm; WindSim; WindFarmer; etc.). There are general simulation and analysis tools like HOMER and RetScreen, which we describe in some detail. The Energy ToolBase Monitor-ETB- is a special software as it provides project modeling, storage control and asset monitoring products for solar and storage projects. It includes an intelligent control system software that makes use of machine learning and AI for forecasting purposes. The tool's URL information is in Annex 1 of the document. The advantages and limitations of the tools will be discussed (Ram et al. 2022).

Table 1. Software tools for renewable energy systems

Simulation and Analysis Tools	Descriptions/Applications	Free/Open-Source
RETScreen	The RETScreen Clean Energy Management Software is used for energy efficiency, RE and cogeneration project feasibility analysis as well as ongoing energy performance analysis.	No. An advanced premium version of the software, is available in Viewer mode completely free-of-charge. Also available in Professional mode on an annual subscription basis.
HOMER	Micropower optimization model, for analysis of the energy technologies individually and in hybrid configurations to determine cost-effective solutions. HOMER models both conventional and RE technologies, either as a microgrid or as distributed generation within a larger grid.	No. Free trial for 21 days.

Hybrid2	Developed by the Renewable Energy Research Laboratory (RERL) of the University of Massachusetts. It is a hybrid system simulation software. The hybrid systems may include three types of electrical loads, multiple wind turbines of different types, photovoltaic generators, multiple diesel generators, battery storage, and four types of power conversion devices. Other components, such as, for example, fuel cells or electrolyzers, can be modeled in the software. The simulation is very precise, as it can define time intervals from 10 min to 1 h. The possibilities with regard to control strategies are very high. NREL recommends optimizing the system with HOMER and then, once the optimum system is obtained, improving the design using HYBRID2. It can be downloaded and used free of charge.	Yes
iHoga/mHoga	Improved Hybrid system optimization program developed by the Electric Engineering Department of the University of Zaragoza (Spain). The optimization is carried out by means of Genetic Algorithms, and can be Mono-Objective or Multi-Objective. It allows optimizing of hybrid systems consisting of a photovoltaic generator, batteries, wind turbines, hydraulic turbine, AC generator, fuel cells, electrolyzer, hydrogen tank, rectifier, and inverter. The loads can be AC, DC, and/or hydrogen loads. The simulation is carried out using 1-hour intervals, during which all of the parameters remained constant. The control strategies are optimized using Genetic Algorithms. It can be downloaded and used free of charge.	Yes
Insel	The user selects blocks from its library and connects them in order to define the structure of the system. The system operation analysis can be carried out with a time frame specified by the user. The flexibility to create the system models and configurations is a very interesting feature.	No
Ares	Developed at the University of Cardiff which very precisely simulates PV–Wind–Battery systems.	No
Solsim	It was developed in Fachhochschule Konstanz (Germany). It has models for photovoltaic panels, wind turbines, diesel generators, and batteries. There is the possibility of including biogas and biomass generators to generate electricity and heat. It simulates the operation	No

	of the system and carries out an economic analysis. The control options are very limited, optimizing only the panel inclination angles.	
System Advisor Model (SAM)	For performance and economic calculations of RE projects. SAM can model PV systems; battery storage with lithium ion, lead acid, or flow batteries for front-of-meter or behind-the-meter applications; CSP systems for electric energy generation including parabolic trough, power tower, and linear Fresnel; wind energy; marine energy wave and tidal systems; solar water heating; fuel cells; geothermal energy; biomass combustion for energy generation, etc.	Yes
Solar Advisor Model	For techno-economic analysis of solar technologies including PV systems for residential and commercial markets to CSP and large PV systems for utility markets.	Yes. Free to use for any purpose whatsoever, except commercial purposes or sale.
PolySun	For flexible and efficient planning, design, and optimization of energy systems.	No. The free trial version expires automatically after 30 days.
TRaNsient SYstems Simulation (TRNSYS)	For simulation of low energy buildings, RE systems including solar systems (solar thermal and PV systems), fuel cells, etc	No
Greenius	Mainly for feasibility studies of solar thermal power plants. However, it includes models for simulations of other RE technologies such as non-concentrating solar collectors for process heat supply, PV plants, and wind power parks.	Yes
Energy-10	Energy-modeling tool for small commercial and residential buildings	No
Archelios Pro	For the design, calculation, and simulation of PV projects.	No
DEKSOFT Photovoltaics	For calculating electricity produced by PV systems.	No. 14-day free trial.
pvDesign	For the study, analysis, design, and engineering of PV plants in all its stages.	No. Free demo.
PVcase	For analysis of solar projects	No
PVWatts calculator	For estimation of the energy production and cost of energy of grid-connected PV energy systems.	Yes
PV Optics	For design and analysis of solar cells and modules	No
PVsyst	For design and data analysis of solar PV systems	No. One month free trial
Aurora	For creating a complete engineering design and sales proposal with an only electric bill and an address.	No. Free demo.
BlueSol	For designing a PV system, from the preliminary assessment of producibility to the	No

	realization of the project documentation. It can provide interactive design of layout over map and 3D view, and single-line electrical scheme as well.	
SolarEdge	A free online tool for PV design	Yes
PV Sol	For PV system design.	No. Free 30-day trial.
PV F-chart	For PV system analysis and design. The program provides monthly-average performance estimates for each hour of the day.	No
HelioScope	HelioScope is a solar design software. Three-dimensional design, rapid proposals, simulations, unlimited designs, live support, single line diagrams, automatic CAD export, library of 45,000 components, global weather coverage, shade reports up to 5 MW systems are its features.	No. Free 30-day trial.
Pylon	Online software for designing solar systems. High resolution aerial imagery, 3D solar shading analysis, interval data analysis and load profiles, financial projections, web and PDF proposals, e-signatures and payment processing are its some features.	No
Solarius PV	For technical design and economic analysis of PV systems. Three-dimensional modeling of parametric PV system objects, solar irradiance data, calculation of photovoltaic shading directly from a photo, activating, sizing and configuring the storage system by defining the battery type and energy metering systems, wiring diagrams of the PV system, and financial analysis are its some features.	No
ETB	Energy Toolbase is an industry-leading software platform. It provides project modeling, storage control, and asset monitoring products. Actually, ETB developer is used to model and propose the economics of solar and storage projects. In addition, Acumen EMS^{TM} is an intelligent control system software utilizing machine learning and AI to forecast and optimally discharge energy storage systems. Furthermore, ETB Monitor is a monitoring platform providing complete transparency into the real-time operation and performance of solar and storage projects.	No
Solargraf	Solargraf is a solar design platform for solar sales teams, installers, manufacturers, and lenders to scope, sell, and manage solar proposals from any device.	No
SolarFarmer	For analysis, simulation and design of solar PV plants. It has a full 3D shading and calculation	No

	model, handling complex terrains and shading obstacles.	
Skelion	Solar system design plugin for Sketchup	No
SolTrace	For modeling of the CSP systems and analyzing their optical performance.	Yes
windPRO	windPRO is suitable for design and planning of wind farms projects. It is used for wind data analysis, calculation of energy yields, quantification of uncertainties, assessment of site suitability, calculation and visualization of environmental impact, and detailed post-construction analysis of production data.	No
ReSoft WindFarm	For analysis, design and optimization of proposed wind farms.	No
WindSim	For optimization of wind turbine placement in onshore and offshore wind farms using computational fluid dynamics.	No
Openwind	A wind farm design and optimization software for creating optimal turbine layouts	No
Bladed	For wind turbine design	No
WindFarmer: Analyst	For wind resource assessment	No
Wind Energy Finance	It is an online calculator for economic analysis of wind projects	Yes
DTOcean	For the design and analysis of ocean energy arrays.	Yes
TidalBladed	It is used for simulating tidal turbines at the design stage.	Yes

Sources: Dufo-Lopez and Bernal-Agustin (2015), Sinha and Chandel (2014), Jafarinejad et al. (2021), Ram et al. (2022).

3.1 HYBRID OPTMIZATION MODEL FOR ELECTRIC RENEWABLES (HOMER)

The Hybrid Optimisation Model for Electric Renewables (HOMER) Pro microgrid software by HOMER Energy is the global standard for optimizing microgrid design in all sectors, from village power and island utilities to grid-connected campuses and military bases. Originally developed at the National Renewable Energy Laboratory and enhanced and distributed by HOMER Energy, HOMER nests three powerful tools in one software product, so that engineering and economics work side by side: simulation optimization, and sensitivity analysis.

Homer is cited in the literature as the most frequently used tool (Sen and Bhattacharyya 2014, Ali et al. 2021) since it can be used in the analysis of different technologies including the photovoltaic, wind energy, hydraulic, fuel cells and boilers, as well as different charges and helps to do time simulations. It has been used to analyse installations out of grid in different countries and also helps to study the economic impact based on the investment cost, the actualised renovation cost, the operations and maintenance costs, in addition to the sensitivity analysis (Figure 6). It includes the possibility to base the analysis in the use of hydrogen as fuel (Khan and Iqbal 2005, Barsoum and Vacent 2007, Karakoulidis et al. 2011, Giatrakos et al. 2009, Türkay and Telli 2011, Luta and Raji 2018 and 2019, Alam et al. 2021, Ani 2021, Razmjoo et al. 2021).

