Business model innovation opportunities in the Dutch downstream photovoltaic industry

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By

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EXECUTIVE SUMMARY

The photovoltaic industry has experienced an unprecedented growth in the past years. 300GW of nominal capacity is installed by now, compared to only 100GW in 2012. In many places, solar energy is already the cheapest electricity source, and prices are expected to decline further. Solar electricity in many ways different or even opposite of conventional ways of electricity production. It is often decentralized, generation is highly volatile, variable costs are close to zero and can be owned by anything from a private household to a pension fund.

This growth combined with the different characteristics, leads to major shifts in the electricity landscape with challenges and opportunities for governments, entrepreneurs, grid operators and utility companies.

This thesis provides insight in the characteristics of photovoltaic business models and how they relate to policy instruments and design considerations. Business models illustrate the rationale of how organizations create, delivers and capture value. The business model approach and more specifically the business model canvas is a tool that is widely used by academics, entrepreneurs and consultants to map out how organizations work and how different characteristics such as value proposition and distribution channels relate to each other.

By studying professional and academic literature on (downstream photovoltaic) business models, a set of six categories are selected. These categories vary from straight forward project providers where customers purchase a small photovoltaic installation to complex business models that include third party ownership and even aggregation of distributed electricity generators that are clustered as a virtual power plant.

Where available, industry experts and business model practitioners with experience in all categories are interviewed, and extensive qualitative research is conducted on the business models and their relation with policy instruments and design considerations. Each category is mapped systematically out after which a cross case analysis is conducted.

The research shows that the business model canvas approach is a valuable tool to assess and describe photovoltaic business models. This thesis unveils that major differences in business models are present between first-party and third-party ownership. The latter projects are often financed by banks, utilities or investment funds that maintain much higher standards in quality control, risk mitigation and are less comfortable with dealing with unstable policy environments. It also becomes clear that third party business models can only succeed in an environment with stable policies and proper access to financing.

As feed-in-tariffs and long term power purchasing agreements are getting less common in mature market, another wave of business model shuffling can be expected in the solar industry. More uncertain revenue streams, curtailment and electricity market exposure will lead to new models with a different kind of investors. Although utility companies have not yet played a major role in the photovoltaic industry, they do have competitive advantages in the coming years as they have experience with energy trading, large scale project development, uncertain revenue streams and have access to a vast number of commercial and industrial roofs.

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Last but not least I would like to thank the people that have supported me in the past years in my career in the PV industry. In only a few years I have had the opportunity to work on both technical and commercial aspects of megawatt scale solar projects and have been able to meet some amazing industry leaders in throughout the world. It has already been a hell of a ride, and I am extremely happy to be in an industry that provides me the opportunity to develop myself intellectually and financially while contributing to low carbon energy transition.

I would like to dedicate this thesis to my son, that hopefully will join us in good health on this beautiful planet by the end of September 2017. I truly hope that he will get the same opportunities as I did, both in terms of education as seeing the most amazing coral reefs and jungles on earth. Let's make sure we do everything we can to preserve this planet for future generations.

Eelco Hoogduin

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LIST OF ABBREVIATIONS

AM	*Asset Management*	*PPA*	*Power Purchasing Agreement*
BMI	*Business model innovation*	*PSS*	*Product Service System*
BOS	*Balance of system*	*PV*	*Photovoltaic*
C&I	*Commercial and industrial*	*PVBM*	*Photovoltaic business model*
DER	*Distributed Energy Resources*	*RES*	*Renewable Energy Sources*
DPI	*Downstream Photovoltaic Industry*	*SBM*	*Sustainable Business model*
DR	*Demand Response*	*SDE+*	*Stimulering Duurzame Energie*
DSO	*Distriubtion System Operation*	*SME’s*	*Small and medium enterprises*
EIA	*Energie Investerings Aftrek*	*SCO*	*Solar Community Organizations,*
EPC’s	*Engineering, Procurement and Construction companies*	*SPV*	*Special Purpose Vehicle*
FIT	*Feed in Tariff*	*TGC’s*	*Tradable Green Certificates*
IPP	*Independent Power Producers*	*TPO*	*Third Party Ownership*
kWh	*Kilowatt hour*	*TSO*	*Transmission System Operation*
LCOE	*Levelized costs of energy*	*VAT*	*Value Added Tax*
MW	*Megawatt*	*VPP*	*Virtual Power Plant*
MWp	*Megawatt peak (nominal power)*	*W*	*Watt*
O&M	*Operations and Maintenance*	*Wp*	*Watt peak*

1. INTRODUCTION

1.1 GLOBAL SOLAR MARKET AND BUSINESS MODEL DEVELOPMENTS

Over the past years, photovoltaic electricity generation has experienced phenomenal growth due to technological improvements, and supportive government policies (Solar Power Europe, 2016; Timilsina et al., 2011).

Although numbers on accumulated world-wide installed capacity differ among sources, at least 290GW has been installed by the end of 2016, with 2016 representing 70GW of new installed capacity. (PV Magazine, 2016) (IEA, 2016) (IRENA, 2017). Figure 1.1 illustrates the exponential growth of the installed capacity over the past decade.

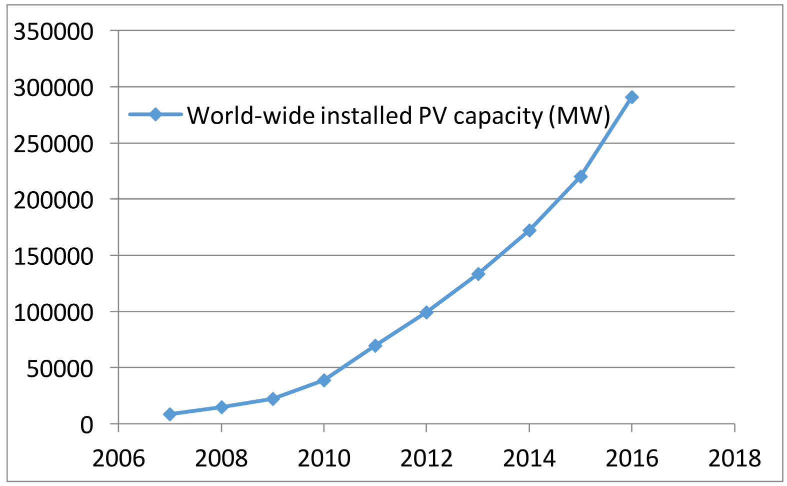


Figure 1.1 Cumulative global installed photovoltaic solar capacity (data source: Irena, 2017)

The 2013 energy outlook report by Royal Dutch Shell clearly shows that PV (photovoltaic) is likely to play a major role in the inevitable energy transition that the world faces (Royal Dutch Shell, 2013).

