Research Insights

Business Models for Renewable Energy Initiatives

Emerging Research and Opportunities

Adrian Tantau and Robert Staiger

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Business Models for Renewable Energy Initiatives:

Emerging Research and Opportunities

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Preface

This book is about present and future business model in the renewable energy sector with the focus on solar and hydrogen. It is a research book about business opportunities in the PV and H_2 field that can explain the main business models for renewable energy, specially photovoltaics and H_2.

In today's society, the awareness of burning fossil fuels is becoming more and more intense. With the problem of climate change, we are now increasingly confronted with the emission of harmful greenhouse gases and smog (fine dust). This challenge requires for all actors, managers, politicians and stakeholders working in this field a rethink about new energy vision, energy concepts, energy structures, innovations in products and services, developing sophisticated control systems, energy networks and energy database systems for a successful energy transition.

Innovative and destructive business models can help as one economic instrument to move in an economic, sustainable and environmental friendly future for our next generations.

This book grew from wider research efforts to improve the integration between the business mentality and the engineer one in the field of renewable energy and hydrogen.

The book is based on research studies in Europe and on the experience of the both authors, Professor Adrian Tantau, who holds a PhD in Electrical Engineering and another PhD in Management and coordinated in the last seven years Doctoral thesis in the field of business models for renewable energy, in special photovoltaics and the practical experience of Robert Staiger, who has 20 years' experience in the field of renewable energy systems with his focused on an interdisciplinary research on Business models for H_2 as a renewable energy source. Over the past 15 years, Mr. Staiger has developed new technical ideas and patents especially in the heat pump sector and in combination (hybrid systems) with other renewable energy sources combined with fuel cell technology.

We both want to find answers on how to design and promote new business models to successfully integrate them into future business activities with renewable energies and to reduce today's catastrophic environmental impacts to a minimum. We know that renewable energy is the key answer for reducing the primary fossil energy usage, the dependency on these energy sources, the economic consequences for using fossil energy sources, the social imbalance in the world and the global environmental impact. We selected the themes from the business and technology development sector and invite you to become more familiar to these themes and to create or improve your assumptions about business models for renewable energy initiatives.

This book, we trust, provides some inspiration for both researchers and readers of the book, which will have the following advantages: understanding the business model as a concept and the evolution of its structure, understanding the specificity of a business model in the solar and H_2 field, identifying and analyzing the main promotion models for renewable energy in Europe, identifying the tendency in the development of renewable energy sources, connected with risk factors and growth obstacles, analyzing of business ideas and technology development for PV and their impact on environment in Europe, better understanding for future use of renewable energy, analyzing possible business models with H_2 and their complementary renewable energy sources like photovoltaic, analyzing the disruptive factors for H_2 as renewable energy source.

As a matter of fact the book can help researchers, business persons and government officials, and not only for a better understanding of the importance of new business models in PV and H_2 field. The book could help researchers, master and PhD students to be more closed to the tendency in the business in the PV and H_2 field and give them the latest information about this.

This book is a research about business models for renewable energy initiatives in the context of the energy transition from a fossil energy driven economy to a renewable energy driven economy, a more sustainable cleaner energy future and a more equitable society.

The main research faced with new business models close to the newest customers demand and the innovations and technology development in the PV and H_2 field. The renewable energy and in particular the PV and H_2 energy has an enormous potential to grow in the future.

New innovations in solar technology, new sophisticated materials, new intelligent controls (sensors, intelligent actuators) energy management systems linked with regional or national databased systems (Big data) new manufacturing processes, higher efficiency, economic scale effect in production brings the energy cost per energy unit produced out of PV nowadays down to today's grid prices.

This opens now a complete new business view for using PV energy in different existing applications and new innovative ideas in combination with hydrogen as a renewable energy source.

We realized that was a need for a book like Business Models for Renewable Energy Initiatives: Emerging Research and Opportunities. The renewable energy field faces with new challenges nowadays due to the continuously technology development and proliferation of information and communications technology (ITC) and due to the transition from the classical energy resources to renewable energy solutions that have a reduced climate impact.

Due to the proliferation of information and communications technology, based on regional or national databases, the energy will be generated, transported and consumed more intelligently and efficiently.

The revolution in the energy sector starts with the transition from a centralized system to a more decentralized one. A more decentralized energy system based on distributed energy resources will enable to increase the renewable energy share in the total energy consumption that will fulfill also the objectives for decarbonization of the existing energy in order to reduce the impact of climate change. In Europe, the distributed energy resources were significant promoted in Germany under the global umbrella of Energy transition (Energiewende) program.

Decentralization will be the success for an independent energy future. Hydrogen as a sustainable, transportable and storable fuel produced out of renewable energy sources can increase the future potential in new and unique opportunities. These opportunities must be taken in new and as well existing business models to improve profitability in companies, bringing new innovative structure, new organizational processes, internal and external processes, new products innovations, new financial or investment models and marketing and customer services.

The Fraunhofer Institute has identified photovoltaic systems as the most important renewable energy source in the next decades. This source of energy will radically change our lifestyle today. These changes lead to new business activities. The study realized by Fraunhofer Institute consider that 98% of solar PV is connected to low- and medium voltage distribution grids and 85 percent of German solar capacity is generated in photovoltaic facilities with a capacity under 1 MW (Fraunhofer, ISE, 2016).

All these transformations are followed by a transition to new business models which will be more focused on the consumer side. The value proposition will play a more important role in the relations between actors in the energy chain. The consumer will play a more active role in the new configuration on the energy market.

Our main research objective is to provide an overview of the most frequently implemented business model characteristics in photovoltaic and H_2 in Europe, as these factors contribute significantly to the future adaptation and development of the technology and the business in the field.

The detailed objectives of our study are fivefold:

1. To introduce how business models are structured and developed based on different perspectives: such as entrepreneurship perspective, resource based perspective, transaction structure perspective and narrative perspective (Chapter 1, Section 1).
2. To present and analyze the main promotions models for the use of energy from renewable sources in Europe (Chapter 1, Section 2).
3. To offer a view about the business development and the environmental impact in the solar PV field (Chapter 2).
4. To analyses H_2 as a sustainable energy source the impact in an energy transition future and destructive situations with the main business models with H_2 (Chapter 3).
5. Finally, to present the new innovative business models in the renewable energy field and the trends in the renewable energy business (Chapters 4 and 5).

The book is organized as follows. We began our research by identifying the main definitions and approaches related to business models. In Chapter 1 we explore the concept of business model and review the main approaches regarding definitions and perspectives of business models. Analyzing the value of business models, and understanding the value proposition creates the general framework to design specific business models for the renewable energy field. This chapter includes also two case studies regarding Quota as a green certificate scheme in Romania and the feed in tariff as a renewable promotion model in Germany. This chapter ends with the analyzes of the main obstacles and risk factors related to the development of renewable energy business models in Europe.

The analyze of business development in the photovoltaic field is accompanied by a quantitative analysis on PV systems in the renewable energy industry based on a case study that estimate the power production costs for PV systems in Romania (Chapter 2). Chapter 2 includes also the analysis of a PV system from an environmental impact perspective following the structure of the life cycle assessment.

Understanding the current business development in the photovoltaic field in Europe is critical to find the proper business models that will be implemented in the future.

Chapter 3 deals with the question of how hydrogen can be a sustainable secondary source of energy and how this can be used profitably for entrepreneurs and businesses. Question will be asked about the present and future energy usage and the consequences of the environmental impact. The process of energy transition from fossil fuel sources to a renewable driven world will be examined and a closer look how H_2 can support this way technically, environmentally and economically. A case study in mobility shows possible impact using H_2 out of a fossil and a renewable energy source. Today's H_2 fuel applications and BM are investigated, important values are displayed and in examples showed. From today's point of view, working with hydrogen is still a very fragile and sensitive business. Many processes with H_2 can have destructive effects on their existing business models. These destructive effects and the risks are discussed in more detail.

In Chapter 4 we are analyzing more in details business models for renewable energy businesses. Especially the PV and H_2 sector are looked more in details. Hybrid renewable energy systems are discussed and how these systems can improve the energy demand in our present centralized energy system. The possible consequences for future models are analyzed and discussed. In the future, innovations will play a decisive role in the use of hydrogen as a fuel. These innovations will generate new and existing business models for accelerate the profitability and sustain the future businesses.

Chapter 5 shows to a closer look for future trends in renewable energy business which we discussed in Chapter 1 to 4. These trends are very promising for businesses working in the field with renewable energy sources. Possible trends in renewable energies can be used profitably for the business interests. Attention is to be paid to the very fragile business structures, which can be changed very quickly and radically by external influences. This requires a very precise and consistent view of the current and possible future situations.

Acknowledgment

We began our journey to analyze the main business models in the photovoltaic and H2 field from the conviction that our research will help other researcher and managers to contribute at the development of measures that will reduce the environmental impact in order to assure a sustainable environment for the next generations.

We are appreciative on the support that we have received from many colleagues in the preparation of this book.

We are grateful to Prof. Alina Dima, UNESCO faculty chair for Business Administration at the University of Economic Studies Bucharest who provided assistance in the editorial process with IGI. We wish to thank Regneala Horatiu, CEO at RENOVATIO Solar who contributes with his expertise from the photovoltaic business field. There are several other people to whom we owe much gratitude, my Phd. Students Ana Maria Santa, Cristian Dobrin and Mihai Macarie that help us in the editorial process.

I (Tantau Adrian) wish to thank my coauthor Robert Staiger for his collaborative spirit, his energy and passion for new technologies, for environmental protection and for renewable energy sources.

On a final note, I am truly grateful to my family (my wife Laura and our two children Carla und Nicolas), to my parents (Rodica and Alexandru) for their love and support through this research.

We wish to our reader's success when working with this material.

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Chapter 1
Business Models in Renewable Energy Industry

ABSTRACT

Business models (BM) are, at present, a dynamic model that is continuously evaluated. The main research approaches are analyzing BM from different perspectives: resource oriented, transaction narrative and also from an entrepreneurship perspective. There remains to be seen how new business models are defined based on innovation and technological improvements for the distribution of renewable energy. Nowadays, on the global political agenda, renewable energy is a solution for reducing the greenhouse gases and their impact to climate change. In order to fulfill the European Union targets for reducing the greenhouse gas emission the EU countries introduced promotion models for renewable energy that are also an opportunity for new business ideas. The selected case studies analyze the main support schemes that are implemented in Europe, for example the Feed in Tariff in Germany and Green Certificates in Romania. Unfortunately, the process of transition to renewable energy is not so easy. The authors are analyzing the main obstacles related to the development of renewable energy and based on a questionnaire research studies they further analyze the main risk factors in the photovoltaic sector in Romania. This chapter should give an overview about the business models and the related opportunities and obstacles for the transition to renewable energy in Europe.

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1. SEARCH ON BUSINESS MODELS IN THE SCIENTIFIC LITERATURE

In the beginning, around 1960, the business model was seen as a "construction plan", a picture of a real enterprise environment with its processes, tasks and communication relations, consequently a basis for business processes and data models (Stähler 2002, p. 38). Meanwhile many specialists present their specific definition regarding business models.

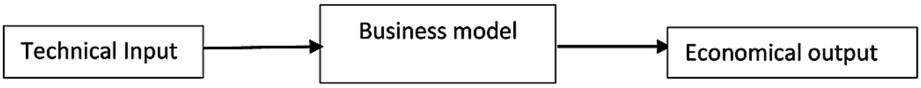
Roland Berger Academy Network defines a business model as a "simplified representation or a picture of the mechanism, the art and mode, how an enterprise or an enterprise system or an industry on the market creates value (Bieger et al., 2002). The same approach can be found at Peter Drucker, who defines a business model as "logic of business" or a "simplified" picture for the reality. It describes the process of creation and internalization of value in a company. In this approach a business model is a static design of the configuration of elements and activities designed to maximize an opportunity with organizational effectiveness (George & Bock, 2011) meanwhile the business strategy is seen as a group of dynamic activities focused on the competitive environment.

According to Chesbrough (2010), the main role of a business model is to connect the technical input with the economic output (Figure 1).

In his opinion, the components of a business model should be the following: value proposition (what is the problem of the customer and how do we deal with it?), revenue concept (sales, costs and targeted profits), channels, chain of value creation and competitive strategy (the pursuit of obtaining competitive advantage). We can refer to Chesbrough as one of the main theorists regarding the *innovation form* of business model. So, a business model is actually a form of innovation which is independent and has a significant influence on the way the technological innovations are commercialized.

In the entrepreneurship approach, the business model concept is a tool for analyzing new business ventures (Chesbrough, Rosenbloom, 2002, p. 532). The entrepreneurship perspectives describe the way a company can capture

Figure 1. Business model according to Chesbrough (2010)



value from technical innovations due to the implementation of a certain business model, after a proper evaluation of its strengths and opportunities. (Bieger et al., 2011, p. 76). In this perspective, an enterprise offers specialized products and services to market niches that are too small to be lucrative to large competitors, but have the potential to grow quickly.

In the energy industry small high-tech firms which create a product are developing innovative prototypes in order to sell not only the product, just the whole company, to corporates like E.ON, Shell Renewables, GE or Siemens.

According to Demil/Lecoq (2010) the business model describes the articulation between the diverse activity domains and the means used by the organization to generate value in a sustainable way. Their dynamic approach based on the following elements: resources and capabilities, organizational structure, value proposition and logistics. They introduce the resource-based approach of business model. The approach based on resources describes the business model as consisting of a series of financial, organizational, know-how and human resources.

Teece (2010) considers that the business model articulates the logic, through which companies create value and redistribute it to clients: as a financial and organizational "architecture" of the business. His model has as elements market segmentation, value proposition, revenue concept, mechanisms for the "protection of competitive advantages."

Business models can be further characterized by their design themes (Zott, Amit, 2008, 3). In the scientific literature novelty and efficiency centered business model configurations are presented as performance drivers (Zott & Amit, 2007). Novelty driven business models create value through new products and services: for example, high investments in R&D, intellectual properties, patents or copyrights. Furthermore, novelty centered business models could create new markets or innovate transactions, when acting on existing markets (Zott & Amit, 2007, 2011). This introduces a transactions structure approach for business models.

Considering the renewable energy business its basic structure consists on: sales before construction, sale after construction, investor ownership flip and homeowner model. The sales before construction business model consist in selling a project that was developed for renewable energy production before construction phase. The project developer acquires land rights, interconnection agreements and power purchase agreements. For the developed project that is sold to a strategic investor the developer receives a development fee from the investor. The business model sales after construction introduces a bank as a partner for the developer until the project will be sold. At investor ownership flip the investor bring the equity and receives a pro-rata percentage of the cash and tax benefits prior to a flip in allocation. At homeowner model the company invests in renewable energy generators, which they will own 100%.

A business model creates the image of a transaction structure (Zott & Amit, 2008). The structure's value and costs must be carefully analyzed in order to make a profitable transaction. Risks should also be taken into consideration by the stakeholders.

A more general definition regards a business model as "an architecture for the product, service and information flows, including a description of the various business actors and their roles, a description of the potential benefits for the various business actors and a description of the sources of revenues" (Timmers, 1998, p. 4).

An attractive and practical oriented model was promoted by Magretta, who defined the business models elements as "a structure of a story and its play mode". "… all new business models are variations on the generic value chain underlying all business." (Magretta, 2002, p. 88). This is narrative perspective, especially to visualize and simplify a firm, in order to communicate how it earns money and what it makes that firm successful.

As a matter of fact the value chain has two main dimensions:

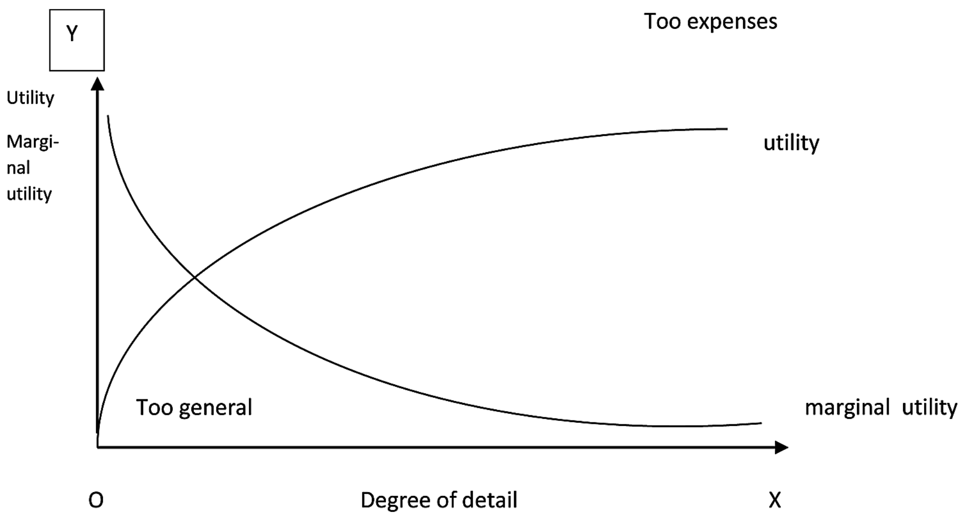
1. All activities, that contribute to the production (from supply to production), and
2. All activities, that are closed to sales as: find clients, transactions, distribution and service.

Magretta considers that a business model has to answer to these questions: Which is the targeted client segment? What is useful for the clients? How can income be generated? Creating a business model is like writing a new story of the old ones. In this approach a new business model is a variation of generic value chain that includes all businesses.

The successful business models presented offer better solutions for the business development and can define standards for a new market. As a result, each enterprise that conducts a sustainable activity has also a fail proof business model. For this reason, "Profits are important not only for their own sake but also because they tell you whether your model is working. If you fail to achieve the results you expected, you reexamine your model …" (Magretta, 2002, p. 89).

All these definitions should take into account that each model is a balance between grade of detail and its utility (Figure 2).

Figure 2. Correlation between utility and grade of detail



The abscissa axis OX consists of the increase of the grade of detail as a variable. The utility or the utility margin is represented on ordinated axis OY. Since the utility can't be represented quantitatively in each specific situation, we can use a qualitative approach for the utility in dependence with the grade of detail. With the increase of the grade of detail the utility is growing. The growth of the utility is reducing when the marginal utility will be achieved. In the case of investing in photovoltaic facilities a business model that describe the main factors that contribute to the business success could generate a good correlation between its utility and its grade of detail. If the business model is to complicate and look for describing in detail all activities that a company is running, then its utility for an entrepreneur is reducing due to the fact that he is focused on his main business idea and as a result the marginal utility is diminishing.

Other business models mentioned in the literature are: customer solutions model, profit pyramid model, multi-component system/installed base model, advertising model, switchboard model, time model, efficiency model, blockbuster model, profit multiplier model and "de facto industry standard model" (Wheelen, Hunger, 2012,166). We hereby provide a short description of each model.

The customer solutions model works like a consulting model by improving customers operations.

In the renewable field the business models could be classified in the classic utility side business models and the more specific renewable oriented customer side business models (Richter, 2012; Wainstein, 2016). The utility side business model describes the classical centralized business with energy that is produced, fed into grid and sold as standard product. In the customer side business model the renewable energy facility is located on the property of a customer. The customer side business model is considered to be an opportunity for new innovations because offers new solutions for energy service providers and introduce a higher level of interactions between actors in the distributions network (Wainstein & Bumpus, 2016).

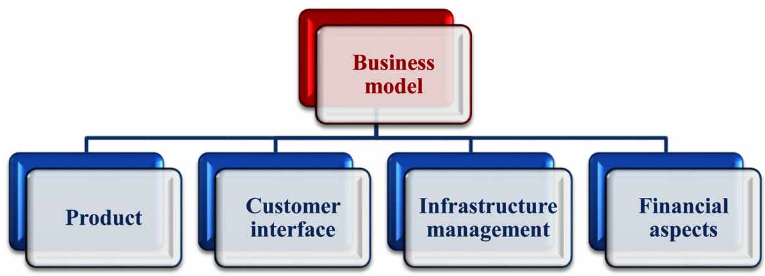
The concept "customer operations transformation" at IBM helps the clients to know how much energy they are using, where can optimize usage and also how to implement their own renewable energy sources. With the "Intelligent Utility Network Solution" IBM can monitor and control operations regarding renewable energy. As an example, the IBM "Wind Power Suite" can provide the real-time information needed to monitor the health of wind assets from multiple manufacturers.

In the profit pyramid model the companies are entering multiple markets with multiple brands. The market segments are positioned according to their size, from the longest (the bottom) to the shortest (the top). The longest segment generates the highest revenues, but with low profit margins. As the segments become shorter, the revenue decreases and the profit margin increases. If we take the example of GE that produced from jet engines, gas and wind turbine to lighting products as bulb in the past or LED (light emitting diode) products at present, we can see that for traditional lighting products as bulb or LED the company registered a lot of units sold per year, but the profit margins are very low. At the top of the profit pyramid GE is selling a few power generators but with high profit margins.

At switchboard model a firm facilitates the encounter among many buyers and sellers. The main purpose is to satisfy as many clients as possible, offering a wide variety of products for all kinds of needs. The InterContinental Exchange (ICE) in Atlanta (SUA) is a on-line stock exchange for gas, oil, energy, precious metals or weather derivatives. ICE is the owner of International Petroleum Exchange (IPE) in London.

In the case of time model first mover advantage is the key issue regarding this model because it allows the pioneer in a certain industry to benefit from all the resources. The early introduced subvention system for the wind turbine industry after the first oil crisis in 1973 create a big home market and gave the Danish producers the first mover advantage in the world market. This

Figure 3. Business model
Osterwalder's approach.



first mover advantage was doubled by a learning-by-doing and technological development approach, which create new competitive advantages.

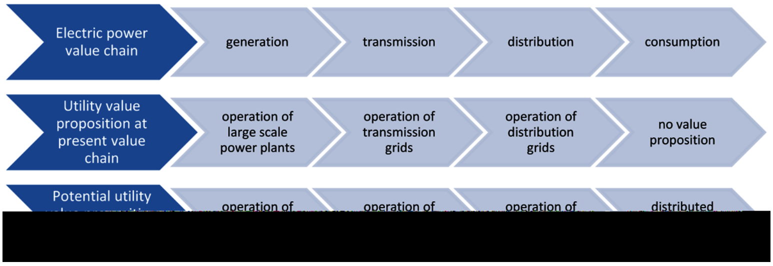
An effective and practical use of business models can be based, from the point of view of Osterwalder & Pigneur, only on a business model, that is intuitive, sustainable, simple and relevant. They define the business model as "the rationale of how an organization creates, delivers, and captures value" (Osterwalder, Pigneur, 2009, 14). Such a business model would help companies to adapt their products and services to the rapidly changing customer expectations and needs.

Osterwalder defines a business model that comprise nine dimensions (Table 2) that are supported by four main pillars. This pillars illustrate the minimal architecture conditions for the eligibility of the business model: the product, customer interface, the infrastructure management and financial aspects (Welz, 2011, p. 46).

The pillar "product" indicates, the industry characteristic to the main activity of the enterprise, which products and which utility it offers to its clients (Osterwalder, 2004, p. 42). Enterprises along with their products can be different from other enterprises.

Each product is a result of the need reflected from its utility. The differentiation represents an advantage that an enterprise offers to its clients along with its product. This characteristic is developed under the name "value proposition". In this approach "value proposition" represents the value creation for customers based on the products and services that a firm create to satisfy the customer needs. From the practical point of view, the value proposition is reflected by the products and services a business offers to the targeted customers and by the needs of target customers which are fulfilled. Customers are playing a central role in business models (Hedman & Kalling, 2003; Morris et al., 2005). As a result, value proposition to customers is a very

Figure 4. Utilities value propositions in the electric power value chain
Richter, 2013, p. 458.



important characteristic for every business model. The previous performance of the company is very important is making customers believe the value proposition (McGrath, 2010).

For example, distributed PV generation promote as utilities innovative and economically sustainable products and services. These new technologies for distributed PV are disruptive technology for utilities, because they include very different characteristics of value creation. The value proposition for traditional utility is the production and delivery of electricity for a fixed price per unit. At present, electricity generation from distributed PV is not cost-competitive with large-scale power plants. Accordingly in order to develop an efficient business model for distributed PV, utilities would have to offer new products and services beyond the mere delivery of electricity for a fixed price per kilowatt hour (Schaltegger et al., 2012, p. 99). In a business that aims to create value, the diffusion of technology may be the key to its success (Inoue & Miyazaki, 2008, p. 1306).

In practice, there are also situations when for a specific segment of the value chain there is no value proposition (for example the distributed PV, Figure 4).

The value creation is the materialization of the value proposition into reality. This materialization can be done by combining the resources (both external and internal) and the capabilities of the firm. In order to obtain the value of a product, we can deduct from the perceived value the perceived costs of products belonging to direct competition. The perceived value is represented by the benefits a customer thinks will obtain by purchasing the product (Belz & Bieger, 2004).

The main attribute for the customer perspective is its precision regarding how the offer will be done. In practice, such precision is one of the most difficult things to achieve.

Table 1. Customer interface

Customer segments
Channels
Customer relations

"Customer Interface" defines the target group for the enterprise, the type of supply, or the services offered for the clients and also a configuration for a strong relation to the customers (Osterwalder 2004, p. 42, p. 60). The customer interface deals also with customer segments, channels and customer relations (Table 1). Mass market, niche market, diversified market or multi-side market are examples of customer segments with their specific needs. The type of relations between a company and its customer is described in the customer relations segment. In order to reach its customer segments a company can use its channels such as own shops, own sales force or web stories.

The pillar "Infrastructure Management" describes the main capabilities that an enterprise has, such as utility to the clients and the customer interface efficiency to help. "In other words, this specifies the business model's capabilities and resources, their owners and providers, as well as who executes which activity and how they relate to each other" (Osterwalder 2004, p. 79).

Elements like "key resources", "key activities" and "key partners" are included in the "Infrastructure Management" pillar. Key resources represent important financial, human or physical resources that make a business model effective. Key activities are presented as main factors that contribute to the creation of the value proposition and are grouped in categories as production or problem solving. Key partners such as buyer supplier relationship, joint ventures or strategic alliances contribute to the acquisition of resources and services, to risk reduction or to business optimizations.

The "Financial aspects" pillar is influenced in Osterwalder's model approach by all others pillars: "Product", "Customer Interface and "Infrastructure Management."

The main "Financial aspects" are "revenue structure" and "cost structure". "Together they determine the firm's profit- or loss-making logic and therefore its ability to survive in competition" (Osterwalder, 2004, 95).

Integrating these elements Osterwalder and Pigneur (2010) developed the nine blocks business model.

The business model developed from Osterwalder has a better presentation of revenue generation. (Welz, 2011, 53).

Table 2. Nine blocks business model

Value proposition
Customer segments
Channels
Customer relations
Key resources
Key activities
Key partners
Revenue structure
Cost structure

Osterwalder & Pigneur, 2010.

This model was developed by Ostervalder and Pigneur (2010) and proposed as a tool for structuring the business models and is known as Canvas business model. The canvas business model is very popular in the last years because is used as a visual tool for representing the elements of a business model and their interconnections. The main elements of the canvas business model are value proposition, customer segments, customer relationships, channels, key resources, key activities, partners, costs and revenues. This structure is easy to be understood and therefore is used in discussions for facilitating analyzes regarding the new business development.

We can apply Osterwalder business model in the photovoltaic field (pV) with the introduction of new key partners as networks or local installers and their specific activities and resources. Besides traditional project developers, research institutions and government there is a need to communicate also with suppliers of photovoltaic systems and local installation firms. Key activities are related to installation of PV systems but also to pre- or post-installation activities as project developing, respective system integration.

A further development of the canvas model is proposed as the Triple Layer Business Model Canvas which expand its structure with two new elements: the environmental and the social value creation. This tool integrates the environmental and also the social dimensions into a more complex concept with three dimensions. The environmental dimension is based on the life cycle assessment (LCA) with its view on environmental impact. Its main elements are: supplies and outsourcing, materials, production, functional value, use phase, distribution, end of life, environmental impacts and environmental benefits. The social dimension has its roots in a stakeholders' management perspective that reflect the social impact of the organization and stakeholders' interests. The proposed elements of this dimension in the Triple Layers Business Model are: local communities, governance, social value, social culture, employees, end users, social impacts and social benefits (Joyce & Paquin, 2016). The Triple Layers Business Model was dedicated to extend a business model structure, as canvas business structure, to an integrated structure that enable the understanding of the economic, social and environmental impact of a business model. This structure can be use also to define a sustainable business model that has as objective the improving of the economic, environmental and social effectiveness of the business. The concept sustainable business model finds its roots in the integration of the business model concept and the theories on corporate sustainability. A sustainable business model is defined as a simplified representation of the elements and their interrelations which an organization use in order to create, deliver, capture and exchange sustainable value for, and in collaboration with, a broad range of stakeholders (Geissdoerfer et al., 2017). Examples of tools that are developed for implementing a sustainable business model are the Triple-Layered or the Business Model Canvas. However, there is a lack of implementation into practice of these tools. Geissdoerfer presents in her study that the gap between conceptualization and implementation of a sustainable business model can be reduced by using the Cambridge Business Model Innovation Process (CBMIP), dedicated for different stages of business model generation, from early conceptualization to implementation. Such a tool could be a guide for managers that are designing the business model.

By developing a sustainable business model a company improved its adaptability in complex environments and gain sustainable competitive advantages.

There are also initiatives which are combining the sustainable development approach with the concept of innovative business models in order to design a business model that could reflect the strategic sustainable development (Franca et all, 2016, Broman & Robert, 2016., Upward & Jones, 2016, Rosca et al., 2016).

The business model was analyzed also from a strategic perspective where in its structure were included strategic elements as: vision, mission, strategy. A representative specialist for this model was Bieger (2004) who introduces the concepts of normative company policy (vision/mission statement), strategy (competencies, strategy of market performance, networks and cooperation) and operative planning (from annual to middle-term objectives and budgets). This approach was promoted by the St. Gallen Model. We have to mention

Table 3. The business model in planning hierarchy of the St. Gallen management model

Normative company policy	Legitimisation of the company Development of vision, mission, ethic code, etc.
Strategy	Accomplishment and protection of the sustainable strategic position Development of strategies on company level, field level and competitive level
Business model	Creation and absorption of value Development of value creating mechanisms
Operative Planning	Operative process control and security of financial solvency

Bieger, 2004; Bieger et al., 2011, p. 25.

that also in the Navigator business model promoted by St. Gallen the core part of the business model known as the magic triangle consist in: value proposition, value chain and revenue model.

This business model consists in analysis, planning and communication of the business activity (Bieger et al., 2011, p. 27).

The business model, due to the fact it is an analysis model, integrates critical elements of the structure of the company and their corresponding interdependencies (Baden-Fuller & Morgan, 2010; zu Knyphausen-Aufsess & Meinhardt, 2002).

Since a business model integrates a planning model, business models are often used not only to plan future operations but also to develop the ones that already exist. (Baden-Fuller & Morgan, 2010; Demil & Lecoq, 2010; McGrath, 2010).

In our approach, we consider that a business model is a method of the enterprise to describe key structural and operational characteristics, how it earns revenue and deliver profit in the current business environment, out of an idea (Figure 5).

This business model force managers to think rigorously about their businesses. It can be used as a planning tool that concentrate main elements of the business and give a clear way of doing business.

Figure 5. Business model based on own approach

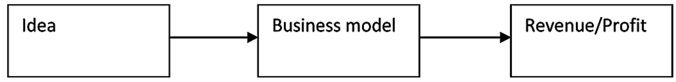


Table 4. Changes of innovation priorities

Type of Innovation	Innovation Priorities 2010-2012 (Ranking and %)	Innovation Priorities 2007-2009 (Ranking and %)
Product innovation	1 (28%)	1 (29%)
Business model innovation	2 (22%)	4 (17%)
Process innovation	3 (22%)	2 (21%)
Organizational innovation	4 (15%)	3 (18%)
Marketing innovation	5 (14%)	5 (15%)

Adapted from Bieger et al., 2011, p. 82.

Regarding the renewable energy industry, the idea is developed in an entrepreneurial context marked by technological, political and market uncertainty.

Nowadays, business models are not static and their dynamic is caused by the continuous changes in the environment as well as the possibility of imitation by competition.

The most important factors that influence the business models are technological improvements and innovations that are promoted in the research studies as sustainable innovations (Bocken et al., 2014). Innovation can create new market offering new technologies.

There are innovations such as products or services that fit with the existing business model. For example, a company that use electrical energy produced by classical methods can also use energy from renewable energy sources.

Business model innovation is more complex than the product or process innovation. Amit&Zott (2012) consider that value is created also through business model innovation. Velu (2016) analysed how the companies innovate their business model based on the incremental and radical business model innovation. He considers that minor changes to the value proposition or value creation of a business model correspond to an incremental business model innovation and major changes of these elements are representative for a radical business model innovation. In the case of an incremental business model innovation the advantage is that the management can maintain control of all aspects of the process and can reduce the associated risk. From a value proposition point of view, by adding content incrementally, the management is ensuring high quality services based on internal resources. However, this process is time consuming, and has to be analyzed if the time needed for designing and implementing the new innovative business model is correlated with the business opportunity (Kindström & Ottosson 2016).

The managerial implication of the business model innovation is related to the management understanding of the importance of innovation also on the business model level. Management has to be strategic flexible also regarding to the business model. If business models are not changed for a period of time then the innovation of the business model is avoided. Therefore, in the energy field, the major utility companies are forced to redesign their business models (Vasagar, 2015).

The innovation of the business model can be postponed only if the business model is able to cover the new domains, using the company's strategic resources, such as capabilities, and core competence. As an example, in the field of large hydro power stations, the ability to react may be high or low, but the motivation for such an action is low. The reason is because the necessary new investments are huge and these are confronted with new regulations regarding environmental impact and with NYMBY (Not In My Back Yard) citizen movements. When the fit is only partial there is a need for migration to a new business model. In practice, there are no innovations or technological improvement without changing the business model.

There are specialists that argue that renewable energies are a techno-economic system that is different from the conventional system. These differences reside not only in terms of characteristics of the power plant and their technological aspects but also in their intermittency, space density, structural and organizational elements, practical regulations and management (Escalante et al., 2013, p. 276; Tsoutsos, Stamboulis, 2005, p. 755). The expansion of renewable energy desire a higher grid flexibility and also supplementary energy services. As a matter of fact, business models for renewable energy have to take into account the *flexibility* and a *timing based approach* in their design phase. A main characteristic of timing based-business models is that these operate active and ongoing timing activities in very short time period. Therefore, the timing based-business models can create and capture value from synchronizing and controlling many demand and supply activities on a micro-level using the information and communication technology. Examples of business models that have timing as a value proposition or value capture in the energy field are: the *power plant optimization*, the *virtual power plant*, the *large scale demand under control* and the aggregation of *small scale demand under control*. The *power plant optimization business model* recommend when and at what capacity a power plant has to run. The motto of this business model expressed that if the timing is correct it generates profit, but if it is delayed it may registered losses (Helms, 2016). Generally, power plants are working with long term, middle term and short tern horizons for optimization. Large power plants are selling their energy also with two years before producing it in order to reduce their risks. On the other side there are firms that create and capture value due to optimizations on a short term approach. These are operating on the day ahead or intraday spot market or on the ancillary services markets where the flexibility is defined in minutes or even seconds. In a *virtual power plant business model* many small generation units are interconnected in order to increase the stability of the system. For example, on the supply side solar and wind facilities are interconnected with diesel generators or battery storage facilities with the goal to create a generation profile that enable the actors in this business model to generate energy into the grid at peak times when the price of energy is high. Also the energy consumers, that represent the demand side have the opportunity to increase, decrease or stop their energy demand. For example, Lichtblick from Germany connected small washing machine plants into the Schwarmdirigent IT platform and offer ancillary services that increase the flexibility in the grid.

Large scale demand response represent a business model that increase the flexibility and optimize the demand side. For such a model, there is a need to learn the industrial consumers, based on intelligent motivations systems, to adapt their energy consumption closed to the grid requirements. *Small scale demand response* business model integrate many small consumers, such as private households, into a smart grid infrastructure. This model is developed in parallel with the new communication and internet technologies that are implemented in the smart grid field (Helms, 2016).

Companies do not choose a business model only based on its theoretical concepts, they need to try it, to see the consequences and then decide whether to adopt it or not. They do that with many models before choosing the one that fits best. Once the new model is adopted, it is adapted to the specificities of the company, usually in the case of start-ups. There is the case of the leader of Internet book commerce Amazon, which didn't invent this type of commerce, but took the idea from a competitor and did it better (Markides, 2008, p. 136).

Building a better business model is more important than getting to the market first.

With the internet and related business concepts such as Internet of Things (IoT) and Mobile Applications (Apps), many new business models have overcome the limitations of time, space, and distance, thus minimizing the locational advantage. Financing is no longer the major barrier when innovative business ideas and opportunities are present. For example, the business model of P2P platforms introduces a new relation between the business actors. In this business model the conventional customers are playing the role of active participants in commercial activities by introducing their own resources to the market place (Belk, 2014). The Internet of Things introduced Internet-connected devices, such as smart phones, that enable the communication between people and smart objects. For example, the Internet of Things technology enable to control a refrigerator or a heating system with a smart phone. Studies indicate that the more novelty-centred an IoT mobile application business model is, the higher is its value retention when venture capital intensity is high. Based on this result the entrepreneurs and managers have to collaborate with venture capitalists in the development process of new Mobile Applications in order to find the proper financial resources and also to provide support for long term radical innovations (Guo et al., 2017).