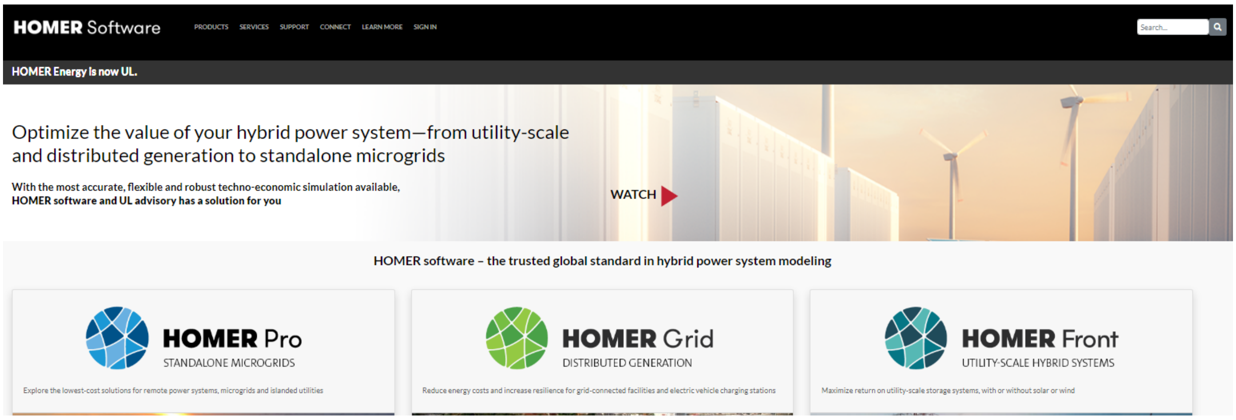

Figure 5. HOMER software.

According to Ram et al. (2022), its most important limitations are that it does not consider the factor of the inner time variability, cannot import data of daily averages or analyse thermal systems, does not regard suitable the download level of batteries (Depth Of Discharge), and the minimisation analysis of the net present cost is limited.

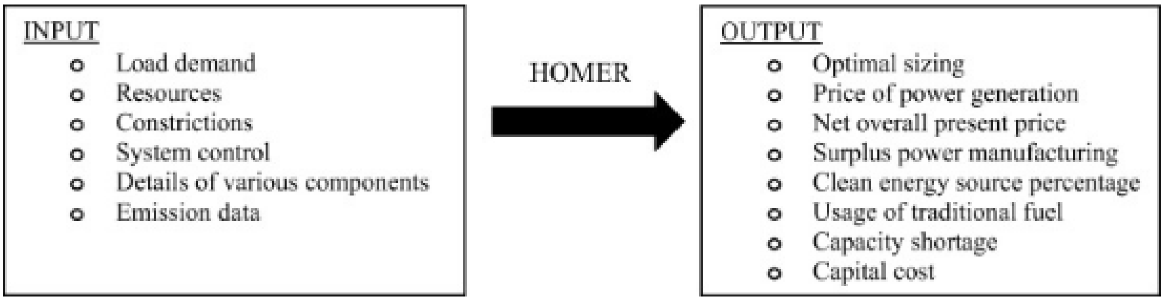

Figure 6. Inputs and outputs generated in a HOMER analysis. Source: Ram et al. (2022)

3.2 RETScreen

The RETScreen Clean Energy Management Software is a software package developed by the Government of Canada (Figure 7). The Government of Canada's Treasury Board Secretariat uses RETScreen Expert as its greenhouse gas reporting tool for all federal departments and agencies required to report emissions. The software allows for the comprehensive identification, assessment and optimization of the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects; the measurement and verification of the actual performance of facilities; the identification of energy savings/production opportunities; and portfolio management of multiple facilities.

Figure 7. RETScreen software

This has been widely used to assess and validate the energetic performances of multiple installations, building and structures in the world, as well as the management of projects that include the monitoring for the further control of the real returns against the expected ones. It is endowed with a virtual energy analyser, a system of comparative assessment, a life analysis of the full project and an expert decision module (expert decision engine). This is particularly useful when a combination of energy sources, both conventional and renewable, is used (Figure 8).

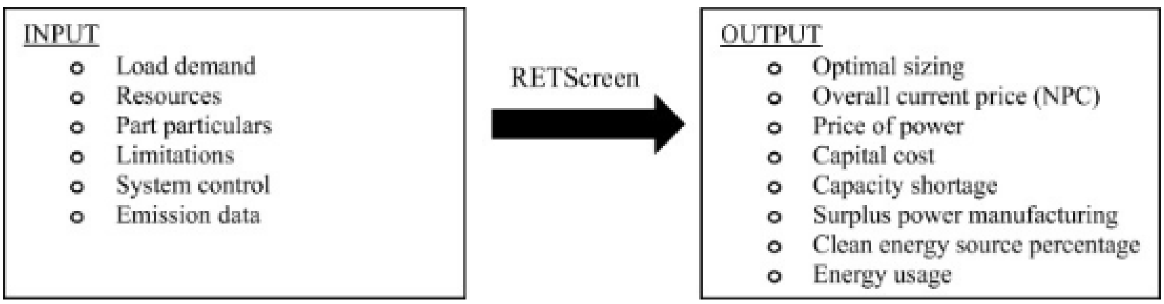

Figure 8. Inputs and outputs generated in a RETScreen analysis. Source: Ram et al. (2022)

According to Ram et al. (2022), the limitations are the impossibility to import data, the difficulties to perform searches and that it does not contemplate any technology.

3.3 HYBRID2

Developed by the Renewable Energy Research Laboratory (RERL) of the University of Massachusetts Amherst in 1996, it had a previous version called Hybrid1 from 1994 (Figure 9). It is easy to use and helps to do economic studies and studies of results for wide time ranges, uses probabilistic analyses based on meteorological data, wind speeds, solar radiations, temperatures and hydric powers. Inputs and outputs of data generated are shown in Figure 10.

Figure 9. Hybrid2 software.

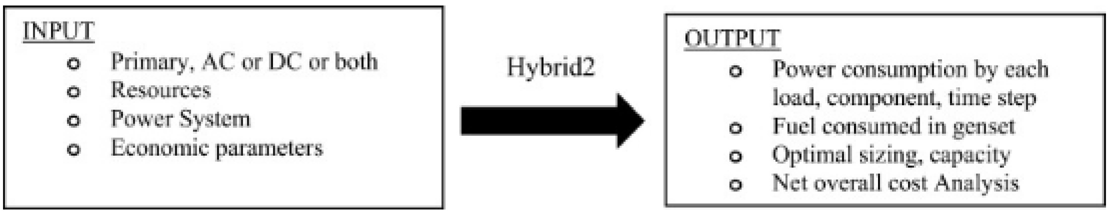

Figure 10. Inputs and outputs generated in a Hybrid2 analysis. Source: Ram et al. (2022)

Concerning its limitations, according to Ram et al. (2022), the most important are the arrangement of technologies (does not allow the simultaneous use of photovoltaic energy and diesel), does not work in versions after Windows XP, and it is too excessively rigid in the definition of the components.

3.4 iHOGA

The Improved Hybrid Optimization by Genetic Algorithms software has been developed by scientists from the University of Zaragoza (Spain). It is based on C++ language and helps to simulate and optimise systems of different sizes, including systems connected to the grid and in cases of net measurement (Net Metering) and net billing (Net Billing) (Dufo-López and Bernal-Agustín 2015) (Figure 11). Like HOMER, iHoga has been widely used in different projects which take into account the GHG emissions (Shezan 2021). Other interesting applications are those of Fulzele and Daigavane (2018), Zubi et al. (2016), and Schiffer et al. (2007). Among its characteristics, the optimisation of capacities and economic performance stand out, together with the analysis of job positions (Figure 12).

Figure 11. iHOGA software.

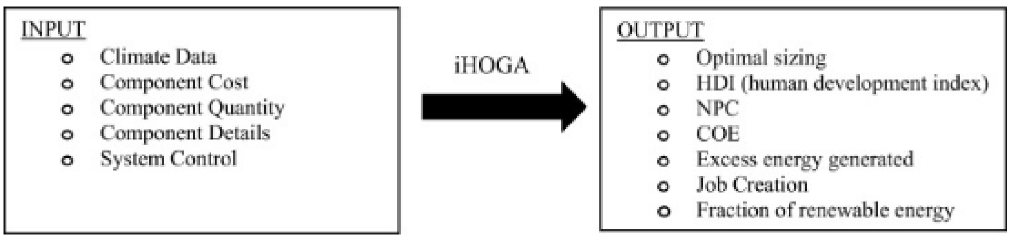

Figure 12. Inputs and outputs generated in an iHOGA analysis. Source: Ram et al. (2022).

In relation to its limitations, Ram et al. (2022) point out three of them: the educational version has a very limited use, the advanced algorithm requires a long time to achieve the results and finally, it does not have capacity analysis of the systems based on bio-energies.

4. GENERAL BUSINESS MODEL DESCRIPTION

The most contemporary approaches in business strategy refer four essential dimensions. On the one hand, there is quality, time and also efficiency. Innovation is subordinated to the first three. It is important not to lose sight of the profitability of the company, though. Overlooking profitability can make any effort or sacrifice useless, even disastrous for the survival of the company. As a result, the improvement of efficiency is a permanent preoccupation for good managers.

In the context of the production of renewable energy, quality refers to the continuity of service as long as there is primary energy (wind, solar radiation or water flow) available and power enough to offer the service. The resonance of time here is to get the demand when energy is available. The sizing of the infrastructure and minimisation of the idle capacity, or not used capacity, will have repercussions first on a satisfactory cost for investors and in a higher substitution of conventional energies so the GHG emissions are reduced (Figure 13).