When considering the benefits of photovoltaic electricity generation (such as: lower transmissions losses, lower dependency on the import of fuels, providing electricity access to rural area's etc.) and solutions to the world's challenges of today, it is fair to expect that the recent growth will continue in the coming decades. This growth will inherently lead to a more important role for distributed generation in the electricity landscape.

Combining this landscape transition with the expected margin falls on electricity generation and retailing for utilities as a result of energy-efficiency measures, it can be argued that the current business models for utilities are outdated and face serious challenges. ''Recent studies on utilities' business models find that the increasing share of renewable energies constitutes a threat to the current utility business models. Utilities need to find ways to better commercialize renewable energy technologies. Otherwise, the energy transition will lead to a massive loss of market share, revenues, and profits. '' (Richter, 2012a).

Utilities will soon need to look for new sources of revenue's which might include financing, distributed solar and wind electricity generation, smart homes and energy efficiency measures (Busnelli et al., 2011).

Distributed solar electricity can be commercialized through a variety of business models. These business models are categorized by Huijben and Verbong (2013) as 1) consumer owned 2) community shares and 3) third party.

Consumer owned business models are well known and straight forward, as local installers or large EPC build a PV-installation that is financed and operated by the end-user. Community shares and third party business models for PV are relatively new and developing fast. In these models rooftops or other suitable area's are made available or rented out to an organization that finances and operates the installation. These models drastically change the stakes and responsibilities of the different stakeholders and have the potential to speed up photovoltaic deployment.

In the United States, third party ownership of PV installations has been a rapidly growing market trend. The third parties involved own and operate PV systems and either lease PV equipment or sell PV electricity to the building occupant (Drury et al., 2012). In the Californian case, that has been studied by (Drury et al., 2012), it is suggested that third party owned PV attracts new customers, rather than competing with customer-owned PV panels. If this statement applies to other markets as well, significant economic and environmental opportunities can be captured by third-party PV solutions. Third party ownership of PV systems is a multi-billion dollar market that has provided access to PV-electricity to thousands of consumers.

Recently, the first signs of a decline of third party market share has been observed and analysts expect direct purchase and regular loans to overtake residential solar in the United States (GTM Research, 2016). This is primarily a result of a wider range of loan options and the high costs involved with third party solar. This thesis is supported by the recent heavy weather that third party residential companies in the US face, including the recent bankruptcy of Sungevity and Verengo and the market exit of Oneroof and NRG home solar (Hoium, 2017).

The achievements and impact of first movers in the third party space, provide reason to research the role business model innovation can play in the photovoltaic industry.

1.2 RESEARCH PROBLEM

Standardization, research and development in the photovoltaic solar industry have led to significant price drops in the past decades, resulting in growth of the industry. This price drop combined with ambitious carbon emission reduction goals of governments has led to a phenomenal growth of the photovoltaic industry. In contrast with conventional electricity generating technology, photovoltaic systems are often decentralized, small scaled and low on maintenance (Schoettl and Lehmann-Ortega, 2011). These characteristics lead to challenges and opportunities for players in the energy field, consumers can become prosumers and all kinds of organizations can start producing and selling their electricity to utility companies. This provides space for new business models in the electricity landscape.

Novel and innovative business models for PV-generated electricity provide opportunities and challenges for, entrepreneurs, EPC's, energy contractors and utility companies. Distributed PV generation provides market space for innovative business models and severely threatens current business models of utility companies (Richter, 2012b). Although utility companies have been active in the field of electricity generation for decades, their role in the photovoltaic industry is limited and they do not seem to benefit from the business opportunities that this growing industry provides. This could be because PV installations have different characteristics than more conventional methods in terms of centralization and ownership.

PV market segments are rather heterogeneous, as the residential market is mainly driven by price of initial investment (€/Wp), where utility scale projects are often backed by investors and banks and the project success depends on the long term performance of the installation. This means that asset management, component quality, uptime rates and reduction O&M costs play a more important role in the latter market segment.

Recently, innovation of PV business models has gained attraction from industry experts and academics and several articles on this topic are published. This literature mainly focuses on the business model theory, and important aspects as the design of installations and the dependency of business models on specific institutional measures are underexposed.

It is clear that specific incentives from governments can make or break photovoltaic markets. As governments have limited resources and ambitious carbon reduction goals, it is important to understand the way these incentives work and how they relate to specific business models.

As photovoltaic installations have an expected economic lifecycle of 25 years, the quality and bankability of the system components and it's installation is vital to achieve the projections that are made at the start of the project. Different business models and customer segments all have their own characteristics. As consumers often have a strong focus on the initial costs of installation, institutional investors are more focused on the reduction of risk and the long term performance of the installation.

Although scientific research is done on business models for PV, no articles can be found on how these business models relate to policy instruments, utility involvement and design considerations.

1.3 RESEARCH GOAL AND RELEVANCE

This research aims to provide insight in the functioning of photovoltaic business models in The Netherlands. Several generic business models for third party PV are expected to be found, and will be linked to specific design and institutional conditions and design consideration. The results of this thesis can help entrepreneurs, EPC-contractors, utility companies, governments and researchers understand the characteristics of PV business models and how they function in specific market environments. It is needless to say that knowledge on the dynamics of the rapidly changing energy landscape can be of great value from economic, environmental and scientific perspectives.

1.4 RELEVANCE FOR INDUSTRIAL ECOLOGY

Industrial ecology is often considered as the science of sustainability. The scientific field of industrial ecology is broad and multi-disciplinary. It positions itself in the middle of the triangle of industry, ecology and sociology.

Innovation system research and renewable energy resources are core components of the MSc. programme of which this thesis is part. However, the link between sustainable innovation and business models is underexplored (Boons and Lüdeke-Freund, 2013). This thesis aims to provide insights in the interconnection between innovation and business models. Rather than looking at technological inventions, the innovation of business models can provide growth and access to new markets. Knowledge on the functioning of innovation and business models for photovoltaic can contribute to further market penetration of this technology that contributes to a more sustainable energy mix. In addition, the concept of solar shares has a large social component in it, which has a strong link with several sub-field of industrial ecology.

1.5 RESEARCH QUESTIONS

As the goal of this research is providing insight in the opportunities of photovoltaic business model innovation in The Netherlands, the central research question is:

RQ1: WHAT ARE THE OPPORTUNITIES IN THE DUTCH MARKET FOR DOWNSTREAM PHOTOVOLTAIC BUSINESS MODEL INNOVATION ?