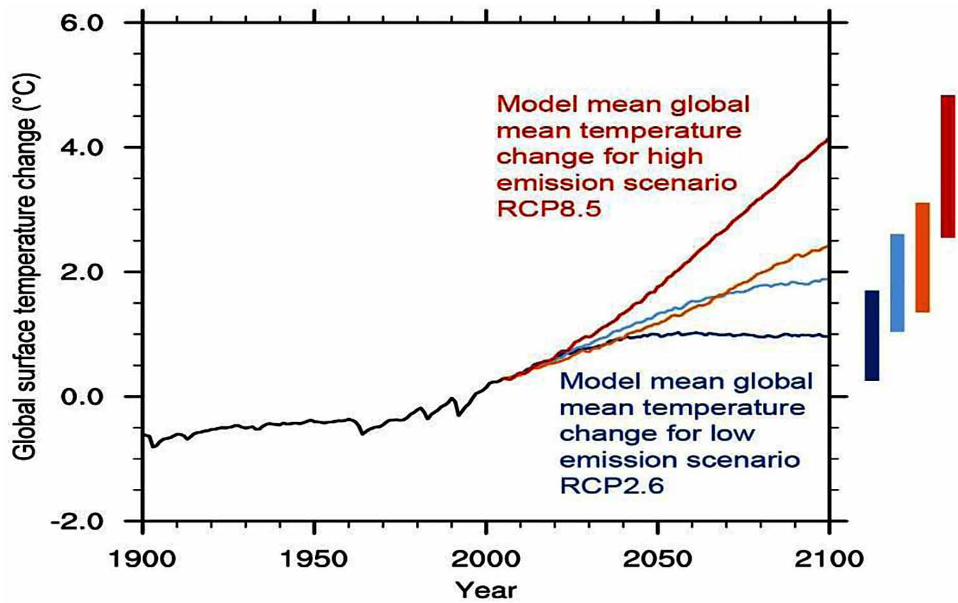
The development of communication and information exchange between Internet of Things mobile devices create advantages to the enterprises which can be direct and continuous connected with their customers. Also, many knowledge workers, consultants, and outsourcing firms are widely available for providing human resources support. Many new innovations that have been hailed as engines of competitive advantage, such as TQM, Business Process Reengineering, Six Sigma, Lean Approach, ERP, Just-in-Time System, on-demand computing, etc. have also become commodities. Many organizations can easily implement these systems and in fact most large firms have either tried it or have them already in place (Lee, Olson & Trimi, 2012).) Thus, the life of competitive advantage based on these systems is indeed very short.

Companies have to develop and implement multiple business models that are using the market opportunities and changing customer demands. New customer needs push companies to generate new business model based on innovations. The main possibilities to develop a new business models are through creating a new hybrid model by combining the new with the current one or a total adoption of a new model, without any connection with the one from the present.

2. PROMOTION MODELS OF THE USE OF ENERGY FROM RENEWABLE SOURCE IN EUROPE

Climate change and sustainable development are nowadays one of the main subjects in the global political agenda. Considering the urgency of the problems and their connection with the impact of greenhouse gas emissions,

Figure 6. Scenarios for global temperature
Source: IPPC, 2013.



many researchers accelerated and advanced their analysis in the last years. The new research results regarding climate change and the increasing of the global temperature due to the impact of greenhouse gases are more seriously taken into account due to new phenomena and figures that characterize the climate change process in the last years. This climate change is more visible due to the loss of sea ice, to the increasing of the sea level, to the increasing of the deserts areas, stronger weather phenomena due to higher energy content in the troposphere like hurricanes, heavy rain and to climate extremes like dry periods.

The main scenarios for the evolution of global temperature indicate an increasing up to 4°C by 2100 (Figure 6). This process is generated, in principle, by the higher concentrated level of greenhouse gas emissions.

The scenario based on a 4°C global warming until 2100 is disastrous. Several studies consider that the 2°C global worming impact looks as well like a disaster (Hansen, 2013, Knutti et al., 2015).

In order to reduce the global warming temperature and its impact a global attitude is needed, which started to be reflected as well on microeconomic and macroeconomic level. Therefore, business models are also an analytical tool for understanding the transition to a low carbon economy (Wainstein, Bumpus, 2016).

The last Climate Conference from December 2015 in Paris set a new agreement adopted by more than 190 countries that has to enter into force in 2020 for limiting the global worming below 2°C above pre-industrial level.

Since 2007, the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC, 2007) recommended substantial reductions in anthropogenic greenhouse gas emissions. It proposed that 60—80% of such reductions would come from energy and industrial processes, an increased use of renewable energy sources as a key mitigation strategy, and it identified numerous policies to support renewable energy expansion.

In the European Union (EU) the climate and energy targets for 2020 where set in 2007, they were introduced in legislation in 2009 and they are known as the 20-20-20 EU Strategy. These represent a reduction with 20% of greenhouse gas emissions (from 1990 level), an improvement with 20% in energy efficiency and 20% of EU energy from renewable energy. Based on the Renewable Energy Directive the EU has to fulfill 20% of its total needs with renewable energy. For example, the assumed share of renewable energy in gross final energy consumption for 2020 are: 49% in Sweden, 34% in Austria, 24% in Romania, 23% in France, 18% in Germany, 17% in Italy, 15% in UK, 15% in Poland and 14% in Nederland (Eurostat, 2016).

Nowadays the EU strategy for 2030 set new target emissions for greenhouse gases by 2030 based on the process of decarbonisation: reducing the greenhouse gas emissions by 40% compared to the 1990 level, increasing the energy efficiency by 27% compared to 1990 and specific for renewable energy an increasing at 27% of the amount of renewable energy consumption is established.

There are many countries where the indirect and direct governmental support for promoting renewable energy is very important. The indirect governmental support is represented by positive discriminatory regulations for the renewable energy technology, such as simplification of authorization procedures and the funding of research and development for technology on the energy supply side. The direct governmental support can be promoted through: the energy regulatory policy (energy targets, feed-in-tariff as premium payment, electricity utility quota obligation for renewable energy), fiscal incentives and public financing (investment or production tax credit, reduction in taxes) and public finance (public investments, public credits).

The countries in the EU have to implement the EU Directives and as a matter of fact have to promote the production and consumption of renewable energy. The main direct support for promoting the renewable energy that we are analyzing in two case studies consist in quotas as green certificates based on the promotion model from Romania and feed in tariff which was implemented on a large scale in Germany.

The research method that we used in order to compare the main promotion models for renewable energy in UE is based on case studies. The case study method can be used for establishing and testing the research questions (Shavelson & Towne, 2002) or, in our case, to analyse a real-world phenomenon, in order to collect data for an experiment oriented study (Yin, 2011).

Case Study 1: Quotas as a Green Certificate Scheme in Romania

The Green certificate scheme combines the obligation of consumers to use green electricity with the certification of green production. As an example, for Romania the quota of energy from renewable energy sources in total energy consumption has to be 24% in 2020 (Low 220/2008). The green certification system brings performance closer to environmental criteria. Its implementation can be design to be technology neutral or technology specific. If for each renewable energy technology is offered the same amount of certificates per MWh generated the promotion model is technology neutral. In this case, the most costs efficient renewable energy facilities are build first. In Romania was implemented the technology specific promotion model where different quotas are established for each renewable energy technology. Such a model has the goal to promote technologies that are in different phases of their life cycle. Investments in in immature technologies for renewable energy generation has to receive more green certificates for each MWh produced as more mature technologies.

The Netherlands were in 1998 the first UE country that promoted a quota certificate system for renewable energy, but only until 2001. Other EU countries that introduced the green certificate scheme are Italy (in 1999), Austria (only between 2000 and 2003, and only for small hydro, but never implemented), Belgium (in 2001), Poland (in 2001), UK (in 2002) and Romania (in 2009).

Each certificate represents the certified generation of one unit of renewable energy (typically one megawatt-hour). As a result, energy producers are entitled to receive a set amount of green certificates for the electricity generated and delivered by them from renewable sources.

In this scheme based on quota (certificates) a certain amount of power is fixed by the state and has to be produced, purchased or bought in a given period by the actors involved in this process. Each state in UE had implemented its own quota promotion model. For example, in Belgium the floor price of certificates has a value of 90 Euro/MWh for off-shore wind and in UK there is an open market for certificates where the brokers can participate (CEER, 2016).

The revenue from green certificates represents additional revenue for the new electricity producers. The market actors with quota obligations have to report each year how many green certificates they need and they receive a certificate account. By trade the green certificates are transferred from the seller's account to the buyer's account.

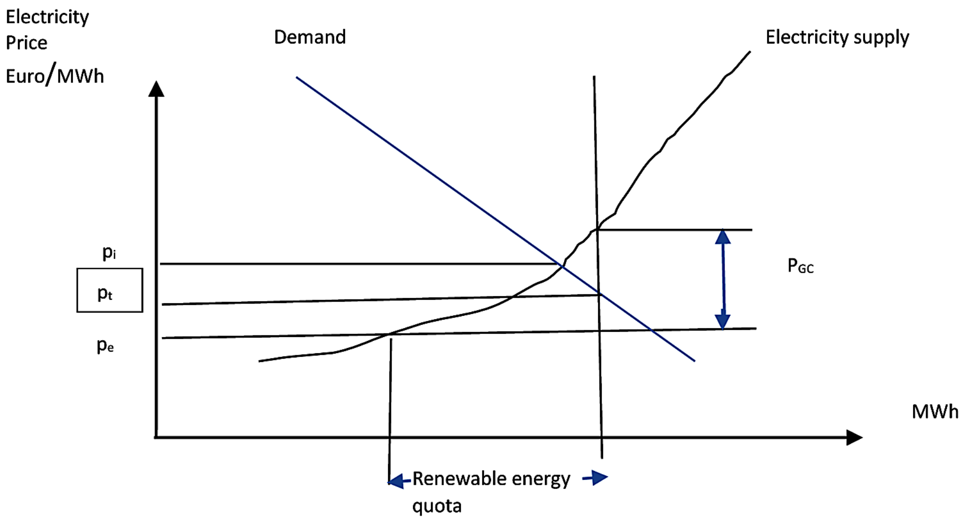
The theory of green certificates has its roots in the Nash equilibrium between agents that are interacting through their payoffs (Nash, 1950, in Helgesen & Tomasgard, 2016). In the last years, there are several studies that develop the modeling part of green certificates transactions (Coulon et al., 2015). The main actors for this process are producers, suppliers, traders and end customers. Electricity distributors and suppliers have the obligation to acquire annually a number of green certificates correlated to the electricity supplied to final consumers.

The basic model for the quota certificate is presented in Figure 7.

The produced energy and the fixed quota is illustrated on the horizontal axis and the price for energy on the vertical axis. In principle, the renewable energy companies will enter the market as soon as the electricity price (p_e) plus the green certificate price (p_g) will cover their short run marginal costs. The resulting green certificate price is given by the intersection between the demand and supply curves. The renewable energy is introduced in Europe as a priority, so it will replace a part of the old energy. As a result, the initial equilibrium market price p_i (before introducing green certificates) decrease to p_e and the old producer reduce their benefits (p_i - p_e) for each MW. The green certificate price that is received by renewable energy producers is covered by a tax rate (p_t-p_e) that the end consumers are paying in addition to the electricity price. As a result, this promotion model finance the more expensive renewable energy compared to the cheaper but more polluting energy generation. From a theoretical point of view, the welfare loss is balanced by the climate benefits.

Certificates provide a tool for trading and meeting renewable energy obligations among consumers and producers. For example, the Law 211/2008, applied from 2011 in Romania gives to the producer six green certificates

Figure 7. Quota certificate scheme and green certificate price
Adapted from Helgesen & Tomasgard, 2016.



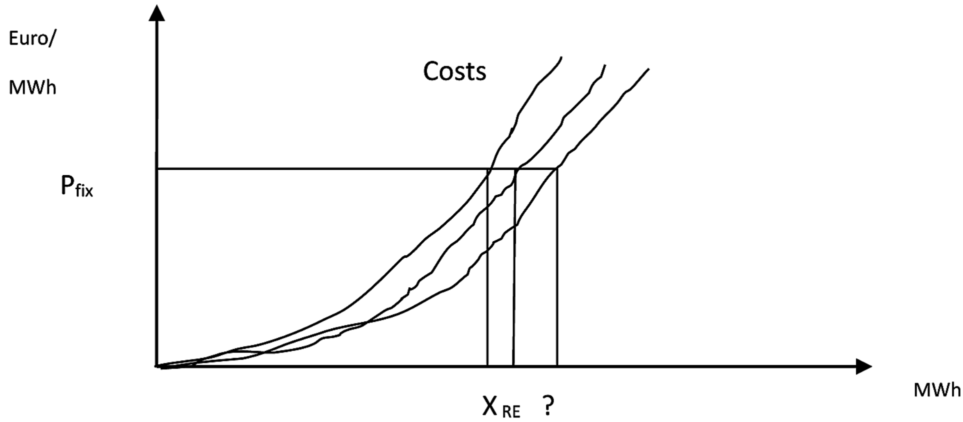
for MW produced by photovoltaic cells and four certificates for wind energy. Each certificate has a value that is between 27 and 55 Euro. The minimum certificate price offer a minimum revenue to the renewable energy producer. We have to mention that the costs related to buying green certificates are added to the utility bill, so that the electricity end users are financing this promotion system for renewable energy.

After the implementation of green certificates model in Romania in 2013, 1.1 GW were installed only from PV. Unfortunately for the investors the new Law from 2013 stipulates that from 1 January 2014 the promotion scheme reduce the number of green certificates from 6 to three for each MW energy from PV that is produced.

Case Study 2: The Feed in Tariff as a Renewable Promotion Model in Germany

A Feed-in Tariff (FiT), also known as a Feed-in Law (FiL), solar premium, renewable tariff is an incentive structure that sets a fixed guaranteed price, at which power producers can sell renewable power into the electric power network. The specificity of feed in tariffs consist in the fact that the producers of renewable energy receive an ex-ante established revenue for every MWh delivered into the grid. Feed-in tariffs are financial schemes ensuring a premium

Figure 8. Feed in tariff
Own contribution.



payment to eligible electricity production. These direct remuneration schemes per unit of energy produces create opportunities for business cases as it can cover the financial gap between renewable technologies and conventional technologies. The feed-in tariff system has been enacted in some countries, in Australia, Austria, Brazil, Canada, China, Cyprus, the Czech Republic, Denmark (in 1992), Estonia, France, Germany (in 1990), Greece, Hungary, Ireland, Israel, Italy, the Republic of Korea, Lithuania, Luxembourg, the Netherlands, Portugal (in 1988), Singapore, Spain (in 1994), Switzerland, and in some states of the United States (APEC, 2009, 12). A FiT is normally phased out once the renewable electricity achieves significant market penetration, such as 20%, as it becomes economically unsustainable.

The implementation of the feed in tariff face some specific conditions related to renewable energy technology, the level of remuneration, the grid access or the equalization of extra costs for renewable energy sources (Held et al., 2014).

The basic model for the feed in tariff is presented in Figure 8.

The feed in support (P_{fix}) is indicated on the vertical axis and the amount in MWh of renewable energy promoted through this scheme is represented on the horizontal axis. The state through government can establish the amount of this support (Farrell&Lyons, 2014). The volume of the produced energy (X_{RE}) in this scheme has to be a result of the market conditions.

Governments can introduce a wide variety of taxes and subsidiaries, but these are usually only maintained for a short period of time, until the market for the energy product is deemed to be established. One of the representative states where feed in tariff was implemented in order to promote the PV renewable energy is Germany (Hoppmanna et al., 2014). In Germany, the Renewable Energy Sources Act (Erneuerbare Energien Gesetzt – EEG), that was revised in 2014, offers to companies that generate electricity from renewable sources the opportunity to receive a fixed remuneration from the transmissions system operators (TSO) for each fed-in-kilowatt-hour for a period of usually 20 years. They need to sell their produced energy themselves on the market and will receive a "sliding" market premium from the grid operators that has to compensate for the difference between the fixed feed-in tariff and the average trading price for electricity. The older companies or the small new installations could continue to claim a fixed remuneration instead of the market premium. The new Renewable Energy Source Act from 2017 stipulates that the feeds paid for generated renewable energy will be established on a competition based by auction. Auctions will be used for funding also the PV energy (www.bmwi.de, 2016). There is to mention that the feed in tariff is financed by the consumers which are paying their electricity bill and are taking the risk associated with this promotion model (Devine, 2014).

Based on the feed-in tariff (FiT) the production of electricity from renewable sources in Germany increase each year from 6.2% in 2000 to 23.7% in 2012 and 28% in 2014 (www.futurepolicy.org, 2016). The new feed in tariff for roof systems starts in 2016 and offer up to 12.31 Euro-cent/kWh for the next 20 years (Fraunhofer 2016, 11).

The paradox of promotion models for PV energy in Germany appears by comparing the promotion business models for households (less than 10 kWp) based on a feed-in tariff (with a maximum of 12.31 Euro-cent/KWk in October 2016) with the own consumption business perspective (www.photovoltaiksolarstrom.de, 2016). The study of Stiftung Warentest (2016) considers that nowadays self-consumption is associated with more profit than the feed-in tariff. This assumption is confirmed as well by Strupeit and Palm (2016), who consider that in Germany, where the photovoltaic sector is dominated by many local installers, the feed-in-tariff and the low interest loans represent an opportunity for building owners to invest in this sector. This opportunity is correlated with the development of storage and technologies for energy transformation. Consequently, in Germany the business model depend on the feed-in tariff scheme. If the feed in tariff (FiT) rates are reduced, then also the PV installation rates registered a reduction.

Due to the high specific costs for feed in tariff the Council of European Energy Regulators (CEER) recommends to use this promotion model only for small scale renewable energy producers and to transform feed in tariff in feed in premiums (CEER 2016). The main promotion models based on feed in premium are: the fixed premium, the floating (sliding) premium and the floor&cap premium. For example, the sliding premium was implemented in Germany and Nederland, the fixed premium model in Italy and Finland and the cap&floor model in UK.

The promotion models for renewable energy production at EU level are enforced by the Energy Efficiency Directive (EED) that mandated Member State governments to set up saving obligation (ESO) schemes for energy suppliers. Such schemes require energy savings equal to a certain fraction of their annual energy sales, for example between 1% and 1.5% (Ernst & Young, 2012, p. 9).

The two case studies presented the main promotion models of the use of energy from renewable sources in Europe. The results show that have a significantly influence to the spread of renewable energy in Europe. Both systems were very generous and encouraged the investments in the renewable energy sector. The green certificates are trading based in renewable certificates market on a short term compared with feed-in-tariff which is more stable and appear to be more successful for a long term. Both systems, green certificates and feed-in-tariff, are establishing an artificial market due to policy maker support.

The main benefits of promotions models that could be easy observed are related to the photovoltaic systems costs. Compared with 2007, when the production of PV modules was in an early phase, with a main pioneer production in Europe, the prices for photovoltaic systems were double as higher as today.

In a long term, the promotion models contribute to the reduction of the generation costs for national energy systems due to developing on new technologies, decreasing investment costs and increasing capacity.

Latest data from Germany, Austria and Switzerland shows that PV electricity generation is in grid parity with today's energy cost. It makes today PV system visible and economically without any energy schemas and subventions (Frauenhofer, 2017). One of the main points are using electricity from PV for the own usage. That means necessary communication and information technology systems (Hardware and Software) must be available. All energy appliances in private, domestic and public building should be suitable for smart grid devices. This features gives another unique business advantages for electrical appliances manufacturer like dish washer, wash machines, heating system (heat pumps device) and future storage system driven with electricity.

From a business perspective, the promotions models for renewable energy represent an important opportunity for new business ideas. In the near future, it is necessary to improve and develop new promotion models for renewable energy in Europe.

3. RISK FACTORS AND GROWTH OBSTACLES FOR RENEWABLE ENERGY IN EUROPE

From a scientific point of view there are two main paradigms that describe the obstacles for the promotion of renewable energy. One is the neo-classic economic paradigm which presents market failures as the main growth obstacle for renewable energy. The second one is the systemic one and it considers that the success of the innovation processes is mainly influenced by the environment where it is developed. This environment takes into account besides market failures other environment systems, as knowledge infrastructure, physical infrastructure, institutions or market relationship (Negro et al., 2012).

Growth obstacles related to the development of renewable energy technologies are grouped by IEA into four categories (based on IPCC (2007), UNEP (2007) and IEA (2008)): *market and social barriers, information failures, regulatory barriers and political risk, economic* and *financial barriers* (Wurtenberger, 2012, 15). These obstacles represent also barriers for renewable energy business models (Engelken et al., 2016).

Market and social barriers include: price distortion, lacking intrinsic interest by energy companies, small scale suppliers of renewable technologies and public acceptance.

The price for energy is too cheap when we take into account the social dimension. A lot of externalities, such as the costs of natural resource depletion, health impacts from pollution, and climate change are not included in the market price for energy. As a matter of fact, project developers do not receive accurate price signals reflecting the true marginal cost of energy use. The relative cost disadvantages of wind and solar power generation compared to traditional fossil fuel sources is balanced by supportive regulatory regimes and financial subsidies.

Energy providers often have no intrinsic interest in energy savings by their customers. Only few companies offer small-scale decentralized solutions, which may compete with their own business model (Powell, et al. 2015). There are small-scale renewable heating and cooling technologies which are produced by local, small and medium sized enterprises. These enterprises have no real economies of scale. On the photovoltaic market the distributed PV generation has also other limits: lack of products and services, lack of customer demand (Karakaya & Sriwannawit, 2015), lack of competences, and lack of profitability (Richter, 2013, p. 461). As a result, there is no sufficient customer demand to justify the development and establishment of a distributed PV business model on a large scale (Yaqoot et al., 2016).

Another market risk is the risk of cost increases for key input factors, such as labour or modules, or rate decreases for electricity generated.

The public acceptance can be observed from different dimensions: socio-political acceptance, market acceptance and community acceptance (Azadian & Radzi, 2013, p. 531).

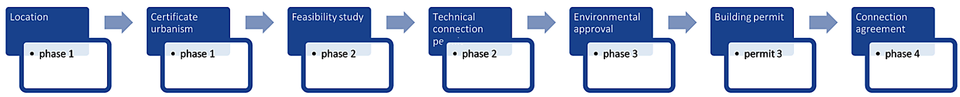
An interesting research result obtained by Bower and Christensen (1995) proved that enterprises which listen to their customers too much, have a higher probability to fail in bringing new technologies to the market. As an argument customers usually show little interest in disruptive technologies that do not address directly to their current main needs within the given environment (Richter, 2013, p. 462). Another observation concludes that the average customer is not able to see the potential benefit of a totally new product before it has come on the market, and that customers do not demand radical innovation, but improvement of existing value propositions. The public acceptance for photovoltaics projects could be reduced if these are geographically dispersed on the field and can induce a NIMBY (not in my back yard) resistance (Tantau & Nichifor, 2016). This can add pressure on local authorities to deny approval requests for new photovoltaic farms projects.

Information failures is described by lack of information on financing options. Regarding renewable technologies there is a lack of adequate information describing financing options available to individuals investing in renewable energy technologies. There is a need to identify the relevant information for PV projects and to find also the proper methods for communication between the main actors in this field (Mosannenzadeh et al., 2017).

Regulatory barriers and political risk are characterized by permitting processes. The risk of a change in policy may affect the profitability of the project, for example changes in levels of the tax credit (Sisodia, 2016). Also, this includes changes in policy as related to permitting and interconnection.

Shifting government fiscal priorities or changes in public support for green energy may thus lead to reversal modification or even abandonment of favorable regulation for renewable energy after they have been implemented (Sen, 2016).

Figure 9. Permitting process for renewable energy investments
Own contribution.



Permits for the installation of renewable technologies solutions are difficult to obtain. As a matter of fact, the implementation process of these technologies is a long one. The implementation of a business model introduces new elements that have to be taken in consideration for an effective investment in renewable energy production. The first phase consists in obtaining the location for the renewable energy facility. In the main cases the investor decides between an ownership title to the land or a superficies right to the land. These rights can be represented through the right of usage, the right of easement or the right of usufruct. For the established location a city planning certificate must be obtained from the local authorities.

The second phase consist in obtaining the technical connection permit to grid. The technical connection permit is given after presentation of a connectivity study that is approved by the network operators. Access can be denied when there is a lack of grid capacity.

The building permit for the construction of a renewable energy plant is part of a third phase of the permitting process. In order to obtain a building permit a complete documentation to the competent authority, that is based on technical documentation, is necessary. This process requires also other approvals or certificates that are specific to the characteristics of the location. Examples of general certificates or approvals are: environmental approval, and examples of specific approvals are: archeological approval, approvals for change of land designation or approval from the aeronautical authority. The general plan that indicates if the building permit for energy production is correlated with other facilities or not is the plan of the municipality; this has to allow the construction on an energy facility. There are municipalities where this plan can be amended by preparing a location or a detailed plan for the specific area considered for the energy production facilities. The environmental approval from the local environment agencies has to give an insurance that the energy facility will not have a significant impact on the local environment (Figure 9).

The next phase includes the sign of a connection agreement and the power-up of the production facility.

The regulatory risk is analyzed in many studies (Tiller & Spiller, 1999, p. 351; Lüthi, 2011) and as a result, in jurisdictions with flexible policy-making processes and less autonomous regulators the risks of policy change is high because governments can update energy policies and introduce policy innovations more rapidly. In jurisdictions with greater regulatory autonomy and more rigid policy processes there is a lower risk of policy change than in the first type of jurisdictions. This result is explained by the fact that regulators are less exposed to short-term political changes and it is more difficult to modify the policies.

As a result, regulatory risks increase the cost of capital, for all renewable energy entrepreneurs (Holburn, 2012, p. 657). Renewable energy pricing is also subject to political control.

In low risk environments, where regulatory agencies maintain autonomy and politicians are constrained from easily changing energy policies, the primary focus for firms is to manage their relationships with the agencies responsible for policy implementation. Since agency decision-making is governed by process requirements and evidence-based reasoning, firms should participate in public hearings and provide comprehensive testimony to support their policy views. Firms need to persuasively demonstrate compliance with agency decision criteria as well as with procedural rules (Holburn, 2012, p. 664).

In order to reduce the regulatory risk the entrepreneurs have the opportunity to create associations or to make specialized lobby that could promote on an institutional level their objectives, by gaining the attention of politicians. Another broad measure for entrepreneurs to reduce regulatory risks is to adjust their market-based strategies in order to respond to politicians' demand. As a response, the politicians will ascribe political value to the business actions of firms that improve their re-election prospects. As an example, by creating new jobs the entrepreneurs give to politicians an opportunity to gain political credit in their election region. The regulatory risk could be avoided by developing technologies and new contractual instruments that limit exposure to adverse policy changes. As an example, entrepreneurs have the opportunity to develop generic technologies rather than jurisdiction specific technologies and to combine different strategies.

- **Economic and Financial Barriers Are Represented By:** Low return on investment, high investment costs, difficult access to capital, higher risk of renewable technologies than of conventional technology and high transaction costs.

The barrier consisting in low return on investment needs to be overcome first. The reality is that renewable technologies are not yet competitive and depend on financial or policy support.

Renewable technologies, for example PV technologies, imply high investment costs (Engelken et al., 2016). The PV systems have high capital expenditures (CAPEX) and low operational expenditures (OPEX). CAPEX and OPEX are continuously reduces due to innovations and improvements in the efficiency of the modules that will make the renewable energy more attractive for investors. In the cell manufacturing innovations will reduce the levelized cost of energy (LCOE) by 2030 in a range between 14% and 17% for conventional c-Si technology, around 22% for high efficiency c-Si and around 25% for thin film technology (Chiantore et al., 2015, p. 23, p. 37).

For the renewable business there is an insufficient access to investment and operating capital (Karakaya & Sriwannawit, 2015).

The lack of profitability is arguably the main barrier of commercializing distributed PV generation. Existing research on innovation and commercialization of new technologies shows that new technologies usually have a disadvantage in terms of costs compared to more mature and established technologies. New technologies for PV modules such as organic photovoltaic, dye sensitized, perovskites or quantum dots have to confirm their efficiency.

Regarding self-generation of renewable energy, the main barriers are mainly related to risk and financial return, and also the payback period that is too long. The future cash flow that has to cover the initial investment in the PV system depends on electricity price (revenue risk) that can also suffer changes in the payback period due to other factors as oil price or carbon price (Tietjen, 2016, p. 174).

Self-generation could come even faster with financing innovations and increasing cost-competitiveness of renewable energy (Ernst & Young, 2012, p. 4). In principle, risk is reflected in the cost of capital that is paid from companies for financing their projects in the renewable energy field.

Renewable energy projects are complex and may entire additional risks. Additional risks related to renewable energies business are: construction risk, climate and weather risk, operational risk, technology risk, sabotage, terrorism and theft risk.

- **Construction Risk:** Is the risk of property damage or liability stemming from errors during the building of new projects.

A relevant risk delays the development approvals for a renewable energy project. The period of time in which sitting, environmental, and grid connection permits are obtained is uncertain for many projects, so that renewable energy entrepreneurs have to deal with these risks. Company risk influences the viability of the project developer. Risks related to personnel, financial solidity and technical ability to execute on plans are examples of company risks.

- **Climate and Weather Risk (Environmental Risk):** Consist in the risk of changes in electricity generation due to lack of sunshine or snow covering solar panels for long periods of time.

Environmental risk represents the risk of environmental damage caused by the solar park including any liability following such damage.

In the case of wind energy, a major risk is the intermittent nature of wind. Electricity must be used as soon as it is generated and the amount of electricity generated by a wind farm is not consistent over time.

The main risk is generated by the high uncertainties regarding speed forecast errors that are reflected in imbalance costs to system operators. Main methods to reduce the imbalance costs are purchasing option pumped-hydro storage (PHS) and new power to gas or liquid systems. Storage alternatives and intelligent controlled systems are the key points for a successful and profitable usage of a fluctuation renewable energy source.

On the other side, if effective and affordable storage technology could be developed, it would be a significant step towards making wind energy more attractive as a viable energy alternative.

Operational risk includes the risk of unscheduled plant closure due to the lack of resources, equipment damages or component failures.

In the case of solar energy one of the major risks is the handling of the equipment and the materials that are used for producing it. The risk for the personal that handle such equipment is to be burned or electrocuted, so that they have to work carefully. Another risk associated with the photovoltaic panels is related to the high toxicity of the materials that are used for their manufacturing. Consequently, the people related risk is also of big concern.

Technology risk can be defined as risk of components generating less electricity over time than expected.

Other barriers related to the technology (Azadian & Radzi, 2013, p. 529) are power losses and power quality. Power quality can be defined by different parameters such as harmonics, voltage variation, and frequency variations.

PV technologies have performance limitations of Balanced of System (BOS) components (e.g., batteries, mounting structures, and inverters) or perceived inadequate supply of raw materials. Currently, Tesla in USA or EoN in Germany are developing and also selling not only new solar batteries with higher efficiency but also photovoltaic facilities with higher performance of the BOS components. Integrated electronics including smart module and micro-inverters or the improvement of inverter lifetime are making PV systems more attractive for inverters.

The risk associated to renewable technologies is higher than of conventional technology due to the characteristics of the new technology and the associated regulations.

Associated services related to implementation of renewable technologies are complex and as a result, also the transaction costs are high.

Development of renewable energy technologies is difficult due to the initial costs involved, the low availability of finance for frontier projects, the frequent need for successful public/private sector participation and adverse public perception (APEC 2009).

Although in the last years the renewable energy technologies are developing, conventional forms of power generation are cheaper to produce than renewables and the governments have introduced dedicated subsidies or other measures for promoting the renewable energy (Holburn, 2012, p. 655).

Sabotage, terrorism and theft risk is evaluated as a risk where all or parts of the renewable energy business model will be subject to sabotage, terrorism or theft and thus generate less electricity than planned.

Close to these typologies is also the study developed by Chavis and Bahill (2010), which grouped the risks related to the solar energy production in: risks related to the utility company and to the grid, project development risks, customer risks, environmental risks and government risks. According to the result of their study the risk of panels receiving less sunlight that expected, especially the weather risk is the greatest one. The second main risk was the grid related to the grid, in principle the grid frequency going out of the +-0.5 Hz limit or feeder circuits disconnects.

Going more closed to the activity of companies in Central and East Europe there is a limited amount of research on risk management in solar energy business. We identified in Romania only a reduced number of articles where some types of risks are mentioned and we have to mention an own research in order to be closer to the risk mitigation strategies in solar energy business (Tantau. et. al, 2013). The study coordinated by Tantau differentiate between internal risk drivers as: workforce, organisational culture, operations, strategy,

Table 5. Internal risk in PV companies in Romania

Risk Source	Type	Description
Workforce	Knowledge	The employees didn/ t have specialised courses and have a low expertise
Organisational culture	Capacity for implementing new ideas	Low capacity for absorbing external ideas and technologies
	Organisational culture	Fear to lose the control on own technology and low trust in other companies
	Management support	Low management support for innovations Level of knowledge regarding risk management is low
Operations	Operational	Damage Stop the PV park production
Strategy	Business	Project feasibility
Technology	Technological	The panels are producing less energy as it was planned
Construction	Construction	The land or the equipment can be damage in the construction or in the test phase

Source: Tantau, Regneala, & Coras, 2013.

Table 6. External risk in PV companies in Romania

Risk Source	Type	Description
Finance	Access to finance	Access to finance for the initial investment is reduced
Environment	Bureaucracy	High amount of documents for each approval Administrative taxis
	Sabotage and theft	Theft of panels or other compounds reduce the level of energy that is produced
Weather	Sun light	The reduced hours of sun light would reduce the quantity of energy that is produced
Legislation	Changes in regulations	The high uncertainty regarding new regulations reduced the predictability and the motivation to invest in PV plants Changes in legislation can influence also the projects for PV that are in the development phase
Policies	Government support	No government support No other incentives for promoting the PV facilities
Market risk	Market risk	The price of input factors could be higher
	Market incertitude	The reduced level on information regarding investments in the PV field

Source: Tantau, Regneala, & Coras, 2013.

technology and construction risk (Table 5) and external risk drivers as: finance, environment, weather, legislation, policies and market risk (Table 6).

According to the results of this study the main risks related to solar energy projects developed in Romania are: bureaucracy constraints, poor access to financing the PV projects and legislation risk. We have to mention that in

Romania the certificate market is heavily regulated by national authorities that introduce a lot of regulatory uncertainty.

This study was focused also on the operational risk expressed by the risk of unplanned photovoltaic system closure like unavailability of resources, system damage or component failure.

In a young industry judging these risks and balancing expected rewards is thus a challenge for renewable energy firms when assessing the attractiveness of alternative jurisdictions for their investments.

The implementation of renewable business models for renewable energy is based on contracts with all parts involved in this process. The contracts define the legal structure of relations between parts and also contribute to mitigate the risk related to his process.

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Chapter 2
Business Development and Environmental Impact in the Solar (PV) Field

ABSTRACT

The techno-economic analysis of a PV system is designed to measure the viability of the designed system from an economical and technological point of view assuming some specific environmental conditions. In this research, for the techno-economic analysis of PV system the authors are focused on four general categories of factors which are highly influential on the investment decision in this field. These are the PV system costs, the electricity cost, the sunlight and other environmental characteristics and the financial incentives. Each of this factors is analyzed in order to understand and evaluate the general conditions that influence the decision in the photovoltaic business. The methodology that is used for explaining the real business environment in PV field and the main indicators that can estimate the investment profitability is the case study related to formal opportunities for developing PV investment projects in Romania. The investors in PV field have to understand the life cycle of a PV system that can give an overlook of the cost reduction opportunities and also make them sensible to the decommissioning phase of such an investment. For future investments in the PV field in Europe the authors identified and analyzed the main factors that characterize the PV business development in the next period.

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Table 1. Decomposed cost of a standard PV system (for 1MWp project in Romania)

System Element	Type	Costs %2013
PV Module	Silicon	40
Structures & foundations	Galvanized steel	11
Electrical equipment	Inverters, trafo substations, connection boxes, cables	26
Works	Electrical, mechanical, civil	14
Others	Fence, lighting, CCTV &	9
Total		100

Source: Regneala & Tantau, 2013.

1. TECHNO-ECONOMIC ANALYSIS OF PV SYSTEMS IN THE RENEWABLE ENERGY INDUSTRY

The techno-economic analysis of a PV system is designed to measure the viability of the system from an economical and technological point of view under assuming some specific environmental conditions. From a scientific point of view there are many initiatives to establish a techno-economic assessment but there is no standard format proposed for doing the assessment, because each project has its particular specifications. The techno-economic assessment is in principle a cost-benefit comparison using different methods as economic feasibility of the project or the cash-flow analysis.

In our research, for the techno-economic analysis of PV system we are focused on four general categories of factors which are highly influence an investment decision in this field. These are the PV system costs, the electricity cost, the sunlight and other environmental characteristics and the financial incentives.