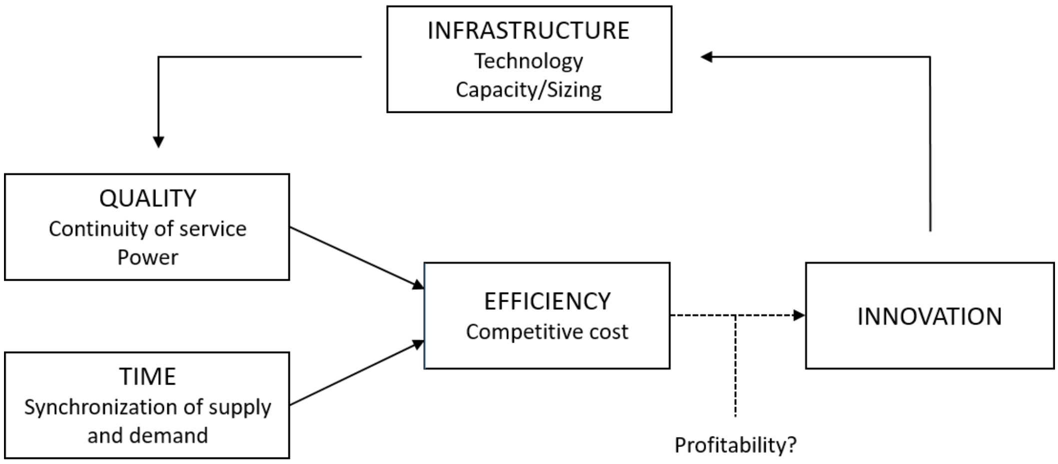

Figure 13. Dimensions of the strategy in RE: quality, time, efficiency and innovation.

While the RE production depends on several variables, the principal one is the geographical place (location) where the renewable energy technology (RET) can be installed due to the connection with the quality and time strategy dimensions. There are also other contextual factors (social and environmental) that limit or promote certain technologies within the countries' legislative and regulatory frameworks. The <u>potential</u> criteria to be considered for the ENROAD's MCDM analysis, as listed in M.5.1, are grouped in four categories:

(1) Technological: power output, energy efficiency, ease of transportation, ease of assembly, ease of maintenance, size, durability, existence of previous similar RET, availability of energy resource, proper access to area and RET, distance to the road, access to the energy network, geological properties, traffic disturbance, and availability of space.

(2) Environmental: visual impact, environmental impact/carbon footprint, and the previous pollution level in the potential location.

(3) Social: social acceptance, closeness to urban areas, remoteness of the area, impact on road safety, security implication, and legal implications.

(4) Economic: cost of installation, cost of maintenance, life cycle cost, the proximity of supplier, local employment generation, and taxes and incentives.

All these criteria hamper, impede or promote the installation of RETs along the road asset and therefore, the objective of the MCDM analysis is to make use of these criteria to sort/rank the different options for each location. The location, the definition of the NRA land/assets is cornerstone for the assessment of the performance. The RES (renewable energy sources) data from the three renewable energy resources (wind, solar, and hydro) are transformed in parameters (wind turbines, PV-panels and hydropower turbines) in the evaluation of the generation technology and by doing so, the outcomes in terms of annual data are the potential energy generation and the levellized cost of the energy (see Figure 14).

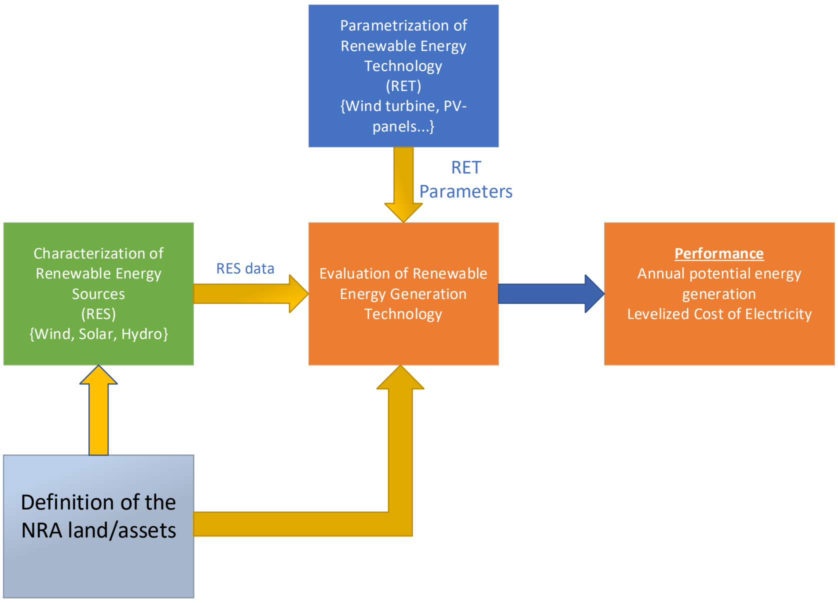

Figure 14. From the definition of the NRA land/assets to the performance assessment.

With the aim of providing the economic and financial approach to this analysis, the design of the general BM considers the following steps (see Figure 15):

1. The RETs screening and the assessment of their applicability involves the further definition of the general data strategy and the detailed technical analysis of the installations. Then, finding data sources, data gathering and selection, will support the construction of BM datasets following the GIS-based project approach.

2. For each RET there must be a basic analysis and further modeling for the estimation of available energy in kWh/m^2/year, which should come from considering the energy resources location, the potential nominal power of the technologies as estimated with climate datasets, and the sequence of power losses because of technical considerations of the components.

3. The listing/ranking of technologies under cost optimization and/or maximum profit criteria according to the RET's nominal power, peak load, cost of installation and cost of maintenance.

4. The BM Cost-Benefit analysis will explain the economic and financial results of the match-up between location and technologies selection, including the installation's life cycle costs (that are related to the specific climate characteristics, technical parameters and road topologies) and the market prices. Hence, in power network-connected facilities, the energy market prices and purchase agreements are crucial, as the provision of energy should be competitive in economic terms, in the consideration of the best-selling price in the country's market for electricity surpluses. When the installation is for self-consumption and non-connected, the BM provides the best price for purchasing the electricity.

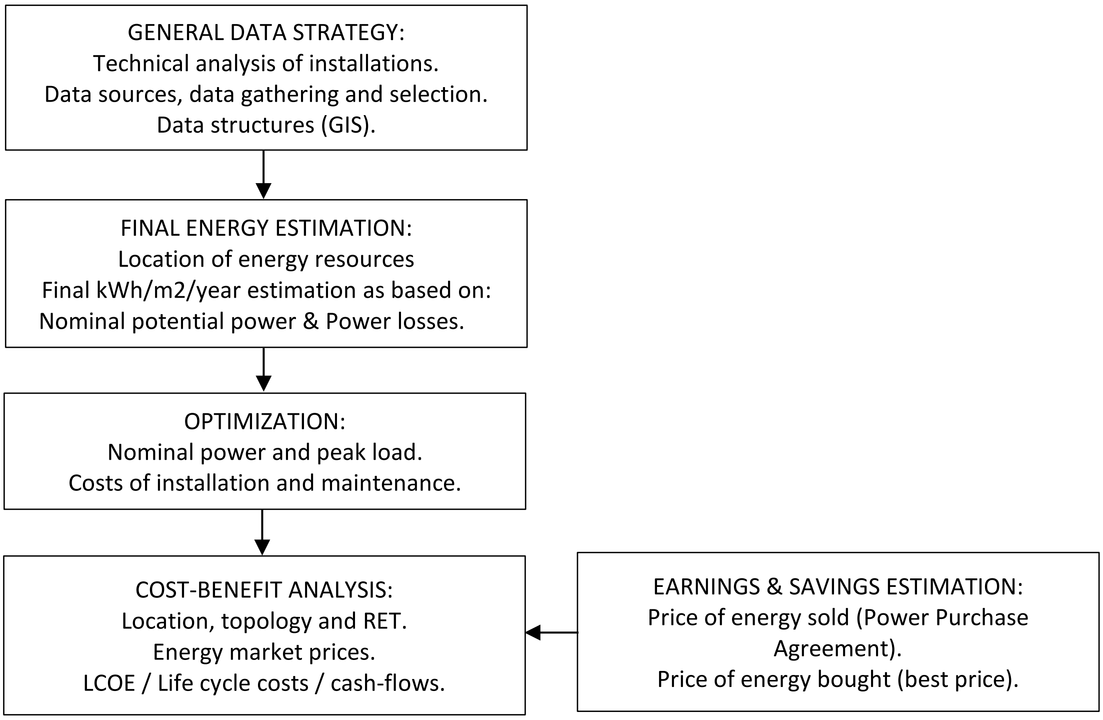

Figure 15. Steps in the design of the General Business Model

Before the approval for the GIS implementation, the model will be tested by means of simulations that enable the assessment of the efficiency in the selection of the RET based on installations life cycles.

While the BM is part of the MCDM, it is necessary to identify the whole design of the BM and its operation into the MCDM framework to explain the interactions between both of them. The general scheme is thus described in the ENROAD Methodology and it is explained in the next section.

5. BUSINESS MODEL: DESIGN AND APPLICATION

The Cost-Benefit analysis or BM application within the ENROAD Methodology is linked to the GIS general database and supplied with the detailed information in WP2 of the different RE technologies, and the barriers and recommendations for the NRAs to act as an electricity producer/retailer in WP3. Hence, the outcome from the GIS application should be affected by the country-based legislative and regulatory framework. The operation of the BM in the GIS system is a multistage process that is based on alternative scenarios and the steps are expected to be as follows (see also Figure 16):

1. NRAs identification: Selection of the NRAs, electricity uses (consumption, selling, and storage), and load necessities (road lighting, tunnel lighting, ITS, etc.). It includes a first approximation to optional locations.
2. Energy market prices: Selection of country's market prices (purchase-sale) for savings estimation and profits from selling the energy.
3. RET electricity output: Optimal location of the installation in terms of electricity production. The nominal power and kWh/m^2/year estimation by RET depends on the technology selection and its configuration. The estimation follows a three-step process:
    - 3.1. Primary energy resource estimation: it depends on the technology. For instance, the wind turbines performance is based on the wind speed distribution approximated by the Weibull distribution; likewise, calculation of the solar panels is based on European solar radiation statistics or the local solar irradiation (kWh/m^2/year).
    - 3.2. Performance corrections: depending on the technical configuration of the installation (connected or non-connected), this considers the losses of power from the production to the consumption or connection to the network.
    - 3.3. Determination of kWh/m^2/year: it is the estimation of the final energy production for the available area of the selected location, in square meters.
4. CAPEX and OPEX estimation: initial investment and investment scaling (modules, structures, connections, transformers, inverters, BOS, batteries and financing) and annual operation costs (manpower, maintenance, insurance, communications, security, monitoring, etc.). The sum of both per kWh has to be considered for each technology configuration and technical life-cycle of the installation.
5. Levellized cost of the energy: in the situations in which two different sources are installed a cost by-source analysis is recommended. Then, the same CAPEX and OPEX overhead costs should be allocated. In any case, in either the situation with a unique source or with two sources, the MB offers a final LCOE for the facility.
6. Revenues and saving estimation: estimation of annual revenues and savings, and tax aids and incentives along the life cycle of the installation.
7. Economic performance: annual profit-losses determination or savings estimation (energy and maintenance) by technology (results of Cost-Benefit analysis).