Prior to drawing conclusions that answer the central research question, five sub-questions are answered in order to provide sufficient background information that allows to provide substantiated claims and conclusions that have both scientific and entrepreneurial relevance:

- *RQ 1.1: How can generic photovoltaic business models be described and framed?*
- *RQ 1.2: What can be learned from the (international) state of the art regarding photovoltaic business model innovation?*
- *RQ 1.3: How do specific business models relate to competencies and other business model building blocks of players in the Dutch downstream photovoltaic market?*
- *RQ 1.4: How do policy instruments relate to the opportunities of practicing specific photovoltaic business models?*
- *RQ 1.5: How do photovoltaic business model characteristics relate to the design considerations of PV installations?*

These research questions will be addressed by combining existing literature, empirical research by the means of interviews and personal communication by the author with industry professionals. After an extensive literature review on the photovoltaic industry and business model literature (chapter two and three), a framework that can frame and describe photovoltaic business models is selected and extended (chapter 4). By using this framework to analyse business model activities and characteristics, RQ 1.1, 1.3 , 1.4 can be answered. After the cross-case analysis, a more general discussion and conclusion are provided that provide insight in the high-level developments in the global PV business models (RQ 1.1). This conclusion ultimately leads to an answer on what the opportunities in the Dutch market are (RQ 1).

2. BACKGROUND

2.1 ECONOMICS OF PV

GLOBAL PV MARKET

Solar photovoltaic electricity generation has grown rapidly in recent years, and this growth is expected to continue in the future (IEA, 2012). PV is currently the fastest growing power source in the world (Asmus, 2008). With over 4GW of new PV capacity installed in 2012, Europe has now a capacity base of 70GW and represented 70% of the world's cumulative PV capacity in 2012. This growth is mainly a result of the German feed-in-tarrif and decreasing PV system prices. By the end of 2016, the global installed capacity was 290GW of which about 35% was installed in Europe (IRENA, 2017). Figure 2.1 illustrates that the European market is now heavily outperformed by India, China, Japan and the United States.

With Germany and Italy historically ranking number one and three in the list of largest PV markets (EPIA, 2013), the performance of Europe heavily relies on these countries. Mostly as a result of national policies, strong differences in the market dynamics of PV systems can be observed among countries.

The heterogeneous character of the European PV market is present both in installed capacity and market segmentation. Major differences in terms of the nature of the investor (private or public) and physical location (ground mounted, residential, commercial, industrial roofs) are present among countries, which is mainly a result of the national policies that are either favorable for industrial, residential or commercial exploitation of the systems. (Solar Power Europe, 2016)

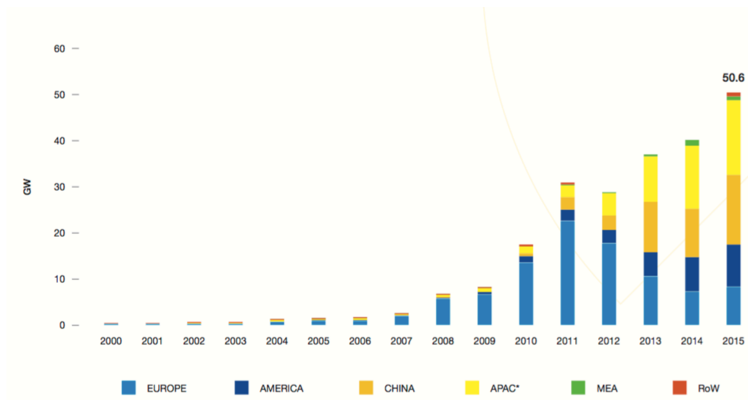


Figure 2.1 Evolution of global new-grid connected PV capacity in GW (adapted from: Solar Power Europe, 2016)

In order to keep this pace of the transition to a clean energy future, trillions dollar worth of new private and public investments will be required. According to McKinsey&Company (2012) solar power could potentially see between $800 billion and $1.2 trillion of investments in the coming decade. Given the current economic situation in Europe, it is not very likely that big investments in energy generation or infrastructure will be made by governments (IEA-RETD et al., 2012). This calls for innovation in financial models and policies, which might shift away from government incentives.

COSTS OF SOLAR PV

As a result of technological innovation, economy of scale and governmental support for PV manufacturing, the costs of PV installations have dropped radically over the past decade. Figure 2.2 shows that module prices in particular have been coming down rapidly. As PV electricity was four to five times more expensive than conventional electricity (IRENA, 2012), grid parity refers to the moment when PV generated electiricy can compete with grid prices (International Energy Agency, 2013). Figure 2.3 represents prices from electricity from the grid and the solar irradiation in kWh per square meter, this illustrates when a market segment in a specific country reaches grid parity. It is important to consider three key elements of grid parity when comparing PV with competing technologies:

- 100% of the generated electricity can be consumed locally, or net metering programs are present
- All components of retail electricity prices are compensated
- kWh prices are based on Levelized Costs of Electricity, which stands for the average price per kWh during it’s economic lifetime, including all capital and operational costs.