Costs of the PV System

The estimated cost of a standard PV system can be decomposed into a sum of five costs categories: PV module, structure & foundations, electrical equipment, works and others. According to Regneala & Tantau (2013) the main costs associated to the investments in photovoltaic projects in Romania in 2013 were the PV modules costs (40%) followed by electrical equipment costs (26%) (see Table 1).

Percentage of the PV components for a standard system is similar in Germany (see Fraunhofer, 2017).

In general, we can determine that the most labor intensive processes for producing PV modules are the solar cell manufacturing and the module stringing and framing.

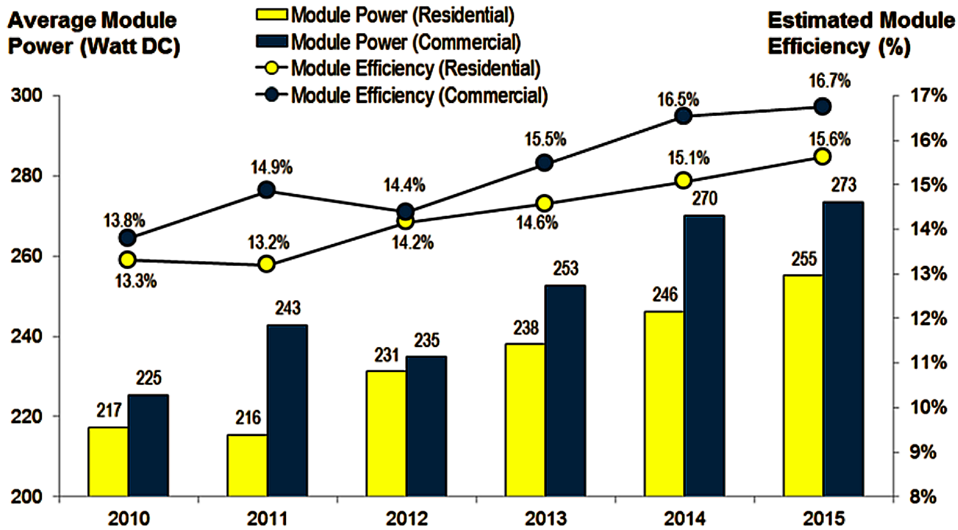
The main metric that is used for estimate the PV systems costs is the price-per-watt (peak) capital cost of PV modules (typically expressed as EURO/W). This metric can be calculated in a number of ways and depend on a wide range of assumptions that span technical, economic, commercial and policy considerations (Bazilian et al., 2013, p. 331). As an example, the price per-watt metric has the virtue of simplicity and availability of data, but has the disadvantages that module costs do not translate automatically into full installed system costs. Different technologies have different relationships between average and peak daily yields, and there is always the question of whether costs quoted are manufacturers underlying costs versus wholesale costs or retail price.

The study coordinated by Chiantore estimate the impact of innovations on the reduction of levelized cost of energy (LCOE). Innovations for c-Si cells, such as nanometric wafers, bifacial solar cells, solar cell structures with contacts on the back, tandem structures optimized for a different part of the solar spectrum, new thinner front cover material, silicone as a new encapsulation material or innovations for thin films, such as improved deposition techniques, improved light management, new materials for improving the efficiency, will reduce also CAPEX and OPEX for PV system (Chiantore, 2015)

The cost and performance of photovoltaic modules and related components of the solar energy system can be estimate with aid of a solar simulator (PV-syst) which gives information about the year round production and emphasize all losses. In parallel, an economic tool such as RetScreen can be used. For effective economic analysis of PV systems, the subsequent sections deal with the knowledge of cost analysis, cash-flow diagrams, payback time and benefit-cost analysis.

A solar module produce a reduced amount of energy and in practice solar panels that consist in an array of solar modules are used. The solar panels require little maintenance and can be used for a long time (up to 25 years). A manufacturer's warranty typically provides that the panels will produce at least 80% of their original capacity for 25 years. This warranty is applied in general for crystalline silicone (both mono- c-Si and poly-mc-Si) as this technology has a good performance over the years and this is a known fact. The first-generation c-Si/mc-Si panels made in the 80s

Figure 1. Dynamic of module efficiency and module power for 2010-2015
Source: Go Solar CA, 2016; NREL, 2016.



have reached 30 years in operation and although they are affected by time (the state of materials), they still work. In the last 10 years' the average commercial efficiency of wafer-based silicon modules increase from 12% to 17% (Fraunhofer ISE, 2016). Similar results are presented in the study realized by NREL (2016) based on the data from the California NEM database (Go Solar, 2016). According to this study the values of module efficiency increase from 13.3% in 2010 to 15.6% in 2015 for residential modules and from 13.8% in 2010 to 16.7% in 2015 for commercial and utility scale modules (see Figure 1).

In the same period the average power increase from 217 Watt DC in 2010 to 255 Watt DC in 2015 for residential modules and from 225 Watt DC in 2010 to 273 Watt DC in 2015 for commercial modules. Not the same thing is applied for the other technologies (e.g. thin film technology as second generation of PV modules), their behavior in time is not very well documented as is new technology and there are not so many plants erected.

From a technological point of view silicon costs represented about 20% of the total module cost in 2012 (Fessler, 2012, accessed in September 2013). The prices for pure silicon have had significant variations due to the supply and demand conditions on the semiconductors and photovoltaic market. From 24$/kg in 2004 the silicon price increased to $450/kg in 2008, dropped to $27/kg in 2012. An important reduction was registered for the polysilicon price with an average spot price of $15.3 per kg in 2016 (pv.energytrend.com). In parallel, average prices of wafers released from $1.00/W in 2009 to $0.35/W in 2012. Average prices of cells diminished from $1.30/W in 2009 to $0.55/W in 2012 (Bazilian et al., 2013, 331) and registered an average spot price of $0.212/W in January 2017 (pv.energytrend.com, 2017).

The price of solar panels has stabilized since the start of 2012, with multicrystalline silicon modules costing less than one Euro per watt. The market price for polycrystalline silicon modules is reduced up to 0.3 Euro in 2015 (www.alibaba.com). The price reduction was unsustainable for many manufacturers and also well-known companies as the German thin-film pioneer Odersun and the German crystalline silicon cell maker Q-Cells. As a paradox, Q-Cells was the world's largest cell maker in 2007, but in 2012 declared insolvency (Ernst & Young, 2012, 7).

Thin film modules have lower production costs compared to silicon photovoltaic modules. These solar cells have one or more thin layers (1-10μm) of semiconductor materials applied on low cost support as stainless steel, glass or plastic. The amount of semiconductor material required for each cell is significant lower compared to c-Si cells and as a consequence also the material costs are lower. Although this technology has lower efficiency rates compared with the technology for silicon modules. The majority of the thin film cells are based on the material called Cadmium-Telluride (CdTe), with a commercial average efficiency of the modules that increase in the last 10 years from 9% to 16% (Fraunhofer ISE, 2016). Also, for CdTe film technology the highest lab efficiency is 21%. (Fraunhofer ISE, 2016). The technology Copper-Indium-Gallium-Diselenide (CIGS) achieved an efficiency measure, in laboratory, that is around 20% (Fraunhofer, 2016).

The main advantages of thin films are their relatively low consumption of raw materials, high automation and production efficiency, ease of building integration and improved appearance, good performance at high ambient temperature, and reduced sensitivity to overheating. Regarding the lifetime performances there is a limited experience.

We can conclude that one of the main performance indicators of PV cells and modules is the energy conversion efficiency and is defined as the ratio between the produced electrical power and the amount of incident solar energy per second. Table 2provides summary the current efficiencies of different commercial PV modules.

The second critical piece of hardware in a solar electric system is the inverter. Inverters are used to convert direct current (DC) into the appropriate alternating current (AC) power required by commercially available appliances

Table 2. Energy conversion efficiency of photovoltaic cells

Type	Energy Conversion Efficiency of PV Cells (Laboratory Tests, Maximum)
monocrystalline-Si (c-Si)	25,6
multi-crystalline-Si (mc-Si)	20,8
Cadmium-Teluride (CdTe)	21
CIS (CIGS)	20,3

Source: Fraunhofer, 2016.

or for grid connection. The power range of inverters used in conjunction with photovoltaic appliances stretches from about 100 W to 1 MW, applying a great variety of circuitry topologies and components (with/without transformer, with multiple inputs/MPPTs, with different voltage ranges, with different construction form factors or with different applications). At present, inverter efficiency for brand products is 98% and higher (Fraunhofer, 2016).

From an economic efficiency point of view, the selection of the invertor with its specific environmental restrictions is establishing a linear programming problem. The objective of this model is to minimize the costs of invertors and PV modules for a required capacity by establishing an appropriate combination of all connected components with their specifications (Báez-Fernández et al., 2016).

The inverter is a relatively small part of the entire system, making up approximately 7 to 12% of the total cost of a photovoltaic system in 2007 (Kaltschmitt et al., 2007, p. 289) and only 5% in 2012 (IRENA, 2012, 20). For invertors, the global average cost has declined from above 1 US$/W in 1990 to 0.14-0.18 US$/W in 2015 (IRENA 2016, 47) and in 2016 the cost was around 10 Euro-cents/Wp (Fraunhofer, ISE, 2016). Invertors registered a significant reduction in material, from 12 kg/W in 2004 to 2 kg/W in 2014 (IEA, 2014, 30). On the whole, inverter prices are going down too, but much more slowly than module prices. Also, inverters do not last as long as solar panels and the case studies assume that they must be replaced after 13 years (Galen et al., 2010).

Inverters as an electronic device are not only transferring DC in AC current very efficiently, inverters are nowadays more intelligent using data´s for controlling energy flows in PV networks, sending out information to the peripherals for energy requirements (WLAN) and trying to increase the profitability of PV systems for tariff feed in and own energy usage in PV applications.

Besides the expenses mentioned above for photovoltaic modules and inverters, mounting frames account for 10 to 15% of the overall investments, depending on the required technology (installation on slanting or flat roofs).

Another indicator that influences the cost of a PV system is the photovoltaic power plant's capacity factor (NCF). Capacity factors vary greatly depending on the type of fuel that is used and the design of the renewable energy system. The capacity factor should not be confused with the availability factor, capacity credit (firm capacity) or with efficiency. The capacity factor is the ratio between the total amount of energy that a PV system produced during a period of time and the amount of energy that the system produced at full capacity. For a PV system, the capacity factor is a function of the insolation at the project location, the performance of the PV panel (primarily as it relates to high-temperature performance), the orientation of the PV panel to the sun, the system electrical efficiency and the availability of the power plant to produce power.

The capacity factor used a standard methodology for the utility industry to measure the productivity of energy generating assets and is a key driver of a solar power plant's economics. The capacity factor indicates the percentage of the maximum potential for a renewable energy system that is actually achieved over time.

When it's comes to several renewable energy sources such as solar power, wind power and hydroelectricity, there is a third reason for unused capacity. The plant may be capable of producing electricity, but its fuel (wind, sunlight or water) may not be available. A hydroelectric plant's production may also be affected by requirements to keep the water level from getting too high or too low. However, solar, wind and hydroelectric plants do have high availability factors, so when they have fuel available, they are almost always able to produce electricity.

The capacity factor's economic impact can be substantial for deciding to invest in the PV field. The highest capacity factor has the nuclear energy where it has increased from 70% in 1970 to 92% in 2010 (NEI, 2016). Average capacity factors for hydroelectricity are 44%. For wind farms these are between 20-40%. The lower values for capacity factors are registered in the photovoltaic field with an average level of 19% (USA) (Hayes, 2011, 49).

For a more exact techno-economic analysis of PV systems there is a need to have a proper estimation based on the following factors (Tiwari, Dubey, 2010, 327): initial investment for the construction of the system, operating cost, annual maintenance cost, life of the system and its residual value.

Cost of Electricity

One main metrics for estimating the electricity costs is the levelized cost of electricity (LCOE) (typically expressed as EURO/kWh). The LCOE is a common way of reporting the present value of the cost of a solar PV project. The Levelized Cost of Energy (LCOE) is defined as the total lifetime cost of an investment divided by the cumulated generated energy by this investment (Talavera, 2016, 237). LCOE is the estimated present value of the cost of 1 kWh of electricity and has a high relevance to stakeholders but require also a wider set of assumptions.

In general, the average levelised cost of electricity generation (LCOE) is calculated with the formula (1)

$$LCOE = \sum_{j=1,n} (I_j+O_j+R_j)/(1+r)^j / \sum_{j=1,n} Ej/(1+r)^j \quad j=1,..n,$$

where:

I_j = investment costs to build in the year j;
O_j = operations and maintenance costs in the year j;
R_j = fuel expenditures in the year j;
E_j = electricity generation in the year j;
r = discount rate; n = life of the system. Source: (http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf; Hernandez-Moro, Martınez-Duart, 2013)

In Germany, due to the learning curve and to the economies of scale, the investment expenditures for photovoltaic systems were reduced on an average value of 14% per year with almost 75% since 2006 (Fraunhofer 2016, 8). The values of LCOE for PV systems are highly influenced by the sunlight and environmental conditions and also by the financial return requirements of investors. The geographical dependency of LCOE is explained due to regional cost differences and due to the different sun irradiation, which influence the amount of energy that is produced (Schmidt et al. 2012). The financial case for PV depends on the financing arrangements and terms available, as well as on the estimations of likely electricity prices over the system lifetime. Since the majority of the expenses of a PV power plant is fixed capital cost, LCOE is strongly correlated to the power plant’s utilization and its capacity factor. To calculate the capacity factor, take the total amount of energy the plant produced during a period of time and divide it by the amount of energy the plant would have produced at full capacity.

The relative cost of energy from a generating source can be compared with the LCOE (levelised cost of energy) parameter. Rather than comparing the present value of the cost directly to the benefits of the solar PV system, it is compared to the cost of grid produced electricity. A review of the methodology for calculating LCOE is provided by Branker (Branker et al., 2011, p. 4475). Making such a comparison is critical in an organization's decision process because they are interested in identifying the least expensive source of electricity. The LCOE of the solar PV system is often compared to the current cost of grid produced electricity, rather than the LCOE of grid produced electricity.

The equation of LCOE evaluates the costs of producing energy and the net production of a plant, allowing comparison of multiple generation technologies with different operation scales, investments and operating time periods. In this way, we can compare a photovoltaic plant with a fossil fuel classic generation plant or another renewable source generator (e.g. wind).

A critical question facing PV generating plants addresses the competitiveness of their energy generation costs as compared with other sources (both fossil or renewable). 10 years ago this question would have remained rhetorical, the current trend of the market places a clear answer to it. The equipment market (cells, panels, inverters) has encountered a real down-flow in the last years and corroborated with the acceptance of these new energy sources into the distribution grids and with the remuneration of green certificates or feed-in tariff, it makes the investments in the photovoltaic generation a profitable business.

This type of comparison is really a comparison of different things because the current cost of grid produced electricity ignores future inflation in energy prices. A better alternative is to calculate the after-tax LCOE of grid produced electricity, taking into account the expected inflation, and to compare this to the LCOE of the solar PV system (Swift, 2013, p. 129).

The electricity costs include possible connection works, both present and future, that will be saved by installing a solar PV system for power residential systems as island or isolated systems. Since solar PV systems have useful lives of 20-30 years it is also necessary to consider future changes in the price of electricity. The EIA forecasts the expected price of electricity in the US for 25 years into the future. In its Annual Energy Outlook 2011, the EIA predicts a nominal average annual increase of 1.6% per year through 2035.

Sunlight and Environmental Characteristics

Sunlight is evaluated by the amount of solar energy yielded in a specific area, where the PV system is due to be erected. The solar energy influence the earth climate system by its solar irradiance that represent the power available per unit area. The irradiance is influenced by the weather conditions and by the sun position in the sky. If we consider only the radiant energy per unit area, we define the solar insolation. Solar insolation is determined by summing solar irradiation over time (Jayakumar, 2009).

The data from the environment conditions will help to design the PV systems on a proper way taking into account the appropriate equipment for grid-connection, the panel planting specificity, the shadowing and the related losses.

According to PV systems the solar radiation can get to an average of 4.1 kWh/m^2/day for a collector plane pointed south and tilted at 30-35 degrees, located in an optimum area. This will yield about 1400 kWh/kWp as net production (Flueraru et al, 2009). Higher solar irradiation values are registered in southern Spain, Sicily and Cyprus (1650 kWh/kWp) and the lowest value is in northern Scandinavia (750 kWh/kWp) (Dunlop, Roesch, 2016, 24). These values can drop if the weather is more than average rainy and cloudy, if the location deviates from optimum (towards North), the tilt is changed, or the pitch of the whole structure is too low (and cause shadowing). Assuming an interest rate of 10%, the PV electricity generation costs in 2008 for utility-scale applications ranged from USD 240/MWh in locations with very high irradiation and capacity factor (2000 kWh/kW, i.e. a 23% capacity factor), to USD 480/MWh in sites with moderate-low irradiation (1000 kWh/ kW, corresponding to a capacity factor of 11%). The corresponding generation costs for residential PV systems ranged from USD 360-720 /MWh, depending on the relevant incident solar energy. (IEA, 2010, 9). The PV electricity generation costs in 2013 in Germany ranged from USD 110 (EUR 78)/MWh to USD 190 (EUR 142)/MWh depending on the irradiance and type of power plant (Kost et al., 2013, IEA, 2014, 15). While these residential costs are very high, it should be noted that residential PV systems provide electricity at the distribution grid level. Therefore, they compete with electricity grid retail prices, which, in a number of OECD countries, can also be very high.

Financial Incentives

Financial incentives include tax and other incentives provided by federal, state, and local governments and by utility companies (Swift, 2013, 138). This category can take into account green-certificates or feed-in tariffs. Much of the deployment of PV has been driven by significant policy support such as through PV feed-in tariffs (FiTs), which have been available in around 50 countries over recent years (see Chapter 1.2). Initially Europe's extraordinary demand growth was stimulated by Germany's successful feed-in tariff program. Other countries followed, and the demand growth has spread to Spain, Italy, France and Portugal among others. At its hearth, the feed-in tariff allows for profits from system ownership. This economically rational stimulus has led to rapid maturity of the market in Europe, encouraging investor groups to view large system ownership as a profitable long-term enterprise.

Once the market for PV is mature the concept of grip parity based on the assumption that the LCOE for PV is less or equal to the price of buying power from the electricity grid is effective. As an example, in Germany the solar PV reach the grid parity in 2011 and the roof solar PV and the scale solar PV reach it in 2012 (Fraunhofer, 2016).

Case Study: Estimation of Power Production Costs for PV Systems in Romania

Currently grid-connected photovoltaic power generation is mainly performed by means of roof-mounted systems as well with an increasing importance by means of so called photovoltaic power plants.

In this case study, we are analyzing three photovoltaic systems. The first system has 7,000 kWp and is a photovoltaic plant mounted on steel frame on the ground. The second system is located on a horizontal roof of an industrial building with an installed capacity of 400 kWp. For comparison purposes and to cover another market segment, a third residential system of 20kWp will also be analyzed. Out of the wide range of solar cell technologies, currently available on the market, exclusively multi-crystalline silicon solar cells with cell efficiencies of 15% will be analyzed, assuming standard test conditions (STC). Under Central European climatic circumstances and current technical boundary conditions, for full-load hours of the analyzed systems amount to approximately 800 hours/year (Site I) for sites in North to Central Europe, to approximately 1000 hours/year (Site II) for sites in Central to South Europe,

Table 3. Technical data of the analyzed photovoltaic systems

		System I	System II	System III
Nominal system capacity	in kW	7000	400	20
Basic material		Silicon	Silicon	Silicon
Solar cell type		c-Si	mc-Si	mc-Si
Efficiency	in %	15.8	14.7	14.7
Technical lifetime	in years	25	25	25
Load hours	in hours/year	1200	1200	1200

Source: Regneala & Tantau (2013).

Table 4. Investment and operating costs of photovoltaic generators (2013)

		System I	System II	System III
Nominal system capacity	in kW	7000	400	20
Load hours	in h/a	1200	1200	1200
Investments				
Modules	€/kWp	600	680	800
Inverter	€/kWp	130	140	200
Further components	€/kWp	620	800	1250
Miscellaneous	€/kWp	150	180	250
Total	€/kWp	1500	1800	2500
Operating costs	€/kWp/year	30	50	100

Source: Regneala & Tantau, 2013.

and to approximately 1200 hours/year (Site III) for promising sites in South Europe to North Africa (Kaltschmitt, Streicher, Wiese, 2007, 288). The unit measure of these variables can also be considered kWh/kWp/year as the unit measure for specific yield. The lifetime of solar modules is estimated to be 30 years for mature technologies (Komoto et al., 2013, p. 92) but in a more realistic and commercial way we consider for our case study 25 years. The technical data of the reference plants is summarized in Table 3.

For these systems, a technical availability of 99% is assumed; i.e. only for 1% of the year power generation is unavailable due to failures or maintenance. This is realistic, as maintenance work can partly be performed when no electric energy can be provided due to the lack of solar radiation (i.e. during the night) (Kaltschmitt, Streicher, Wiese, 2007, p. 288).

The installation costs of photovoltaic systems generally include module and inverter costs, costs for frames, design and mounting as well as further expenditures (including e.g. costs for building permits).

Generally, specific costs decrease with increasing plant size. For instance, the overall specific plant investment costs of a complete 20 kW plant manufactured on the basis of multi-crystalline silicon stretch in average from 2,500 to 4,000 €/kW (excluding value-added tax). For the 400kW plant defined in Table 10 they vary between 1,800 and 2,500 €/kW for the same side conditions. For a 7000 kW system, the overall investment costs for the plant, also based on multi-crystalline photovoltaic cells, are around 1,500 to 2,000 €/kW (Regneala, 2013).

Besides reduced module prices, in case of higher sales quantities, cost digression is also given due to decreasing inverter costs for increased installed capacities as well as by the reduction of other specific costs (including electric facilities, planning and mounting). These cost advantages apply even more to larger plants.

However, due to higher specific expenditures for pedestals and electric installations required for ground-mounted modules, cost advantages are partly compensated. The major share of the expenditures accounts for module costs. For monocrystalline modules, the expenditures are currently roughly between 600 and 800 €/kW (Regneala, 2013). The prices for multi-crystalline photovoltaic modules are slightly below this order of magnitude; they vary roughly between 500 and 600 €/kW. These prices are usually considered for large quantity orders, for example for several MW. For lower installed powers the price goes up proportionally.

Additional costs occur for the installation of the photovoltaic module.

Assuming sufficient experience of the contractor, design costs can be estimated between 1 and 2% of the overall plant investment costs.

Operation costs include maintenance and servicing costs as well as further expenses (e.g. repairs, module cleaning, meter rent, insurance). PV systems do not have moving parts, so operating and maintenance (O&M) costs are relatively small, estimated at around 1% of capital investment per year. There are also technologies that require major maintenance half way through the lifetime of the plant. As an example, inverters in solar plants may need to be replaced before the modules.

Power Production Costs

By means of the annuity method electricity generation costs can be calculated on the basis of overall investments and annual operating costs. For this purpose, a real interest rate of 4.5% and depreciation period over a technical lifetime of 25 years is assumed.

With continuing increasing plant capacities, specific production costs are even further reduced. Operating costs and interest rate have, by contrast, only a minor impact on photovoltaic power generation costs.

Business ideas in the renewable energy industry have to be evaluated for different flows of benefits and costs arising over different time periods. As an example, for this we use discount future costs and benefits in order to compare in a common way the present value. The evaluation has to take into account also various energy resource technology combinations for a given end use. For such comparisons, it is necessary to reduce monetary values at different points in time to an equivalent basis.

Based on these technical assumptions and on the specific environmental and business conditions in Romania we are analyzing these three PV systems from a business perspective. The main indicators that are analyzed are: Cash Flow, Net Present Value and Internal Rate of Return.

In order to estimate these indicators, we should take into consideration some general assumptions about the photovoltaic systems that will be analyzed (Table 5).

Table 5. General assumptions about selected photovoltaic systems in Romania

Assumption	Value
estimated performance	1200 kWh/kWp;
own capital	30% of the total investment
banc credit	70% of the total investment
bank credit duration	7 years
bank credit loan	7% (in Romania)
absorption period	15 years
decrease performance of the system per year	0,5%
number of green certificates per MWh produced	6 (until 2013)
selling price of energy produced	40 Euro/MWp
green certificate value 1st year	Planned 57 Euro but normally about 30 Euro because the offer is much higher as the demand (2015, 2016)
green certificates volatility	-10% in second year of operation and -25% in 4th year of operation (up to 40% in 2016)

Source: Regneala & Tantau, 2016.

For most of the projects that are implemented in Romania the investment is supported by long term loan and own capital investments. In our case, it is assumed that 70% of the investment amount is borrowed at an annual loan interest that is constant and 30% is own capital investment.

For the cash flow analysis, we are estimating the operating incomes as the difference between operating revenue and operating expense. Besides operating expenses, the company must invest in buildings, equipment and in working capital to support its business activities. Last but not least, the firm must pay income taxes. The amount that remains after all these elements have been paid is the estimated Cash Flow. The cash flow analysis for the three photovoltaic systems of 7000 kW, 400 kW and 20 kW is presented in Table 6, with the general assumptions that were presented in Table 4.

The difference between the present value of the benefits during the operational life time of the investment and the costs resulting from an investment is the net present value (NPV) of the investment. A positive NPV occurs when the present value of the future cash inflows exceeds the initial investment. This positive surplus indicates that the financial position of the investor will be improved by implementing the photovoltaic system. Obviously, a negative NPV would indicate a financial loss (Brigham, Daves, 2007).

$$NPV = \sum_{j=0,n} (B_j - C_j) / (1+i)^j$$

Table 6. Cash flow for selected photovoltaic systems in Romania

		System I	System II	System III
Nominal system capacity	in kWp	7000	400	20
Investor own capital	€	3,360,000	204,000	11,400
Bank finance encashment	€	7,840,000	476,000	26,600
Taxable Income				
Insurance cost	€	-252,000	-15,300	-855
Rent, Operations & Maintenance	€	-2,016,000	-122,400	-7,125
Profit tax	€	-3,592,555	-199,714	-9,545
Dividend tax	€	-3,017,746	-167,759	-8,018
Power commerce income	€	42,693,857	2,439,649	121,982
Bank finance cost	€	-2,287,079	-138,858	-7,760
Construction cost	€	-11,200,000	-680,000	-38,000

Source: Regneala & Tantau, 2013.

where Bj stands for benefits at the end of the period j, C_j for costs at the end of period j, n for the useful life of the project and i for the interest rate.

It often happens that (Bj – Cj) is constant for all j except for j= 0. In such a case, the equation can be modified as:

$$NPV = \sum_{j=0,n} (B_j - C_j) / (1+i)^j$$

$$NPV = (B_0 - C_0) + \sum_{j=1,n} (B_j - C_j) / (1+i)^j$$

Since B_0, the benefits in the zeroth year, is invariably zero and (Bj – Cj) is constant (B – C) for j=1 to n (Tiwari, Dubey, 2010, p. 350)

$$NPV = - C_0 + (B - C) \sum_{j=1,n} 1 / (1+i)^j \text{ or}$$

$$NPV = - C_0 + (B - C) ((1+i)^n - 1 / i(1+i)^n$$

with C_0 representing the initial capital investment in the project.

In Table 13 the Net present value (NPV) for the three photovoltaic systems of 7000 kW, 400 kW and 20 kW is presented, with the general assumptions that were presented in Table 5 and 4.

One of the main economic indicators that is used for the economic analysis of renewable energy projects is the same as for other similar investments and known as internal rate of return (IRR). The internal rate of return method provides a rate of return from an investment, rather than using a cost of capital in the calculation, and it is defined as the rate of return, or discount rate, that forces the NPV of the investment to equal zero.

The internal rate of return (IRR) is a widely accepted discounted measure of investment worth and is used as an index of profitability for the appraisal of projects. The IRR is defined as the rate of interest that equates the present value of a series of cash flows to zero. Mathematically, the internal rate of return is the interest rate i_{IRR} that satisfies the equation. (Tiwari, Dubey, 2010, 357).

Table 7. Net present value (NPV) for selected photovoltaic systems

		System I	System II	System III
Nominal system capacity	in kWp	7000	400	20
NVP	€	12,641,817	701,436	33,395

Source: Regneala & Tantau, 2013

Table 8. Internal rate of return (IRR) for selected photovoltaic systems

		System I	System II	System III
Nominal system capacity	in kWp	7000	400	20
IRR	%	13.20	11.24	7.75

Source: Regneala & Tantau, 2013

$$NPV\ (i_{IRR}) = \sum_{j=0,n} (B_j - C_j) / (1+i_{IRR})^j = 0$$

The internal rate of return (IRR) is a dynamic indicator of the investment process. When the internal rate of interest is greater than the achieved rate of interest on the capital market or the Weight Average Cost of Capital, the investment is successful. On the other side for each investment the risk has to be taken into account. Each technological measure has its risk (Hesselbach, 2012, 288).

In table 14 the Internal rate of return (IRR) for three photovoltaic systems of 7000 kW, 400 kW and 20 kW is presented, with the general assumptions that were presented in Table 4.

Based on own calculations the results obtained after the calculation of indicators as net present value or internal rate of return were very good and it is important to mention that calculations have been referred to the year 2013. The results presented highlight the economic profitability for different investments in Romania in 2013 mainly due to the support schema with green certificates. There was a real business opportunity to invest in photovoltaic projects in Romania, where the promotion models for PV with quota and green certificates were very attractive (see Chapter 1.2). This is also the reason why 1100 MW in PV projects were installed in 2013 in Romania compared with the year 2012, when only 46 MW (EPIA, 2015) were installed.

Unfortunately for the business investors starting with 2014 the promotion models were not seen as an opportunity anymore, because there was a significant reduction in the number of green certificates obtained for each MWh energy produced.

In our case study, we analyzed the input data for the three PV systems from 2013 with the new conditions in Romania in 2016 (Table 9).

In Germany, the investment and operating costs of photovoltaic systems in the decay July 2016 and January 2017 are similar (Fraunhofer, 2017).

The PV systems cost decreased in the last years due to the economies of scale effect based on the production on a larger scale of PV modules in China

Table 9. Investment and operating costs of photovoltaic generators in Romania (2016)

		System I	System II	System III
Nominal system capacity	in kW	7000	400	20
Load hours	in h/a	1200	1200	1200
Investments				
Modules	€/kWp	500	550	600
Inverter	€/kWp	60	70	80
Further components	€/kWp	340	400	500
Miscellaneous	€/kWp	100	150	200
Total	€/kWp	1000	1170	1380
Operating costs	€/kWp/year	7	30	15

Source: Regneala & Tantau, 2016

and due to the experience effect based on highly improved manufacturing technology off all components and also due to the availability of large stocks.

We are confronted with a paradox, while the investment and operating costs of photovoltaic generators in Romania are in 2016 (Table 9) sensible lower compared with 2013 (Table 10), nowadays the companies are not investing in the PV sector in Romania and there are almost no new PV projects implemented. The arguments are coming from the reductions in the number of certificates, from the lower predictability of promotions models for photovoltaic projects in Romania after 2014 and from the retroactivity of some measures.

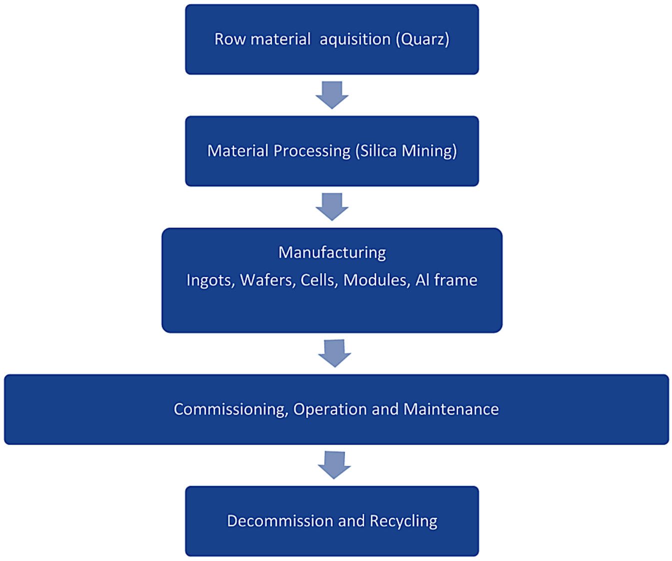
As a final conclusion, there is a need to develop new promotion models for photovoltaic projects in Romania.

2. ENVIRONMENTAL ANALYSIS OF PV SYSTEMS IN EUROPE

The classical environmental impacts assessment of renewable energy systems (RES) has the following basic structure: impact identification, impact assessment relative to traditional power generation, impact classification and prioritization. In our analysis, we describe the impact of PV systems in a variety of specific situations, either beneficial or detrimental.

An important tool used to compare two competitive activities or products is life cycle impact assessment (LCIA). Defined by ISO 14044 in 2006, this

Figure 2. Lifecycle of the photovoltaic panels
Own contribution.



tool enables the understanding and evaluation of the potential environmental impacts of a product or service throughout its duration of life. A PV system environmental analysis, from LCIA's perspective, quantifies the resource consumption and the PV manufacturing technology impact on the environment. Life cycle assessment can be used to analyze the impact of power sources in various life cycle stages, starting from all steps necessary for the extraction of raw materials, manufacturing of components of a photovoltaic system, commissioning, operation and maintenance, decommissioning and recycling of components and ultimately of the whole system (Figure 2).

In the specific case of building integrated photovoltaic (BIPV), the decommissioning and recycling phase may be eliminated thanks to a special architectural design and installation process that increase the integration grade of the PV infrastructure into the building's structure. Such BIPV facilities may replace conventional construction materials, components integrated into the standard architectural concept within the functional building perspective. For example, BIPV resources can replace roofing materials or can be part of facades or building glass. The architectural processes have to take into account that the building structure influences the performance of BIPV facilities, due to the fact that energy efficiency is influenced by the orientation and tilting angles of the PV modules, by latitude or building's surroundings.

Generally speaking, PV power is characterized by the absence of emissions to air, soil and water, waste by-products and noiseless operations. The actual conversion plant lacks any release of toxic substances or particles to the surrounding environment. Consequently, PV electricity, is one of the cleanest forms of electricity generation. Another situation appears when we are analyzing the entire lifecycle of the PV system (Figure 2) where the emissions and also the energy consumption cannot be ignored. Appropriately, the analysis of the environmental impact has to be done for each element of the photovoltaic system and for each corresponding lifecycle. Our analysis is focused on the manufacturing impact upon the environment.

Manufacturing of Solar Cells

Environmental effects related to the commissioning and operating of photovoltaic plants occur especially during the production phase of solar cells. In recent years, they have been discussed primarily in the context of scarce mineral resources usage and process toxicity.

The classical commercial standard for PV modules uses solar cells made from wafers of silicon (first generation), usually 0.3 mm thick and 10 cm x 10 cm in size (Aguado-Monsonet, 1998, p. 9). The thin film modules represent the second generation technology of solar cells, using mainly cadmium telluride (CdTe) which has less energy requirement per W.

Studies indicate that the production of mono-crystalline and multi-crystalline PV systems is more energy intensive than thin film modules (Tsoutsos et al. 2005, 293). It is an assumption based on the materials that are used for manufacturing the PV modules. The basic material for classic PV modules is silicon. Metallurgical grade silicon has as major silica emission, dust which can cause lung diseases. Moreover, the process requires a substantial energy input. In order to obtain high grade silicon purity (more than 99.99%), hazardous materials, such as silane, can be used, together with doping the silicon in inert gas for which small quantities of toxic chemicals, as diborane and phosphine, are diluted. The monitoring and controlling of these materials is well established, according to standards of the microelectronics industry. During the process of PV cells production, which are made of polycrystalline silicon, the continuous purification of industrial silicon proves to be energy intensive and highly polluting (Ye, 2011).

A main indicator for evaluating the environmental impact of a product, from an energy perspective, is the energy payback time (EPBT), representing the period required for the PV system to generate the same amount of energy that was used to manufacture the system itself. The energy payback time (EPBT) depends on the type of technology, production quantity and the region where the PV system is installed.

EPBT = Total primary energy demand (MJ) / Annual power generation (MJ/year)

Annual power generation = Power (W) * Peak sunshine hours (h) * Performance ratio

For multi crystalline silicon cells, studies indicate an energy payback time (EPBT) of 1.5-7.5 years (Sumper et al., 2011). For example, in Germany where the average annual horizontal irradiance is 1055 kWh/m2, the energy payback time is two years (Fraunhofer, 2016, p. 42). Considering a minimum average life time of 25 years for PV modules, the currently installed PV systems are forecasted to produce more than 12 times as much energy as they required during manufacturing.

Due to the technological improvements, a reduction of the EPBT values have been recorded.

In terms of emissions, the environmental impact is estimated through the GHG emission rate. The GHG emission rate of multi crystalline silicon cells varies between 12 to170 g CO2-equivalent/kWh (Fu et al., 2015, Sumper et al., 2011). Emissions are mainly generated during the manufacturing processes of photovoltaic cells and system commissioning. Due to the fact that the main large PV manufacturing facilities are located in China, where the coal used in power plants has a significant proportion of Sulfur, 73.4% of emissions contain Sulfur dioxide (Fu et al., 2015).