8. Financial assessment: cash-flow analysis for the life cycle of the installation (NPV, IRR and payback analysis).
9. Environmental analysis: estimation and assessment of economic-related environmental issues (e.g. CO_2 savings per year and square meter) and contrast with current regulatory barriers.
10. List of ranked technologies with Key Performance Indicators (KPI).

As another important outcome, the Business Model could simulate an if-then analysis to benchmark countries, needs and technologies, identifying this way the barriers and obstacles for the NRAs to become active in the energy market.

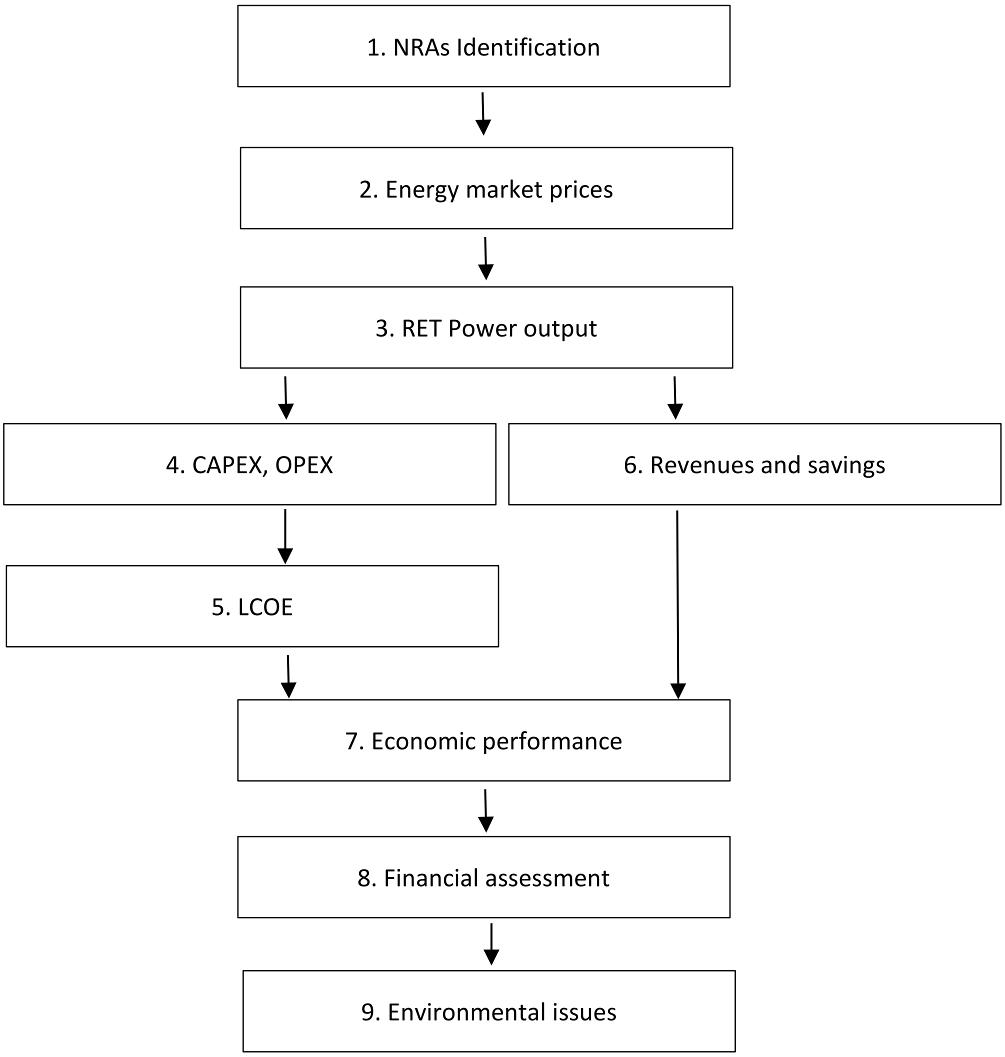

Figure 16. Business Model application

5.1 DEFINITION OF THE NRA LAND/ASSETS

In the first step, for the RET electricity production estimation, even though it will be explained in more detail in future deliverables, there are two approximations for the definition of the NRA land locations. In fact, it is interesting that the proposal uses the term *location* considering its meaning of *area*. Hence, the estimation considers the number of panels or turbines that the NRAs can set up in such area. Since there are different approaches to the determination of the area, by now, we have under analysis two options to point out in the map: a singular point with a fixed width and length and a four-points area.

As soon as the area is determined, the next phase is the estimation of the RET electricity production.

5.2 RET ELECTRICITY PRODUCTION

The outcome of the estimation of the electricity production is in kilowatts per hour, square meter, and year (kWh/m2 year). Due to the particularities of the technologies, models are presented in separate subsections.

5.2.1. Small- and large-scale wind energy

The estimation of the primary wind energy in the case of the horizontal axis turbine (they are more efficient than those of the vertical axis and represents approximately 99% of the total) is based on the formula:

$$\boldsymbol{E_{wind}} = \sum_{\boldsymbol{i=Cut\ in}}^{\boldsymbol{Cut\ off}} \left(\frac{\mathbf{1}}{\mathbf{8}} \cdot \boldsymbol{\rho} \cdot \boldsymbol{D^2} \cdot \boldsymbol{v_i^3}\right) \cdot \boldsymbol{hours/1000}$$

$\forall\, i \in E$ y $\forall\, i = [Cut\ in - Cut\ off]$

Where the wind speed ($\boldsymbol{v}$) is estimated in the location using the Weibull distribution; D is the diameter of the blades; and Rho is the wind flow pressure.

The primary wind energy should be corrected to estimate the Energy Extracted ($\mathbf{K_e}$), which takes into account the subsequent equipment losses of performance. These depend on the type of the turbine, the wake effect, multiplier, generator, transformer, converter and wires. In isolated facilities, batteries are also included in the estimation.

In Deliverable 2.1 (subsection 2.1.4. Location and distance to the road), it was explained that the optimal location for wind turbines is an important issue that affects the accuracy of the estimation and economic performance of the installation. Since adjacent turbines placed perpendicular to the wind direction are not as affected, the turbines facing the main wind direction should be arranged to obtain lower losses of energy (Figure 17).

Distances are shown in Table 2, in which the column Spacing estimates for each technology the separation based on diameter shown in the previous column. For the purposes of the business model, in the area capacity analysis, the number of turbines is estimated according to the following formula:

$$\mathbf{N} = \left\lfloor \frac{\mathbf{A}}{\mathbf{n1} * \mathbf{n2} * \mathbf{D}^2} \right\rfloor$$

Where N is the number of turbines, A is the area, and n1 and n2 are standard separations based on Table 2. Then the energy extracted, K_e is calculated as follows:

$$K_e = \frac{E_{wind} \times Power\ corrections}{A} N \left[\frac{kWh}{m^2} \cdot year\right]$$

The estimation results should be compared with RET meta-parameters with similar parameter trends.

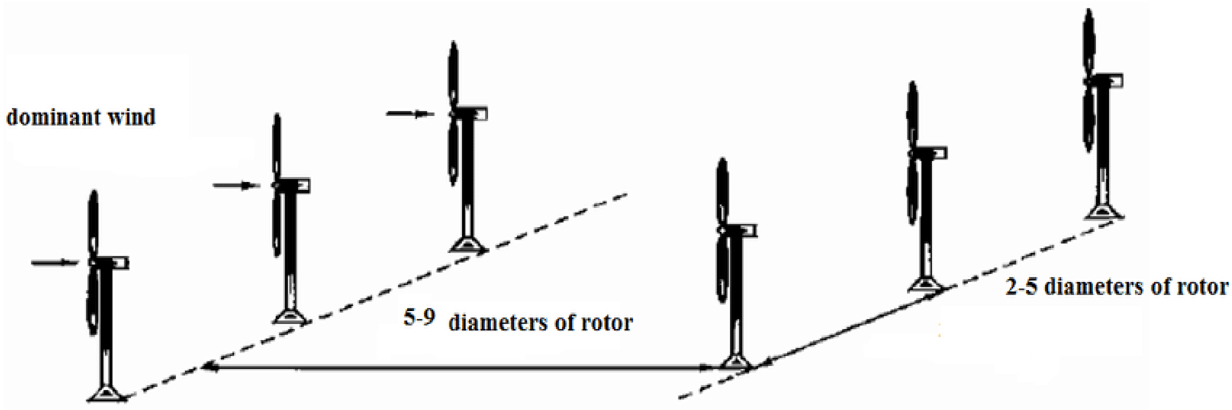

Figure 17. Distance between turbines in diameters of rotor.