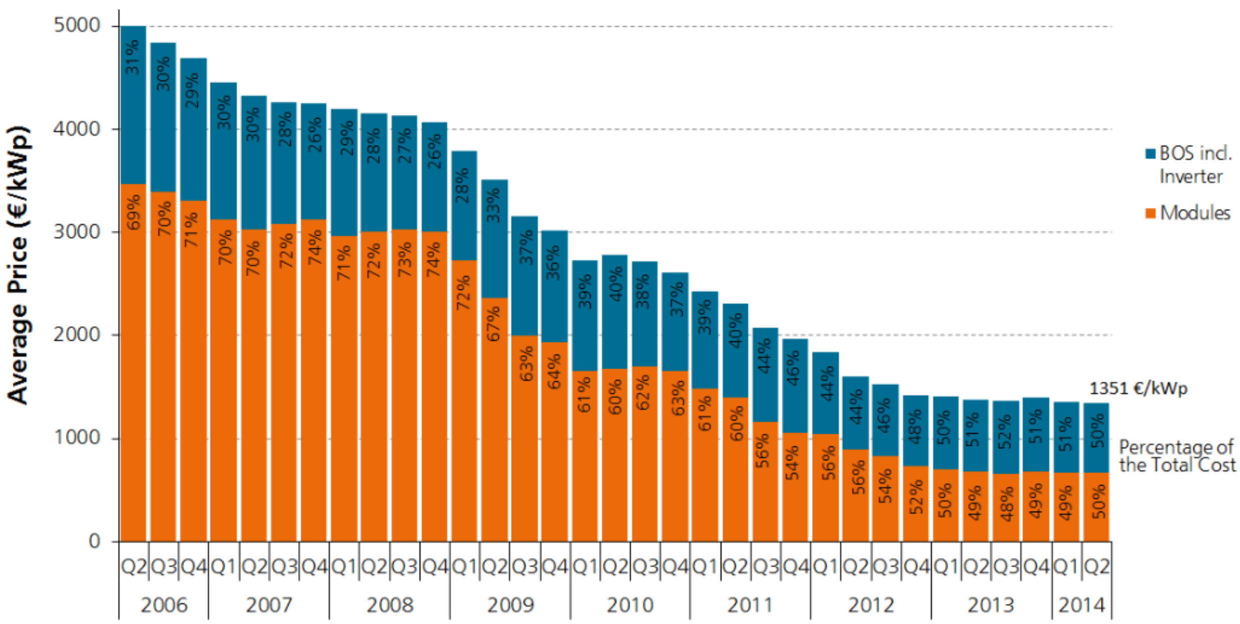


Figure 2.2 Average Price for PV Rooftop Systems in Germany (10 kWp - kWp) (adapted from: Frauenhofer ISE, 2014)

When both climate, market conditions and LCOE are considered, grid parity forms an interesting tool that can help to identify market opportunities for PV electricity. As following paragraphs will explain, electricity price differences among countries strongly depend on tax policies, availability of natural resources, and infrastructure. (Breyer and Gerlach, 2010).

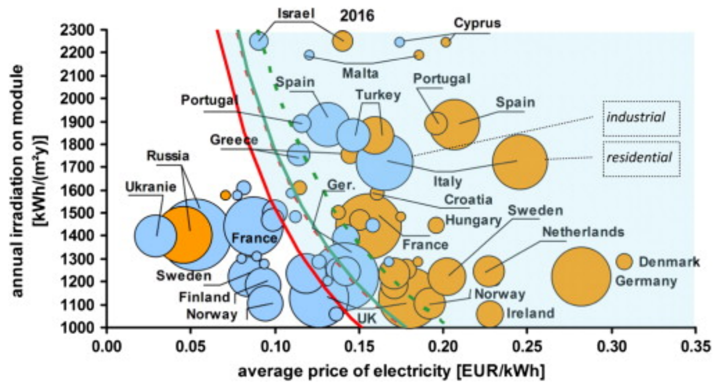


Figure 2.3 PV Grid parity in European markets 2016 (shaded area). (adapted from: Breyer and Gerlach, 2010)

MARKET OUTLOOK

Drastic decreases of support programs for PV will have a negative impact on the European PV market. At the same time, emerging markets in Europe may show some capacity growth. According to EPIA, stabilization or decline can be expected on for the short term for Europe. As non-European countries grew fast in 2012, it is expected that these new markets will be able to secure the global PV market growth (International Energy Agency, 2013). It is clear that the non-EU countries have the biggest growth potential. Europe’s share of the global PV market has declined from 74% in 2011 to 55% in 2012 (EPIA, 2013). This is more a result of a growing electricity demand and increasing competitiveness than a declining European market.

According to industry reports, PV will remain a policy dependent market. However, even in the growth scenario’s where governmental support is low, the global PV market is still expected to see a significant growth.

Especially the so called ‘sunbelt’ countries are expected to see a strong growth, as in some of these countries the decline in PV system prices has led to so-called ‘’fuel parity’’ where PV electricity is at, or below price levels of retail electricity generated by diesel-generators (International Energy Agency, 2013).

In the Netherlands the SDE+ subsidy scheme has been doubled from €4 bln. in 2015 to €8bln. in 2016 (Energeia, 2015)This has been done to increase the effort for the climate goals in 2020. Although this budget is shared with other renewable energy resources such as wind, biomass and solar thermal, it is expected that the policy measure will increase the installed PV capacity in The Netherlands.

In the recent COP21 forum in Paris, several international agreements have been signed. One of the most important is an annual €100 bln. budget for renewable energy in developing countries (Ministerie van Algemene Zaken, 2015). This can have a large impact on the global PV industry.

DRIVERS AND BARRIERS FOR PV MARKET DEVELOPMENT

There are several important drivers for a successful PV market. The financial return of an investment in a PV plant mainly depends on the electricity price and system costs. Grid parity is the point where PV installations are cost neutral, compared to purchasing electricity from the grid (Breyer and Gerlach, 2010). When the LCOE (Levelized Cost Of Energy) is lower than (expected) grid prices, grid parity is achieved. From an economic perspective, presence of grid parity is the most obvious driver for PV market growth. Both electricity pricing and system costs are factors that can be influenced by governmental interventions such as electricity taxes and subsidies. In recent years module prices have dropped significantly as a result of large scale production and Chinese production subsidies (Goodrich et al., 2013). Figure 2.4 shows that that feed in tariffs have the most successful driver for PV development.

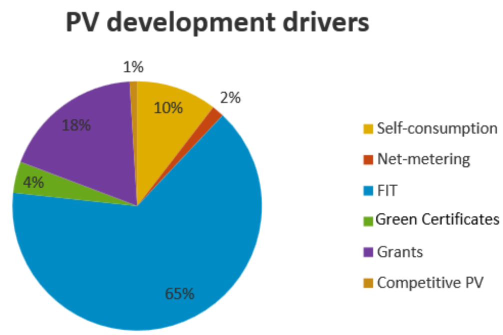


Figure 2.4 PV Development Drivers (adapted from: PVGRID/EPIA 2013)

Although many studies expect a further growth of the global PV industry, there are important barriers that can slow down further development. Once these barriers are identified and understood, one might look for solutions that can have a positive effect on the development. Recently there has been tremendous media attention on whether or not the high portion of renewables in Germany has a negative impact on the European market dynamics and grid stability.