Table 10. Environmental impact of electric and electronic equipment for PV systems

	Mining	**Technology Production**	**Conversion**	**Decommissioning**
Exhaustion of row material	-	medium	-	-
Energy needed	medium	medium	-	low
Global worming	low	medium	-	low
Waste	medium	medium	-	medium
Land use	high	low	-	low

Source: Aguado-Monsonet, 1998, p. 14.

Other resources that are analyzed in order to estimate the environmental impact of PV systems are the materials used for manufacturing electric and electronic equipment. PV's electric and electronic equipment is made of steel, aluminum and cooper, which have a reduced environmental impact and are associated with the standard industrial hazards. (Table 10).

A widely agreed environmental impact reduction can be achieved by reducing the energy consumption of PV modules manufacturing. The mono-crystalline silicon technology employs the highest energy consumption, while ribbon-Si modules require the lowest energy demand (Alsema & de Wild-Scholten, 1996).

In terms of toxicity, only low environmental effects are expected from crystalline silicon technologies. However, CdTe and CIS cell technologies are considered more problematic due to their high content of cadmium (Cd), selenium (Se), tellurium (Te) and copper (Cu). Cadmium is generating cardiovascular problems and osteoporosis especially to old people (Pre, 1999). Presenting low concentrations of the chemical elements, it is expected that even in the case of complete cadmium (Cd) release, harmful cadmium concentration to the surrounding air masses can only be reached from plant capacities of more than 100 kW. Other technologies for manufacturing of thin film solar cells, belonging to the second generation, are based on a solid solution of cooper, indium and selenium (CIS). During manufacture of CIS based modules, gaseous toxic substances may be produced (e.g. hydrogen selenide (H2Se)). These are generally associated with a certain environmental hazard potential. In, Ga and Te are critical hazardous materials, together with Cd posing a threat to harm the environment if they are not recovered or disposed properly (Marwede et al., 2013, p. 220). This is the reason for which we consider that CdTe panels must be properly insulated and must be collected for Cd recovery at the end of the life time. Another gas used for the production of thin films PV is nitrogen trifluoride (NF3). Used for cleaning the coating system, it has a significant impact to the environment, 17000 times more significant than carbon dioxide (Fraunhofer, 2016, p. 51).

On the whole, the environmental effects related to solar cell manufacturing are equivalent to those of the semiconductor industry. However, the described environmental effects are relatively low due to the challenging legal environmental protection regulations. This is also true due to the required material purity during solar cell manufacturing.

On the other hand, there might exist a manufacturing related hazard potential in case of malfunction (Kaltschmitt et al., 2007, p. 292).

Commissioning and Operation Phase of a PV System

For a photovoltaic system to become operational, it must also be interconnected with the transmission grid and road system, representing off-site impacts. These site impacts are estimated by the current level of degradation (On-Site Degradation) and by the additional degradation that would be generated by connecting the site to existing road infrastructure, substations or transmission lines (Off-Site Impact). Research studies show that site degradation is evaluated by removal of vegetative cover (Impacted Native Cover) and by fragmentation of habitat (Fragmentation). Whereas Impacted Native Cover represents the ecological condition within an individual grid cell, landscape-scale impacts on connectivity are represented by measures of fragmentation.

Developers of PV systems have to take into account also the conservation objectives of environmental groups. Investors prefer that the renewable energy systems are located close to roads and grid infrastructures, solution also embraced by environmental groups. The use of degraded lands for energy projects is another solution that reduces the impact upon environment.

During the normal operation of photovoltaic modules, no noise is created and no gaseous or liquid pollutants are emitted into the atmosphere. Only the inverters currently available on the market are characterized by a low level of noise, development to be minimized with special design measures. This allows a priori for very environmental friendly power generation.

The main options to locate the PV systems are on roofs (for small power generation systems) and on ground (for large PV systems).

Photovoltaic modules are similar to roofs in terms of absorption and reflection properties. Thus, no major impacts on the local environment is to be expected. Yet, modules mounted on slanting and flat roofs are in some cases visible from long distances. This might impact the appearance of cities and villages. However, such installations do not require any additional space.

Ground mounted photovoltaic generators have the disadvantage of reducing the cultivable land. However, only a small part of the ground is lost for other purposes (for example, around the foundations of the support frames of the solar modules). More space is needed for access roads, electrical equipment and spacing between panel array. The major remaining part can still be greened or extensively be used for cultivation or for sheep pasture, even though other activities among PV panels might pose a security risk.

The land impact can be quantified with the land-use intensity based on following metrics: land area transformation per unit of time-average power output (km^2/GW) or per nameplate "peak" capacity (km^2/GWp), land area transformation per unit of electric energy generated (km^2/TWh) and land area occupation per unit of electrical energy generated (km^2yr/TWh). The metric transformation is based on the changing of the physical nature of the land by installation and the metric occupation quantified the land that was used for a known period of time. The metric occupation estimated the impact both to the installation and operation phases (Turney & Fthenakis, 2011, p. 3264). The appropriate impact assessment on land has to take into account also specific factors such as: topography of the landscape, area of land covered by the PV system, type of the land, distance from ecosystems areas and biodiversity.

The operation of photovoltaic generators is also related to the transmittance of electromagnetic radiation (aspect of electromagnetic compatibility). Unlike classical power plants, photovoltaic plants are generally provided with extensive direct current cabling and with regard to the solar generator, a correspondingly large radiating surface. Furthermore, they are partly installed in the vicinity of residential areas. However, during the installation of such plants, it is generally ensured that the wiring loops acting as antennas are kept as compact as possible. This is a protective measure against both irradiance and receipt of electromagnetic radiation. The latter is particularly critical with regard to lightning strikes in the vicinity of solar modules that could create excess voltages and excess currents, if a wide enough area has been the recipient of the excess power. Also, the destroying of electric components could be an unwanted result. However, the low-frequency magnetic fields emitted by photovoltaic components are equal or lower than those of household appliances. Emissions are considerably lower than those of e.g. television sets. The efforts of manufacturers in terms of module design will further reduce emissions, so that no major impacts have to be expected.

Decommission and Recycling of a PV System

One issue focuses on the recovery of the soil and ecosystem following disturbance, which might require many years or decades. Compared to coal strip mining that affects the land and has a recovery period of 50 to 100 years (mostly the soil takes decades to regenerate) the land used by PV systems will be recover mode quickly, yet there is a need for further studies (Burger, 2002).

Usually, damaged PV modules have been discarded and buried, without any recycling process involved, action negatively impacting the environment (Kang et al., 2012, p. 152). However, a real need for recycling of the PV module is looming. According to current knowledge, extensive recycling of solar modules is conceivable. For instance, widespread recycling of glass components is possible with only little effort. For the recycling of other module components or materials, such as CdTe, highly sophisticated chemical separation processes are employed. Pyrolysis can be used for the recovery of crystalline silicon wafers from mono or poly crystalline solar cells. Amorphous frameless modules are best suited for recycling, as they may be transferred to hollow glass recycling without any pre-treatment.

Possible recycling methods suitable for "classic" photovoltaic modules include acid separation of solar wafers from the bond, transfer of frameless modules into ferrosilicon suitable for steel production, as well as complete separation of the modules into glass, metals and silicon wafers. It is important to analyze the environmental benefits of the recycling. Yet, cadmium tellurium (CdTe) and CIS technologies need to be further assessed in order to determine whether their heavy metal content precludes or requires further processing.

Currently, recycling of photovoltaic modules is not economically viable because the waste generated volumes are too small and only after 2025 or 2030 these volumes will increase by the end-of life of many PV modules. The main treatment and recycling methods for PV modules being tested and used are Deutsche's Solar (treatment and recycling process for crystalline silicon cells) and First Solar (treatment and recycling process for cadmium telluride cells) (Bio Intelligence Service, 2011, p. 6).

In practice, the decommissioning of silicon photovoltaic modules has low environmental impact and can be considered as construction waste. With the expanding of PV energy production and installations, the recycling of photovoltaic waste will be more efficient.

The ensuing environmental effects largely correspond to the common impacts of this industrial branch on the natural environment. However, the recycling of photovoltaic systems is still in its infancy, the related environmental effects will be possibly reduced in the future.

Reducing the Environmental Impact of Silicon PV Modules

Researchers are analyzing the potential to reduce the environmental impact of silicon PV modules. As a result, the environmental impact of PV systems can be reduced in all important phases of the life cycle impact assessment: production, installation, operation and decommissioning and recycling.

Table 11. Environmental impact of silicon PV modules

	Mining	Technology Production	Conversion	Decommissioning
Exhaustion of row material	-	medium	-	-
Energy needed	medium	high	-	low
Global warming	medium	high	-	low
Waste	medium	low	-	medium
Land use	high	low	low	-

Source: Aguado-Monsonet, 1998, p. 12.

The main environmental impacts of the silicon PV modules taken into account are summarized in Table 1.

The increased efficiency and the longer lifetimes should be stimulated for the modules, as for the total system to increase the environmental performance of PV systems. The use of biomaterials based components has the potential to create biodegradable structures with very low impact to the environment. In 2006 the efficiency of organic photovoltaic was only 3% and after some few weeks the photoactive substances were degraded. Heliatek R&D increase its stability and its efficiency and in 2016 announced a new world record of 13.2% for the efficiency of organic photovoltaic multi-junction cell. This result was confirmed also by Fraunhofer Institute for Centrum for Silicon Photovoltaic (Heliatek, 2016). Researches have to find new capsules for stabilization of organic cells in order to increase their lifespan.

As a prevention role, the impact of photovoltaic systems may be analyzed also from the point of view of a malfunction and overall unwanted events.

To prevent hazards to humans and the environment, due to operational malfunctions of photovoltaic generators, generator failures and inadmissible fault currents must be reliably identified and signalized.

The inverter and photovoltaic plant design must allow for power disconnection detection and auto shut-down. Photovoltaic systems must only be connected to strong grids. There is a potential danger of electrocution from the direct current produced by the systems, especially to untrained users. Modern inverters usually include the corresponding safeguarding equipment, so that the above defined requirements are usually met, with protections of voltage, frequency, grid impedance.

By accidental damage of the PV system, that can occur, (for example in the case of earthquakes or fire) the contact of the semiconductor materials with humans and the environment must be avoided. The most serious type of disaster that could occur at a photovoltaic systems is fire, because the semiconductor material could release into the environment and also could cause chemical reactions to take place, producing additional toxic chemicals. Decentralized photovoltaic systems mounted on buildings are potentially exposed to fire. Burning buildings can provide temperatures necessary for oxidation reactions to take place. These, may cause evaporation of certain components contained in the solar cells. These chemical vapors will eventually condense and settle in the surrounding area, generating a source of continued exposure to humans and the environment. However, with regard to cadmium telluride and CIS thin-film solar cells critical amounts of cadmium (Cd), tellurium (Te) and selenium (Se) may be released. For centralized solar farms, fire is not so dangerous because the structures for PV modules can be protected from fire. There are structural materials that are nonflammable or can be treated with fire retardants. As a result, the high temperatures necessary for the chemical reactions to take place can be avoided (Slusarczuk, 1982).

Furthermore, experience has shown that in case of extreme, hardly realistic, elutriation (e.g. due to rain or modules being submerged into brooks or rivers) the limits of the potable water prescription act are not exceeded.

Injury hazards due to falling solar modules, improperly mounted onto roof panels or facades, or in consequence of electrical voltages between electrical connections, may be largely excluded by adhering to the applicable standards in terms of construction and operation of electro-technical plants.

All in all, photovoltaic power generation has a very low propensity towards malfunctions, and malfunctions are always limited to a certain location. Provided that the modules are appropriately installed and operated, hardly any significant environmental impacts are expected.

In conclusion, we consider that the analysis of the environmental impacts of the photovoltaic technology has not to be limited only to production and operational phase of the PV system. It has to take into account the whole life cycle including the decommissioning of the PV panels and also recycling. The analysis indicates that the main environmental impact of the production of PV modules is generated by silicon wafer which is high energy intensive. Due to the growth of photovoltaic facilities will increase the PV waste in the coming decades. In order to reduce the environmental impact of photovoltaic systems it is important to monitor and increase the efficiency in the whole life cycle and also to find proper measures for recycling the valuable materials. The ecological design of the photovoltaic system will be an interesting solution to enable an appropriate treatment of waste from photovoltaic modules.

3. PHOTOVOLTAIC BUSINESS DEVELOPMENT IN EUROPE

The global photovoltaic market registered a continuous growth in the last years. Photovoltaic (PV) systems are increasing in popularity as source for electrical energy. The demand for PV systems has grown by an average of 30% per year over the period 1990–2010, on the background of cost reduction (Solar Energy, 2011; Paicu & Regneala, 2013). The costs for solar PV systems decrease between 2008 and 2015 up to 60% (MIT, 2016). This decreasing cost has been driven by manufacturing economies of scale, manufacturing technology improvements, and the solar cells improved efficiency.

The growth phase of photovoltaic business reached its limits in 2013, from a European regard. Due to the rapid growth of the Asia region the market share of European PV installation was in decreasing trend since 2013. A generally comparative view could easy show the turnover trend on the photovoltaic market (in special the manufacturing sector) of 20bn Euro in 2010 and only 2.5bl Euro in 2014 (IEA, 2015). However, the solar installed capacity in EU exceed in 2016 the historic milestone of 100GW and for that moment EU was a world leader (Dunlop & Roesch, 2016).

One important year for the European business in the PV field was 2011 when in manufacturing equipment Europe reached 50% markets share. A huge market shares for the PV systems in Europe were also for construction (70%), financial services (70%), operations and maintenance (70%) (Ossenbrink et al, 2015). The decline of photovoltaic manufacturing in Europe was generated mainly by Asia low cost competition, driven by China and the relocation of important production facilities for cell module production from Europe in that region. In 2015 China with largely manufactures registered, leaded the production of PV with 71% market share. In the same period, Europe owned 5% share (6% in 2014) and USA with Canada only 3% (Fraunhofer ISE, 2016; Frankfurt School-UNEP Centre, BNEF, 2017). The competition was as dramatic as Suntech which was the leading company in the world for photovoltaic manufacturing in 2010 and 2011 declared bankruptcy in 2013. In 2015 in top ten world photovoltaic manufacturing companies from Europe was only Hanwa Q-CELLS (Mints, 2016). Also, the Joint Company Hanwa Q-CELLS with ownership from South Korea, Germany, China and Malaysia and with production facilities in Germany switched its manufacturing facilities to Korea. The main activity of Hanwa Q-CELLS in Germany remained the technology development and innovation. The Asia paradox, due to an excess in the photovoltaic production capacity and a high imbalance between product supply and demand on the local market in China rice news problems.

In Europe, main photovoltaic production facilities are located in Germany, Italy and UK. In the European Union, the most of PV module producers have smaller capacities (typically < 100 MW) with niche products. The EU companies that have a PV production capacity with more than 200 MW are: SolarWorld (Germany), Sonnenstromfabrik (Germany), AleoSolar (Germany), Hecker Solar (Germany), SolarWatt (Germany), Astro Energy (Germany), Solaria Energia (Spain) and Jinko Solar (Portugal) (Fuhs, 2016). The leader Solar World AG produced silicon wafers, solar cells and solar modules for solar energy systems. The SolarWorld has one main production capacity of 500 MW in Germany that is located in Freiberg (Saxony) and another production capacity in USA.

The new perspective for PV renewable energy consists in reaching a cost-competitiveness position through elimination and reduction of reliance and unreliable government subsidies. The strategy consists in lowering fossil fuel subsidies and obtaining suitable carbon floor prices. The solar market offer a high potential for new market entrants (low level entry barrier) than wind market. A solar PV installation is less likely than a wind project to create problems with the local community, either in the planning process, or in relation to concerns about wildlife and the local environment. Barriers to entry are coming down, and there have been improvements in technology and efficiency, creating a huge potential for costs to fall. With increase in efficiency and large amounts of solar manufacturing, the price should continue to fall.

The PV price reductions represent an important subject for the design of business models. The value proposition in the PV business models has to illustrate the reduced complexity and transaction costs of PV systems. However, the value proposition has different values in different EU states. In Germany, value proposition is focused on delivering to the customers a green energy that is correlated with a low risk for the financial investment and with an appropriate rate of return for building owners (Strupet&Palm, 2016). In Romania, the value proposition is more focused on the lower consumer transaction costs and on the possibility to reduce the total energy consumption on the electricity bill. Another main subject for the value proposition in Romania is the access to dedicated photovoltaic credit programs and to financing mechanisms for PV systems. These differences explain why the business models are specific for each state and depend also from the location.

Today, the vast majority of PV modules, up to 93%% of the global annual market, are based on wafer-based c-Si (Fraunhofer ISE, 2016). Crystalline silicon PV modules are expected to remain a dominant PV technology until at least 2020, with a forecasted market share of about 50% by that time. This is due to their proven and reliable technology, long lifetimes, and abundant primary resources. The main challenge for c-Si modules is to improve the efficiency and effectiveness of resource consumption through materials reduction, improved cell concepts and automation of manufacturing.

New studies related to crystalline technologies estimates that the cost of modules will decrease between USD 0.30/W and USD 0.41/W by 2025. The greatest cost reduction potential will register the polysilicon production (IRENA 2016, 12,13). Other cost reduction will be reflecting in the cost of PV invertor technologies out to 2025. IRENA study consider that invertors cost will be reduced with 33 and 39% between 2015 and 2025 (IRENA, 2016, 47). All these cost reductions will contribute to a significant reduction with 59% between 2015 and 2025 of LCOE of utility-scale PV systems. In this case the PV project costs will be situated between USD 0.03 and USD 0.13/kWh (IRENA, 2016).

Major improvements will be made to multicrystalline silicon module efficiency which is estimated to increases from 16% in 2015 to 19.5% in 2025. In the same period the module efficiency for monocrystalline modules will grow from 17% to 21.5% (IRENA 2016, 43).

Thin film technologies are in the process of rapid growth. In the last years, thin film production units have increased from pilot scale to 50 MW lines, with some manufacturing units in the GW range recently announced. In 2015 the market share for all thin film technologies was 7% of the total annual production (Fraunhofer ISE, 2016). CdTe cells are a type of second generation semiconductor thin film that is mainly used for solar cells. These have a relatively simple production process, allowing for lower production costs and a lower cost-per-Watt among thin films. CdTe has an energy payback time of eight months, the shortest time among all existing PV technologies. For other thin films as CIGS cells, the fabrication process is more demanding and results in higher costs and efficiencies compared to CdTe cells. The most important disadvantage of CdTe cells is that Cd is a highly toxic element which is must not be allowed to enter the environment (see Chapter 2.2).

Concurrently, the use of energy and materials in the manufacturing process will become significantly more efficient, because the energy pay-back times is reducing continuous. This is expected to be reduced from two years in 2010 to 0.75 year in 2030 and below 0.5 year in the long term. There has to be taken into consideration that the energy pay-back time of PV systems is influenced by the geographical location and solar conditions. This is 2.5 years in Northern Europe compared with 1.5 years in South (Fraunhofer, 2016).

The operational lifetime of PV is expected to increase from 25 in 2008 to 40 years in 2050 (IEA, 2010, 22).

The current price drop has released some pressure on this trend, moving cost down pressure to increase the solar cell efficiency. R&D and industrialization have led to a portfolio of available PV technology options at different levels of maturity.

Emerging PV technologies comprise advanced inorganic thin film technologies (e.g. Si, CIS) and organic solar cells. Organic solar cells are potentially low cost technologies for specific applications. For concentrating solar technologies an emerging technology is combining a photovoltaic cell with a thermal radiation source.

New PV concepts are developing active layers for the solar spectrum or which modify the incoming solar spectrum by using nanotechnology and nanomaterials. Quantum wells, quantum wires and quantum dots are new types of structures introduced in the active layer.

Also, the CPV technology is presently moving from pilot facilities to commercial-scale applications. The tendency is to improve the optical systems, module assembly, tracking systems, high-efficiency devices, manufacturing and installation.

Researchers but also investors are looking for new technologies to gain energy and heat energy simultaneously (Othman et. al, 2013, 171). The new opportunity in business could be the hybrids system known as Photovoltaic-Thermal or PV/T collectors. Another emerging technology that is deep analyzed in research centers for PV systems is the building integrated photovoltaic (BIPV) that can use both crystalline and thin films technology. The BIPV is used for roofs, skylights and facades because is semitransparent, flexible, has a low weight due to its thickness and also lower installations costs compared with the traditional PV systems. However, there is a need to balance the transparency and the energy efficiency because as more transparent the thin films are, the energy efficiency of BIPV modules is lower. More flexible BIPV products are made from foil, but from a design perspective solar cells glazing have a more esthetical look (Tripathy, 2016). For the BIPV facilities that are installed close to the roof or building insulation the temperature on the surface of the modules is higher. Due to the fact that the energy efficiency decrease when the temperature on the surface of the module increase up to a specific temperature there is a need to find solution for reducing the temperature or his influence. The building integrated photovoltaic is technological possible to be implemented (Yang & Athienitis, 2016) and may transform buildings from energy consumers to energy producers, but is still connected with high costs and also there are no real standards implemented for this technology. However, the building-integrated photovoltaic has to play an important role for achieving the new EU objectives for a nearly zero-energy building.

The photovoltaic sector trend is to reduce the manufacturing costs and to improve the supply security by integrating in a single location the value chain associated with the production of PV modules (EPIA, 2011). In order to reduce the costs of the photovoltaic systems companies are looking on measures to optimize the whole value chain of photovoltaic systems. In the production chain the companies are investing in manufacturing automatization and in high capacities in order to reduce the costs. Another measure to reduce the manufacturing costs is connected to the technology innovation in order to reduce the production costs as well to increase the module efficiency. The classic cost reductions in the procurement chain are realized through the leveraging scale of contracts for materials and equipment. The next cost reduction strategy will consist in positioning the manufacturing of photovoltaic systems close to the clients, close to the largest available demand in order to cut the transport costs and also to develop new business models for PV energy services.

For the photovoltaic business, the global trend is to increase the installed capacity of PV systems in order to increase the energy efficiency. The goal of EU to achieve 27% share of renewables by 2030 is based also on the high potential of photovoltaic systems to increase the efficiency of the PV modules and to reduce the costs of this systems. Besides this, in EU there is a need to develop new policies that will reduce the administrative barriers and soft costs for the renewable energy and will insure a stable investment environment for new PV systems.

The estimated growth on the photovoltaic market in 2030 the photovoltaic will represent 15% of the overall electricity demand (Ossenbrink et al., 2015). Accordingly, to these assumptions the photovoltaic business models will be significant different compared with the classical business models that are implemented in this field. The distributed photovoltaic power will promote new principles for electricity allocation as "spontaneous power for private use, surplus power on-grid, and grid adjustment" (IRENA, 2016). Large scale distributed PV systems will be promoted especially in industrial parks where the electricity price is high by industrial but also commercial companies. On the other side hospitals, schools, institutions, households will implement small scale PV systems. The electricity market will be dominated by large size capacities of multi GW with mass production. As a result, the large scale manufacturing facilities and big companies will have an important impact on the global photovoltaic business. Also in EU rise a need to implement new PV concepts that could be more competitive. Regarding this, Fraunhofer ISE researchers are promoting the concept xGWp for a Gigawatt-size PV cell and module factory in Europe. For the future EU policy, there is a need for a systemic approach that could integrate the industrial and energy policy. This has to be supported also by a new fiscal and taxation policy in EU where the energy price is much higher than in USA.

The new competition will force the small and medium companies to rethink their photovoltaic business that has to be focused on products or services with a high added value. The small and medium companies are seen as the next innovators on the photovoltaic market. These companies have to develop new technologies and new ideas that may reduce the solar cells costs.

There is a need to support the innovation ability by training the human resource in the PV field.

The solution to develop the photovoltaic business will be supported by new research in the field of emerging technologies and the smart integration of PV systems in energy systems, which could be promoted through long-term cooperation between leading companies and research institutes.

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Chapter 3
Business Models With H_2

ABSTRACT

Energy transition from a carbon energy driven world to a decarbonized world (H_2) is essential for the living for our next generations. Our existing energy source with contents in the beginning (1850) nearly only the element C are used with all their consequences for the burning process and environmental impact. Nowadays the C element in our present energy sources are getting less and less. The environmental impact using fossil energy is huge and with the climate change more and more deadly for the inhabitants on the earth. Producing H_2 as a sustainable and renewable energy is only possible using renewable energy sources like PV, Wind, Hydro, Biomass. With today's technology and the constant falling energy prices since the last 20 years H_2 is now an alternative secondary energy source for a substitute for fossil sources. Using H_2 will give new and unique business advantages. With these business advantages, new and innovative business models can be designed and developed. These novel approaches can be very sensitive to external influences. This destructives situations are making these BM very fragile. Finding ways to stabilize these on a long term without aid from the outside the key for success are new innovative technologies and new innovative BM.

ENERGY TRANSITION WITH HYDROGEN AS A RENEWABLE ENERGY SOURCE

Limited and unlimited energy sources are the key factors for the humankind in all areas of live. Depending of the quality of energy more or less work can

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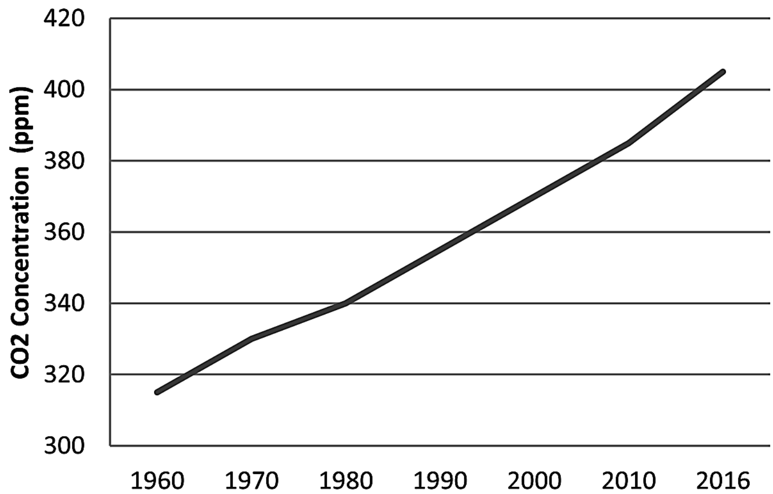
Figure 1. CO_2 concentration keeling curve
Moauna La, 2017.



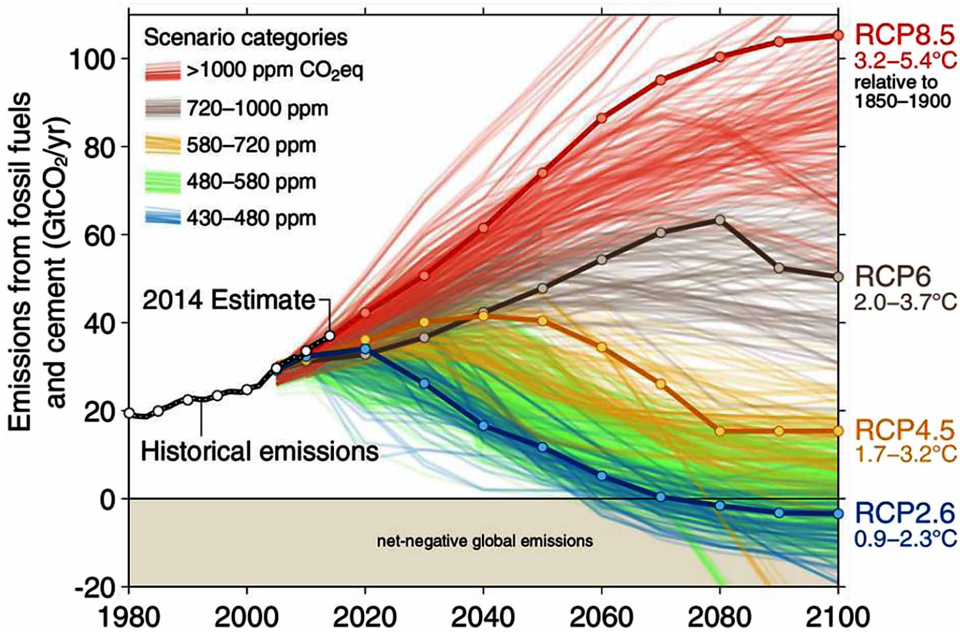
be done. Today's energy conversion processes with fossil fuels substantially contribute to global warming and climate changes. (Vallero, 2014; Drake, 2014; Stern, 2014; Howar, 2014; Le Quere, 2014).

To reduce the anthropogenic greenhouse gases, new ideas and concepts for RES and energy conversion systems are required. Anthropogenic greenhouse gases, which results from burning fossil energy sources like coal, gas, and oil are changing our climate rapidly. CO_2 is the second most important greenhouse gas, which influence our global warming process and therefore our live on earth in different ways. Since the start of the industrialization in the 1850th, the CO_2 emission increased over 40%. The amount of burning fossil energy sources in 2015 is more than oil equivalent of 10.500 million tons (BP 2017). At present, more than 400-ppm CO_2 concentration in average is in the air (Figure 1). This CO_2 concentration is increasing constantly each year through human activities.

One of the most important greenhouse gases which influence the global warming process is the amount of CO_2 in the air. In order to achieve the global climate targets, which were agreed in Paris January 2016 rapid action globally is required to reach the 2°C scenario (Rogelj, 2015; Hansen, 2015; Crastan, 2015) keeping the warming process in human hands.

Compared to the reference year 1990 the amount on CO_2 increased over 60% to today's figure. The IPCC global warming scenario in 2015 shows the curves in which direction we are moving.

Figure 2. IPCC scenarios
Fuss, 2014.



Research of climate changes and sea level rise over the last 20.000 years shows an increasing of 3.5 K and a sea-level rise of over 100 m up to 10.000 years B.C. Since this time, the temperature change was only around +/- 0.3K and sea-level rise were constant (Gornitz 2015). Since burning fossil energy sources beginning in the 19^{th} centuries the temperature rise around 1,4 K and rapidly increasing (Marcott 2013). The amount of ice which is left on the earth would theoretical rise the sea-level max 60 m until no ice is available any more. Looking to the rapid temperature change in the last 100 years (1.4 K) in comparing the sea level rise from 20.000 B.C. to 10.000 B.C. (3.5 K) of over 100 meter we should start thinking what will happening for the next decade if we cannot stop the climate change!

International crisis were a starting point for the transition at global level. The first and second energy crisis in the 1970s, the meltdown in Chernobyl in 1986, the Fukushima catastrophe in 2011, the scientific evidence of the anthropogenic greenhouse gases and there creeping ever increasing climate change are the main economic and environmental trigger point, moving in a more save and secure energy transition future (Vaclav, 2014; Henning, 2015; Brow, 2015).

The first and second energy crisis in the 1970^{th} (Yergin, 2008; Merril, 2007), political discussion, changes with the green movement and the new approaches for an economic future (Club of Rome 1975) started an energy transition process at national and international level.

The consequence of the meltdown in Chernobyl was huge. In Europe, radioactivity is still measured and detected. Through human error the reactor exploded (Medwedew, 1991). More than 10^{18} Becquerel were released (Fairlie, 2006).

Strongly exposed groups of people of the general population were about 116,000 persons who were evacuated in 1986, about 230.000 persons who were resettled in subsequent years, and about 270.000 persons who were displaced in "heavily contaminated" areas (WHO, 2005).

In December 2016 thirty years after the disaster one of the biggest engineering project closed the reactor core with a special shielding roof to try to protect the environment for excessive radiation exposure and costed over 1 bill €.

Official figures of people killed by radioactivity lay at 4,000 (WHO, 2005). Other scientific investigations (Fairlie, 2006) talking about fare higher deaths.

The World Health Organization (WHO 2005) estimates that the radioactivity of Chernobyl was a total of 200 times higher than the released radioactivity of the atomic bombs of Hiroshima and Nagasaki. 40% of the total areas in Europe were contaminated with cesium-137. In Germany, the cesium-137 values in the muscle meat of wild boars reached 40,000 Bq/ kg. The average value is 6 800 Bq/ kg, more than ten times the EU limit of 600 Bq/ kg.

The Japan earthquake in March 2011 and the consequences on the Fukushima nuclear power plant is still a mayor issues worldwide. Human failure in the planning and construction of the nuclear power plant, right on the sea caused three core melting through a Tsunami in March 2011.

Most of the radioactivity moved to the Pacific Ocean because of the wind direction and water distribution. An evacuated area of more than 2.000 km^2 was necessary highly polluting land 150.000 people were moved to other places. Still the radioactivity is releasing to the Pacific Ocean (Smith, 2015; Madigan, 2013; Neville, 2014)

The Japanese government now expects demolition costs of several billion euros annually and a great post has not yet been received.

Regardless of the location of a nuclear power plant, future generations have to pay the demolition cost and the storage of contaminated materials for hundreds of generations. These costs for the public must be addressed and included in future energy assessments.

Energy transition means "a change in composition of primary energy supply", or a gradual shift from a specific pattern of energy provision to a new state of an energy system (Brown 2015). Changing today's limited energy sources such as oil, gas coal, and nuclear material with unlimited energy sources like solar energy, biomass, wind, hydro, geothermal are the objectives of an energy transition

This Paradigm shift from a limited energy source to an unlimited energy source has changed in present almost all areas of human life (Strunz 2014).

Depending of the driving force for an energy transition the important areas are technical, economic, environmental, political, social, security and safety.

Economist and scientist in the 1900th already mention the use of fossil energy source and there limited availability with their risk on dependency for the economy (Adam Smith, W. Jevons, Sombart). The necessity to use solar energy was already discussed at the time.

The global unlimited energy resources as so called renewable energy resources are huge. Alone with direct solar energy, wind and hydropower the demand of energy would be enough driving the present "energy hunger" globally 4.000 to 7.000 times more (Perez 2009). Over the last 30 years, new and more efficient renewable energy systems with higher efficiency, lower investment cost where developed.

Latest publication and case studies show that renewable energy sources getting cheaper than conventionally operated conversion processes like fossil and nuclear (Wirth 2016). Studies showing that PV system will be the cheapest energy source in the future (Wirth 2016).

Another issue is the external electricity costs for environmental damage and greenhouse gas emissions. These additional costs must be included in future energy cost considerations.

The use of emission factors and the environmental costs per ton of emitted pollutants is used to calculate the avoided environmental damage and environmental costs for the different technologies for electricity generation. Table 1 shows the environmental cost for the production of electricity with different energy sources (Breitschopf 2012, BMU).

The difficulty working with renewable energies is the fluctuating intensity of the energy source. Direct solar energy and wind intensity is dependent on weather conditions and day and night.

This research is focused on new storage alternatives for RES. The possible solution are based on H2 as a sustainable secondary energy source.

Hydrogen is the first element of the periodic table of the elements and usually occurs under ambient conditions to a molecule consisting of two

Table 1. Environmental damage in cents / kWh

Electrical Generation	Air Pollution CO_2 Cost in € Cent/kWh	Greenhouse Gases CO_2 Cost in € Cent/kWh	Total Environmental Cost € Cent /Kwh
Classic Fuels			
Brown coal	2,1	8,7	10,8
Fossil gas	1,0	3,9	4,9
Oil	2,4	5,6	8,0
Nuclear			(* 6 - 18)
Renewable Energy Sources			
Hydro	0,14	0,04	0,18
Wind	0,17	0,09	0,26
Photovoltaic	0,62	0,56	1,18
Biomass	1,1	2,78	3,9

Source: Kuechler & Meyer

hydrogen atoms. H2 is the most common element in the universe represents about 90% of all atoms, approximately ¾ of the total earth mass. In nature, H2 reacts very quickly with an oxygen atom to water. Atomic hydrogen reacts with organic compounds and form complex mixtures of different products as methane CH4, petrol C6H12. In nearly all organic compounds, H_2 is integrated (Riedel, 2015).

In our research, we find that hydrogen, as a secondary energy carrier must be produced out of different chemical compounds like water, methane gas (bio), biogas, and biomass.

Secondary energy source means a conversion process from a primary energy source to another type of energy with a possible energy quality change and efficiency losses.

H_2 as a secondary energy carrier has special characteristics in compare to fossil energy sources. These positive characteristics consist in the highest energy density per mass, none toxic, environmental neutral, not radioactive, not carcinogenic, storable and as a negative aspect the lowest gas density and volatile of $H_{2.}$

The main application for H_2 as a secondary energy carrier for the future are intelligent decentralized energy conversion systems using locally produced stored H_2 and high efficient fuel cells in an integrated systems. Sustainable hydrogen production could be the key strategy for a hydrogen economy future.

Table 2. Today's H2 production

Fossil Energy Source	Process	Fuel Type	Efficiency	Cost €/kW
CO_2 impact	Auto thermal reformer (methanol reforming)	CH_4	< 80%	> 0,04
Huge impact	Partial Oxidation (oil gasification)	Fossil oil	< 80%	> 0,05
Huge impact	Kvaerner process	Fossil energy		< 48% H_2
ca. 10% thermal Energy	< 40% C	> 0,05	Little impact	Electrolyser fossil energy
Fossil Energy				
< 70%	> 0,08	Huge impact	Renewable energy sources	Process
Fuel Type	Efficiency	Cost €/kW	CO_2 impact	Steam reformer
Biomass	Max 80%	> 0,05	Carbon neutral	
Electrolyser	- Hydropower	- Wind	- PV	electricity
Max 60%-80%			> 0,08	> 0,09
> 0,20	No impact	Photocatalytic water splitting	Solar Radiation	> 15%

Source: Ryutaro, 2011; Godula, 2015; Machhammer, 2015; Fang, 2017; Dincer, 2016.