Table 2. Comparison of wind energy technologies

Technology		Power (kW)	Height H (m)	Diameter D (m)	*Spacing [in no. of diameters D]*
Large Wind	Three-blade	800-12000	50-180	40-150	4D-10D
Small Wind	Savonius	10	9	3	1-2D
	Darrieus	5-20	23	10	2-3D
	Venturi	2-3	5	1.3	1-2D
	Vortex	0.1	2.5	0.2	H/2
	Mini Three- blade	1-20	16	9.8	4D-10D

5.2.2. Solar photovoltaic energy

The estimation of the primary solar photovoltaic energy is based on the formula:

$$\boldsymbol{E_{solar}} = \boldsymbol{\eta_{\mathbf{PVGenerator}}} \cdot \boldsymbol{I_{Average}} \cdot \boldsymbol{S}\ [\mathbf{kWh}\ \times\ \mathbf{year}]$$

Where $\eta_{PVGenerator}$ is the performance of the panel, $\mathbf{I}_{Average}$ is the average of solar irradiance (power of the radiation by surface unit) per year, and S is the surface area of the panel. Then, estimation of the energy extracted $\mathbf{K}_e$ includes the subsequent equipment losses of performance in both grid-connected or isolated facility (power corrections); the number of panels (**N**); the panel's width ($\boldsymbol{a}$); and the distance between the rows of panels from an axis parallel to North-South Axis (**X**).

$$\boldsymbol{K_e} = \frac{\boldsymbol{E_{solar}} \times \boldsymbol{Power\ corrections}}{\boldsymbol{X \cdot a}} \boldsymbol{N} \left[\frac{\boldsymbol{kWh}}{\boldsymbol{m^2}} \cdot \boldsymbol{year}\right]$$

The parameter **X** includes the panel length, the elevation and the latitude (Figure 18).

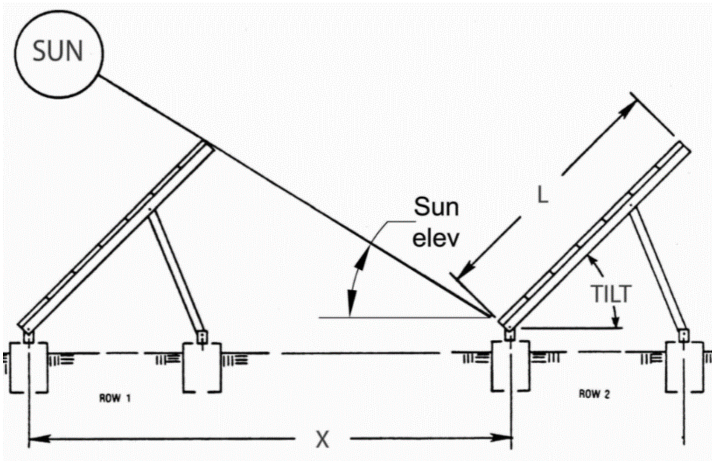

Figure 18. Distance between PV panels.

5.2.3. Mini-hydro energy

The estimation of the primary mini-hydro energy is based on the formula:

$$\boldsymbol{E_{Hydro}} = \boldsymbol{g} \cdot \boldsymbol{Q_{average}} \cdot \boldsymbol{H} \ \cdot \boldsymbol{hours}\ [\mathbf{kWh}\ \times \mathbf{year}]$$

Where $\boldsymbol{g}$ is the earths' gravity (9.68 m/s^2), $\boldsymbol{Q_{average}}$ is the average flow of water, $\boldsymbol{H}$ is the average jump (m^2), and ***hours*** is the running time. The average flow of water is supposed to be constant during the operation and it is based on historical records. As similar to PV and Wind technologies, the estimation of the energy extracted $\mathbf{K}_e$ includes the subsequent equipment losses of performance (power corrections).

5.3 COST ESTIMATION MODEL

The cost estimation models are a measure of efficiency, as the non-financial measures, and must be adequately defined, measured and assigned (Mowen et al. 2014) so that the energy production must be related to the inputs used to calculate the global financial effect of any modification in the BM. As a result, the cost is intimately linked to the quality of service for the right functioning of the installation during all the time that the circumstances allow it minimising the non-used capacity.

5.3.1. Intermittence in the production and non-used capacity

The main problem in the use of renewable sources is their intermittence, what affects in a conclusive way the installation´s efficiency, both from the perspective of the idle time of the installation and the variations of primary energy coming from the wind, the solar radiation or the water flows. This is due to, as we will see later, the structure of the costs of the installations is based primarily on the fixed costs assigned to the kWh, the estimation both to tackle the decision to carry out the investment and the estimation of results is an exercise not exempt from difficulties due to the differences between the expected costs and the reality of this variation in productivity resulting from the idle capacity (Marques and Fuinhas 2012, Flora et al. 2014, Notton et al. 2018). This is an important characteristic as it affects growth models as the so called hydrogen economy (ETC 2021). Cloete et al. (2021) highlight the difficulty which the producers of the called green hydrogen face beyond the low capacity of the electrolyser, who must also face investments in hydrogen piping, storing infrastructure to manage the intermittent production and the electricity transmission.

This idle capacity is a basic element in the business model of RE from the producer perspective by Ritcher (2012) (Figura 3). Against the customer model, the producer´s acknowledges his importance and assesses its effects on the different types of costs and the quality required of the data under the premise of efficiency; that is, the one of minimising the costs associated to the energy production along the life cycle of the installation over the basis of its design and its performance according to the profiles of power, climatology, specifications of the equipment and the specific economic variables (prices of purchase, sale, tolls) and conjunctural (interest types, inflation) (Barley et al. 1995).

5.3.2 Tendencies in the generation costs of RE

According to the International Renewable Energy Agency (IRENA), renewable energies are increasingly more competitive: between 2010 and 2020 the cost of electricity coming from these sources has been reduced remarkably. The cost of electricity of photovoltaic origin was reduced 85%, being followed by sea wind (48%). More outstanding is that from their analyses and estimations it is deduced that up to 800 gigawatts (GW) of the existing coal capacity could be economically replaced by new capacity of renewable energies, saving the electric system up to 32000 million of U$/year and reducing the emissions of carbon dioxide (CO2) in up to 3 gigatons (GT). This would provide the 20% reduction of emissions necessary for 2030 for the climate route of 1.5°C sketched out in the World Energy Transitions Outlook by IRENA (IRENA 2021).

The study of costs by IRENA is based on data about costs and auction prices of projects around the world and highlights the last tendencies for each of the main RE technologies. Figure 19 shows the tendencies in the pondered average cost for the available capacity for each technology of the LCOE (USD/kWh) during 2010-2020. In the technologies we are referring to, terrestrial wind RE decreases from 0.162 USD/kWh to 0.039 USD/kWh, solar photovoltaic from 0.381 USD/kWh to 0.057 USD/kWh, and hydraulic slightly increases from 0.038 USD/kWh to 0.044 USD/kWh.

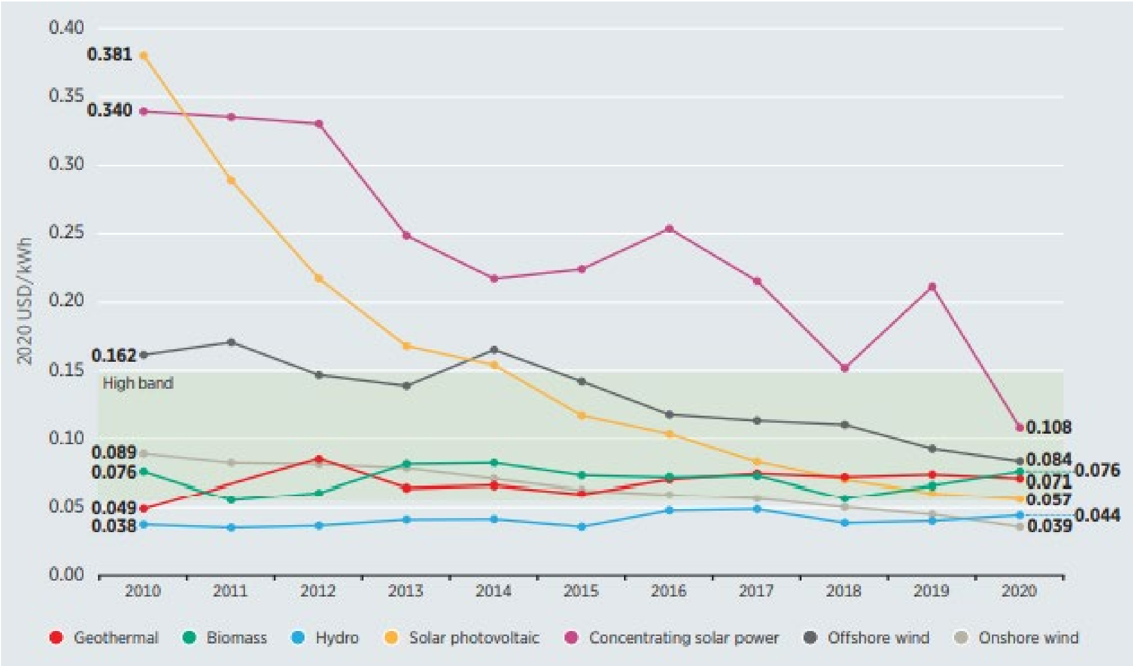

Figure 19. Global weighted-average utility-scale LCOE by technology (2010-2020). Source: IRENA

In USA, the Energy Information Administration (EIA) publishes the estimations of the LCOE for the installations that will start running between 2023 and 2026 (EIA 2021). Together with the LCOE, it also publishes the Levelized Cost of Storage (LCOS). In this publication, for the RE technologies, terrestrial wind RE has a LCOE of 0.031 USD/kWh, solar photovoltaic 0.029 USD/kWh with single tracking axis and 0.042 USD/kWh if it is hybrid with an accumulation system for four hours (Figure 20).