According to the World Bank (Timilsina et al., 2011) , PV market development barriers can be separated in three categories: technical economic and institutional. PVGRID recently published a study (PVGRID, 2013) with the results of a more practical approach in the European market. Combining these reports the following barriers appear to be the most relevant for this research:

Technical barriers

- Current technical **conversion efficiencies** of photovoltaic cells are around 25% for thin film and 20% for polycrystalline PV panels (National Center for Photovoltaics, 2013).
- Development of some PV technologies like CdTe and CIGS thin film can be capped as a result of **scarcity of raw materials**. However crystalline and more unconventional thin film technologies look very promising in terms of material constraints (Kleijn, 2012)

Economic barriers

- For large scale PV projects, the **costs of grid connection** can be extremely high when grid-operators charge project developers for required improvements on the grid
- Initial investment costs and the lack of consistent financing options is a major economic barrier for the successful development of PV electricity (Timilsina et al., 2011)

- Investing in solar project is often considered as **high risk** as there is a lack of experience with the technology

Institutional barriers

- The **administrative permitting** process for commercial and ground-mounted PV systems is complex and challenging. This can be a result of land use plans, complex procedures for grid connections, regional regulations and environmental impact assessment requirements (PVGRID, 2013).
- As a result of grid capacity issues, in some European countries it is **not guaranteed that PV systems can be connected to the grid**. However this reasoning is often questioned by developers and stakeholder (PVGRID, 2013)
- At least five countries in the EU have a **market cap** for renewable energy support schemes
- **Regulatory uncertainty** can be a major barrier for investors in renewable energy projects. The Netherlands is a strong example of this, as policy towards net-metering and support schemes are only guaranteed for a short period of time, resulting in uncertainties in the business case calculation.

PV IN THE NETHERLANDS

Until 2003 the Dutch PV market was successful as a result of investment grants. As these grants have been cancelled, the market has been going down to lower levels (International Energy Agency, 2013). In recent years, the residential market has seen major growth. This is mainly a result of high electricity prices and many collectively purchasing initiatives (PVGRID, 2013). In comparison with other European countries, the share of households in the Dutch installed PV capacity is remarkably high. This, again is a result of tax policy as small scale electricity pay a higher energy tax on their electricity usage which makes PV electricity more competitive for them. Figure 2.5 shows that the Dutch market has been mainly driven by the residential segment, where other European markets clearly show other patterns.

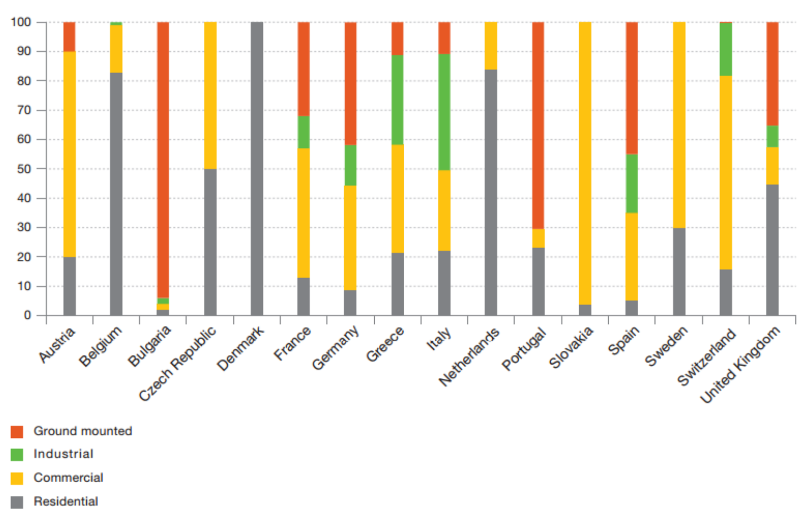


Figure 2.5 European PV market segmentation by country in 2012 (adapted from: EPIA, 2013)

Between April 2012 and October 2012, system prices have dropped with over 9%. This has resulted in grid parity for systems where VAT and installation costs are included in the calculations. With current grid prices, over a 25 year timeframe PV electricity is 10% cheaper than grid electricity (Van Sark et al., 2012). This grid parity counts for households since 2011 and 60% of small and medium enterprises at 2013 price levels (DNV KEMA, 2013). Net-metering and high electricity prices allow the Dutch residential market to develop rapidly (EPIA, 2013), however the recent stop on investment grant can have a negative impact on the market development in 2014. The current net-metering policy in The Netherlands is expected to change on the long term, which can have a large negative impact on the market.

As in 2014 the SDE FiT scheme was favorable for PV projects in The Netherlands, a major increase in large projects can be expected in the coming years. In total 2.973 projects are approved in 2014, with a total capacity of 882,6MW ("Solar Magazine - Nog 101 miljoen euro voor beschikking SDE+ 2014, pv-teller op 882,6 megawatt," n.d.) . Besides these larger projects, a market growth in the residential can be expected as regulations for building permits require higher sustainability (energie prestatie) standards than in prior years (Energie Vastgoed, 2014). As described earlier the FiT scheme budget for large renewable energy projects in The Netherlands has been doubled from €4bln. to €8bln. per year (Energeia, 2015).

2.2 POLICY INSTRUMENTS FOR PV STIMULATION

As mentioned earlier, most PV markets are strongly driven by policy measures, aiming to stimulate PV development. Several supportive instruments have been implemented around the world, including feed-in tariffs, tradable green certificates, bidding/tendering schemes, low-interest loans, subsidies, net-metering and fiscal incentives (del Río and Mir-Artigues, 2012) and TGC's are the most widely implemented schemes, and are well known for the German and Italian PV boom. After an extensive literature review, 8 major support schemes are identified:

1. Feed in tariff's (FIT'S) are a policy tool to develop a stable residential PV market. In Germany, private solar power producers can sell surplus electricity to grid operators for a fixed and guaranteed price (20 years). This model has been replicated by over 40 countries (Schleicher-Tappeser, 2012) and has allowed thousands of consumers and investors to purchase PV panels at a low risk. According to Del Rio and Mir-Artigues (2012) in the EU, nearly 100% of the new PV capacity between 1997 and 2012 was installed in countries using FIT's. Literature shows that FIT's are generally the most effective policy tool to stimulate decentralized renewable energy production(del Río and Mir-Artigues, 2012). Recently Germany, United Kingdom and Spain have reduced the feed-in rates as a result of high future costs. (Simon Zadek, 2013).
2. Tradable green certificates (TGC's), known in the US as renewable energy certificates (REC's) are tradable certificates that proof that one unit of electricity was generated from an eligible renewable energy source (Shum and Watanabe, 2009). The owner of the TGC can claim that he has purchased renewable energy. This can stimulate the use of renewable energy sources when subsidies or production tax are empowered by governments. Currently several countries in the EU have a TGC's system empowered. However, since value is added green electricity production by subsidies or tax exonerations on a national level, it may be argued that it is a form of state-aid, which is prohibited by the EU (Nielsen and Jeppesen, 2003). This situation clearly shows the paradox of the current EU energy policy which stimulates liberalization of the energy

market and sets targets for renewable energy sources at the same time. GTC's can be a cost-effective policy scheme that is compatible with a liberalized energy market.