Today's 98% hydrogen production is from methane gas, coal and oil sources. Worldwide over 600-bill m^3 on hydrogen gas are produced mostly for the chemical industry.

Table 2 shows the present H_2 production, the efficiency of the processes, the environmental impact and the economic values of H_2.

Efficiency of the conversion processes is the key factor for producing H_2 out of a primary energy source. A production of H_2 with a RES source is in present through biomass steam reforming process and hydro electrolysis feasible. Looking to the energy production cost of other RES like PV, Wind, this sources nearly reaching the grid parity. Another important aspect is the use of overcapacity of RES especially wind and PV. This overcapacity can be used producing and storage H_2 in the existing gas networks (power to gas), special caverns, changing in methane or new liquids fuels. This overcapacity can be controlled through IT communication systems, which are connected on decentralized/centralized networks. Data´s like local weather situations, charging capacities of storage systems, energy prices, regional and national data´s can be used (big data´s)

Table 3. CO_2 calculations of a reforming process for a fuel cell heating system producing H_2 out of hydrocarbon methane

	Chemical Elements		Chemical Elements		Reaction Product	ΔHR
Chemical Equation for Reforming Process (Fuel Cell Heating Systems)						
Elements	CH_4	+	2H2O	→	$4H_2 + CO_2$	165 KJ/mol
Molecular Mass g/Mol	12+(4*1)		2(2*1+16)		4(2*1)+12+2*16)	
Mass equation	16		36		8+44	
Mass per g	1		2,25		0,5 + 2,75	

Producing H_2 over a reforming process with a fossil resource like methane (CH_4) has environmental impacts. To calculate the possible CO_2 impact stoichiometric calculations are used (Table 3).

For each produced H_2 gram, 5.5 gram on CO_2 is generated through the stoichiometric calculation. If methane gas would be burned in a condensing gas boiler 0,24 kg/kWh would be polluted. The energy contents of 1 kg H_2 is 33.33 kWh/kg. In the reforming process per 1kg H2 5.5 kg on CO_2 is polluted means 0,165 kg/kWh CO_2 (5.5 kg CO_2 / 33.33kWh). The result of this comparison is that the reforming processes with methane gas to H2 gas still pollute ca. 65% CO_2 emissions in compare to a normal burning process.

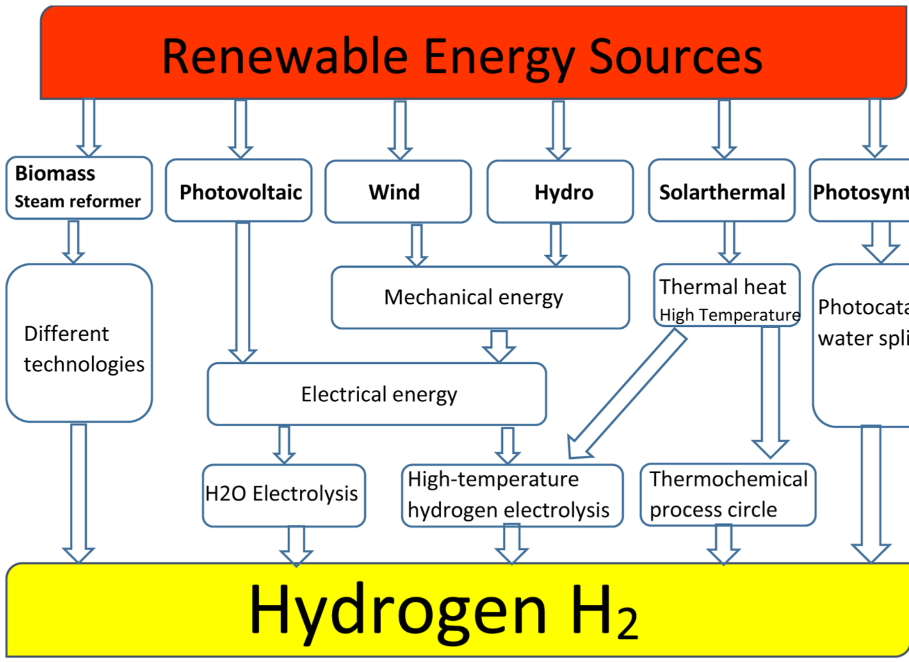
Another important part of our research is the production of sustainable secondary H_2. A sustainable energy sources is defined as an energy source, which is infinite, pollution neutral. Our solution that we are promoting is producing H_2 with a RES energy source (see Figure 3).

Today's technology for renewable hydrogen is mostly over an electrolyzer in form of fuel cells. Pilot project for biomass steam reforming are successfully in place. This technology could solve our future energy problems economically and environmentally (Tezlaff 2009). Solar thermal heat (high temperature, over 1.000 °C) is proofed and working in regions with high solar radiation. New promising technologies with photosynthesis systems will be a further future solution for producing a sustainable H2.

In order to produce H_2 we selected the main technology for the conversion process with the highest efficiencies. This process efficiency is used in Table 4.

Biogas steam reforming processes has the highest efficiency to other H2 generation processes. That is depending of the technology of this type of reactors (Tezlaff 2011). New technology and learning effects will raise the efficiency to 90%.

Figure 3. RES for producing H2
Own contribution.



Because of the volatile character H_2 and the low weight density, storage technology will be the key element in the future. Today's H_2 storage alternatives are low/high pressure systems with efficiency of 90% or liquefy H_2 with efficiency of 80%.

In following case study, we comparing produced H_2 with different energy sources from classic grid electricity, PV systems and wind. As a reference, we compare a FCV with H_2 produced out of the standard electricity grid (fossil fuel source).

The Table 5 shows the results of the amount of primary energy units (PEU in kWh) used and the total environmental impact (TEI in kg) over the whole efficiency chain for the production of H_2.

One Primary Energy Unit (PEU) is the base of the calculation. The environmental impact is based on PEU and the CO_2 conversion factor (KEA 2015) for the present electricity generation.

In case 1, the electrical generation is with a fossil fuel source. The total efficiency chain from well to wheel is 11%. The amount of primary energy is 8.5 kWh. This primary energy is out of a fossil energy source with an

Table 4. Efficiency chain from different conversion processes

Conventional Processes	Efficiency %
Fossil production (Well)	0,9
Electrical generation (Germany)	0,4
Distribution losses (Power Cables/Transformer	0,9
Hydrogen Production	
Hydrogen production electrolysis	0,8
Reformer (CH_4)	0,8
Steam Reformer	0,8
Biogas Steam Reformer	0,8
Pressure raised Hydrogen	0,9
Liquid Hydrogen	0,7
Application	
Fuel cell car (Input to Wheel)	0,5
Electrical vehicle (Input to Wheel)	0,8
Petrol/Diesel car (Input to Wheel)	0,24
Fuel Cell Heating (55% electrical/45% thermal)	0,8

Source: Konstantin, 2016

environmental impact of 0.567 kg/kWh produced kWh from the electrical grid. The environmental impact is 8.5 kWh multiplied with 0,576 kg/kWh. The total environmental impact this 8.5 kWh is 4.9 kg CO_2. In case 2,3 and 4 the same calculation method is used.

In case 2, the electrical generation is a RES (PV). The total efficiency chain from well to wheel is 5%. The TEI is 0,4 kg for 20,5 kWh PEU. This PEU are high through the efficiency chain of the PV system.

In case 3, the electrical generation is a RES source (wind). The total efficiency chain from well to wheel is 15%. The TEI is 0,13 kg CO_2 with 6.8 kWh PEU used.

In case 4, the electrical generation is a fossil source like in case 1. The car is an electrical car with Li batteries'. The total efficiency chain from well to wheel is 72%. The TEI is 0,4 kg CO_2 with 1,3 kWh PEU used. In compare with a FCV with RE generation the environmental impact is still > 50% higher. Electrical cars will be an alternative to FCV if the electrical energy is generated from a RES (disruptive situation).

The result clearly shows that hydrogen produced by fossil fuels has a very high environmental impact ca. 10 - 30 times higher. The critical aspects

Table 5. Well to wheel analysis FC car

Process	η%	PEU kWh	TEI Kg CO_2
Case 1: Reference Classic Fuel (Fossil, Etc.) 0,576 kg/kWh			
Primary energy source		8,46	
Fossil energy production	90	7,6	
Electrical generation	45	3,4	
Distribution looses	90	3,1	
Electrolysis	80	2,46	
Pressure raised H_2	90	2,22	
Fuel Cell car	45	1	
Total	11%	8,5kWh	4.9 kg
Case 2: PV System			
Primary energy source		20,5	0,02
PV System	15	3,1	
Electrolysis	80	2,47	
Pressure raised H_2	90	2,22	
Fuel Cell car	45	1	
Total	5%	20,5 kWh	0,4 kg
Case 3: Wind Generator			
Primary energy source		6,8	0,02
Wind generator	45	3,1	
Electrolysis	80	2,47	
Pressure raised H_2	90	2,22	
Fuel Cell car	45	1	
Total	15%	6,8 kWh	0,13 kg
Case 4: Fossil Fuel Grid Electrical Car			
Primary energy source		1,4	0,576
Fossil energy production	90	1,25	
Electrical car	80	1	
Total	72%	1,4 kWh	0,8 kg

Source: Author's own contribution.

working with PV is the low conversion efficiency from today 15%. That means to generate enough PEU the PV system must be correct sized. Through the lower total efficiency means more roof/field area for PV technology. With wind energy the space is far less in compare to PV system, which results from the higher efficiency of a wind turbine system.

Hydrogen as a secondary energy carrier is an ideal energy source and a perfect substitution for conventional fossil energy sources. It will reduce the environmental impact, the global warming situation through CO_2 emissions and helping to make the world more independent. H_2 produced decentralized and locally makes the independency on fossil energy less critical. For the production of H_2 all renewable energy sources can be taken what is available locally. There are countries with more solar radiations, countries with more wind and ocean energy or more biomass driven counties. H_2 as a storable fuel can reduce power and grid problems through the volatile character of more RES. Decentralized units will store and deliver energy through demand. Intelligent controls are essential for these future systems. Decentralized system means as well less energy conversion losses, higher efficiency through energy on demand and less grid network problems. New heating appliances, new storage technologies and conversion process gives new business opportunities with new innovative business models for higher revenue.

The energy costs for renewable energy are becoming even lower due to increasing numbers of units and technical improvements. We have already reached with Wind and PV grid parity with conventional fossil fuels. From a microeconomic view, there a huge amount of new business opportunities in all market segments. This gives a fantastic alternative to existing energy business concepts. From a macroeconomic view, these change our dependencies of energy worldwide, reduces the risk of energy wars, can help to reduce the living conditions in the third world and can save the world from a climatic catastrophe. Over one billion people are without electricity (World Bank, 2017). 40% of the world population cooking with harmful energy carrier like coal, timber, animal waste and other biomasses. New business concepts can improve the livelihood in poor countries and reducing the risk of civil wars and dependencies from corrupt politicians.

BUSINESS MODELS WITH H_2 AS A SECONDARY RENEWABLE ENERGY CARRIER

A Business model describes the way in which a company makes profits. In the scientific context there is no universal definition of a “business model”. The variations are too extensive to fix only one scientific definition of BM. The business model is not defined by an existing product, but by the generation of benefits and thus indirectly by the need to satisfy the customer.

There are common characteristics, dimensions and elements for BM which can be used. Depending of the type of businesses (technology orientated, innovative orientated, common good orientated) more or less characteristics, dimension or elements are used for the describing process and investigating process in a particular enterprises (see chapter 1.1).

Since the 1950th different approaches for development of business model concepts where published (Wirtz 2013). Various authors and scientists have defined characteristics/dimensions/elements of business models in the past decades (Schallmoe 2014, Osterwalde 2004, Osterwalde 2010, Osterwalde 2014).

One of the most important dimensions of BM is the value proposition. Value proposition for business model for using H2 as a sustainable secondary fuel means which benefits a user or customer can be extracted from the different H2 products, H2 fuel and services which are offered.

In order to analyze the possible fields and segments for business models, there are some classifications. For this research, there is an opportunity model used which is described in Fig 13.

In this model, there are the spheres for the customer segments used.

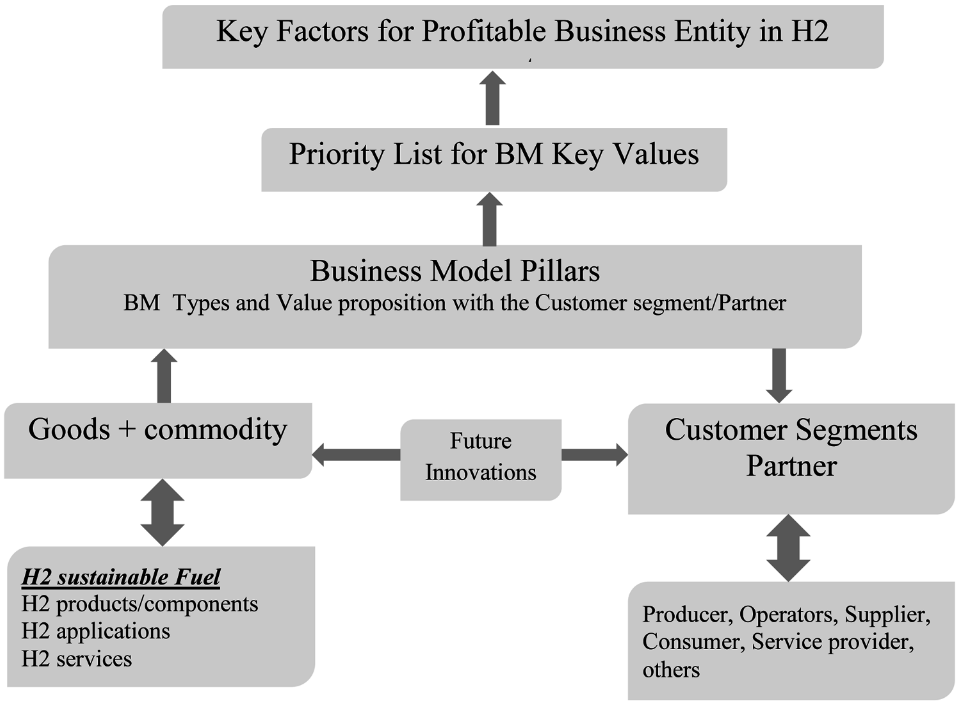
These actors are looking for product and product opportunities on the market for their own needs. On the other hand, there are existing goods and commodity for this H2 customer segments available. The task of business models is to combine these two sides with the help of elements (value proposition, key partners, key activities, key resources, cost structure, customer relationship, distribution channels, revenue stream) into a profitable entity.

We differentiate between hydrogen as renewable and sustainable secondary energy fuel see chapter 3.1, systems or applications with hydrogen, components and customer services which using hydrogen as a fuel for driving our heating processes, power process and mobility or transport needs.

The commercialization paths place very different requirements on the product hydrogen Commercialization paths for Hydrogen as an energy carrier can be: power generation, heat market, fuel (substitute natural gas, liquid fuel), utilization in industries and emissions trading.

This path gives different customer segments with a huge variation of existing and future business opportunities with new BM depending of the present and future commodity or goods. These possible opportunities can be explained in the characteristics/elements of business model pillars. The feedback between customer and products is a main important issue for innovations, new products and viability of a company. For our research in

Figure 4. Business opportunity model hydrogen (profitable entity)
Own contribution.



this chapter we are looking for key values for H2 fuel as a renewable energy source and the possible customer segments for using H2 fuel.

Without the presence of hydrogen as a fuel which is produced in sufficient quantity, at low cost and from a renewable energy sources, all goods and services which are using H2 would be useless. That shows the existing problem about the availability of the fuel, the infrastructure and the possible different products and applications. The infrastructure is one essential issue for promoting H2 in the market. This dilemma is sometimes called "chicken or egg" situation, which will react and invest at first. Should we wait until the infrastructure for H_2 is there or waiting for the applications for H_2.

There is a variation of H_2 applications, components and services for special niche markets. One of the main products for these applications is a fuel cell. A fuel cell (FC) energy converter is the most promising system for future hydrogen usage (Töpler, 2014; Staiger, 2016).

A fuel cell (FC) is a chemical energy converter which converts H2 in electricity and heat with an efficiency of > 80% without any pollutants only water. In compare to an energy conversion system with a Carnot Cycle machine, the efficiency of a FC could be two times higher (example cars). There is a huge variation of different types of FC and their different applications available (Töpler, 2014). Without special components, components groups, subassemblies like valve, protection parts, special membranes, control systems, storage alternatives, cryogenics, FC modules, electrical motors, battery systems, H_2 appliances and equipment's would not exist. Another important aspect is the research work, training, information materials and communication channels around H_2. National and International institutions, government institutions, scientific laboratories, universities are concerned with the topic of hydrogen and applications working on new ideas, products and bringing new basic knowledge and new innovations forward. Important technical issues are storability of H_2 fuel, the distribution systems (fillings station), the availability of H_2 locally, H_2 production units, possible renewable energy sources and the conversion processes for producing H2 are main issues.

The conventional production pathway of H_2 in present is, by byproduct through chemical processes, coal gasification processes, natural gas reforming processes and electrolysis out of today's electricity grid systems. Since a couple of years new innovated systems are installed producing local H_2 fuel out of a volatile RE source.

The renewable pathway for H_2 production will be electrolysis through wind, hydro and solar energy. Biomass gasification (solid biomass), bio liquid reforming, biological metabolism and steam methane reforming from Biogas (animal waste, treatments plants, landfill sewage) will be future technologies (Machhammer, 2015; Vielstich, 2003; Godula, 2015; Dincer, 2016; Fang, 2017). Table 6 shows a variation of different appliances, systems and services with H_2. Further innovative new products or applications and services will be discussed later in chapter 4.

In the last 10 years the market for H_2 fuel, H_2 applications and H_2 as a fuel substitute for gas networks and liquid fuel increased continuously and the forecast looks very promising (NOW, H2Mobility, DWV, IAHE, NREL 2016).

Value propositions are the reason way actors in the market tend to turn to the one entrepreneur rather than to the other. It solves an actor's/customer problem or meets actor's/customer requirements. Value proposition (VP) describes the benefits a company promises its customers with a mix of product, price, service, as well as special relationship and image factors to the customer. This value propositions can be generated through a special business model. The product and service self could have special technical key values like efficiencies, power, noise emissions, which can be measured

Table 6. Present hydrogen systems, components, service

Systems/Applications	
Stationary systems	• Fuel Cell Heating Systems • Micro CHP Systems • Energy generation MW • Electrolyzes • Power to gas/h2 storage
Mobile Systems	• Cars • Busses • Transport vehicles • Bicycles, motor bikes
Portable	• Storage systems, batteries • Power supplies
Fillings stations, Storage, Production	• Small mobile stations • Portable self-contained liquid • Large retail systems • Chemical companies • Hydrogen production units • Storage system (long, short term) • Filling station, distribution network • H2 reformers • RES generators (Wind, Solar, Biomass, Hydro) • Power to Gas
H2 Components	• Fuel Cell Materials • Fuel Cell safety components, Systems • Control systems • Storage systems and materials • Cooling technology components for h2 generation
Information, services, communications	• R&D work national/international in Universities and Scientific institutions (Information Materials) • Training and Maintenance Systems (Safety, Working Principals…)

Sources: Vielstich, 2003; Töpler, 2014.

and documented in technical data´s of the product. Taking the technical value and implementing it in business models for new value propositions for customers is the key to success. The Table 7 shows the technical key values and possible value propositions for H_2 as a fuel.

For our research we are looking to value proposition for H_2 fuel and the customer sphere. With this values propositions and customer sphere we are using for this investigation an opportunity model to illustrate possible BM models and future innovation (Figure 4). There is a variation of H_2 fuel production processes for the different customer segments.

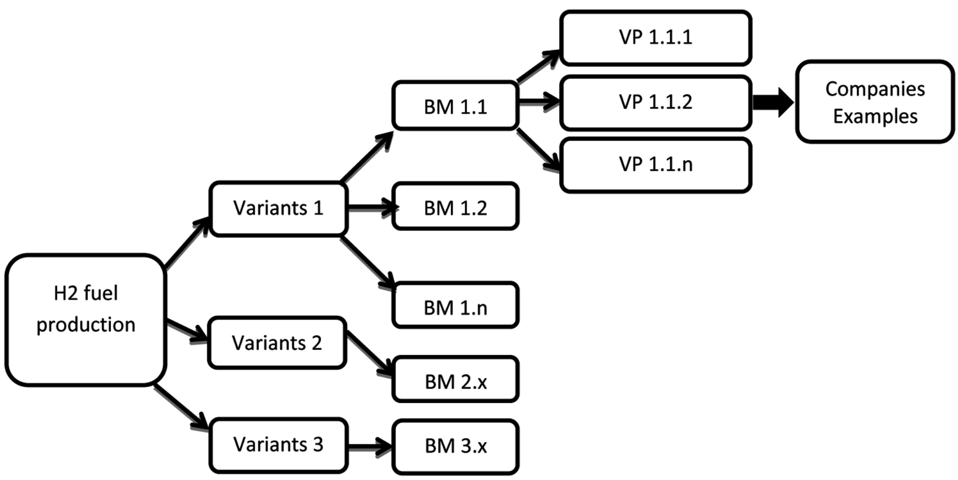
In order to be able to classify the possible business models and their range of values, the following scheme is used (see Figure 4). The outcome of this investigation is a classification of similarities of the values propositions for BM for H_2 fuel.

Table 7. A few key values and value propositions for hydrogen fuel as a renewable energy source

General Value Propositions (VP) H_2 Fuel	Key Values H_2 Fuel
storability	Diffusion coefficient 0,61 cm^2/s
transportable	Ignition temperature 585 °C
clean burning process	Liquid density 70,8 g/l
Hardly pollutant emissions/environment friendly	Gaseous density 0,084 g/l
easy to generate	Ignition range in air 4 - 77 Vol %
Outdoors not explosive	Gaseous calorific value 3,0 kWh /Nm^3
Not radioactive	Energy density Liquid 33.33 kWh/kg
no resource issues	
available resource (H_2 Most common element on the earth)	
high energy contents	

Source: Geitmann, 2011.

Figure 5. Scheme for classifying BM in H_2



Scientific studies, investigations, analyses and market studies are used to assess the key factors of business models.

For variant one, we can define hydrogen production using electrolytic processes with the help of renewable energy and pressure increases. Depending on possible hydrogen production processes and the customer segments different business models can be identified and certain benefits derived from this and identify.

The question must first be asked, for whom we should create value propositions and who our most important customers are. Customer segments can be on mass market, niche market, customer segmentation or special diversifications.

From the value proposition point, the clear question should be answered what values do we provide the customer, which problem can we solve for the customer, which customer needs can we meet and what kind of product/ service can we offer.

H2 fuel is used today mostly in chemical industries and is mostly a byproduct in this industries. Price and environmental aspects play a subordinate role because it is a byproduct.

Using the fuel as a substitute to today's conventional fuels the competitive cost of H_2 fuel is one of the main important issues. Sustainability matters are less important for customers. H_2 fuel would be only substitute to existing conventional fuels. H_2 fuel outside of the industrial industry is in present a niche market. 99% of H_2 applications go in petroleum refineries, petrochemical industries, metal industry, electronic industry, government NASA institutions, food industry, optical glasses and cooling from generator in power stations.

Through the global warming situations and the worldwide agreements reducing greenhouse gases (Paris 2016), the governments are under pressure reaching this targets.

Consequently, efforts put in places to promote alternative fuels with subsidies, tax reliefs and special incentives for possible users of alternative energy sources. These political instruments will boost higher amounts of H_2 technology and consequently the amount of units that will reduce the production cost and increase higher profitability for businesses. The produced units in present for H_2 applications are not high enough for competitive price structures. Examples in Japan, with the ENEFarm program, for FC Heating systems shows, how prices and efficiency can change. They installed over 100.000 FCH units with efficiency of over 90% (EneFarm, 2015). As well, the PV sector as another example cost reduction of 74% for the last 20 years. In present, only a combination of possible subsidies and a consequence political intention can boost this technology forward in a shorter period of time.

Producing H_2 fuel as a sustainable energy carrier there are a variations of systems and usages to consider. Production of H_2 can be central and decentralized. Decentralized systems (distributed hydrogen production at the point of use) may be the most viable approach for introducing hydrogen as an energy carrier because it does not require a substantial transport and delivery infrastructure or large capital investments as high as those needed for large central production plants.

Large hydrogen production facilities that can take advantage of economies of scale will be needed in the long term to meet increases in hydrogen fuel demand. Central hydrogen production allows management of greenhouse gas emissions through strategies like carbon sequestration, power to gas, methanation, power to liquid.

Important aspects for H_2 fuel are: Energy source without environmental impact for the production process with RES like biomass, wind, pc, hydro, solar thermal and special processes like Kvaerner method. This Kvaerner process use a fossil source producing H_2, pure C and thermal heat with over 90% efficiency, but without an environmental impact. Cleanliness of H_2 fuel is another important issue for the different appliances like FC system. The fuel storage time with H_2 defines technical systems or applications and the variations of customer segments. Short term storage, medium term storage and long-term storage can be a different way for producing H_2. There is a low pressure, high pressure and a liquid phase fuel used for storage alternatives. Other consideration producing H_2 is the environmental impact, the economy of fuel, the production (financial and investment models) and possible consequences from the decentral plant self with important location factors. Here especially the volatile energy sources for solar and wind. Locations factors would be for example wind speed atlases like in the west of Ireland, in Spain on the Pyrenees massive. Solar energy in the south EU countries and biomass were biomass sources growing and are viable available not influence the food sector and there prices. Biomass waste material is available for recycling for another ideal output product in biomass steam reforming processes. Existing infrastructure for H_2 fuel production in the region can supports these effectively and efficiently - from storage to transport. The development of technology-related cost reduction potentials, including the realization of technological leaps or scale effects and the use of existing remuneration systems (CO_2 certificates), is intended to establish this form of energy transformation and storage economically viable.

Table 8 shows a variation of H2 fuel production processes with possible business models, related customer segments, key value and some customer examples.

Table 10 shows only a small excerpt of possible business models with a certain value propositions. Variant 2 can be extended by other renewable energy systems such as photovoltaics biomass or other combinations for example

Table 8. BM H_2 fuel generation

Business Model Variants (V)	
V 1.0	H_2 fuel from electrical hydro generation systems (decentralized)
Business Model (BM)	
BM 1.1	H_2 pressurized fuel for mobility/stationary H_2 applications
Value Proposition (VP) for the Different Customer	
VP 1.1.1	competitive fuel price
VP 1.1.2	reliable renewable energy source
VP 1.1.3	cost of renewable energy
VP 1.1.4	No major interruptions due to technical errors
VP 1.1.5	easy to use
VP 1.1.6	easy to handle
VP 1.1.7	availability 24 hours
VP 1.1.8	no environmental issues (green fuel, green production, no environmental impact)
VP 1.1.9	locally produced fuel
VP 1.1.10	no safety concerns
VP 1.1.11	dynamic driving according to power price and / scarcity and surplus signals
VP 1.1.12	no emissions for indoor use (fork lift/lifting machines)
VP 1.1.13	higher efficiency of mobility units
VP 1.1.14	low primary energy factor → environmental tax breaks, substitution, CO_2 tax
VP 1.1.15	easy refuelling (Filling station FCV, transport vehicles, lorries
VP 1.1.16	fast refuelling process
VP 1.1.17	easy transport from production to the point of use
VP 1.1.18	transport cost, Transfer cost
VP 1.1.19	flexible storage systems (low pressure/high pressure)
VP 1.1.20	green marketing (presentation to the outside → Marketing instrument)
customer	COOPs, end users FC cars, industries transport equipment's, energy contractor, H2 service provider, H2 trader, service station operator, public transportation fleet, etc.
example	Arau CH COOP, Rhine valley Badenwerke, Wyhlen, Norway, Japan Tokuyama, Nitol Solar,
BM 1.2	H_2 fuel for stabilizing energy on demand take advantage of high-cost energy times in the electrical grid network
VP 1.2.1	energy prices on demand
VP 1.2.2	energy fluctuation (energy control grid)
VP 1.2.3	Online data access to current energy market prices and fast changing network conditions (sophisticated control system for optimizing energy flow for grid or H2 production)
VP 1.2.4	planning subjects
VP 1.2.5	reliable energy source on time
VP 1.2.6	short duty cycle
VP 1.2.7	availability on time
VP 1.2.X	further key values from KV1.1x
Customer	energy supplier, energy providers, grid operators,
Example	Wyhlen

Table 9. Further future BM 1 innovations with hydro energy (see chapter 4)

V 2.0	H2 fuel produced out of electricity from Wind Generator Systems decentralized
Power to Gas	
BM 2.1	There are a variety of applications from power to gas with special business models
Some Main Key Value for Power to Gas Applications for Different Customer	
VP 2.1.1	seasonal energy storage
VP 2.1.2	energy price/fuel price
VP 2.1.3	energy on demand with higher added value
VP 2.1.4	energy grid control
VP 2.1.5	energy price control/ competitive advantages
VP 2.1.6	flexibility
VP 2.1.7	peak load shift
VP 2.1.7	grid support
VP 2.1.7	volatile source of energy (RES)
VP 2.1.7	higher share of RES
VP 2.1.7	Gas network access
VP 2.1.x	further key values from KV1.1.x and 1.2.x
Customer	Industry, energy supplier, energy providers, Cooperatives
example	ZSW/Audi, Windgas Falkenhagen, Windgas Hamburg
V 2.0	H2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.2	H2 fuel for stabilizing energy on demand take advantage of high-cost energy times in the electrical grid network
VP 2.2.1	energy fluctuation (energy grid control), grid balancing
VP 2.2.3	planning subjects (safety, regulations, Building authorities)
VP 2.1.x	further key values from KV1.2.x
customer	energy supplier, energy provider
example	NEL, Linde,
Variant 2.0	H2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.3	Methanisation and feed in gas network
VP 2.3.1	availability natural gas network
VP 2.3.2	fuel price and energy prices
VP 2.3.3	energy cost for RES
VP 2.3.4	seasonal energy storage
VP 2.3.5	energy on demand with higher value creations
VP 2.3.6	energy price control/ competitive advantages
VP 2.3.7	flexibility usage of energy sources
VP 2.3.8	peak load shift
customer	Industry, energy supplier, energy provider, chemical businesses
example	Windgas Falkenberg
Variant 2.0	H2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.4	H2 fuel for mobility/stationary applications

continued on following page

Table 9. Continued

VP 2.4.1	energy fluctuation (energy grid control), grid balancing
VP 2.4.3	planning subjects (safety, regulations, Building authorities)
VP 2.4.x	further key values from KV1.1.x
customer	end users, transport companies, bus company, energy provider/supplier,
example	Filling stations EU wide, NEL, NOW
Variant 2.0	H2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.5	self-sufficient energy system (isle systems) grid independencies regional
VP 2.5.1	energy independency
VP 2.5.2	simple to use
VP 2.5.3	reliable
VP 2.5.4	investment cost
VP 2.5.5	maintenance free
VP 2.5.6	energy cost
VP 2.5.7	control system (remote maintenance)
VP 2.5.8	electricity network in remote regions
customer	End user, cooperatives
example	Insel Utsira Norwegian island community

Table 10.

Variant 2.0	H_2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.6	Power to Fuels/Liquids
VP 2.6.1	electricity cost
VP 2.6.2	energy availability
VP 2.6.3	CO_2 source available
VP 2.6.4	methane customer
VP 2.6.5	transport of fuel
VP 2.6.6	price for fuel
VP 2.6.7	reliable source
VP 2.6.8	Location (advantages)
VP 2.1.x	further key values from KV2.3.x
customer	Chemical Industry, methane provider/supplier
example	Audi, Sunfire, Mitsubishi Hitachi Power systems, CRI Iceland, STEAG Lünen,

wind. High-temperature solar systems are also possible in southern countries. The business models and value propositions are similar with PV and wind.

Alone the power to gas/power to liquid/fuel concepts gives new variations of innovative future BM.

In today's existing business models mostly in niche markets, the value proposition "comparable Energy Cost/Energy cost/ fuel prices" (1.x.x-2.x.x) for H_2 is one of the main important issues for customer. Today's energy costs for hydrogen vary greatly depending on the technology, the energy used for the process and the efficiency of the whole conversion process to the H_2 consumer. Latest research from H_2 producer shows an energy cost saving potential from 2010 to 2020 of over 60% for H_2 fuel for filling stations (Linde 2017).

Only under certain circumstances, these energy costs are marketable compared to today's conventional energy costs. This circumstances makes H_2 fuel in present competitive enough. Like locally produced H_2 from a RES, which is cheaply enough because of the technical and tax/subsidies situations in the different EU countries. This niche market can give values for the customer, which improves the existing businesses in different ways. As an example, BM 1.1 a COOP Business in CH which distributes locally (radius 200 km) food products in FC driven lorries. This FC lorries with trailer having 34 ton usages. The FC lorries are interested for large companies like ASKO, Colruyt and communal businesses. That is the reason way lorry manufacturer like MAN, Mercedes, Volvo, Scania, ESORO and part manufacturer (Power Cell, Luxfer) producing this in a niche markets. The efficiency of these FC vehicles is over 50% and in compare to a standard lorries better. The investment costs are more expensive in compare to conventional lorries in present. The fuel in present will not be taxed because it is a RE fuel (H2). With the running cost comparisons these lorries in Switzerland have a similar running cost like conventional lorries. In future FC lorries having a substantial saving potentials for production costs. Another advantage for these applications is the usage of H2 fuel for cooling purpose for goods. This gives another competitive advantage for the fuel (fuel substitutions). These companies can also use this competitive advantage to show the carbon footprint and using this as a qualitative value in communication channel for marketing purpose. These advantages can boost the business and the profitability and getting new customer clients. From a customer point a reliable, safe, more efficient and green energy source are other important values. Filling stations for H2 infrastructure are another important instrument for a future H_2 energy economy.

H_2 fuel produced on the point of sale/usage (filling stations) is economically the best solutions. The advantages for H_2 provider are no transport costs and simpler system. Worldwide there are ca. 400 filling stations available, in Europe ca. 100 station in use and planed (H_2 mobility). Special standardized filling stations are developed (Linde 2017). In Denmark, Sweden, Norway, UK, Germany and Italia standalone filling system a now in place driven with PV and Wind. The electricity from the volatile RES is stored in high pressure tanks for usage for mobility applications like FCV, FC busses and transport (FC fork lifts). Using in future FC micro CHP´s this filling stations would be ideal point for selling H_2 fuel for private applications as well.

Decentralized applications for producing H_2 locally in buildings for heating and electricity are possible. In CH and Germany systems are place. The potential of energy savings is huge. More the 50% of thermal heat in the EU is used in buildings. Producing electricity decentralized will also help to stabilize the electrical grid system with special IT systems like smart grid controls, hardware tools, home sensors, clever smart grid systems (Veith, 2017).

Linde as a main supplier of H_2 Gas in the EU are interestingly involved in this new system. NOW as a state organizations in Germany are promoting this technology in the last couple of years with grands and incentives. Incentives for promoting H_2 as a fuel are EU wide in place. Programs like FCH JU which are focused on energy and transport pillar. In Germany since 2016 a Micro CHP program for fuel cell heating system is in place to promote this new technology (BMWI 2016).

This FCH systems are using still a fossil energy source (CH4). Special reformers in the FCH systems taking the H element out of the fossil fuel. Another way for a H_2 heating system is shown in Staiger (Staiger, 2017). A combination (hybrid system) using H_2 direct in combination with other renewable energy source and a refrigeration cycle process.

H_2 fuel as a secondary renewable energy source gives a variations of business opportunity in present. The use of hydrogen in today's market segments and their various applications can still be strongly influenced by different market players and stakeholders. Alone taxation on H_2 fuel through government bodies and their energy policy can boost or cancel business opportunities immediately. Energy producer and their lobby work could also change business opportunities.

Hydrogen as energy storage can compensate for the fluctuations in the energy network. Decentralized system driven with H_2 fuel can help stabilize and smooth the energy network with the help of intelligent communication systems. H_2 fuel produced out of a renewable source is one key aspect for a sustainable environmental friendly resource. The climate change policy put governments under pressure to reach certain agreements. This pressure gives new impulses to entrepreneurs to try new ways in H_2 technology.

Producing H_2 fuel in present is only for niche market possible. That will change in the nearer future through new innovative technologies, less energy production cost and investment costs for renewable energy systems. Important value propositions for the different customer clientele are the Energy fuel price for H_2 in compare to the actual energy prices, economic aspects of H_2 fuel process (finance/investment/viability), dependencies of the necessary RES, availability of the fuel, safety and risk aspects with H_2, transportation and storage alternatives are some of the values.

DISRUPTIVE SITUATION FOR BUSINESS MODELS WITH H_2 AND THEIR RISKS

Disruptive situations describe the influences from outside and inside to a business flow. Disruptive products/services can create new markets and values. It can transform existing markets, significantly weaken markets and destroy existing markets, industries and products.

As a disruptive, so called destructive technology, new products, services or business models are used to replace existing ones. They provide for market shifts. These innovations are not innovations of the old technologies, so-called evolutionary innovations. They are radical innovations because they are completely new and open up a new market (Christensen, 2012). The worst case in disruptive situation for a company would be bankruptcy and the end of a business.