According to Oliveira e Silva and Hendrick, the cost of self-sufficiency of a photovoltaic battery system is calculated in detail for the Belgium electric regulatory frame. This derives from the typical feels levels of 30 to 40 cents /kWh for self-sufficiency levels of 70% to 80%. The negative effect of the accumulators on the LCOE effect is documented by Meuris et al. (2019) who state that when there is electricity storage available at low cost, the wind and solar energy are competitive for the highest part of the electricity generation. Batteries, by being the main storage of distributed electric energy, even add a significative overcharge to the electric system in spite of the current and expected future fees falls.

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[2]	Levelized variable cost	Levelized transmis-sion cost	Total system LCOE or LCOS	Levelized tax credit[3]	Total LCOE or LCOS including tax credit
Dispatchable technologies								
Ultra-supercritical coal	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Combined cycle	87%	$7.00	$1.61	$24.97	$0.93	$34.51	*NA*	$34.51
Combustion turbine	10%	$45.65	$8.03	$45.59	$8.57	$107.83	*NA*	$107.83
Advanced nuclear	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Geothermal	90%	$18.60	$14.97	$1.17	$1.28	$36.02	-$1.86	$34.16
Biomass	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Battery storage	10%	$57.51	$28.48	$23.93	$11.92	$121.84	*NA*	$121.84
Non-dispatchable technologies								
Wind, onshore	41%	$21.42	$7.43	$0.00	$2.61	$31.45	$0.00	$31.45
Wind, offshore	45%	$84.00	$27.89	$0.00	$3.15	$115.04	*NA*	$115.04
Solar, standalone[4]	30%	$22.60	$5.92	$0.00	$2.78	$31.30	-$2.26	$29.04
Solar, hybrid[4, 5]	30%	$29.55	$12.35	$0.00	$3.23	$45.13	-$2.96	$42.18
Hydroelectric[5]	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021*
[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2024 to 2026. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or *not built*.
[2]O&M = operations and maintenance
[3]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2026 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA*, or *not available*. The results are based on a regional model, and state or local incentives are not included in LCOE and LCOS calculations. See text box on page 2 for details on how the tax credits are represented in the model.
[4]Technology is assumed to be photovoltaic (PV) with single-axis tracking. The solar hybrid system is a single-axis PV system coupled with a four-hour battery storage system. Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[5]As modeled, EIA assumes that hydroelectric and hybrid solar PV generating assets have seasonal and diurnal storage, respectively, so that they can be dispatched within a season or a day, but overall operation is limited by resource availablility by site and season for hydroelectric and by daytime for hybrid solar PV.

Figure 20. USA estimated capacity-weighted levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2026 (2020 dollars per megawatthour). Source: U.S. Energy Information Administration.

De Oliveira e Silva and Hendrick (2017) found that the LCOE of a system of photovoltaic batteries was 30 to 40 cents/kWh for self-sufficiency levels of 70% to 80%. Finally, Ramli et al. (2017) compared three RE by HOMER and RETScreen, simple photovoltaic, hybrid photovoltaic and wind, and found that it is preferable to install the independent photovoltaic system in Malaysia (1.96 RM/kWh; that is to say, 0.42 €/kWh) in comparison with the independent wind system (3.22 RM/kWh; that is to say, 0.68 €/kWh) and the autonomous photovoltaic system (4.21 RM/kWh; that is to say, 0.89 €/kWh). Besides, both softwares reported fees significantly different.

5.3.3 Target costing, sunk costs and net margins

The Target Costing is a methodology of cost management of a process, product or service that is focused on the reduction of design and development costs present and future. It is the methodology that has allowed Toyota and Boeing to achieve reductions between 75% and 90% of the costs of important productive processes. In short, an objective cost is the difference between the necessary sale price to cover a predetermined market share and the desired price per unit (Mowen et al. 2014):

Target Costing = Expected Sales Price per Unit – Desired Per Unit Profit

The sale price represents the measure of the value created in the BM according to the customer specifications, which may be the NRAs or third parties to which the energy and/or services are provided to. In this case, the prices are different for the countries conforming the project. In Figure 21, the Electricity prices for non-household consumers (EPNHC) are listed.

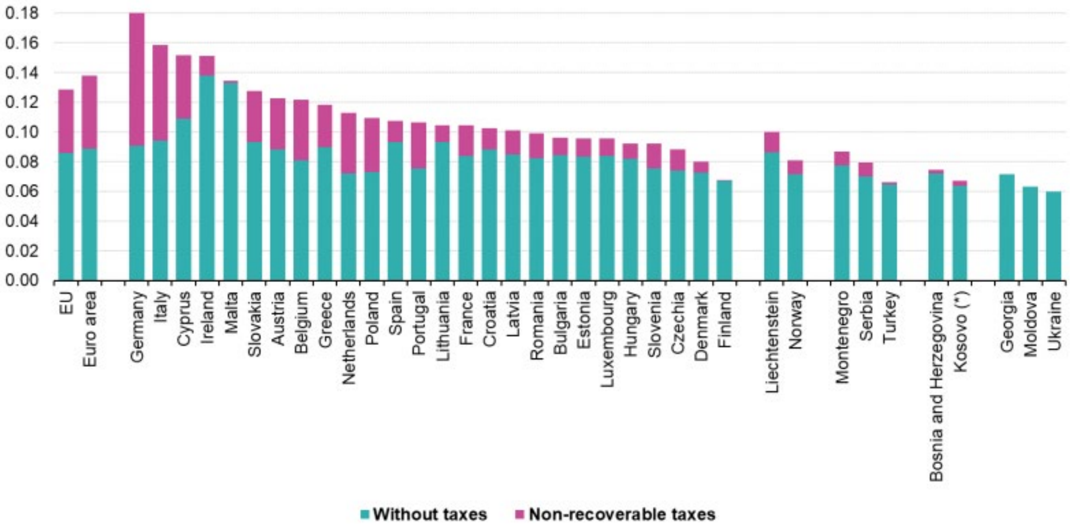

Figure 21. Electricity prices for non-household consumers (€/kWh) (first half 2021). Source: Eurostat

Due to the reference for the NRAs are the Price Purchasing Agreements (PPA), in Figure 22, an indicator of the competition situation for each country can be considered the difference between the sale prices to different household consumers and the PPA.

Table 3 shows the margins before distribution of the electricity prices for consumers different from household. In the nordic countries, as Norway for instance, PPA is of 0.023 €/kWh what supposes 32% of the electricity price of EPNHC, and however, they would not cover the total of the objective costs of the RE in this country. Germany, in turn, with a PPA 0.042 €/kWh (46% above the EPNHC) helps to get positive net margins, higher for the Solar Photovoltaic of 0.017€/kWh (40% above PPA and 19% above EPNHC), followed by Onshore Wind of 0.017€/kWh (37% above PPA and 16% above EPNHC), and finally, the Hydro for 0.005€/kWh (12% above PPA and 5% above EPNHC). As a result, in a first approximation, if the net margin for distribution shown in Table is used as reference, this would have to be around 59% or 60%. In that case, the Hydro would have scarce viability in some countries, and the onshore wind would be in the limit of other. In view of the results, only the costs of the solar photovoltaic would be competitive in all.

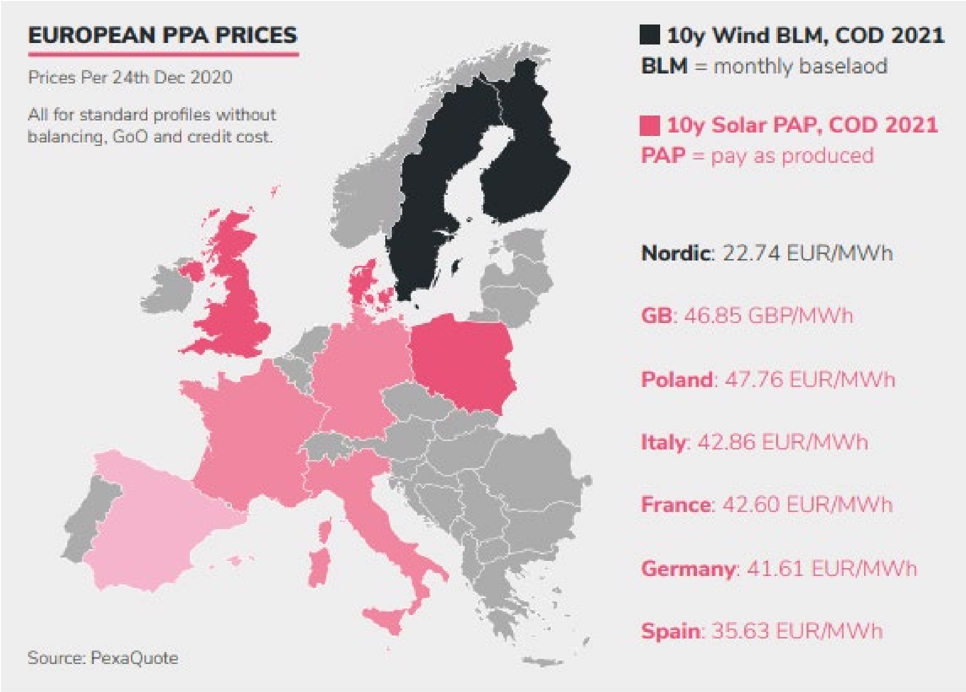

Figure 22. European PPA Prices Dec 2020. Source: PexaQuote

In the case the objective cost for each RE, **PPA for each country, was below the estimated cost,** then savings formulas would have to be looked for in the costs committed or to commit, according to a prefixed order that will be presented later.

As a first approach, cost savings are those about which NRAs have a higher negotiation capacity. If we pay attention to the costs of the design stage, these correspond to the development and engineering costs (DEC) which by their nature are not recoverable costs or sunk costs in the development of the project.