3. Renewable portfolio standards (RPS) oblige electric power companies to use a certain percentage of renewable sources in their energy portfolio (Shum and Watanabe, 2009).
4. Low interest loans can be provided by a government to make the investment of a PV installation more attractive to residents or third party companies. This can be done by either directly providing loans (development bank), stimulating banks to offer 'green loans' or allowing residents to include PV investments in their mortgage. Recently Japan has started to offer low interest loans through government financial institutions towards third party ownership PV companies (CleanBiz.Asia, 2013)
5. Investment subsidies are a financial stimulus for hardware (or sometimes installation) of PV plants. It is relatively easy to administrate, and are often based on the price or capacity of the new installation. An example of this instrument was the Dutch PV variable subsidy. This investment subsidy was meant to fine-tune the PV development in The Netherlands (German Energy Agency, 2007)
6. Net metering is a protocol that allows customers to offset their electricity consumption over an entire billing period with the produced electricity from PV panels). This means that the economic value of PV electricity injected in the grid is equal to that of electricity taken from the grid, at a different time or day (Campoccia et al., 2009). The practical and economical implication for the consumer is that the grid serves as a 100% efficient battery which can 'store' their surplus electricity. Figure 2.6 schematicaly shows how net-metering works.

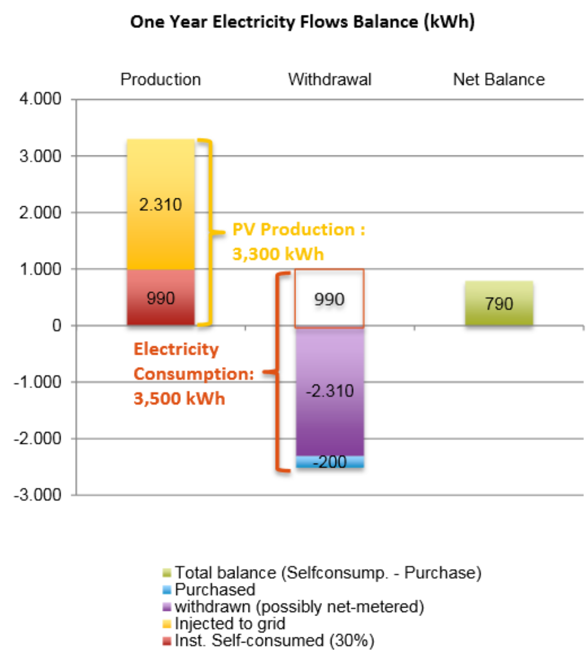


Figure 2.6 The principle of net-metering (adapted from: EPIA, 2014)

7. Tax credits are a fiscal policy tool that allows companies or individuals to lower their (corporate or income) tax by a part of the investment costs. In the United states, for example a tax credit that is equal to 30% of the investment costs for a solar electricity installation is provided by the national government (Timilsina et al., 2011).
8. In The Netherlands it is mandatory to make an energy assessment before a building permit can be obtained. The Energy Performance Norm (EPN) relies on a calculation that accounts all energy features of a building (Noailly and Batrakova, 2010). This EPC-calculation (energie prestatie coefficient) provides a certain value, that is lower when a building is more energy efficient. The norm for the calculated values has become stricter over the last decades. From 2015 onward the EPC value of a new residential building has

to be 0,4. In practice this value is hard and expensive to achieve without installing a PV system.

9. Virtual net-metering is known in The Netherlands as ‘postcoderoos’. This policy allows local participants to invest in a large-scale solar project in their neighborhood. The kWh production of this plant is discounted on their electricity bill (including electricity tax). Recently several successful projects have been installed in The Netherlands.
10. In The Netherlands there is an regressive electricity tax scheme in place. This comprises that the first 10.000kWh of the annual electricity demand is taxed at a higher level (€0,1013) than the demand above 10.000kWh (€0,04901 up to €0,00053 for >10mln kWh). For most residential customers this means that the electricity tax is at least twice as high as the price of the electricity itself (Rijksoverheid, n.d.).

Each of these support schemes have specific opportunities and barriers for different PV business models. Some of them investors for nominal power, whilst others have a focus on the production of electricity throughout the plant exploitation.

2.3 DESIGN OF PHOTOVOLTAIC SYSTEMS

The design of photovoltaic systems is one of the key components that determine the long term performance in terms of energy generation and O&M costs. Uncertainty and variability of the components and environmental factors result in significant design challenges of PV systems (Zhang et al., 2013). Knowledge on risk, reliability, operational costs and performance can play a vital role in choosing the right business model for utilities.

TOPOLOGY OF GRID-CONNECTED PV SYSTEMS

Figure 2.7 shows the electrical architecture of a grid-connected PV system. Each electrical component has it’s own electrical and reliability characteristics, which influence the risks and long term profitability of a PV system. The PV modules generate DC electricity, which is converted to an AC current by the inverter. The performance of a PV system strongly depends on the positioning of the modules and the configuration of the module strings and inverter.

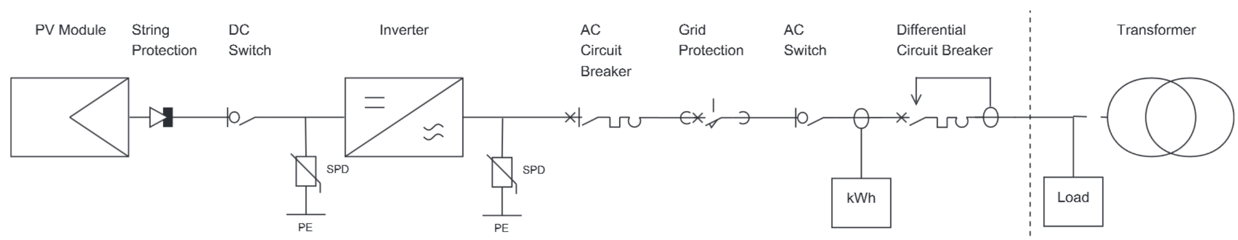


Figure 2.7 Electrical architecture of a PV System adapted from (adapted from: Zini et al., 2011)

PV SYSTEM PERFORMANCE

The performance of a PV system can be predicted and simulated relatively easily with industry specific simulation models such as PV-Sol, PVSyst and PVGis. By doing this, the optimal azimuth and inclination of the panel can be determined, and the electronic characteristics of the components can be modelled. The performance of a PV system is measured in PR (Performance

Ratio). This is a measure of the system quality independent of the location. The performance ratio is stated as percent and shows the ratio between theoretical and actual electricity outputs of the plant (SMA, n.d.).