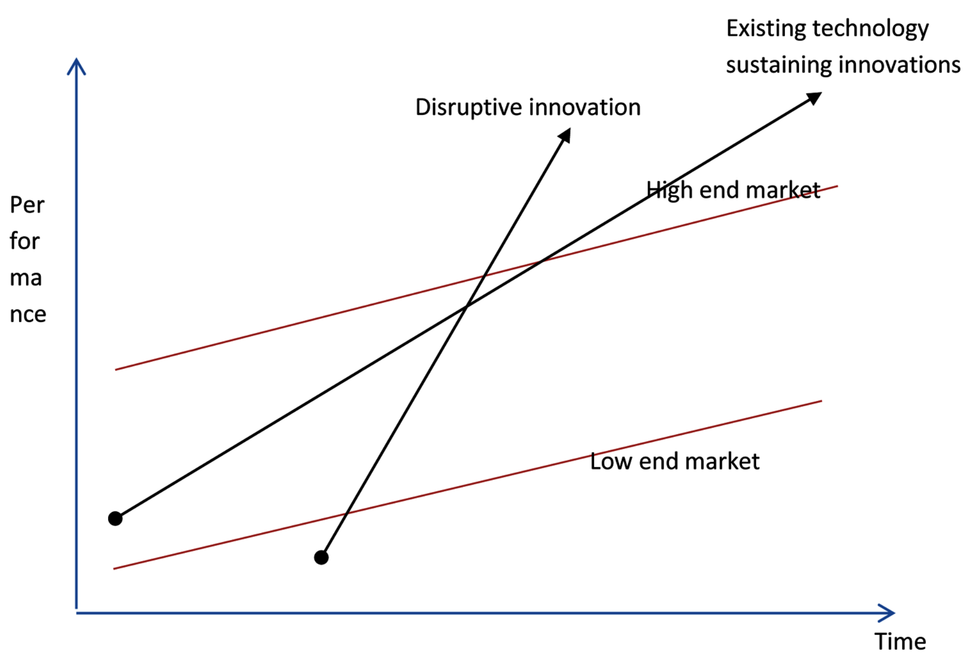
A disruptive innovation is a process that begins in a small, inconspicuous niche of an industry. Products or services that initially address a smaller part of customers are developed based on a new technology or a novel business model. It becomes disruptive if the supply gets the capital and dominates a market so that established companies and their products are displaced. Disruptive innovations are a process that extends over a period of time. In some cases, a rapid repression occurs, in other cases, it can take many years.

Disruption is about questioning classical process steps. Inefficient stages should be radically eliminated according to the ideas of disruptive thinkers such as Marc Andreesen and Clayton M. Christensen. The innovation vacuum of established energy services providers must be constructively reflected, if necessary eliminated. Because established companies, if they are still among the market leaders in their segment, are looking too closely at the needs of their regular customers, they lack the view for revolutionary innovations. Often, they leave the lucrative business to newcomers and start-up companies. "Leading companies often fall victim to one of the most popular and highly valued beliefs: they stick too closely to their customers." (Christensen, 2011).

Businesses fail and entrepreneurs appreciate situations wrong because they do everything right. They assess an innovation or a new market competitor from the point of view of their current company, from the point of view of the current business situation and also the view of the current clientele. They conclusively conclude that the new product (which is often of poor quality as established on the market) will not be of interest to the existing company target group - precisely because the quality leaves something to be desired and the existing customers with the existing product. But in fact, all consumer wishes and product requirements are fulfilled. This principle is also called "innovation dilemma".

Figure 6 shows the performance/time diagram. Disruptive innovations achieve in a shorter time higher performances in compare to the exiting

Figure 6. Disruptive innovation model
Sources: Christensen, modified.



technology. The resulting advantage can bring new ideas and technologies into the market and destroy current technologies and their business models.

As an example, the new electrical vehicle TESLA X in compare to a fare higher priced PORSCHE Carrera with similar performance, less maintenance cost and 70% less fuel cost will disrupt markets and businesses and gives as well new business opportunities.

Another example is the price reduction of battery systems for cars and for short term storage of electricity from RES systems. These price reductions through mass production brings an enormous boost to electrical vehicles, electrical RE storage and disrupt the future market on conventional driven cars. Today's big player could lose a huge market share. These changes could have a complete disruptive situation for the present car supply industry, because of less parts which will be used (electrical motor compared to a combustion engine 80% less), the service intervals are less means the workload and profitability for motor vehicle workshops and quantities produced are lower. As well this new technology will engender a new technical education skills in mechanics and electronics/electrical.

Important questions about disruptive situation around the value propositions are:

- Is your value proposition well aligned with customer needs?
- Could someone offer a better deal?
- What other jobs could you do on behalf of customers?
- Are you continuously acquiring new customers?
- Could the market become saturated and the reasons why?
- What new segments could you serve?

Disruptive situations in BM with H_2 fuel as discussed in chapter 3.2 will be more investigated and main aspects and risk factor described. With different value propositions for H_2 production variants, the analysis looks to sensitively parameters that can disturb actual BM and their possible risks.

One of the critical key values producing H_2 fuel out of a RES is a comparable energy fuel price/energy price in compare to present conventional energy. The market price depends on variations of parameters like, foundings, grands, tax situations, tax reliefs, energy market prices on spot market, energy cost for conventional fuels, energy cost for RES (levelized cost), CO_2 certificates, new technology in the RE field and new regulations.

Analyzing the data´s for the last two decades of renewable energy conversion systems (wind, PV, Biomass), energy production cost out of this RES reaching grid parity to conventional conversion systems.

Innovation in existing products and services can boost new markets segments and changing existing product and services. The beginning of building large scale wind generators in middle 1980th this technology was technically vulnerable, immature, prone to failure, ineffective and expensive. Currently, wind generators up to 3 MW are commercial available, reliable, efficient and economical significant. Complete new markets in the steel, composite industry, mechanics (gearboxes, shafts), electrical control system, IT systems (Software/Hardware), maintenance systems (automatically controlled processes) with direct networks to the manufacturer for qualities check, safety and defining flexible maintenance intervals where developed.

Over the last three decades, photovoltaic systems have become more effective, less expensive and more economical due to new production processes

Solar PV cost from the 1970th to today is more the 200 times less. This improvement is still an ongoing technical process. The PV capacity from 2000 to 2015 is 174 times higher means a growth rate of over 40% over the 15-year period. If solar PV continues growing at 40% in the next 15 years, nearly all electrical power could be driven with solar system by 2030. PV electricity costs are in these 3 decades 3.000 times improved in compare to fossil gas. Studies shows that Solar PV reaching grid parity in 80% of the market by 2017 (Deutsche Bank, 2017). PV will be in future the cheapest energy source in compare to cheap fossil coal. A similar picture shows the electrical generations with wind power. Producing H_2 fuel out of these fluctuating RES, it will get more and more economical feasible.

Another critical value would be the availability of the RE fuel source for H_2 production purpose. This could be disturbed through technology changes, changes of the produced energy source like less water for hydro plant, less biomass source through higher land demand or changes in volatile energy sources like solar and wind through other substitutions technologies like new storage systems.

In the last five years, investments in battery technology increased dramatically (Seba, 2016). Since 2010 the price has dropped at 15% per year and still accelerating. In 2014 the price per kWh stored energy in batteries was around 600 US$/kWh. That price was reduced in 2016 to 300 US$ per kWh. The forecast for storage prices in 2020 are 200 US$/kWh in 2030 100 US$/kWh (Seba, 2016). This storage prices will change RES and storage alternative radical and will disturb a lot of business applications with complete new challenges and new opportunities (decentralized systems). Like producing H_2 fuel as a short storage alternative for balancing the grid systems. If these storage systems installed in mass production with intelligent IT systems (smart grid, database, decentralized power network) a complete virtual storage power plant is available for stabilizing the grid network. Different electricity costs over a day can be used at a favorable electricity price tariffs in the night in order to bridge the high-priced period of time. This price information can come in time constantly over sophisticated IT network systems, from the energy spot market and other energy demanders.

H_2 fuel for mobility applications like fuel cell vehicles (FCV) fuel cell lorries (FVL), Fuel Cell Busses (FCB) and fuel cell transport vehicles (FCTV) are one aspect for using H2 fuel. Clear destructives signal for this FC market comes from companies like TESLA and Volkswagen with aggressive and clear positioning to bring electrical cars for reasonable competitive prices, long distance drive, high performance and fast rechargeable early on the market. These key values will open a new market segments and will change the whole fossil engine car market. Higher efficiency with electrical motors, less components, services friendly (less maintenance) are some key values.

Using electricity for the fuel of these new transport vehicles, the fuel must come out of a RES. If not the environmental impact with conventional electricity would increase enormous and there is no competitive advantage against conventional driven vehicles. The environmental impact and the total efficiency chain from well to wheel would be similar like conventional cars (Staiger, 2016) The infrastructure for mobile electrical charging stations is build up with new ideas and new business models like TESLA is doing with cost free charging on Motorways for the S class FCV. Vehicle manufacturers form alliances for the development of electro mobility infrastructure. This new approaches will disturb todays conventional fossil fuel driven car engines and the whole business network and supplier network. As well H_2 driven fuel cell cars will be disturbed as well.

New thinking and looking to innovative key values for comparison between electrical cars and FCV must be analyzed and new innovative technology and innovative business models developed.

Fuel cell driven vehicles (FCV) with electrical motors, FC and H_2 tank are facing in future a competition with electrical cars. Key values like long distance range and filling time will be important key values for this new technology.

Looking to technical and future market aspects, both technologies will have a market place depending of the market needs and the competitive advantages of the vehicles.

Through this technology push in renewable energy generation new products, new markets are emerging. Destructive situations in the PV production sectors the most companies moved in low wages countries like China and India to be price competitive. Producing H_2 fuel as a sustainable storable source are alternatives to conventional fuel. With fuel cell energy converters, alternative products are developed for mobile, stationary, portable applications. Through new EU regulations (like EPBD, efficiency directives in the EU) standard gas and oil boiler are forbidden from 2017 because of the calculation methods of primary energy usage. Only condensing boilers with high efficiency and in combination with a RES are possible. These disruptive situations are changing the heating business market completely. Like old oil boiler manufacturing buying companies in RE applications like biomass boiler, heat pumps manufacturer. Others are developing complete new heating devices like FCH systems (Staiger, 2017). Using H_2 from a fossil energy source today (availability) other components are necessary like reformers. This market is changing in present rapidly to a renewable energy heating market. Innovations in niche market beside existing products increasing new destructive innovations like a FCA system (Staiger, 2017).

From an H_2 fuel aspects Table 1 shows possible destructives situations working with H_2 fuel as a sustainable renewable energy source. Because of the new and not established technologies and product with H_2 fuel as a sustainable energy carrier a lot of disturbing factors will have huge influence on existing products and the H_2 fuel self. Not only business related factors are important. Possible trigger for destructives situations are governmental related situations and reactions, innovations in existing product/services, innovations in new products/ services, new market needs.

Governmental related situations are the energy policy in general, legal compliances, regulations, laws, support programs, financial aid and subsidies. These governmental instruments should help moving in an energy wanted direction.

Today's energy direction is clearly focused on energy saving, energy dependency, energy availability, environmental impact, climate change, promoting renewable energy sources and sustainability.

Table 11 shows the summary of possible disruptive situations with H_2 fuel as a sustainable energy source and possible related risk. BM and key value from chapter 3.2 are taken.

Table 11. Summary of possible disruptive situations with H_2 fuel as a sustainable energy carrier and possible risks

V 1.0	H2 fuel from electrical hydro generation systems (decentralized)
BM 1.1	H_2 pressurized fuel for mobility/stationary H_2 applications
BM 1.2	H_2 fuel for stabilizing energy on demand take advantage of high-cost energy times in the electrical grid network
Disruptive Situations	**Risks**
Energy policy changes, tax reliefs, grands,	Energy price increasing, H_2 fuel less interesting, substitution with other sources, promoting other technologies like EV,
Environmental impact, climate change	Less energy flow, no Economic viability
Demand on energy increasing new alternatives	Investment uneconomical, new applications, competitiveness
RES not any more available (higher demand)	No fuel, no availability, searching for alternative
volatile source	Availability, shortage, price increasing, searching for alternatives
New regulations	Price increasing, less demand, higher cost, investment cost, profitability
Technical fault	Availability, reliability, no usage, alternatives, fuel contracts cancellation, punitive payments
Technical innovations like storage systems (Li batteries, higher efficiency, new charging systems…	No customer benefits, Substitution of current products, bankruptcy, redundancies, less profitability,
V 2.0	H_2 fuel produced out of electricity from Wind Generator Systems decentralized
BM 2.1	Power to Gas
BM 2.2	H_2 fuel for stabilizing energy on demand take advantage of high-cost energy times in the electrical grid network
BM 2.3	Methanisation and feed in gas network
BM 2.4	H_2 fuel for mobility/stationary applications
BM 2.5	self-sufficient energy system (isle systems) grid independencies regional
BM 2.6	Power to fuel/liquid
Disruptive Situations	**Risks**
Same like V 1.0	Same like V 1.0
CO_2 source substituted through technical innovations	No methane gas, equipment obsolete, economic visibility
more	more

Business models can be interfered with in Table 11. This influence can be caused by internal and external circumstances.

These external influences can be for example the weather conditions. The risk for the customer is that the energy source H_2 is not sufficiently available, means probably an interruption in business processes transport, heating, electricity supply. Another example could be new energy policy and new regulations which can increase the expenditure for the production process. The risk is to high fuel prices which customer moves to other alternatives. Through higher possible energy demand, the operators of PV/wind generators decide to deliver energy on a more profitability way to the energy network. The risk for the H_2 customer is that contracts could be canceled. And no available energy source H_2. Electrical mobility for example is one disruptive situation for FC vehicles. More storability in batteries, higher mileage range, cheaper production processes and governmental incentives will disturb the introduction of higher volumes of FCV and thereby H_2 fuel usage. The risk for H_2 mobility is through technology innovations and price reduction through higher quantities not competitive enough. Only through new innovations like production cost, FC cost, performance factors (mileage range, reliability, safety) can compare to the new disruptive situations through electrical vehicles.

Internal effects could be technical difficulties, high maintenance cost and too complicated to use.

As well H2 as a storage fuel could be disturbed through new short and middle time storage systems like battery system. Power wall would be one example from tesla storage systems. EON is installing as well for short term storage these systems in present.

H2 fuel for Power and gas application could be stopped from gas network operators. Reasons could be safety aspects, legislations or ordinary business interest.

Interfering influences in hydrogen production are complex. Environmental influences, regulations, regional and international energy supply, technical innovations, funding conditions, legal regulations, energy transport routes, energy prices, energy demand, political direction and many other influences can have disruptive effects on the production and spreading of H_2.

One of the biggest uncertainties for H_2 is the existing fuel price, reliable renewable energy source, competitive energy cost and governments policy behavior. Today's politicians are more and more unsettled. Many problems seem to be insoluble. The one who cries loudest gets right. Truths are ignored and disregarded.

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Chapter 4
Evolving Business Models in the Renewable Energy

ABSTRACT

New business models in the solar PV business were pushed from government policies worldwide for reducing GHG emissions. Therefore, PV system installments increase exorbitant in the last years with the consequences of constant falling of prices for PV system and energy. All these quickly changed conditions, means new flexible BM. Power purchase agreements, Product Service Systems, demand resource provider, energy performance contracts are evolving rapidly in the renewable energy business. There is a variation of new PV BM for use. PV represent a new energy source for producing H_2 as a storable renewable fuel in an overcapacity situation. Using H_2 in combination with other systems, like hybrid systems, heat pumps gives new unique business opportunities. Decentralization will be the key to success. Other applications like mobility and long term storage are other further alternatives in connections or combination with the volatile renewable energy sources.

1. NEW BUSINESS MODELS IN THE RENEWABLE ENERGY FIELD

Business models in the renewable energy field are confronted with new challenges due to the development of the technology, liberalization and the increase of competition and due to the new approach besides the energy concept as a product or as a service.

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The major transition between old business models and new business models has its roots in the new business mentality where the role of energy producers has many faces and in the societal shift from a passive to an active user role in the renewable energy value chain.

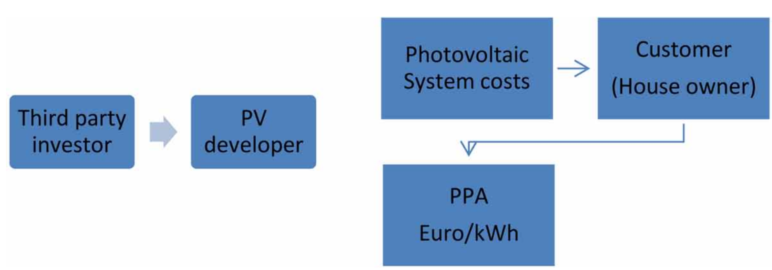
Nowadays main companies in the energy field are diversifying their activity also in the renewable energy field and are looking to reconfigure their business models main due to the new distributed energy companies which are implemented new business models (Schlandt, 2015; Jeevan Vasagar, 2015; AGL, 2015a).

Business models that extend power purchase agreements (PPAs), investment and lease options to the residential sector are likely to become more widespread and available. In the future, instead of system ownership, at least half of the systems for residential, commercial and utility applications are likely to be investor owned (Mints, 2008, p. 63).

Meanwhile in the classic power purchase agreement (PPA) the project developer is selling energy to an intermediate company, in the case of distributed photovoltaic the PPA is a direct agreement with the residential or commercial end-user. From the business model perspective, the value proposition consist in paying only for the energy that is consumed, with no upfront costs. In this case the PPS introduce its own added value through the low carbon energy transaction and through the creation of a direct contact between the customer and the producer of renewable energy (Wainstein & Bumpus, 2016).

The next generation of PPA is represented by the distributed solar PPA with third part financing which represent the innovative tool added to the classic business model for PV systems. This business model introduces a long term agreement to purchase solar energy at an agreed competitive rate between a household or commercial owner and a private firm which installs the PV equipment and maintains ownership on the equipment (see Figure 1).

Figure 1. Structure of a distributed photovoltaic power purchase agreement



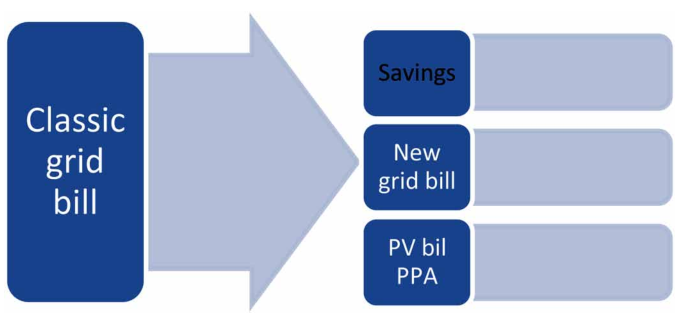
A special type of PPA financing is the joint venture model of the third part ownership financing. In this case the project that is built by the developer is sold to the joint venture created by the developer with a finance fund. The customer is signing the PPA contract with the joint venture. In the special case of a sales-lease back model the project that is built by the developer is sold to the finance fond and then is leased back (Zhang, 2016).

From the cost perspective of the new business model the classic bill is exchanged by the PPA costs and new grid costs. These have to be less than the old classic grid costs (See Figure 2).

In the case of distributed solar photovoltaics fund raising is a mechanism that support large investments and has as actors the government, state-owned companies but also private corporations for electric utilities, banks, insurance companies, private equity firms and retail investors (Donovan, 2015). The energy corporates represent strategic investors due to the fact that they prefer to invest in physical properties, such as real assets for wind or photovoltaic facilities. Financial assets that are less tangible as real assets and are preferred by financial investors.

New business models in the renewable energy field are reflected the transition from the product to the service approach based on the Product–Service Systems (PSS) concept. The energy service companies (ESCOs) represented by energy companies but also product manufactures or technical consultancies are looking for innovative solutions for energy saving. The main activities of ESCOs are energy audits, energy analyses and implementation on new energy solutions to customers. Compared to the business models based on low production costs and low customer interaction the ESCO business model promote energy solutions that are developed in close interaction with customers. The value proposition of this business model deal with economic

Figure 2. Bill structure for a PV PPA



benefits for customers by reducing the energy bill due to energy savings. For the revenue part of this business model the energy service company receive a percentage of money saved for their customers (Ceschin, 2013).

The PSS business model is a shift from the classic business model (selling a product) to a value proposition based on performance offering that increase the customer satisfaction (selling a home comfort service). The product service system (PSS) is defined accordingly to Tukker as "a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs" (Tukker & Tischner, 2006). In a PSS business model the revenues are estimated per unit of performance delivered and not per unit of product sold. And the economic value is decoupled from material and energy consumption (Vezzoli et al., 2015b). The revenues of this business model are as much higher as the consume of material and energy resources is reduced.

The main classification of PSS models regarding the ratio of services involved consist in: product oriented PSS, use oriented PSS and result oriented PPS. These categories were detailed by Tukker (2014).

In the product-oriented PSS business model the company sells a product and offer also additional after sales services as maintenance or upgrade. In this case, the product will be owned by the customer. Emili differentiate between the business models pay to purchase with training, advice and consultancy services and pay to purchase with additional services (Emili et al. 2016). The value proposition of the business model pay to purchase with training, advice and consultancy services consist in selling energy systems and giving advices regarding the disposal of the system, the efficiency of the system or other contractual agreements as training courses. The business model pay to purchase with additional services include in the selling packet besides to the energy system other services as installation and use of the system, maintenance services, financing services, upgrading services or end-of-life take-back services.

In the case of use-oriented PSS the business modes is based on a contractual relation between the customer which buy the use of the product and a company which is renting the product. Tukker (2004) distinguish between product lease, product sharing and product pooling. The business model for product lease is based on a regular fee that a customer is paying for the access to a product that is offered. In this case the provider is the owner of the energy system and is in the most of the cases responsible for the maintenance, repair and disposal of this system. A special case of this business model is product sharing where a product can be sequentially used by different customers.

This product pooling business model is an extend of the product share model where different customers can use simultaneous the product that is offered.

The result oriented PSS business model offer to the customers a mix of services that contribute to achieve a specific result. In this case the provider owns the products and sell the results of products. This type of business models can be detailed in: activity management (outsourcing), pay per service unit and functional result. The activity management or outsourcing business model outsourced a part of an activity to a third party (e.g. outsourcing of maintenance). In the case of pay per service unit business model (pay per energy consumed) the customer is paying for the output of the main equipment (pay-per-kWh). The business model that is more focused on the final result is the functional result business model. For this business model the contractual agreement is focused on the result that the provider has to achieve without to be obliged to mention any technology or product that is used for achieving the result. The business model where the customers are paying for a certain amount of energy per day is known as pay-per-unit of satisfaction.

A more detailed classification of PSS business models that include the categories product oriented PPS, use oriented PPS and result oriented PPS consist in 15 archetypal models (Emili et al. 2016) and is presented in Table 1.

Another classification of PSS business models was proposed by Gaiardelli et al. (2014) and takes into consideration five main dimensions: value proposition, product ownership, product operation, provider (customer relationship) and environmental sustainability potential. For PSS business models the value proposition is configured around the specific combination of products and services that are offered to the customers. In the case of the product ownership the products that are offered could be owned by the end user, by the provider or shared by a number of customers. Product operation business model is developed on the relation to the main actor (the customer or the provider) that is operating the product from the PSS contract. The provider (customer relationship) business model is detailing the nature of interactions between the parts that are involved in the PSS agreement.

The PSS business models extends the value creation related to a specific product form the designed and manufactured phase, to another phase where the product is distributed and the provider offer also new services or even to the recycled phase where the provider promote new remanufacture solutions (Yang, 2015).

Another approach that indirect can create new value introduce the concept of value uncaptured. Before developing a new business model is important to analyze also the current business models. The value uncaptured is the value

Table 1. PPS archetypal models for PV business

Archetypal Business Model	Main Characteristic	Ownership for the PV System
A. Product Oriented PPS **A1. Pay to Purchase with Training, Advice and Consultancy Services**		
1. Selling individual energy systems with advice and training services	Sale of the PV home system and of services for training and education on design, installation, repair or basic maintenance etc.	Customers become owners of the PV system.
2. Offering advice and training services for community-owned and – managed isolated mini-grids	Sale of mini-grid to communities and in addition offers of training services	Communities become owners of the PV system
3. Offering advice and training services for community-owned and – managed connected mini-grids.	Sale of mini-grid (that is connected to the main electric grid) to communities and in addition offers of training services.	Communities become owners of the PV system and can also distribute energy to the local network.
A2. Pay to Purchase with Additional Services		
4.Selling mini-kits with additional services.	Sale of mini-kits with additional services, such as financing, so that customers can pay through small, flexible instalments over time.	Customers become owners of the PV mini-kit after the credit period.
5.Selling individual energy systems with additional services Offering individual energy systems (and energy-using products) in leasing.	Sale of individual PV system with additional services, such as financing, so that customers can pay through small, flexible instalments over time.	Customers become owners of the PV system after the credit period.
B. Use Oriented PPS **B1. Pay to Lease**		
6.Offering individual energy systems (and energy-using products) in leasing	Leasing of home systems.	Customers do not become owners of the PV system but have unlimited access to it
B2 Pay to Rent, Share or Pool		
7.Renting energy-using products through entrepreneur-owned and - managed charging stations	Sale of charging station to a local entrepreneur with additional services.	The local entrepreneur rents out the energy using products to the customers which are paying a fee.
8.Renting energy-using products through or community managed charging stations	Rent of charging station to the community with additional services for a leasing fee.	The local community rents out the energy using products to the customers which are paying a fee.
C. Result Oriented Models **C1. Pay per Energy Consumed**		
9.Offering access to energy and energy-using products on a pay-per consumption basis through individual energy systems.	Installing of individual energy systems to customers which are paying for the energy that they consume.	The provider is the owner of the system.
10.Offering access to energy (and energy-using products on a pay-per consumption basis through isolated mini-kits.	Installing of mini-grids to community which are paying for the energy that they consume. End consumers are paying the energy that they consume.	The provider is the owner of the system.
C2. Pay per Unit of Satisfaction		
11.Offering access to energy (and energy-using products) on a pay-per consumption basis through isolated mini-grids.	Installing of mini-grids to consumers which are paying for the energy services that they use.	The provider is the owner of the system.
12.Offering access to energy (and energy-using products) on a pay-per unit of satisfaction basis through individual energy systems	Installing of energy home systems to consumers which are paying a fixed monthly fee for the energy services that they use.	The provider is the owner of the system.
13.Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis.	Installing of charging stations to a community or a local entrepreneur. Offer of energy services. End user are paying for the energy using products.	The provider is the owner of the system but the entrepreneur is responsible for the operation and maintenance.
14.Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis.	Sale of charging stations and additional services to a local entrepreneur who offer recharging services to customers. End user are paying for recharging their products.	The entrepreneur is the owner of the system.
15.Offering access to energy (and energy-using products) on a pay-per unit of satisfaction basis through mini-grids	Installing mini-grids in a community. End user are paying for few hour energy per day.	The provider is the owner of the mini-grid.

Source: adapted from Emili et al., 2016

that is missing in current business models and can represent an opportunity for new values in a new business model. Examples of value uncaptured are a low service effectiveness and efficiency, a poor design quality, quality problems in production, inefficient use of human resource or unclear planning. The proposed forms of value uncaptured are: value surplus, value absence, value missed and value destroyed (Yang, 2017). Value surplus is defined as the value that exist in a business model but is not required by the stakeholders. Value surplus can be represented by repeated work and energy or heat that is wasted. Value which is required, but does not exist is defined as value absence such as lack of experts for photovoltaics or for wind energy or lack of specific services for photovoltaics or wind energy. Value which exist and is required but is not exploited represent the missed value such as the inefficient use of human resources or underutilized facilities. Pollution or a low level of service quality represent values with negative outcomes defined as value destroyed (Yang, 2017).

Other new business models represent a response to new technologies that change the classical business models and point the importance of smart grid. Shomali and Pinkse (2016) defined a business model through value creation, value delivery and value capture and determined the main impacts of smart grids on such a business model in the case of electricity companies. The new value creation is based on a new value proposition oriented on a clean energy source, such as renewable energy, on an increasing demand for high-quality energy and on a customer demand response that will improve the balancing of the network. Value delivery consist in an improved optimization of the electricity network, in an improved marketing based on real time data on electricity usage, and on leveraged assets of specialized ICT or energy service providers. For the value capture dimension, they take into account new revenues streams based on services and big data, the potential to become a central actor in a multi-side-market, and the reduced costs for less grid maintenance and load shift.

New technologies for smart grids (grid device), bilateral communication, local controllers for power computation, smart appliances for power or new energy storage solutions are changing the classical demand side management (DSM) model. The demand side management model consists on energy efficiency measures such as building automation upgrades, new lighting technologies and recommissioning that reduce permanently the energy consumption and on demand response resources. Demand response (DR), also known as load management, is a business model in which utilities offer to end-customer incentives to reduce temporarily their demand for electricity when the electricity system is particularly in a peak period. This may stabilize the transmission grids and reduce the market price volatility.

One development of a DSM model introduces the role of demand resource provider (DRP). The demand response provider is a “stakeholder that turns the DSM activity into a business by offering its added value to another stakeholder”. The demand response provider can be a demand response aggregator, an ESCO, a load provider or a load owner (Behrangrad, 2015). In the DPR business model the energy service performance contracts (ESPC) named also energy performance contracts (EPC) enable to a user named load stakeholder to achieve a predetermined energy performance level. A load stakeholder is a user for energy that received the energy at a level that is influenced by other stakeholders as transport, distribution and retailer stakeholder. The demand response provider offer the financial instruments for the energy efficiency project implementation. After the energy efficiency measures are implemented the energy bill will be reduced and the earnings represent an income for the demand response provider for the calculated the ROI period. Up to this period the earnings will represent a benefit for the load stakeholder.

A specific tool for the demand response business model that permit the integration of intermittent renewable energy resources is known as smart demand response program is that in this specific case the customers can receiving assets without having capital costs (Geelen et al., 2013). In such a case the DRP is selling the possibility to change its demand profile due to a system operator request in specific conditions. The system operator has to maintain a balance between energy generation and load by adjusting the demand profile. The value proposition of such a business model consist in the fast response and high flexibility such as a lower startup of the DRP. The main business model that insure the energy system reliability is based on offering ancillary services, such as frequency control, spinning reserves or operating reserves, that are required to maintain grid stability and security in the process of energy generation and transmission. These services were normally provided by generators but after the development of smart grid technologies and the integrated of intermittent energy generation these are developed also in smart DRP business models. The condition is that the DRP has to fulfill the system operator standards and to be in a stand by position. The main revenue source of this business model is a fee that is paid to the DRP, even the DR is not activated. Due to the increasing use of intermittent renewable energy new DR resources will be integrated in the ancillary service markets that will enable systems operators to reduce the costs (Rejc & Cepin, 2014).

Another DR business model focused on energy system reliability is based on a contract for reliability services that is a bilateral contract for one year or only for a summer peak with the system operator for providing DR services. This contractual model has three main forms: interruptible load, direct load control and frequency-controlled load curtailment. The interruptible load it's a relative quick voluntary interruption of the own consumption of energy of a large company or industrial facility, in the case of a notice about a contingency situation. These companies have installed backup generators, such as diesel engines, to supply power in the case of unexpected interruption in power supply from electrical grid. However, the operating cost of such generators are high. Compared to the ancillary service the required reduction duration is longer and also the advance notice to DRP is longer and are not proper for compensating the intermittency of renewable resources. In the case of direct load control the system operator can control the equipment of the DRP due to communication and monitoring infrastructure, that is relative simple and inexpensive. This model is typically oriented to small commercial and residential customers, which can turn off their air-conditioned equipment or other equipment for a limited period of time. In the frequency-controlled load curtailment model, that is dedicated to large customers, the load is reduced automatically when a grid indicator, as frequency is deviated from the normal value. This model has a very fast speed response even the communication infrastructure is inexpensive.

The photovoltaic power generation, is an intermittent renewable energy resource and is difficult to maintain a very exactly operation schedule due to different environmental conditions, such as night, clouds, dust and snow. All these atmospheric perturbations will represent a loss of revenues of an energy producer. These losses will be reduced by developing new battery storage technologies but also by developing new types of business models. The proper business model for this case is the reducing variable generation unit intermittency cost by installing a DRP energy storage or another DR resource to increase flexibility. This could increase the capacity factor and reduce the losses cause by energy intermittency.

New business models in the renewable energy field are promoting also new financing mechanism as crowd-funding financing. Crowd-funding financing is a form of funding by raising contributions from many individual investors through the internet. The individual investors received interest and after a specified number of years are payed back. This financing mechanism enables investors in renewable energy facilities to get access to loans even their financing capacity is low and also to have a higher grade of independence compared to the traditional financing contracts with banks or large financial institutions.

In the photovoltaic field the most of the new business models are focused on new services due to the development of new technologies and due to the increase of the life standards quality. In parallel with the development of technology appear new needs and demands that are reflected in new contractual business models. All these are also an effect of the liberalization process of energy market and of the new relations between main actors which are playing new roles in this sector. The end-consumer will play a more important role due to a new competitive environment in the energy sector and due to the bilateral communication between energy entities, such as institutions or companies and end-consumers. The feed-back from the end-consumers is integrated in the new Big Data business which will be the motor for revolutionary changes also in the energy field.

Big Data was defined by Leanes in 2001 based on the 3V model as "high volume, high velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making". The definition was developed by Gartner (http://www.gartner.com/it-glossary/big-data/) that consider Big data as a high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization" (Koseleva & Ropaite, 2017). In the definition of Big data was introduced also veracity as a more stable element (Edwards & Taborda, 2016).

The digitalization of energy systems lanced a new opportunity for the energy business based on the large amount of data related to the energy consumption and production that is registered. Currently, smart meters are registering information about the electricity consumption of the customers every 15 minutes. IBM, SAS, Oracle, Teradata, EMC and SAP General Electric, Siemens/eMeter, ABB/Ventyx, Schneider Electric/Telvent, Toshiba/Landis Gyr and not only these companies are developing new technologies for Big data and smart grids. The innovations in the field of Big data is changing the view of the traditional energy field. There are opened windows for new control tools and systems, new energy management structures, new services and the new information flow of the smart grid in the energy field. Big data introduce new opportunities on the path to a smart energy management (Zhou, 2016). The smart grid operates with complex data structures, with different volumes and types of energy data which are collected but also analyzed, classified and optimized. For example, based on the data measured by the advanced metering infrastructure (AMI), the power generation can be optimized in real time. More complex is the demand side where are developed algorithms that enable the detection of a consumer profile. Such softs can increase the precision of the estimations regarding the electricity consumption patterns. Other new integrated sensors, thermostats and hardware components can detect and restore the smart grid rapidly after a failure. Very important, for the renewable energy and for the smart energy management are specific weather data e.g. wind speeds, temperature or the angle of the sun. These data in used for forecasting the renewable energy generation. Big data help managers to use better the knowledge management resources such as data and analytics capabilities in order to protect the organization against multiple risks.

Zhou analysed new challenges for an effective and efficient Big data approach such as: collect, store and manage, analyze and use it as support for efficient management decisions, obtaining values from it but also prevent risks and protect privacy (Zhou, 2016).

The development of information technology for Big data represent also one of the most important fields that contribute to the new social media and Internet of Things phenomenon (Lee, 2017).

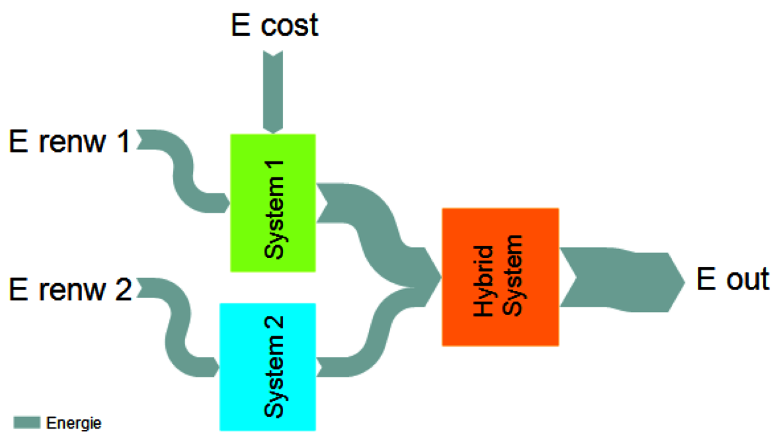
2. PHOTOVOLTAIC AND H_2 AS A NEW BUSINESS MODEL FOR RE SYSTEMS

For the energy transition we a phasing at present two complex situations. Firstly, the grid systems are not design for volatile energy sources like renewables. Secondly the thermal heat demand and mobility is in the transition periods underestimated and concepts are missing. The energy is used mostly on the point of usages like in buildings, industries and vehicles. Energy generations are mostly done central with efficiency factors fare from technical possible. Hybrid system can solve their problems easily with existing technologies.

There are variations of renewable energy systems on the market. Nearly all RE systems are working as separate systems like PV or Wind system generating electricity for standalone application or grid systems for using tariff feed systems.