Table 3. RE Target Costs and Countries' Net Margins for distribution

(€/kWh)	Electricity prices for non-household consumers	Target Cost (€/kWh)			Net Margin EUROS per kWh			Energy Distribution Net Margin % EPNHC		
Country	(EPNHC)	Solar PV	Onshore Wind	Hydro	(Max) over SPV	(Med) Over OW	(Min) over Hydro	(Max) over SPV	(Med) Over OW	(Min) over Hydro
Austria	0.084	0.025	0.027	0.037	0.059	0.057	0.047	70%	68%	56%
Belgium-Flanders	0.081	0.025	0.027	0.037	0.056	0.054	0.044	69%	67%	54%
Denmark	0.073	0.025	0.027	0.037	0.048	0.046	0.036	66%	63%	49%

Germany	0.091	0.025	0.027	0.037	0.066	0.064	0.054	73%	70%	59%
Ireland	0.130	0.025	0.027	0.037	0.105	0.103	0.093	81%	79%	72%
NL	0.072	0.025	0.027	0.037	0.047	0.045	0.035	65%	63%	49%
Norway	0.072	0.025	0.027	0.037	0.047	0.045	0.035	65%	63%	49%
Sweden	0.061	0.025	0.027	0.037	0.036	0.034	0.024	59%	56%	39%
UK *	0.1061	0.025	0.027	0.037	0.0811	0.079	0.0691	76%	75%	65%
EU27*	0.086	0.025	0.027	0.037	0.061	0.059	0.049	71%	69%	57%

Note: Target Costs based on IRENA & EIA estimations (1USD = 1,15€). Non-Household prices sources: Eurostat and UK BEIS. (Note *Eurostat does not offer UK EPNHC data).

The sunk costs are costs of the resources already acquired or which must be acquired and which cannot be changed by any decision after the moment of their acquisition (Drury 2018). The only way to recover these costs is by the depreciation, what means they will not be recovered if the investment is a failure.

Since this type of development costs of the project conform the first stage in the investment process, the economic assessment of the RE will be carried out by the growth of the costs according to their participation in the energy production, postponing the assessment of the development costs to define them as a maximum spending budget (Figure 23).

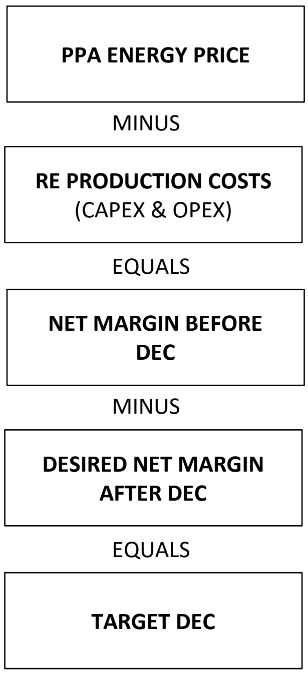

Figure 23. Net margins based on target development and engineering costs.

Hence, the potential investments projects to be considered are opportunities in the production of the renewable energy demanded by the NRA with a competitive cost. The cost target is the estimation of the cost of a Renewable Technology Facility of electrical power for a specific site.

5.3.4 Classification of costs

The elaboration of the cost accounting has the purpose of answering three questions, what in this case follow this order: (1) what costs are involved during the consumption of good and services in energy production (renewable or not?) (2) where (in what departments or sections?) are the costs produced? (3) for what services are those costs produced and what are the operating results achieved with these services? (Figure 24).

The first question is framed in the classification of costs, in fact the cost analysis's first step is the cost classification on a functional basis: equipment (wind turbines, PV panels, connections, transformers, converters), labour, administration expenses, and financial expenses. The analysis is a preliminary assessment to ascertain if the location is likely to warrant further attention through the application of more sophisticated analysis.

In general, energy costs are classified according to the basis of the production factors; that is to say, material costs (for instance, the fuel in a thermal station), personnel costs (for example, wages of the maintenance team when they are hired by the own company), external services costs (for instance, security service) and depreciation costs (e.g. solar panels) (Bierer and Götze 2012). These costs are conformed as costs of the activity of energy production, or operating costs. The operating costs become operating expenditures or expenses of operating operations (OPEX) in the moment the suppliers of the services are identified and the decision horizon incorporates the corresponding payments according to the conditions agreed or to be agreed.

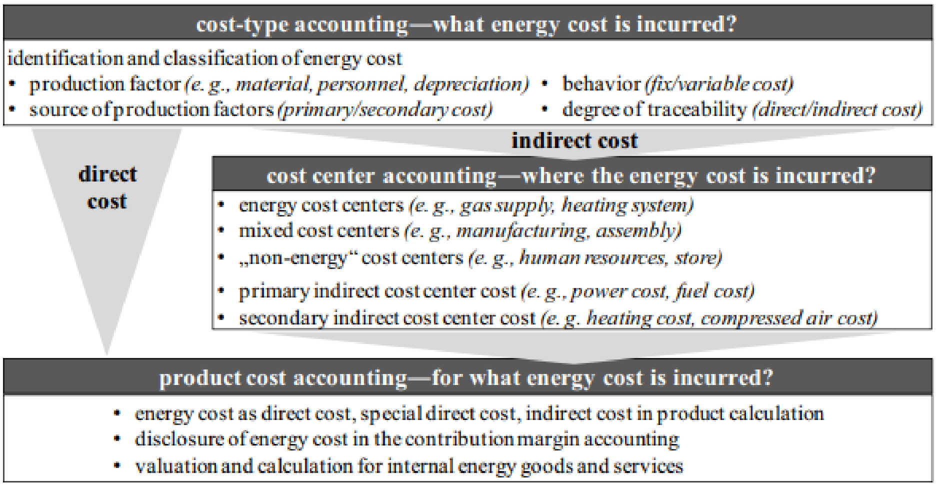

Figure 24. Basic structure of the energy's cost accounting. Source: Bierer and Götze (2012)

One of the OPEX is the depreciation conformed as an exception in the sense it is an expenditure that does not entail a future payment. On the contrary, previously the payment will be carried out in part or fully at the beginning of the economic activity, in order to make the necessary installations available to the company. These decisions of capital investment (or capital expenditures) also known as CAPEX consist on the process of planning, objective and priorities setting, provision of funds, and the use of criteria to select the assets that will be used for longer than a year, in the long term, and which bestow stability to the company.

Due to the exploratory characteristic of the BM a third group has been created starting from the development expenditures, which although are initially identified with the CAPEX, will be included in a third group of development and engineering costs. The end of this group is to gather all the sunk costs derived from the preliminary studies before the decision (or not) of investment. As we will see later, the BM will determine the benefit margins by an accumulative process of the costs but with the consideration of the effects on the liquid assets; that is to say, that depreciations are incorporated at the end because they do not imply cash outflows. This way, the determination of margins facilitates the understanding of the cash-flows and explains the final balance in cash and banks. Alternatively, for a BM based on self-consumption it is explained where and how much money is being saved.

5.4 CAPITAL EXPENDITURES (CAPEX)

The outcomes of the model are the estimated cost per typology, the average cost per kilowatt and square meter, and finally the LCOE for the facility life. The majority of costs are fixed and proportional to the power of the installation. The facility affects the capital costs (CAPEX) in two levels:

- The installation configuration in the range of power from the lowest P < 300 kilowatts that require simple control systems (electric switchboard and connection), medium 300 kilowatts < P < 1000 kilowatts (substation and connection), and largest P> 1000 kilowatts.
- The number of panels, or turbines that require specific configurations of rectifiers and inverters.

Hence, there is not a relevant effect of changes in the dialy level of activity. On the contrary, unitary cost behavior descends rapidly in the short-term and tends to the minimum cost (shows the economic efficiency level) in the long term. It should be noted that the BM does not include sales or income taxes due to the differences between countries.

Capital expenditures (CAPEX) are the most important decisions that an organization makes as they commit in the long-term financial and human resources in the expectation of future benefits. In the economic valuation of CAPEX decisions, we include investments in the necessary engineering, the purchasing and installation of the power system. This includes the equipment in the energy production facility: the power sources (windmills, panels, and hydro-turbines) and their specific structures and elements (for instance, the balance of solar PV systems or BOS), the substations, inverters and transformers, the grid connection, the batteries, and the construction of buildings and yards (Table 4).

Table 4. CAPital EXpenditures

FACILITY ELEMENTS	COST	YEARS	ANNUALIZED (FACILITY DEPRECIATION)
Power sources			
Structures			
Inverters			
Transformers			
Grid connection			
Batteries			
Yard & building constructions			

Regarding the useful life of the facility elements, life expectancy and the depreciation are estimated based on how much of their value has been used. There are many types of depreciation. For this project, we estimate the annual depreciation based on the life of the element on a straight-line basis, then we divide the cost of the element by the years of life. As the the useful life of the installations generally matches that of the component with the shortest life in operation, if the reposition for the calculation of the costs of a full cycle is not considered, it will be necessary to amortise the pending years of the components still in use. If the dismantling costs are also taken into account, both types of costs will be periodised by dividing them by the years of useful life, giving rise to a second amortisation epigraph of such costs in the OPEX (End-of-cycle depreciation and dismantle).

5.5 OPERATIONS EXPENDITURES (OPEX)

The OPerations and maintenance EXpenditures are the annual costs associated with the operations aimed at producing the renewable energy: manpower, maintenance, insurances, communications, security, monitoring, energy, and other general and administrative costs. When the NRAs are assumed the owners of the installations' land, the cost estimation includes the property taxes, otherwise, the land rentals are incorporated (Table 5).

When the financing of the long-term investments is fully or partially based on loans, the assessment includes the debt leverage and the debt payments (the yearly annuities), which are constant over the debt term. Then, the estimation of the loan's debt term and the interest rate are necessary.