Another way to measure the energy efficiency of a PV plant is the kWh/kWp ratio. This can be calculated with simulation models, and depends mainly on:

- Azimuth of the PV array
- Inclination of the PV panels
- Efficiency of the solar panel in % or Wp/m^2
- Geographical location and local climate
- Ventilation of the PV array
- Size and resistance of the system's wiring
- Efficiency of the inverter
- Configuration of the PV panels/inverter

ARRAY AZIMUTH AND ORIENTATION

The azimuth (orientation) and inclination of the solar panels are by far the most decisive when estimating the performance of the system. Based on climate data in The Hague the optimal inclination of a solar panel facing south is 32°. In this configuration an energy yield of 1022kWh/kWp can be expected (SMA Sunny Design, 100 Yingli panels, 1 x STP 25.000 Inverter). When lowering the inclination angle or turning the panel away from the south, the expected yield drops. However, hardly any commercial project in The Netherlands is built with these parameters. This is the result of the bad performance of crystalline solar panels in shaded circumstances. When panels are inclined at 30° large areas behind the panels cannot be used because of the inter-panel shading. As space is often scarce or expensive in commercial projects, more and more east-west oriented systems can be observed. By designing the system with a -90° +90° azimuth and 10° inclination the expected yield is only 893kWh/kWp. However, the available roof area will be significantly higher.

MODULE

The PV module is the component that is often referred to as 'solar panel', consisting of several layers as illustrated by figure 2.8. PV modules are packaged, connected and assembled PV cells that convert solar radiation is electrical current. This is the so called photovoltaic effect. Typically 5-20% of the sunlight is converted into electricity, depending on the specific cell technology. Although solar modules are often considered as one of the most reliable components of a PV system, failures and performance degradation do occur. Common defects are delamination, corrosion in electrical components, discoloration and bubbles in the PV module. Most manufacturers provide at least 10 years of product warranty and a

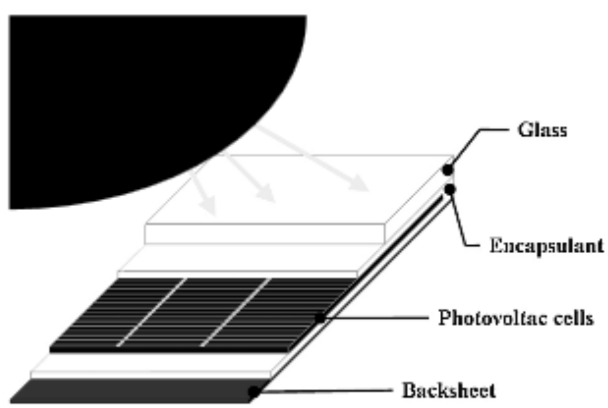


Figure 2.8 Sectional view of PV Module (adapted from: Ndiaye et al., !2013)

linear module performance warranty of 80% of the nominal power in year 25. As PV is a relatively new technology, which has only been widely applied in the past decennium, reliable field studies on degradation rates are limited. Experimental studies on 20 year old C-Si modules show a degradation of 0.526% per annum (Kaplanis and Kaplani, 2011). It must be considered that external conditions such as humidity and solar radiation can cause differentiation in panel degradation and failure rates (Ferrara and Philipp, 2012). It is worth mentioning that larger projects, that are financed by third party are often build with so called 'bankable modules' that are manufactured by firms that have a strong financial position, which decreases the risk of lacking warranty issues when the manufacturer faces bankruptcy.

INVERTER

The inverter is a key part of the photovoltaic system, as it converts the DC current from a string of solar panels to a AC current that is injected in the grid. Both from an efficiency and reliability point of view, it is widely accepted that the choice of the inverter is important for the long term performance of PV systems.

Table 2.9 PV System component failure rate (adapted from: Ahadi et al., 2014)

Component	Failure rate (10^{-6} failures h^{-1})
PV modules	0.0152
String protection	0.313
DC switch	0.2
Inverter	40.29
AC circuit breaker	5.712
Grid protection	5.712
AC switch	0.034
Differential circuit breaker	5.712
Connector (couple)	0.00024
Battery system	12.89
Charge controller	6.44

Table 2.9 clearly shows that the inverter is the most vulnerable component of a PV system. Typically manufacturers provide 5 or 10 years of product warranty on inverters, and offer warranty extensions at a premium. Recently several manufacturers started full service packages that guarantee a certain uptime of the PV system, which sometimes include reimbursement of yield losses during downtime.

The efficiency of inverters can be measures at STC (standard test conditions). Results of the industry magazine Photon show that efficiencies among inverters vary from 98,6% to 85,%. This efficiency is a weighted average of the amount of DC power from the PV panels that in converted to usable AC power (Photon Laboratory, 2014).

MOUNTING STRUCTURE

The mounting structure of a photovoltaic connects the module to the ground or roof. Often, these structures are made out of aluminum, steel or synthetic materials. It is vital that the mounting structure is build according to wind load calculations, often provided by manufacturers. As module prices have been dropping in the past years a clear trend towards east/west and lower tilt angle systems is visible. This results in a lower performance of the panel and higher utilization of the available roof/field area.

RELIABILITY

The yield of photovoltaic systems is often calculated over 20 years of operation (German Solar Energy Society, 2013), with relatively low operational and maintenance efforts. This means that the operational costs of photovoltaic installations are among the lowest of all electricity generating technologies. However, components may fail and thus should be calculated in operational forecasts (Ahadi et al., 2014). Especially in environments with high temperatures and humidity, delamination of solar modules is common. This delamination is the result of aging of plastic components in the module that detach from the cell (German Solar Energy Society, 2013). As stated earlier, inverters are the most vulnerable component of photovoltaic systems, as they have an average life expectance of 5 to 8 years (German Solar Energy Society, 2013). The risk of component failure and reduced yields can be reduced by insuring the installation. Especially in larger projects, investors often ask for insurance against vandalism, fire hazard, construction-errors etc.

DESIGN AND GRID INTERACTION

The performance of photovoltaic installations is largely determined by the positioning of the solar panels. In The Netherlands, panels faced to the south with an angle of about 36° will generate the most kWh's. However, in some cases it can be beneficial to design a flat roof system with an east-west configuration. This allows the system to use more of the available roof space as there is less direct mutual shading among the panels. Although east-west configurations generate less energy in absolute terms, the yield is spread out over the day, which can beneficial for grid operators who currently face problems with electricity production fluctuations from wind and solar energy.