Using different renewable source together in one system, so called hybrid systems, are getting more and more developed steadily. The objectives of these systems are: higher efficiency, better economic results, less environmental impact, new innovative products, new markets, higher profitability and new business areas. Figure 3 shows a Sankey diagram of a hybrid system with different energy flows.

Figure 3. Hybrid system
Own contribution.



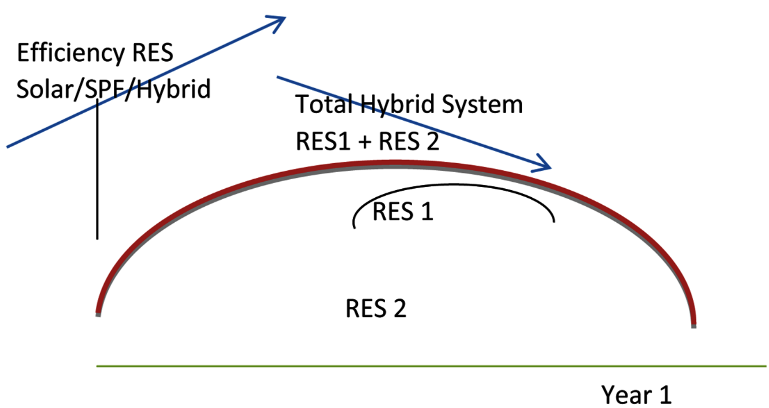
Using this hybrid systems, one key factor is the control of different energy sources in the system and a regional or national network for controlling energy supply and demand as efficient as possible. Hybrid systems could produce thermal heat and electricity for buildings, standalone applications, energy storage, tariff feed in and for mobility units such as: cars, bikes, buses, transport vehicles (Weert, 2017; Abdi, 2016; Ruokarno, 2016).

A hybrid system could be a Heatpump (HP) system with different combinations of RE sources. A HP is using cost free energy sources from air, ground water, geothermal system or waste energy resources (Erenw1). For these different sources of energy, different HP like geothermal HP, Air/ Water HP, Split Systems are available. The HP self needs an energy source for operation (Ecost). This energy source is mostly electricity which will cost money for the HP user. A combination using a thermal solar systems (Erenw 2) for boosting for example the temperature of the geothermal site directly or over the evaporator can increasing the efficiency of the solar thermal system through wider temperature range and on the other side the efficiency (seasonal performance efficiency SPF) of the HP. The E out would be higher with the same energy cost. With more sophisticated control system heat pumps using renewable sources more efficient, they can stabilizing the electrical grid system and using variable energy prices increasing the benefit using such systems. This new integrated smart grid technologies in heat pump devices gives complete unique competitive advantages to other heating appliances (Fischer, 2017).

Another example is using PV systems for driving the HP system directly. Today PV generated electricity reached nearly grid parity means producing electricity with the same energy cost like todays conventional generated electricity. This situation opens new business opportunities for supplier, manufacturer and user of this energy source. HP manufacturing using now smart grid controls in the devices for controlling direct energy usage from PV systems. New incentives are given from the government (innovation program Germany) for these devices. In Germany, the electricity cost from the grid for the end consumer is ca. 0,23 €/kWh. The energy cost of a PV system in the south region in Germany is around 0,12 - 0,14 €. The surplus is 0,10 - 0,12 €/kWh. If the electricity could be used 100% for self-powered use with the help of battery systems, electrical appliances, sophisticated control systems through smart grid controls the payback time would be less than 12 years of the PV system. With a warranty of more than 20 years the investment is also economically viable without subsidies from the state. Similar situations are in Austria, Switzerland, Netherlands and Belgium gives unique new business opportunities and new innovative BM not only for the PV supplier and installers. New technical innovations in controlling all different electrical appliances in private, public, as well industrial buildings and storing electricity in batteries and thermal puffer tanks.

For developer and entrepreneurs there is a huge variation of new innovative hybrids products possible. Figure 4 shows possible influence of the combination of two different systems and the efficiency increasing.

Figure 4. Hybrid system efficiency performance increasing
Own contribution.



Through these combinations of RES new key values can be generated through these evolving combinations. Reducing the energy bill for heating systems, reducing the environmental impact, reducing the dependencies of electricity from the grid, be self-sufficient, control of the own energy amount and payback of the investment of the PV systems in a shorter periods of time.

H_2 fuel and PV systems in combination for private consumer is only in small individual systems in present available. These systems are designed mostly from entrepreneurs and idealists with some visons for a new H_2 economy world. The objectives are mostly not economically driven, that are more individuals showing practicability of such systems. Examples are housing estates in Switzerland with a central storage H_2 and different combinations of renewable energy systems like thermal solar, PV for H_2 production and tariff feed system, a FC electrolyser system for producing electricity on demand and thermal heat for heating (nights). Key values for the home owner are: independency from the existing grid, self-sufficient, less energy cost, higher efficiency, no environmental impact with RES. A similar system was developed from an Austrian PV DC/AC converter company (Fronius). This system is using PV power in a hybrid inverter system. If PV electricity is not usable in the building it will transferred over an electrolyser in the long-term storage medium H_2. If energy is necessary, H_2 will be converting back in electricity and heat for heating and domestic water purpose.

These applications are not economically visible at present, because of the low production quantities and the present energy cost for conventional fuels. As well technical difficulties specially for the storage technology needs another innovative boost for reducing size and production costs.

Other Examples are FC boat as a pilot project from universities on the Lake of Constance. Key aspects are: no energy cost, unlimited range, loud less, maintenance free, environmental friendly using in summer times (University Konstanz).

H_2 fuel and PV systems are available in industrial application like power to gas in combination mostly with wind generators.

An application in Germany/Bavaria (Neunburg vom Wald) was the first solar hydrogen system for testing PV and H2 fuel production with Solar PV. Low pressure electroliyzer with over 111 kWel. power was installed. H2 fuel is used for mobile applications like forklifts and cars.

Other projects are the Phoebus project in research center Julich, Emmental CH building with PV and H2 electrolyser, Haernoesand Sweden with H2 electrolyser and Wind generator, FH Stralsund Germany and some more worldwide.

Table 2. Characteristic for classification of BM with PV/H2

Characteristics	Details
Small, medium, large systems	Size of the RE system in power kW
Decentralized/centralized	Decentralized usage close to the generation or point of use
Customer segments	Private, public, industry, services
Energy/Fuel generation	Generation of thermal heat, electricity, H2 production
Fuel/Energy distribution	Electricity in grid network, H2 gas, Methane gas, Liquid fuel to energy grid/ network/, H2 in liquid form LCOP
Fuel/Energy diversification	Refining energy
Energy value creation	Exploit all possible energy benefits Feed-in tariff, quota model, tendering, trading with certificates
Long/short term storage	Storage time and the amount of energy

Source: author's own contribution

There are different (archetypes) classification for BM for PV (see Chapter 2) defined. In order to get a structuring of possible business models the following characteristics for these H2/PV systems are used (see Table 2)

Following possible BM types (archetypes) can be diverted from today's view. Out of this analysis new types could be developed and evaluated.

General aspects H_2 with PV:

- H_2 usage for heat and electricity,
- H_2 grid systems (stabilizing, balance),
- H_2 mobility usage,
- H_2 storage long term/short term,
- H_2 storage in fuels/liquids.

BM types:

BM Type 1: H_2 produced from PV electricity used as a long-term storage fuel for power grid applications. This long-term storage fuel can be used in existing gas networks or caverns for fast response energy power usages in the public grid system.

BM Type 2: H_2 produced from PV electricity and changed with CO_2 in methane as a long term storage fuel. This long-term storage fuel can be used 100% in existing gas network or stored in existing gas network storage tanks.

BM Type 3: H_2 produced from PV electricity as short term storage H_2 fuel for direct use. H_2 fuels used directly for mobility and stationary applications in different pressure and storage tanks on the point of use.

BM Type 4: H_2 produced from PV electricity and changed with CO_2 in liquid for direct use. This liquid fuel could be used as a substitute for conventional combustion engines and thermal heat processes.

BM Type 5: H_2 produced from PV electricity and changed with a new LOCP in a transportable liquid form. This liquid transformation (H_2) can easily handle and transported with a high-energy density to the point of use which will be released back to pure H_2 without efficiency loses for H_2 applications like FCV, FC Heating and other H_2 driven appliances.

Type 1-5 BM can have further variations like central systems or decentralized system with different power sizes, different customer structures and segments, energy value creations methods for increasing the profitability using different fuels under certain tariff feed systems. This variation gives new BM views and possible new innovative systems and models.

PV and H_2 fuel can match perfect for applications which the mount of H_2 is manageable. For this applications hybrid systems are a perfect solution for reducing the fuel amount of H_2 and generating/amplifying through other renewable source the energy output. With less fuel needed, smaller H_2/PV systems can be designed. Especially for building applications, a small modular system can provide energy in form of storage (H_2), electricity for building demand and heating/electricity over a FC system.

3. INNOVATIVE BUSINESS MODELS WITH H_2

The combination of Business Model (BM) elements is an essential component within the definition of BM. The term elements in BM are also used in other contexts such as components, objects, concepts. The combination of elements is used to create products and services, to create, to provide, and to secure values. The created values serve to strengthen customer relationships and to support a differentiation against competitors or to secure a competitive advantage. A BM is at the same time a communication tool and also an analysis and planning instrument. A BM is therefore the result of the analysis of existing business model elements and, on the other hand, the planning of new combinations of BM elements (Schallmo, 2014).

The goal is to combine the BM elements so that the BM elements mutually reinforce each other. Growth is thereby achieved and the imitability is reduced.

Innovation is characterized by two perspectives. Result-oriented and processor-oriented view

The result-oriented view means innovation on the market or corporate innovation, with the aim of improving its own economic success.

The detailed differentiation is based on the innovation object, the degree of innovation, and the reference unit for the determination of the new property

Innovation objects or innovation types are: Performance innovation means demand-oriented renewal and improvement of products and services. Process innovation means more sufficient manufacturing of product and services. Market innovations mean identification new and development of existing markets. Social innovations mean changes in personal and organization and legal area. The business model innovation partly incorporates the existing innovations types.

There are two distinguishing criteria for the degree of innovation. Incremental innovation is minor changes that are associated with low risk and opportunities. Radical innovations are fundamental changes of quantitative and qualitative nature and are associated with high economic and technical risks and opportunities.

Depending on the degree of innovation, incremental and radical innovation business models can be developed. For radical business model innovations, new and so far, unknown business models are designed.

There are a variety of BM innovation definitions similar to the BM definition without consistency (Johnson, 2010; Labe, 2005; Lindgardt et al., 2009; Osterwald, 2010; Skarzynski, 2008).

BM innovations focus on the changes and further development of individual elements of BM and the company as a whole. These changes are intended to create new mechanisms and have a novel composition of the elements as results. This makes it possible to provide products and services that have not yet been available. Thus, satisfying new and hidden customer requirements and providing the customer with a new way of using it. This generates new revenues and, on the other hand, differentiates them from competitors. The advantage of the BM innovation is the heavy imitability in contrast to the product or process innovation. The BM innovation serves to change the value creation in an existing industry or to enable the development of new industries. BM takes place in the form of a process of the further/new development of a BM.

We discussed in chapter 3.2 present H_2 BM produced out of a sustainable fuel. This fuel can be generated central and decentralized. The fuel can be used direct on the production facility or transport to the point of usage. The fuel can be converted in gaseous forms for storage in gas networks or changing in liquid conditions with CO_2 as a byproduct from a conversion system or out of the air. H_2 could be stored in liquid condition for better transport and better storability. H_2 can be used in FC system for mobility, stationary and portable applications. The H_2 fuel could be a byproduct which is generated out of overcapacity from a renewable energy source like wind, solar or hydro systems.

Storage and production efficiency are the main technology aspects for producing and the usage of H_2.

In order to be able to describe and evaluate innovative BM, the individual elements of the BM must first be captured. Pigneur distinguishes four starting situations of the BM innovation. Resources driven, supply driven, customer driven, financial driven and a mix of this situation can influence the whole innovation process.

For our research, we are looking to value dimension of a BM. This dimensions includes elements like services or products and their values. This value propositions is the key factors for a successful profitable innovative BM.

Depending of the operator of H2 fuel producer and the customer segments different variations of BM are available and exist. Operators could be electricity producer or traders, gas storage traders, biogas operators wind and PV operators, gas network operators, hydrogen service provider, grid operators, filling station providers, industrial plant operator, public transport, public building operators, private households, public sector operator.

To go new ways, you have to get rid of old patterns of thinking and open up the mind for new visions. Visions for hydrogen-based models:

1. Change from a power electrical energy economy back to a thermal energy economy:
    a. Fossil gas network to a hydrogen gas network,
    b. Decentral virtual power generations controlled centralized,
    c. Reducing electricity grid transmissions,
    d. Shorter ways to consumer,
    e. Feeding the electricity from renewable energies directly into the low- and medium-voltage grid,

   f. Using thermal energy direct on the point of usage (higher efficiency..),
   g. Reduction of grid losses.
2. Centralized power system reversing the electrical power direction from consumer (consumer load switching, demand management):
   a. Controlled over energy prices with the customer,
   b. Incentive systems (governments, electricity grid operator.
3. Decarbonization with H_2 as a RES:
   a. Away from carbon (Coal, oil gas),
   b. Reduction of weight-specific proportions of carbon in the fuels.
4. Carnot Cycle process obsolete:
   a. Energy converters (Fuel Cells),
   b. Electricity and heat with micro CHP/CHP's.
5. Hydrogen society:
   a. H_2 gas network,
   b. Decentralized FC systems (CHP's).

The following innovative business model variants are discussed in more detail in table 29 their applications and possible effects. The value of the business field dimension is particularly taken into account. Other important dimensions are listed as well.

Table 29 shows possible innovative BM model with H_2, the innovation feature with different BM elements, which can results in complete new business opportunities

The main aspect in H_2 energy innovations is the type of storage of H2 fuel, the availability and competitive prices of RES, the infrastructure for H2 fuel, the conversion technology like fuel cells, high efficiency conversion processes like electrolyser/fuel cells, new biomass steam reforming processes with high efficiency, H2 gas network for a H2 economy, change from power driven network in a thermal driven network.

This technology must compete with existing technology and energy storage possibilities like todays innovation BM from electrical vehicles (TESLA, VW) and alternative storage units (Li Batteries) Panasonic, Tesla, Samsung, TDK, BYD which are spending over 5 Bill $ for factories and production facilities at the moment (Seba, 2016).

Future technology fields for hydrogen, innovation potentials and possible technical requirements are small, highly intelligent decentralized energy units for storing, discharging, heat and electrical supply with different renewable energy combinations.

Table 3. Innovative BM model with H_2 and their effects

BM V1	Decentralized H_2 Fuel System for Heating and Electricity with Renewable Energy Sources
applications	For domestic buildings 1-2 family houses, for housing estates, RES Photovoltaic, RES Wind in urban areas, for commercial buildings, government buildings, tariff feed systems, future nearly energy buildings through EPBD EU,
BM Variations	• Private households using PV system and optimizing electricity PV for storage H2 and electricity for tariff feed and thermal energy • Community for a housing estate using central PV/Wind and optimizing electricity PV/Wind for storage H2, electricity for tariff feed and thermal energy for housing estate • Municipalities for their public buildings using and optimizing electricity PV for storage H2, electricity for tariff feed and thermal energy • Industrial operation using renewable sources for H_2 storage, electricity for tariff feed/own use, H2 production short term storage and thermal energy • Wind/Solar PV operators deliver electricity for heating and electricity supply with H2
Innovation features value propositions	Standardization of electrolyser/FC systems, Modular Systems higher quantities/cost reduction, mass production, higher efficiency in the technology chain, new storage materials for H2, simpler storage concepts, new biological H_2 production processes, PV system producing H2 direct, intelligent appliances for energy usage, automatically software system for controls of metrological and energy price data's online,
Innovation features other BM elements	financial instruments Leasing, renting, no energy cost, Energy cost accounting, government incentives, legislations changes, carbon tax, new customer segments, software customer services, metrological data's support, internet based energy,
Effects	Economic impacts (value added effects, Lower import rate for energy), lower investment cost, more competitive prices (fuel/energy), less dependency, own control of energy flow, higher volatile energy source, self-sufficient, higher application efficiency, new technologies in storage and FC technology, smaller decentralized modules smart control systems controlled central for decentralized power systems, intelligence appliances for energy usages, software controls on met data's, energy price data's online, synergy effects,
BM V2	**Decentralized H_2 Fuel Production System Short-Term Storage Use With Renewable Energy Sources**
applications	Mobile applications, FC Vehicles, FC Busses, FC lorries, FC airplanes, FC trains, FC bikes, filling stations Stationary applications FC heating systems, FC converter, CHP's, H2 Engines
BM Variations	• Service station operator produce on the point of use H2 with renewable energy sources • COOP's operators producing H_2 on the point of use for transport/heating/cooling purpose • Public transport fleet operators produce locally H_2 with renewable energy sources for own usage • Power producer produce locally H_2 out of a renewable source (hydro/PV/Wind) • Business operator producing H_2 fuel for own warehouse/Industry transport/mobility usage • PV/Wind operator producing H_2 fuel a diversification and higher contribution margin, selling energy for best price situations,
Innovation features value propositions	Standardization of electrolyser/FC systems, Modular filling stations, competitive fuel prices, own production, independency, modular Systems higher quantities/cost reduction, mass production, higher efficiency in the technology chain, new storage materials for H_2, simpler storage concepts, new FCV models,
Innovation features other BM elements	financial instruments Leasing, renting, no energy cost, Energy cost accounting, government incentives, cooperated identity, marketing instrument, green marketing, external partners (regional energy operators PV/Wind systems,
Effects	Cleanliness mobile applications, new variations, higher range, prices for FCV competitive, fuel cost competitive, intelligent storage controlled centralized, virtual storage room,

continued on following page

Table 3. Continued

BM V3	Decentralized H_2 Fuel for Short/Medium-Term Storage and Grid Systems Demand
applications	Power to head in gas network, H_2 tanks for medium/long term storage, H_2 conversion system electrolyser (FC systems (high temp, low temp, etc.), H_2 fuel in H_2 liquid fuel(LOHC) for better, higher storage value, simpler transport purpose, RES Wind/Photovoltaic/hydro Biomass reforming
BM Variations	• Grid operators • Power producer • PV/Wind operator producing H_2 fuel for storage and for energy demand with higher energy prices • Grid/Power/PV/Wind/Industrial operators changing in Liquid Organic Hydrogen Carrier, LOHC • Filling station operator using regional LOHC storage possibilities • Fuel trader using LOHC technology for distribution purpose of H_2
Innovation features value propositions	Short/medium term storage, energy on demand, energy price/fuel control, intelligent control mechanism (energy spot market, weather other data's), levelling grid problems, transport of H2 fuel in liquid form, higher energy density in liquid conditions, safe and simple change, no environmental impact, modular systems from low power to high power applications
Innovation features other BM elements	New customer segment through new distribution logistic, new market in H_2 fuel,
Effects	Economic impacts (value added effects, Lower import rate for energy), lower investment cost, more competitive prices (fuel/energy), less dependency, own control of energy flow, higher volatile energy source, self-sufficient, higher application efficiency, new technologies in storage and FC technology, smaller decentralized modules smart control systems controlled central for decentralized power systems, intelligence appliances for energy usages, software controls on met data's, energy price data's online, synergy effects,
BM V4	**Centralized H_2 Fuel Production System Long-Term Storage Use with Renewable Energy Sources**
applications	Gas network use, industrial usages, for methanation and liquefaction processes
BM Variations	• Industrial operator using H_2 for artificial gas • Gas network operator using H_2 as substitute to fossil gas • Gas network operator using H_2 for a methanation process for gasnetwork input • Gas network operator using H_2 for long term storage in caverns • Grid operator using H_2 for grid stabilization for longer periods of time
Innovation features value propositions	Standardization of electrolyser/FC systems, Modular Systems higher quantities/cost reduction, mass production, higher efficiency in the technology chain, energy on demand with H_2, flexibility,
Innovation features other BM elements	financial instruments Leasing, renting, no energy cost, Energy cost accounting, government incentives,
Effects	Economic impacts (value added effects, Lower import rate for energy), lower investment cost, more competitive prices (fuel/energy), less dependency, own control of energy flow, higher volatile energy source, self-sufficient, higher application efficiency, new technologies in storage and FC technology, smaller decentralized modules smart control systems controlled central for decentralized power systems, intelligence appliances for energy usages, software controls on met data's, energy price data's online, synergy effects,

continued on following page

Table 3. Continued

BM V5	Decentralized H_2 Fuel for Short/Medium-Term Storage Produced with a Biomass Steam Reforming Process and Hydrogen Gas Network!
applications	Hydrogen factory, H_2 in H_2 network, H_2 conversion system electrolyser (FC systems (high temp, low temp) on the point of use
BM Variations	• H_2 network system • Decentralized hydrogen factories regional • Decentralized FC Heating systems on the point of energy use
Innovation features value propositions	High efficiency production of H_2 (> 70%), different Biomass sources, Hydrogen from waste materials, Short/medium term storage, energy on demand, competitive energy price/fuel, flexibility, cheaper than conventional fuels, safe and simple change, no environmental impact, modular systems from different power level applications, own filling station on the building
Innovation features other BM elements	new customer segments, network and customer together, leasing, renting of network connection, leasing/renting FC systems in the building
Effects	Economic impacts (value added effects, Lower import rate for energy), lower investment cost, more competitive prices (fuel/energy), less dependency, own control of energy flow, self-sufficient, higher application efficiency, new technologies in storage and FC technology, smaller decentralized modules smart control systems controlled central for decentralized power systems, intelligence appliances for energy usages, software controls on met data's, energy price data's online, synergy effects

Source: author's own contribution

The innovation potential lies on the different storage technology and conversion processes. Saving potential for Fuel cells as main conversion technology for H2 fuel are given through new material combinations and the scale effect if the production quantities are increasing. The key for a successful implementation of such systems are the modular build concept and the flexible energy use for the different customer needs.

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Chapter 5
Trends in the Renewable Energy Business

ABSTRACT

The renewable energy business increase its volume each year due to the technology development and due to new business opportunities based on international (e.g., EU) and national support schemes, that have the goal to reduce the CO_2 and other emissions of GHG. This chapter presents the main trends in the renewable energy business with main focus on the PV and H_2 business. The objective of this chapter is to design a picture of the future of the renewable energy and not only. It is a view of the future of our planet in a dynamic environment characterized by proliferation of new renewable energy installments that are more personalized due to the diffusion of new information and communication technologies (IoT, Big Data, Smart grid) and new business models. The chapter offer an answer regarding to the future of renewable energy business in general, and to the future of PV and H_2 business in special.

1. ESSENTIAL TRENDS IN THE RENEWABLE ENERGY BUSINESS

Future challenges for companies are to identify new trends in a timely manner and to incorporate them into the management process. Management process means developing strategies, changing or developing existing or new business models and the operative work on the projects to get the ideas successful and profitable on the market.

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Trends are a pattern of gradual change in a condition, output, or process, or an average or general tendency of a series of data points to move in a certain direction over time, represented by a line or curve on a graph. A trend is nothing more than a change of movement or a change process. The basic direction into which is something develops. Trends are only useful if we can dimension and classify them correctly.

You can find trends in the most varied areas of life - from the economy to the politics to the consumer world. Therefore, trends are to be arranged differently and cognitively anchored: they only make "sense" when we look at them in their respective environment and reference systems.

Trends can be classified as follows.

In 1982 the term "Megatrend" was coined by the American futurologist John Naisbitt (Naisbitt 1982). Naisbitt is one of the most recognized trend and future researchers.

Naisbitt originally defined:

Megatrends ... [are] large social, economic, political, and technological changes … they influence us for some time - between seven and ten years, or longer.

Megatrends are long-term, they are not finished after two years, but they can influence decades. A megatrend influences our social world view; it influences our values and our thinking. It is an exciting and not finally discussed question whether a megatrend can change a value or whether a value change initiates a megatrend. A megatrend can fundamentally influence the supply and demand of a product or service. In most cases, it affects the political and economic position of entire sectors, organizations and countries. In the past, the concept of an "epoch" would have been used, but now it is apparent that different, sometimes even contradictory, megatrends can overlap and that they can have different effects in different regions of the world and in different social milieus.

Megatrends are long-term and encompassing change processes, effective influencing variables that shape the markets of the future. They differ from other trends by their long-time horizon, by their reach and their effectiveness. As a stable driver of change, Megatrends are often the starting point for strategic-foresight and innovation-foresight processes.

There is a variation of different megatrends. One megatrend is the change in energy and resources. In a WWF study, they defined megatrend in global energy transition (WWF, 2015).

- **Sociocultural Trends:** These are medium - term change processes, People's feelings of life are shaped by social and technological change, but are also strongly reflected in consumer and product worlds. The larger of them have a half-life of about 10 years.
- **Trends in Time or Consumption:** Are rather short-term "infection trends", which have a fashionable character, but can also reflect sociocultural or value-change processes.
- **Micro Trends:** Styles in the area of design and self-design consumerism and habitual phenomena (Horx, 2007).

If the trends are derived from the investments in the renewable energy business sector, the following picture emerges (UNEP BNEF, 2016). For Wind and Solar (PV) nearly 90% of the investment goes in these technologies. Biofuels, Biomass, Small hydro geothermal and marine (ocean) RES are only a small portion.

The view to the growth of RES by countries looks completely different. China has the highest growth in new renewable energy investment in compare to 2014 figures. Germany and other European countries having a negative growth rate since 2014.

Globally, the consumption of energy, water and other strategic raw materials is increasing dramatically. This increase is due to population and economic growth, especially in emerging and developing countries. Fossil resources will continue to play a major role in the energy supply in the future. However, their growing scarcity makes the use of renewable energy sources, the improvement of energy efficiency and the decentralization of power supply more important.

The last two decades RE plays more an important role in our economy's, the estimation economic value of RE systems and related aspect are more than 10 bill € with a constant increasing. Renewable energy growth for the next decades for nearly all type of renewables sources looking very promising (Crijns-Graus, 2016)

They main focus on RE energy is the fit in today's actual energy systems. The compatibility is in the most cases not given trough the volatile character of RE. That brings new trends, complete new concepts and innovations on the

Table 1. Renewable energy businesses

RE Energy Systems	PV Systems
	High + low temp Solar Thermal
	Wind
	Biomass
	Hydro
	Geothermal deep
	Ocean
	others
RE Energy Storage Systems	Hydro (pumped storage power plant)
	RE liquids (power to Liquids)
	RE gas (power to gas)
	Physical based H2 *Low/ High pressure, cold/cry compressed, liquid* H_2
	Material based hydrogen *Absorbent, liquid organic, interstitial hydride, complex hydride, chemical hydrogen*
	Electrical Batteries
	Liquid Organic Hydrogen Carrier (LOHC)
RE Fuel Production	Electrolysis H2
	Bio reforming (Bio Material) H_2
	Methanisation CH_4
	Liquid fuel (Artificial fuel)
RE Service	Software and Simulations
	Prototyping and Tests
	Information channels, Publisher
	Electronic Control systems / smart metering
	Central/decentral control system
	Big data's/ Cloud computing
	Internet Energy
	Energy Management Systems
RE and Economics	Financial systems
	Outsourcing
	Energy contracting
	Crowed sourcing
	Social cost of carbons
	Emission trading scheme

Source: Author's own contribution.

market place with new business concepts and new innovations. Renewable energy businesses can be classified according to the Table 1.

2. TRENDS IN PV BUSINESS

The renewable energy will play an important role in the next decade due to technology development in this field and new business opportunities. The general perspective is that the renewable energy it is positioned on a growth curve but the competition with classis fuel sources is high and the real comparative break-even-point for renewables systems is not even achieved. If we come back in 2007 we realize that photovoltaic systems where very expensive and the prices were double as higher as the prices for wind energy. The production of PV modules was in an early phase with a main pioneer production in Europe which was expensive. If we jump in 2016 the situation was total different with prices for PV systems on the same level as the prices for wind systems with a production of modules in China that increased every year. Today we read grid parity with PV and wind systems. This evolution can be observed by analyzing the share of energy from renewable sources in gross final consumption of energy in the European Union. This was 8.5% in 2004 and increased to 14.2% in 2012, to 15% in 2013 and to 16% in 2014 (Eurostat, 2016, EEA, 2016). The continuous growth of renewable energy share in final energy use is also an effect of PV growth. This growth enabled an increasing in the PV production scale that reduced the costs across technologies. We consider that this evolution will continue in the next decades also in the photovoltaic field. There are scenarios that estimate a reduction of PV module prices by 29-38% between 2015 and 2020 (Woodhouse et al, 2016). Regarding this cost reduction tendency, the European Commission consider that overcompensation of the renewable energy costs due to renewables support schemes should be avoided (EC, 2014). This conclusion is based on the new market development conditions and on the related cost reductions for renewable technologies due to large scale technologies.

New photovoltaic modules will be more efficient and will contribute to the efficiency of photovoltaic systems. This will contribute to the reduction of LCOE but for a more significant reduction of energy costs the system in general had to perform. New technologies have to improve the system reliability and its main indicators as system lifetime or degradation rate.

Other cost reductions are expected to appear due to following factors: the kerfless wafer technology that produce very thin wafers of silicon, the PERT architecture that increase the cell efficiency, the light absorbing layers at thin-film that are more thinner and have an improved light transmission and also the industry maturation (Woodhouse et al, 2016).

The research and development of new materials and structures influence also the renewable energy field.

The research about organic photovoltaics (OPV) offer new opportunities for the business in the renewable energy field due to the improvement of the indicators that increase the power conversion efficiency up to 9% for laboratory scale test devices (He et al, 2015) with a certified efficiency of 11.5% (NREL, 2016). Main advantages of the organic photovoltaics technology consist in the production facility that use scalable printing or coating technologies. The high-speed roll to roll manufacturing lines that are used for the plastic substrates reduce the production cost of organic photovoltaic modules by comparing with other photovoltaic technologies (Apilo, 2015). For this field the printed organic photovoltaic technology is seen as a commercial opportunity due to the research progress in the large scale continuous printing. This manufacturing process is relative simple and has less plant set-up costs by comparing with other manufacturing processes for photovoltaic modules (Gambhir et al., 2016). Another advantage of the organic photovoltaic are the lower energy pay back and the abundance of input material availability. The tendency for cost reduction has to be focus on the material cost, the plant manufacturing scale, the power conversion efficiency, the module life time and the geometrical fill factor. For the material and manufacturing costs the potential for large scale production will reduce the costs due to the economics of scale effect. For the geometrical fill factor, there is a need for new design innovations. The conversion efficiency and the module life time has to be increased in order to make it more competitive. The main barrier that has to be remove is the instability of printed organic photovoltaic modules to oxygen and water vapor. The research has offered also for this problem solutions based on encapsulation protocols with new materials that can stop the ingress of oxygen and water vapor into the modules (Kim, 2014). This encapsulation increase the life time of organic photovoltaics modules (Weerasinghe et al., 2016).

The potential for building integrated photovoltaics BIPV is huge and balanced also the lack of ground space for new PV facilities in towns (see chapter 2.3)

The producers of photovoltaic systems and the designer of buildings have to collaborate in order to find and develop new products that can generate electricity and can be used also as construction materials. There is a need to develop new methods for an effective building integration. PV systems with integrated short medium term storage (battery systems) for optimizing tariff feed system and own energy usage through demand, increase rapidly over the last two years. The trend in PV system is going from a grid based control system to a decentralized driven system, where energy will nearly all used in the decentralized units (Fuchs, 2017). It is improved the maximum energy amount from solar energy source and increased the profitability of the systems. The control systems in inverters are integrated and are developed intelligent energy networks for large PV system. Large PV system will be more controlled from actual situations outside of the systems. Looking in time to Tariff feed prices, alternative storage system beside large PV systems are trends for the future. Through cheaper PV system prices and therefore competitive energy prices, new ways of mounting systems in urban locations are essential. Periphery elements of PV system like inverters will be more intelligent for input information's from sensors and outside data's for controlling PV systems as efficient and economical as possible. Crowd Energy (everyone could be an energy producer) as a cooperation could be a new energy concept especially in urban areas (Meier, 2017). Producer and consumer are coming together as energy prosumers.

3. TRENDS IN H_2 BUSINESS

Storage of Energy out of a volatile renewable energy source is the key for energy generation and distribution in the future. This is not depending of the type of RE source.

Medium and Large power to gas system is one process for generating H_2 gaseous fuel for storage and substitution in methane gas and liquid fuel for compensation purpose for the energy network system like electricity and gas network. Main objectives in this technology are the intelligent usage of overcapacity from renewable sources. Other powers to X processes are in place like power to liquid, power to fuel. This coupling element will produce electricity, heat and energy for mobility for households, industry, Trade and services. Fuel cell technology for different application like mobility, transport and stationary system are increasing. The fuel will be only a small portion of pure H_2 fuel produced out of renewable source. Mostly it will be a fossil gas used. As more renewable source is installed the future alternative will be using H_2 fuel as a secondary energy source for FC applications. Application for heating and electricity so called CHP´s or micro CHP's will be installed in private households and in industrial application for increasing the efficiency. Storage technology will be a key element for using H_2 fuel. In this field, new technical innovation will come forward especially in the material based H_2 storage systems (metal hydride) and Liquid Organic Hydrogen Carrier (LOHC).

The infrastructure for H_2 fuel filling stations for mobility with FCV will improve with new modular concepts and support from the EU governments (H2Mobility, 2017). That will give a chance to promote and increase the quantities of FCV on the roads. This technology is disturbed at the moment from the push of electro mobility with electrical cars. This push comes from vison driven companies for changing the whole mobility sectors with environmental friendly products such as LNG (liquid natural gas).

4. FURTHER TRENDS IN RENEWABLE ENERGY SYSTEMS BUSINESS

Energy distribution in the form of heat, electric current and fuel characterizes today our energy supply systems. Central very ineffective energy conversion processes characterize the global generation of energy. The saving potential in efficiency moving from a centralized system back to a decentralized system is over 30-40% means reducing our primary energy consumption. With high efficient decentralized conversion systems with renewable energy sources an ideal solution. For heat market which makes more than 30% of our energy demand new technology in biomass systems (burning a biomass source like wood, pellets) district heating systems fired with wood chips or strew will increase stately. Reasons are the fuel cost, independency and less environmental impact. For private home heating another renewable source could be generated through heat pump system. This technology in combination with other renewable sources (so called hybrid system) likes PV for direct electrical usage for driving the HP or thermal solar to boost the efficiency (seasonal performance factor) of such kind of systems. The forecast and growth projection for HP system looking very promising (BWP/BDH). Micro CHP driven with a FC and condensing gas boiler will increase. This system can reduce the environmental impact, but that is not a renewable energy system because of the usage of a fossil energy fuel.

Hybrid systems as for example minigrid PV systems have a high potential for growth, especially in the developing countries and outside the centers.

This system combining two or more energy sources, possible storage units to local AC distribution networks (Minigrid) (Rosenbusch, 2014)

Decentralized renewable energy system for heating, electricity generating and storing, needs sophisticated control system for optimizing the energy flow, resulting profitability and the flexible reaction of different changes in the energy network. Therefore, there must be an online access to all important data´s for the system. The future will give us also the response of the transition from a centralized offer of energy services to a decentralized one. The development of the renewable energy sector in parallel with the development of information and communications technology and the proliferation of the smart grid will change the view on the decentralized energy landscape in a world dominated by the distributed energy resources (see Chapter 4.1).

Big Data represent a new business or minimum a business opportunity also in the renewable energy field (see Chapter 4.1). In the energy field, Big Data is connected with the new electricity grid structure where the trend for digitalization based on new information and communications technologies open the door for implementation of new smart solutions. In a smart grid, there is a bidirectional communication flow between producers and consumers of energy that generate information regarding consumption data. This information has to be used for grid optimization but also to develop new service solutions that create value for the consumers. The new value proposition will not be focused on the amount of kWh of electricity and more on new services for heating, cooling, lighting, automatizations that will improve the consumer's life standard. The data from smart grids represent an input resource for companies that are interested in customize products based on consumer's preferences. Electricity companies will have a new revenues flow by selling the information to companies that are unrelated to energy market today (Valocchi et al., 2014). Big data represent also a knowledge management resources that help managers protect the organization against different risks.

The digitalization will enable the proliferation of the energy internet that integrates the energy flow with the information flow and the business flow. This is an extension of smart grid, known also as web-based smart grid (You et al., 2015). The Big Data in the Energy Internet include the internal data of the energy system but also other types of data, such as weather data, social media data (Moreno-Munoz et al., 2016). Specialists consider that weather data will represent the next generation of infrastructure platform of energy-saving services and applications, like maps and location data that form the basic platform for a lot of services (Zhou et al., 2016).

As a result, energy internets integrate the smart grid with the prosumer, with the micro grid and with the Virtual Power Plant. The prosumers can consume the produced electricity himself but they can also inject it to the grid and sell it. The energy internet structure offers consumers the possibility to play also a new role as a system service provider. In such a role, some consumers will have the opportunity to provide new decentralized services to the local energy system that could be used by other agents. This introduces new energy consumption devices and new business models focused on smart grid. New micro grids will enable the implementation of demand response services also for small power distributions systems (see Chapter 4.1). The Virtual Power Plants will integrate several types of power sources such as distributed generators that are in stand-by, storage systems or electrical vehicles, with a new arbitrage role in optimizing the relation between all these actors in a new cluster structure. The new cluster can develop a new business model for the whole market or for the system operator (Zhou et al., 2016). The energy internet will integrate various energy networks and transportation networks, in which power system is the core and the joint element. This concept has developed a brought spectrum of connected appliances, such as: Global Energy Internet, National Energy Internet, City Energy Internet, Building Energy Internet and Household Energy Internet (Zhou et al., 2016).