Table 5. OPerations EXpenditures

Annual costs
Manpower
Maintenance
Insurances
Communications
Security
Monitoring
Energy
Other general and administrative costs
Interest

5.6 DEVELOPMENT AND ENGINEERING COSTS (DEC)

In addition to CAPEX costs, a more sophisticated analysis following the RETScreen costing model suggests the incorporation to the detailed feasibility study of other important costs such as the site investigation, resource assessment, environmental assessment, preliminary design, Green House Gas (GHG) baseline study, report preparation, project management and travel and accommodation expenditures (Table 6). They are also initial costs; however, the difficulties in the basis of the estimation lead us to propose a general net margin assessment.

Table 6. Development and Engineering Costs (DEC)

Detailed Feasibility Study (DFS)	
Site investigation	GHG Baseline
Resource assessment	Report preparation
Environmental assessment	Project management
Preliminary design	Travel and accommodation
Development costs (DS)	
Contract negotiations	Project financing
Permits and approvals	Legal and accounting
GHG validation and registration	Project management
Engineering expenditures (EE)	
Site and building design	Tenders and contracting
Mechanical design	Construction supervision
Civil design	
Development and Engineering Costs Depreciation **DEC Depreciation = [(DFS) + (DS) + (EE)] / Years**	

Other costs under this approach are the **development costs**, which include the contract negotiations, the permits and approvals, the GHG validation and registration, the detailed project financing analysis, the legal and accounting issues, and the project management.

Finally, there are important **engineering expenditures** related to the site and building design, mechanical design, electrical design, civil design, tenders, contracting, and construction supervision. As in the CAPEX section, these costs are annually considered; i.e., they are depreciated during the project life.

5.7 COST ANALYSIS STRUCTURE, MARGINS AND THE LEVELIZED COST OF ENERGY

Table 7 shows the complete cost structure on the yearly basis. The annual cost per kWh is calculated by dividing the Annual Net Margin before DEC by the electricity produced in the period. The Levellized Cost of Energy will be estimated over the annual net margin before DEC during the facility life:

$$LCOE = \frac{\sum Annual\ Margin\ Before\ DEC}{\sum kWh}$$

Table 7. Cost analysis structure and margins (yearly)

	Electricity production (kWh year)	**Unit Price (€/kWh)**	**Total (€)**	**%**
Energy revenues or savings				100
Expenditures:				
Manpower				
Maintenance				
Insurances				
Communications				
Security				
Monitoring				
Energy				
Other general and administrative costs				
Interest				
ANNUAL NET MARGIN BEFORE DEPRECIATIONS				
Facility depreciation End-of-cycle depreciation and dismantling				
ANNUAL NET MARGIN BEFORE DEC				
DCE depreciation				
ANNUAL NET MARGIN AFTER DEC				

The order in which the expenditures are presented is based on a criteria of prudence. The higher in the list, the lower the risk of error in the estimation. In the first place, the personnel and the maintenance costs are the most important among the OPEX, then the amortisation of the CAPEX and, finally, the development and engineering expenditures. In this way, the BM offers a maximum spending limit in this last item that offers an adequate margin. On the contrary, if the BM presents a negative margin before these expenditures the investment is not recommendable. The BM is based on some cases of example that can be modified and actualised to adapt to the NRA needs.

5.8 CASH BUDGET AND CASH-FLOW MANAGEMENT

To know liquid assets, collections and payments flows is basic for the proper management of a business. The cash-budget is an accounting document (Table 8) that gathers the initial availabilities of liquid assets and collections for a period or for the RE installation life cycle. The addition of both composes the cash available from which payments are deducted or disbursed to determine the expected final balance.

Table 8. Cash budget (investment cycle in years)

	Year 1	Year 2	…	Year n
Beginning cash balance				
Cash inflows (or non-outflows): Energy revenues (or savings)				
Total cash available				
Payments or cash outflows for:				
Total CAPEX payments:				
- Property, Plant & Equipment (PP&E)				
- Dismantling costs				
- Developing and engineering costs (DEC)				
Total OPEX payments:				
- Manpower				
- Maintenance				
- Insurances				
- Communications				
- Security				
- Monitoring				
- Energy				
- Other general and adm. costs				
- Interest				
Total disbursements				

Excess (deficiency) of cash available over needs (Net cash flow)				
Financing (borrowing, repayments, NRAs equity).				
Ending cash balance				

The cash budget is an estimation of collections and payments to be included in the BM. If as a result of the analysis of all the information the NRA favourably decides to carry out the investment in RE, the collections and real payments are collected in an accounting document called statement of cash flows, which starting from Table 8 would collect all the collections and cash payments coming from the operations, the investments and the funding operations.

5.9 RE INVESTMENT FINANCIAL ASSESSMENT

Although there are different models to assess the investment decisions in capital, we are going to follow two types of models as based on the classification by Mowen et al. (2014):

- Models without financial discount: Payback period, and Accounting Rate of Return.
- Models with financial discount: Net Present Value (NPV), and Internal Rate of Return (IRR).

5.9.1 Payback Period

The payback period is the time necessary for the NRA to recover the original investment. It is determined adding the yearly cash flows up to the moment when the original investment is recovered. One way to apply it to consider a maximum recovery period, above which the investment would be rejected. This approach would be interpreted as a risk measure because the longer the time to recover the investment the higher the risk assumed. The calculation formula is the following:

$$\boldsymbol{Payback\ period\ (in\ years)} = \frac{\boldsymbol{Original\ invetment}}{\boldsymbol{Annual\ cash\ flow}}$$

5.9.2 Accounting Rate of Return (ARR)

The accounting rate of return (ARR) measures the performance of a project in terms of the margin or benefit. It is calculated by dividing the average annual profit (which is calculated starting from the accumulation of all the benefits and losses of the investment period) among the value of the initial investment. In the application /implementation of the data from Table 7 it would imply the calculation of the ARR before or after the DEC. In the case of a final ARR the calculation will be:

$$\boldsymbol{ARR_{AFTER\ DEC}} = \frac{\boldsymbol{Average\ Annual\ Net\ Margin\ after\ DEC}}{\boldsymbol{Initial\ investment}}$$

5.9.3 Net Present Value (NPV)

The Net present value is the difference between the discounted or present value to the type of interest agreed or requested of the cash inflows and the cash outflows of a project. The interest rate requested is the minimal accepted and a positive NPV implies that the investment will make a net value contribution for the NRA; that is to say, that such investment will have been recovered, and the minimal rate has been reached. The formula is the following:

$$\boldsymbol{NPV} = \left[\sum \frac{\boldsymbol{CF_t}}{(\mathbf{1}+\boldsymbol{i})^{\boldsymbol{t}}}\right] - \boldsymbol{I}$$

$$= \left[\sum \boldsymbol{CF_t}\,\boldsymbol{df_t}\right] - \boldsymbol{I}$$

$$= \boldsymbol{P} - \boldsymbol{I}$$

Where:

- I is the present value of the project's cost (usually the initial cost outlay)
- CF_t is the cash inflow to be received in period t, with t = 1 … n
- i is the required rate of return
- t is the time period
- P is the present value of the project's future cash flows
- df_t is the discount factor $\frac{\mathbf{1}}{(\mathbf{1}+\boldsymbol{i})^{\boldsymbol{t}}}$

5.9.4 Internal Rate of Return (IRR)

The Internal rate of return (IRR) is the type of interest that matches the discounted value or current value of the cash flows of the RE project to the initial investment value. The formula is the following:

$$\boldsymbol{I} = \sum \frac{\boldsymbol{CF_t}}{(\mathbf{1}+\boldsymbol{IRR})^{\boldsymbol{t}}}$$

The IRR is the assessment method of an investment most used due to the IRR is comparable to other profitability rates, either of financial or banking products or as profitabilities from business activities comparable or of reference. The information is available in paid databases or even free, as for instance the Central Balance Sheet Data Office from the Banco de España.

6. FINAL COMMENTS

This deliverable 4.1 gathers the proposal for the design and application of the BM of the project ENROAD. The Model is expected to be incorporated to the MCDM so that it is conformed as another layer of the GIS system. This layer collects the estimation of the amount of value created for the NRA or a third party with the sale of energy produced or the savings when its destination is the consumption. Due to the intrinsic limitations of the RE linked to meteorological events, the model follows a “Demand Response” (DR) approach so that three different types of actions are included in this context.

The complexity of estimating the BM parameters that the production estimation of RE implies is very high, so there is special software available since years for this task. We have included a long list of this type of software, as well as a brief explanation for some of the most popular ones. In this way, the BM proposal has been designed taking into account already existing solutions.

In consequence, taking into account the difficulty of reaching in general a satisfactory profitability for an investor of low profile, typical of short-sighted positions, we carry out a design proposal that is based on the concept of sunk cost, so that a first estimation of net margins is offered after the CAPEX and OPEX, postponing the development and engineering expenditures up to the end of the budgeting process. In this way, we fulfill three requirements.

On the one hand, we achieve the main objective of reaching the estimation of the annual cost per kWh and the full life levelized cost of electricity (LCOE). On the other hand, there is the effort of approximation to reality, in the sense of making efficient use of the use of the surface available and the use of current equipment at real market prices.

The prudence criterion is applied that establishes a priority according to the error risk in the estimation. Firstly, the personnel and maintenance costs (OPEX), then the amortisation of the CAPEX and finally, the expenditures of development and engineering. In this way, the BM offers a maximum spending limit in this last item that offers an adequate margin. On the contrary, if the BM presents a negative margin before these expenditures the investment is not advisable from a financial perspective. The BM is based on some examples of cases that can be modified and updated to adapt to the NRA needs.

For Deliverable 4.2 a spreadsheet-based model will be developed for the application of the cost analysis structure and the cash-flow projections to different cases, with the multiyear analysis being based on the inflation rate, the reinvestment rate, the project life, the debt ratio, the interest rate, and the debt term. It is important to remind that the income taxes are excluded from the analysis.

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ANNEX 1: LIST OF CURRENT SIMULATION AND ANALYSIS TOOLS (CHAPTER 2)

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