All these new technologies and concepts will introduce new business models based on a radical change from the centralized energy structure that dominate in the last century the energy field. We have to abandon the top-down paradigm and to rethink the roles of transmission and distribution system operators, the borders between transmission and distribution, the procedures for allocating network costs and the role of the new distributed energy resources that will introduce new electricity services in the market (MIT, 2016). The distributed energy resources have to face with a resource mix that will be more renewable and intermittent.

This vision is focused on the lower voltage distribution and retail levels where most agents are connected and where there is the most opportunity for technological developments. (MIT, 2016).

The new market structure with lower voltage distribution and retail levels, with new energy services will change also the financing business models. Crowd funding represent a proper tool for the development of innovative business ideas also in the renewable energy field but also a support tool for a future venture capital investment (see Chapter 4.1). Connected with the proliferation of distributed energy networks crowd funding will help business ideas in the start-up or early stages to find financing for small and local projects from investors that want to contribute to the local community benefits, or for environmental protection.

The energy market will have to be more liberalized and the competition has to play a more important role. The concept Social Cost of Carbon (SCC) is a reaction to the external costs of GHG emissions that reflect the shadow price or carbon. This cost has to be considering both in policy and also in investment decisions. This cost offers a more real estimation of the economic impact of the avoided emissions.

The markets for renewable energy are worldwide increasing. In particular, in the wind and PV sectors, the energy costs generated are equal to today's energy costs of conventional fossil fuels, thus creating entirely new fields of businesses. The energy cost of PV is still reducing similar like in the past with semiconductor industry. That means in the nearer future PV will be the cheapest energy source globally on the world. This will boost new trends in storage capacity like batteries, new technologies, and combinations of PV systems (hybrid systems). The thermal heat market will change as well radically with decentralized system. Producing energy on the point of use will be the future trend. New buildings must be nearly energy buildings in the EU from 2017. This will give a huge opportunity to generate this little energy on the building self with solar energy, geothermal or biomass sources. This building are producing viable in the future more energy what the building needs (positive energy buildings). Companies, industries will look for more independency in regards to energy. Producing energy direct on side with the help of RES and more efficient technology will boost as well new business opportunities.

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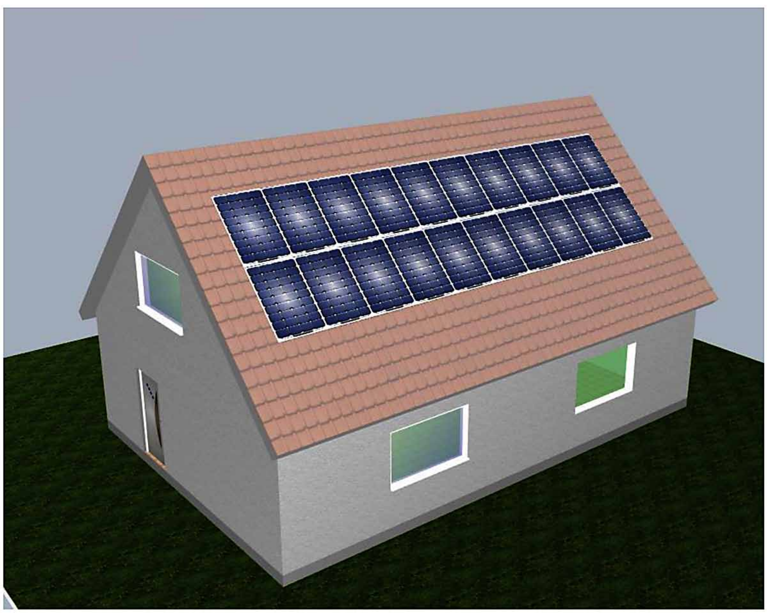
Appendix

1. CASE STUDY: GENERAL PARAMETER FOR IMPLEMENTATION OF THE PV SYSTEM IN A LOW ENERGY BUILDING IN SOUTH OF GERMANY (2017)

Figure 1. A private low energy building in south of Germany



The case study is based on the energy demand and the associated costs for a low energy building with a heated surface of 250 m² in south of Germany (Table 1).

The total yearly electricity demand for the 250 m² house is calculated in Table 2.

Table 1. Parameter for energy demand of the low energy building

Calc. No.	Technical Data's	Data
A	Heated surface	250 m^2
B	Heat demand per kWh/m^2	50 kWh/m^2a
C	Total energy amount per year	12.500 kWh/a
D	Domestic Water	2.500 kWh/a
E	PV size	5 kWp and 10 kWp
F	Solar radiation south of Germany/Buchheim (see simulation calculation	1.153 kWh/kWp
G	Electricity Energy cost net	0,24 €/kWh
H	Investment cost PV system net	1.300 € /kWp
I	Heat pump system	12 kW thermal
J	Seasonal performance factor SPF	4.5
K	Electricity demand electrical appliances for 4 people	2.500 kWh/a
L	Grid price for tariff feed net	0,12 €
M	Battery 6 kWh net	4.000€

Table 2. Electricity amount per year for heating, domestic water and electrical appliances

Description	Equation	Amount
Electricity for Heating kWh/a	C/J	2.500 kWh/a
Electricity for Domestic Water	D/J	500 kWh/a
Total electricity for the HP		3.000 kWh/a
Electrical appliances (lights/appliances	K	2.500 kWh/a
Total electricity		5.500 kWh/a
Energy Profile for user (EN18955) and own profile (smart grid)		

Before the implementation of the PV system are analysed the specific climate data for the installation location (see Table 3). The collected data for outside temperature, for solar radiations have to be compared with other data from specialized data bank systems (see Table 3, Figure 2, Figure 3).

Table 3. Climate data's for the installation location (out of the data sets)

Location: Buchheim Germany	
Lowest outside Temperature	-13,5 °C
Average Outside Temperature	7,8 °C
Highest Outside Temperature	30,1 °C
Highest Radiation	994 W/m²
Average Radiation	129 W/m²
Total Radition	1127 kWh/m²

Figure 2. Outside temperature over a year from met office databank systems

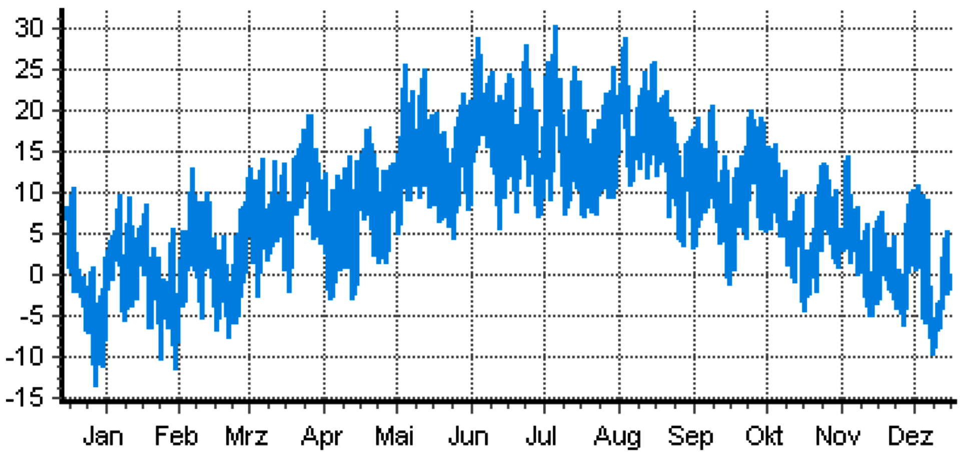


Figure 3. Global direct and diffuse radiation from radiations data and radiations maps

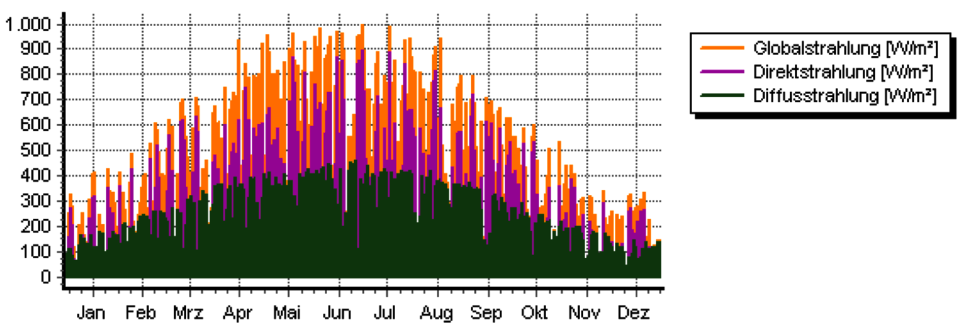


Figure 4. Energy profile user (electricity usage calendar)

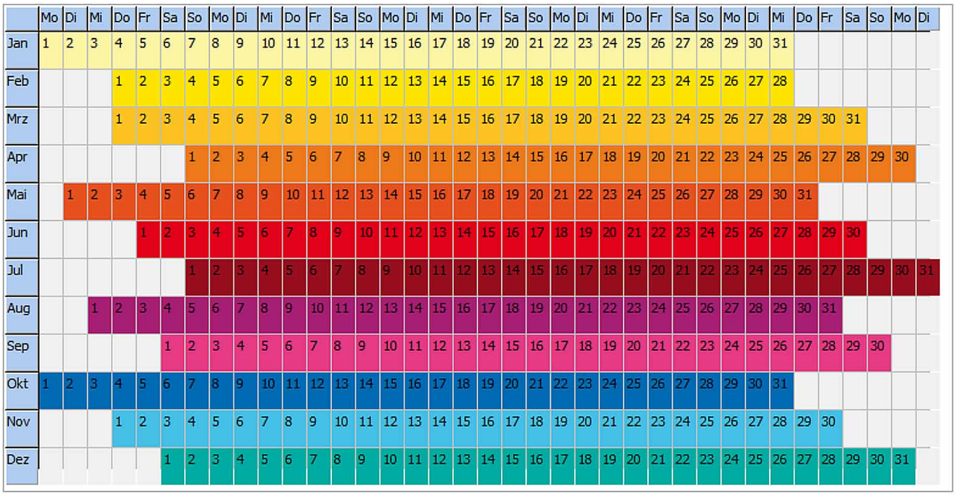


Figure 5. Global radiation

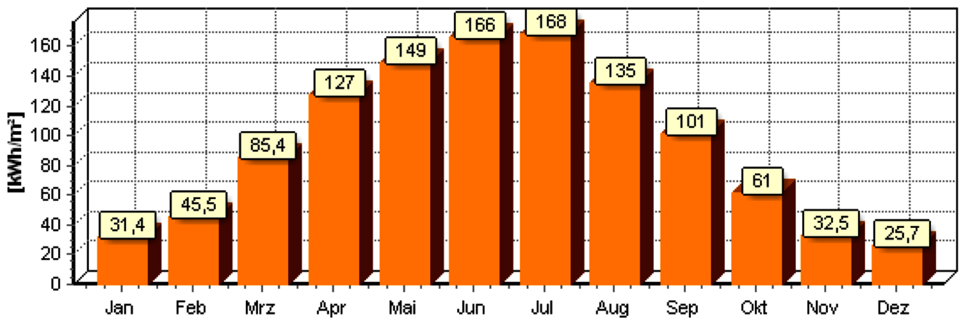


Figure 6. Diffuse radiation

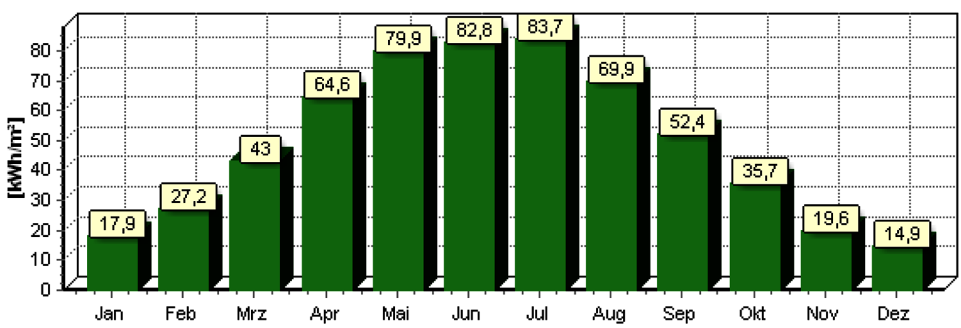


Figure 7. Direct radiation

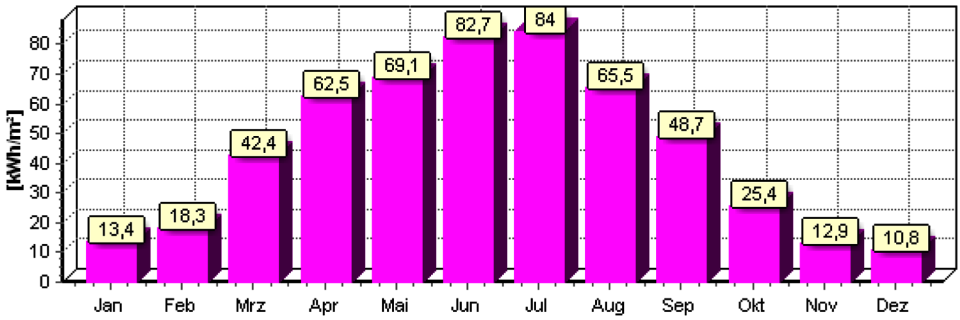
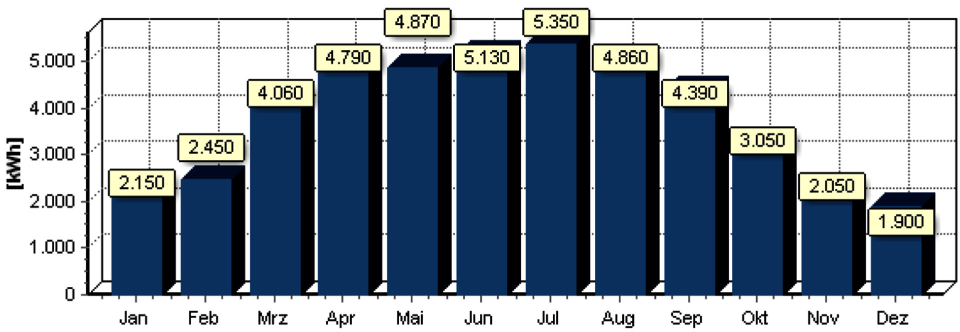


Figure 8. Irradiation on module surface



2. CASE STUDY: SIMULATION OF THE FUNCTIONING OF A PV SYSTEM IN A LOW ENERGY BUILDING IN SOUTH OF GERMANY BASED ON THREE SCENARIOS

Based on the general energy parameter for a low energy building with a heated surface of 250 m^2 in south of Germany presented in Appendix 1 it is simulated the functioning of the PV system. The simulation is realized with the *Software packages from ETU Software in Cologne Germany.*

For the simulation are analysed three scenario:

1. PV 5 kWp energy distribution grid and direct load (EN DIN 18955).
2. PV 5 kWp energy with smart grid system for own usage, surplus goes in 6 kWh battery system.
3. PV 10 kWp energy with smart grid system for own usage, surplus goes in 6 kWh battery system.

The objectives of the simulation is to calculate the yield of solar radiations, the own consumption share in the 250 m² building depending of the energy profile (smart grid) and the self-sufficiency with the help of battery/larger PV system. Out of this information and the different investment cost a technical and economic analysis can be diverted.

The results of the simulations for the three selected scenario are presented in the following figures and tables.

Simulation for Scenario 1: Standard Energy Profile User EN DIN 18955 5 kWp

Figure 9. Simulation configuration of a standard energy profile user EN DIN 18955 5 kWp

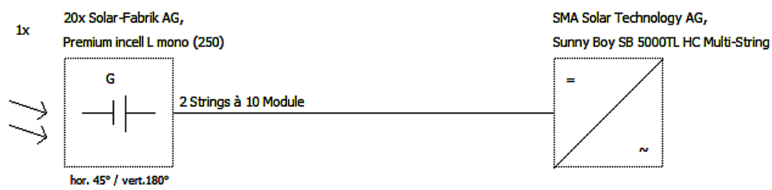


Table 4. Results of the simulation for a standard energy profile user EN DIN 18955 5 kWp

Total gross area	35,0 m²
Total power	5,0 kWp
Specific yield	1055,1 kWh/kWp/a
Performance Ratio	81,9%
CO2 savings	2830 kg
Own consumption share	44,3%
Self-sufficiency	42,3%

Appendix

Table 5.

Description	Yield/a	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Global Rad	1127,3	kWh/m^2	31,4	45,5	85,4	127,1	149,0	165,6	167,7	135,4	101,1	61,0	32,5	25,7
Radiation	45055	kWh	2150	2451	4064	4791	4868	5132	5349	4857	4394	3052	2048	1898
DC Yield	5528	kWh	276	313	516	597	590	614	637	579	535	374	257	241
AC Yield	5276	kWh	262	298	493	571	563	586	608	553	511	357	244	229
load profile	5522	kWh	469	424	469	454	469	454	469	469	454	469	454	469
Load cover	2336	kWh	115	140	207	237	255	259	269	243	219	168	120	106
Grid feed	2939	kWh	147	159	286	334	308	327	340	310	293	189	124	123
Own consumption share	44,3	%	43,8	46,8	42,0	41,5	45,3	44,2	44,2	44,0	42,8	47,1	49,1	46,3
Self sufficiency.	42,3	%	24,5	33,0	44,1	52,2	54,4	57,1	57,3	51,8	48,2	35,8	26,4	22,6

Figure 10. Load profile

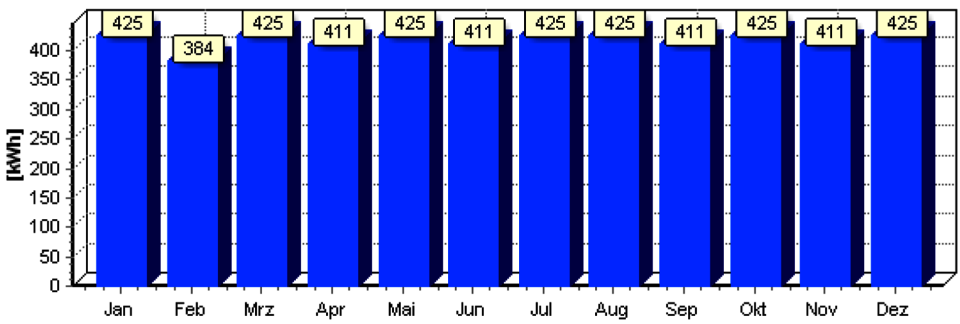


Figure 11. Net cover load cover

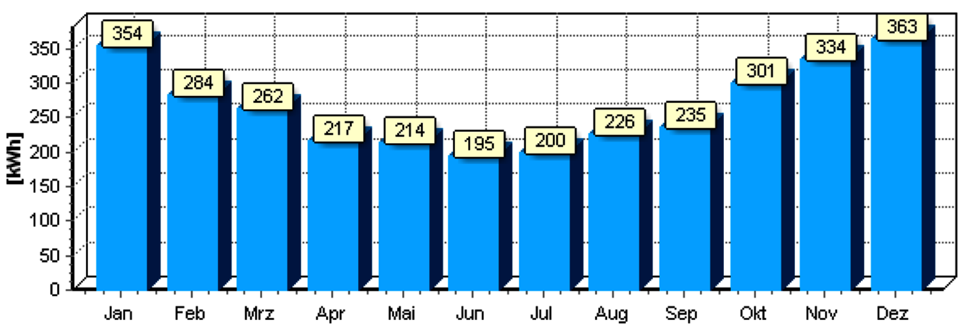


Figure 12. PV energy load cover

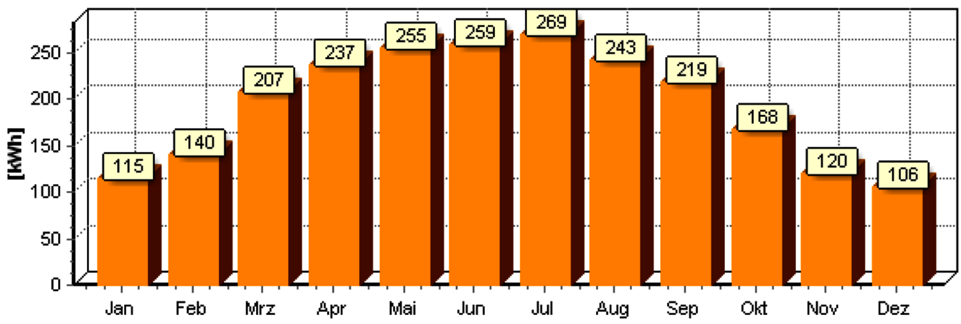
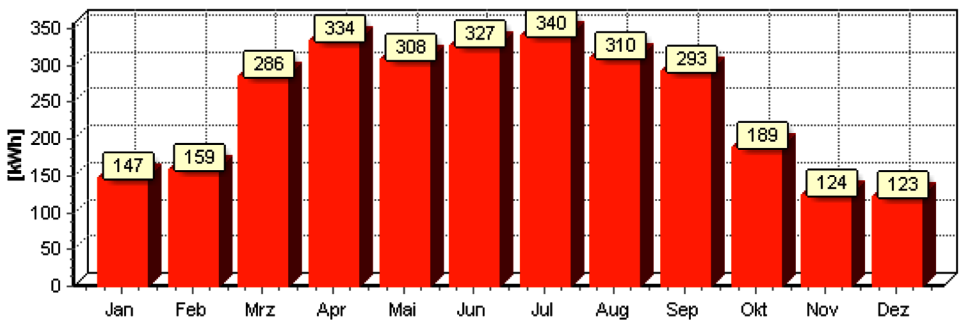


Figure 13. PV power grid feed



Simulation for Scenario 2: Smart Grid, 6kWh Battery, and 5 kWp PV

Figure 14. Simulation configuration for the scenario smart grid, 6kWh battery, and 5 kWp PV

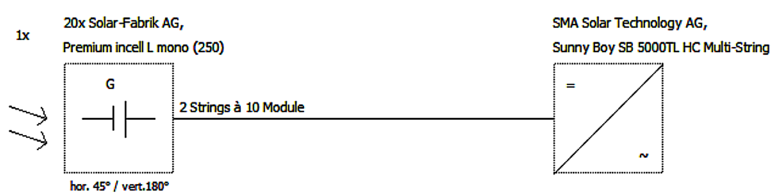


Table 6. Results of the simulation for the scenario smart grid, 6kWh battery, and 5 kWp PV

Total gross area	35,0 m²
Total power	5,0 kWp
Nominal load Battery	6 kWh
Usable capacity battery	4.2 kWh
Number of cycles battery	183/a
Specific yield	1055,1 kWh/kWp/a
Performance Ratio	81,9%
CO2 savings	2830 kg
Own consumption share	71%
Self-sufficiency	68%

Table 7.

Description	Yield/a	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Global Rad	1127,3	kWh/m²	31,4	45,5	85,4	127,1	149,0	165,6	167,7	135,4	101,1	61,0	32,5	25,7
Radiation	45055	kWh	2150	2451	4064	4791	4868	5132	5349	4857	4394	3052	2048	1898
DC Yield	5528	kWh	276	313	516	597	590	614	637	579	535	374	257	241
AC Yield	5276	kWh	262	298	493	571	563	586	608	553	511	357	244	229
load profile	5522	kWh	469	424	469	454	469	454	469	469	454	469	454	469
Battery discharge.	749	kWh	46	44	69	77	77	76	81	68	74	54	42	42
Load cover	3008	kWh	156	185	265	305	321	331	338	311	282	212	157	146
Grid feed	1417	kWh	54	64	149	178	154	169	179	164	145	85	39	36
Own consumption share	71,2	%	76,9	76,5	67,8	66,9	70,5	69,3	68,9	68,7	69,7	74,6	81,7	81,8
Self sufficiency.	68,0	%	43,0	53,9	71,2	84,2	84,7	89,5	89,3	80,9	78,5	56,7	43,9	39,9

Table 8. Battery backup system

Battery	
Nominal load	6 kWh
Low charging minimum (DoD)	70%
Usable capacity	4,20 kWh
Time charging/discharging	2,5 h
C-Rate load/charging	0,40
System efficiency	88,0%
Constant power rating	1,68 kWh
Numbers of cycles DoD	6500

Figure 15. Load profile

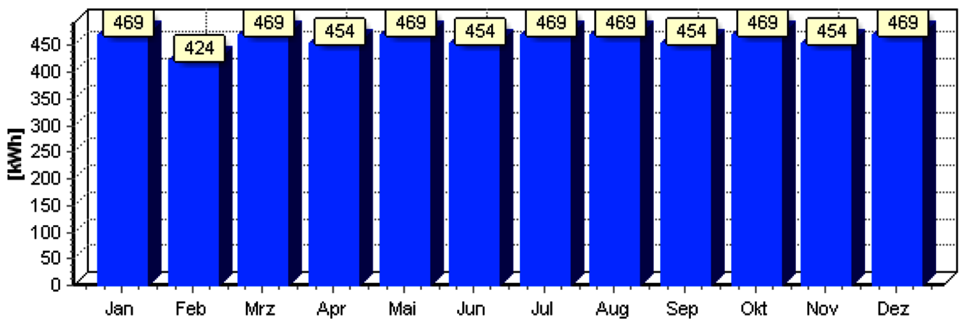


Figure 16. Net cover load cover

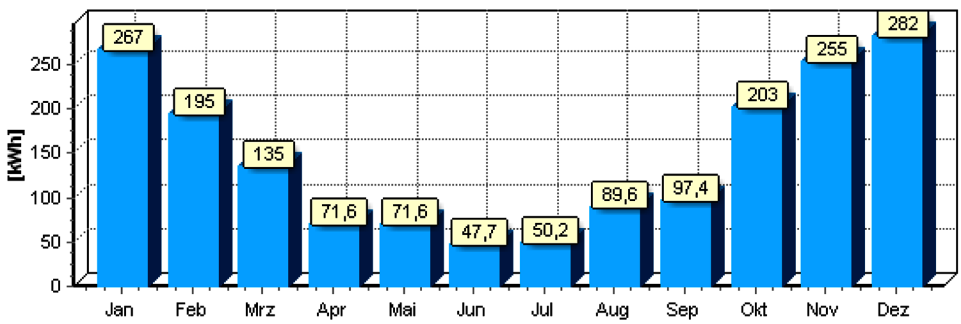


Figure 17. Battery charging net cover load

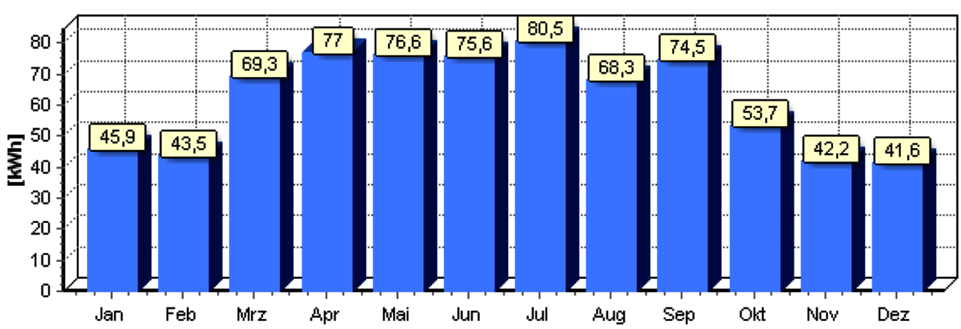


Figure 18. PV energy load cover

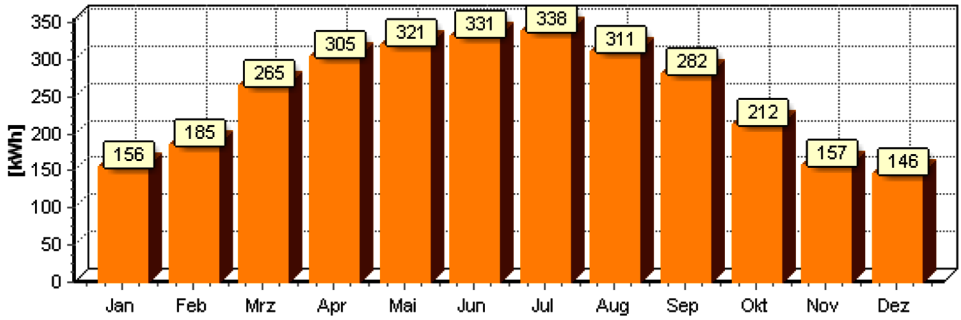


Figure 19. PV power grid feed

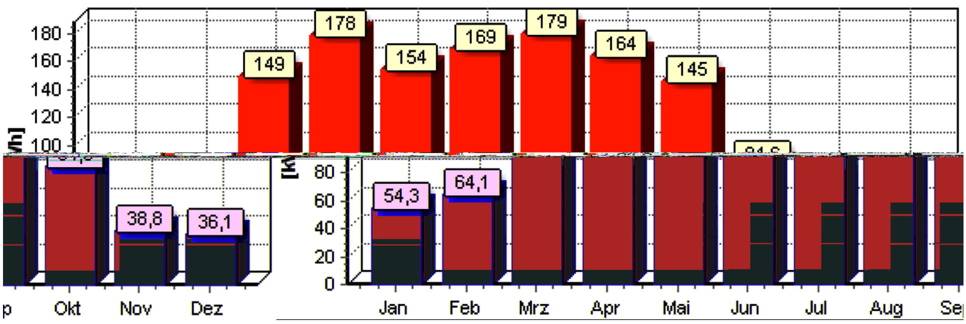
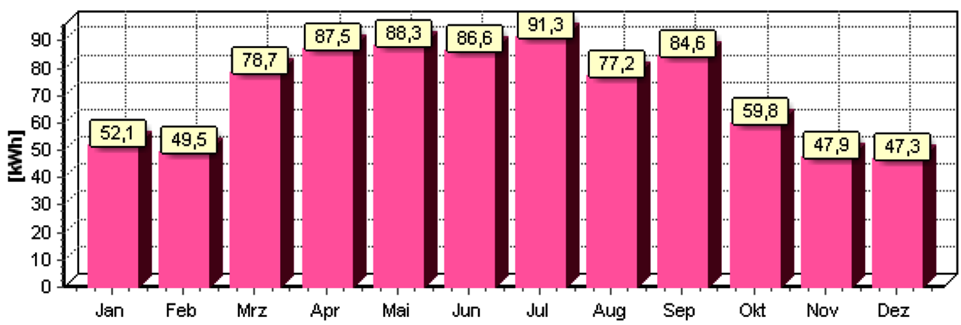


Figure 20. PV energy battery charging



Simulation for Scenario 3: Smart Grid, 6 kWh Battery, and 10 kWp PV

Figure 21. Simulation configuration for the scenario smart grid, 6 kWh battery, and 10 kWp PV

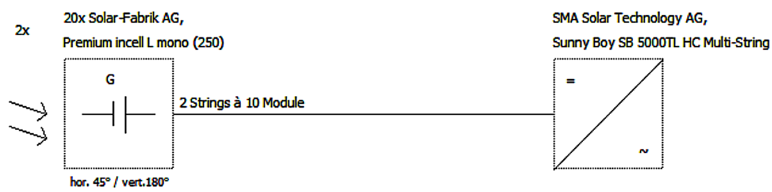


Table 9. Result of the simulation

Total gross area	70,0 m²
Total power	10,0 kWp
Nominal load Battery	6,0 kWh
Usable capacity battery	4,2 kWh
Number of cycles battery	227 /a
Specific yield	1056,1 kWh/kWp/a
Performance Ratio	82,0%
CO2 savings	5665 kg
Own consumption share	41,8%
Self-sufficiency	80,0%

Table 10.

Description	Yield/a	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Global Rad	1127,3	kWh/m²	31,4	45,5	85,4	127,1	149,0	165,6	167,7	135,4	101,1	61,0	32,5	25,7
Radiation	90109	kWh	4300	4902	8129	9583	9736	10265	10697	9713	8788	6104	4096	3797
DC Yield	11067	kWh	552	627	1032	1196	1181	1228	1274	1158	1071	749	514	483
AC Yield	10561	kWh	525	597	986	1144	1128	1173	1218	1106	1024	714	488	458
load profile	5522	kWh	469	424	469	454	469	454	469	469	454	469	454	469
Battery discharge.	926	kWh	61	76	85	91	82	72	83	76	92	80	73	56
Load cover	3491	kWh	192	231	318	343	363	361	372	356	316	267	193	179
Grid feed	6018	kWh	263	278	572	699	670	729	752	664	604	358	213	215
Own consumption share	41,8	%	48,3	51,4	40,8	37,9	39,5	36,9	37,3	39,0	39,8	48,6	54,4	51,3
Self sufficiency	80,0	%	54,1	72,4	85,9	95,6	95,0	95,5	97,0	92,1	89,7	73,9	58,5	50,2

Graphics are similar like in simulation for scenario 2.

RESULTS AND CONCLUSION

The three PV Simulations are based on the same general parameter as explained. The difference is the energy demand profile in the building.

Simulation 1 has a standard energy demand load over a period of times. Simulation 2 and 3 have a smart grid energy demand power profile (only in daytime usage of electricity for appliances). A 6 kWh battery is used for a higher share of Solar Energy radiation.

In simulation 1 ca. 44% of the PV input energy is used *direct* in the building. In simulation 2 this share is over 71% (battery) and in simulation 3 is 41% (larger PV field). The reason in simulation 3 is the larger size of the PV system. This amount of input energy cannot be used direct in the building. Therefore, the grid generated energy is bigger and the share of direct usage smaller (41%).

Another important aspect is the independency or self-sufficiency of the systems. Simulation for scenario 1 has an independency of 42%. For simulation of the scenario 2, witch has the same PV size (5 kWp) but has a battery system, the self-sufficiency percentage is 68%. For simulation of scenario 3 with the larger PV system (10 kWp) there is a 80% self-sufficiency.

These PV simulations for the three scenario shows the different dependencies and possible variations improving self-sufficiency, direct energy usage, power loads (profiles smart grid systems) and a lot of other variation parameter like alignment, roof angel, type of PV panel, DC/AC converters, the electrical module connections. All this parameter can be changed in the simulation with different results. These will give a huge variation of data's for improving such PV systems.

From the economic point of view out of simulation like the grid feed amount and the direct energy usage an economic calculation (static/dynamic) can be made with the aid of the simulation data

In simulation 1 the amount of energy which are brought back in the grid and the load cover is 2.393 kWh and 2.336 kWh. With 0,12 € energy prices for TiF and 0,24 €/kWh direct usages the income would be 560 €+ 287€ → 847 €. The investment cost for a 5 kWp PV system is 5 * 1.300 € → 6.500 €. If a dynamic economic accounting is applied, the repayment time is approximately 10-11 years at 5% interest rate.

In simulation 2 the amount of energy which are brought back in the grid, the load cover and battery usage is 1.404 kWh, 3008 kWh and 749 kWh. The income are 1.068 €. The investment cost for 5 kWp and 6 kWh battery system is around 6.500 € + 4.000 €. Repayment time ca. 13-14 years.

In simulation 3 the amount of energy which are brought back in the grid, the load cover and battery usage is 6.018 kWh, 3.491 kWh and 926 kWh. The income are 1.780 €. The investment cost for 10 kWp and 6 kWh battery system is around 13.000 € + 4.000 €. Repayment time ca. 13-14 years.

With the help of a simulation it was shown that a PV plant to be erected depends on a variety of parameters that determine the efficiency and the economic side.

If PV electricity is to be used in the future for the production of hydrogen, such simulation calculations are indispensable for additionally overcapacity must be precisely analyzed and evaluated.

3. WHAT ARE CEOs SAYING ABOUT THE FUTURE OF POWER SUPPLY?

The head of the first pure green-electricity provider in Germany, LichtBlick, Mr. Heiko von Tschischwitz, spoke in an interview with the Hamburger Abendblatt end of 2016 about the future of power supply, how energy is about, the role of politics and new business fields. The energy expert believes the Germans could completely cover their private electricity needs with solar power. Tschischwitz is even “convinced” that companies such as LichtBlick, EnBW or E.on will become superfluous in the future. At LichtBlick, we are already working on “new concepts”: When no more energy companies generate electricity, but the people with their photovoltaic plants on the house roofs, the batteries in the cellars, electric cars in the garages, which can be connected to the electricity network. When all these small power stations and storage are networked and intelligently controlled, IT platforms need to take over this task. This is “like a brokerage: if you have more power with your photovoltaic system or your battery than you need, give it LichtBlick - and we will help you to market it and make money.” “The future of power generation will be regenerative and decentralized - and thus much more complex than before. Without extensive IT support this is no longer possible.

Related Readings

To continue IGI Global's long-standing tradition of advancing innovation through emerging research, please find below a compiled list of recommended IGI Global book chapters and journal articles in the areas of economic development, business productivity, and business technology. These related readings will provide additional information and guidance to further enrich your knowledge and assist you with your own research.

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