DESIGN QUALITY AND PLANT COMISSIONING

In larger scale PV project is common to have a third party perform a commissioning test of the plant. This validates the engineering, design and building quality and reduces risks for (external) investors. NTA 8013 and NEN-EN-IEC 624496 are common norms that describe the building criteria and minimum requirements for commissioning, tests and system documentation. In addition to this, consultants can be hired to do the due diligence of the PV plant. In this process all facets (electrical, safety, structural, shading etc.) of the plant are extensively reviewed and satellite solar irradiation data is used to compare actual generation data with yield forecasts.

END OF LIFE AND COMPONENT RECYCLING

The PV technology is often considered as a ''low waste'' energy resource, as no waste is produced during it's operations (McDonald and Pearce, 2010). However, with the current production numbers the solid waste of the modules should be seriously considered. After 2030, a dramatic growth of PV related waste can be expected, as there is a lag of around 25 years after the production boom. Policy action is required to address the challenges ahead (Weckend et al., 2016) . Some solar modules contain harmful materials such as cadmium, tellurium, lead and selenium (McDonald and Pearce, 2010).

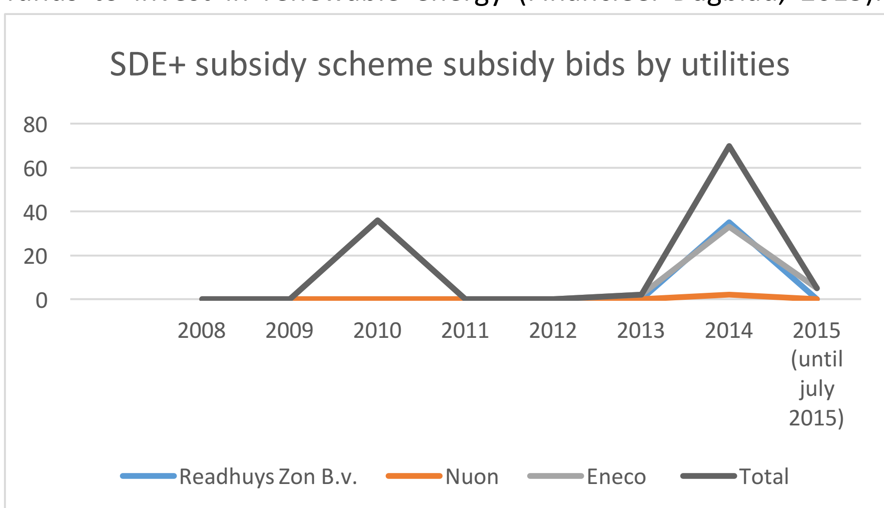
Studies show that the value amount, concentration and value of reclaimable material of decommissioned solar panels are rather low (Fthenakis, 2000; McDonald and Pearce, 2010). As a result of this, and the fact that PV modules are scattered over the countries, rather than concentrated in one plant, economic opportunities of PV recycling are limited.

The recent IRENA report on recycling of photovoltaic modules expects that end-of-life management of modules can become an important part of the photovoltaic value chain, as inexpensive raw materials can become available. In monetary terms, a USD450 million market of technically recoverable materials will be present in 2013 (Weckend et al., 2016).

As recent research shows, significant material flows and business opportunities are likely to become increasingly available after 2030. It must be considered that the decommission and maintenance of plants takes place in the operational stage of the plant, which is highly downstream, whereas the recycling process should be done on the module manufacturing side, which is upstream. Although there is only a very limited number of companies that have vertically integrated the whole value chain, this might provide these companies a competitive advantage on the long term.

2.4 UTILITIES AND PV

Although utility companies are important actors in the energy market, until recently renewable energy resources have not been of much interest of most utilities(Richter, 2012a) (Schoettl and Lehmann-Ortega, 2011). It is widely acknowledged that decentralized renewable electricity generation is challenging the status quo of utilities' business models. Major players in the Dutch electricity market such as Nuon and Essent are not yet able to adapt to the rapidly changing market as a result of the energy transition. As a result of large write-offs on these companies balances there are limited funds to invest in renewable energy (Financieel Dagblad, 2015). Recent research shows that utilities executives reckon renewables to have the greatest potential for disrupting the current energy system (PWC, 2009).



F Figure 2.10 SDE Subsidiy applications by Dutch utilities (Data source: RVO 2015)

In recent years, hardly any utility in the Netherlands has been investing in PV-plants. It appears that this is currently changing rapidly. However, in the past years, only few utilities have been making bids for the SDE+ subsidy scheme. Eneco is currently building a 6MWp plant on Ameland (Solarmagazine, 2015) which is subsidized by this SDE+ scheme. This project will be the largest PV plant in The Netherlands until now. However, several media reports that a 20 MWp will be build and operated by Pure Energie, which is a new utility on the Dutch market. Figure 2.10 illustrates the historic SDE+ applications of Dutch utilities, which are very limited)

From an utility perspective, it is interesting to integrate the electricity grid in the model, some utilities have a strategy to enter the PV market on the short term, while others think that PV should be integrated in their business models on a 10-20 year term (Schoettl and Lehmann-Ortega, 2011).

Frantzis et al., (2008) describes three generation of photovoltaic business models. This is mainly based on ownership and the role of utility companies. In the zero[th] generation, the end users own the PV system themselves. In the first generation, which is currently emerging, third parties own PV systems and use the consumer to sell electricity back to the grid. The second generation of PV business models is based on full integration of PV in the grid, where utility companies have new business models where their customers are important electricity producers as well.

ELECTRICITY VALUE CHAIN

In order to describe an analyze business models for the electricity industry, it is important to understand the value chain of electricity. Until the unbundling of the Dutch electricity market in 2004, 85% of the Dutch consumer electricity was produced, distributed and retailed by four major utilities (Schenk, 2005). After the unbundling of the Dutch electricity sector and the privatization of the utilities that were often owned by regional and local governments, the position of utilities in the value chain has changed. The value chain of both bundled and unbundled markets are represented in figure 2.11 and 2.12.

Figure 2.11 Pre-unbundling value chain of electricity in The Netherlands

Figure 2.12 Post-unbundling value chain of electricity in The Netherlands

Generation of electricity is the transformation of primary energy resources into electric power (Richter, 2012a). This is mainly done on a large scale by burning fossil or nuclear fuels in order to drive a turbine. Generation of electricity is often done by utility companies. About 85% of the electricity in The Netherlands is sold in the 'bilateral market'. In this market, the generating companies sell electricity directly to large consumers, traders or retailing companies (De Vries and Correlje, n.d.).

The *transmission* of electricity is the high voltage transportation from the generation source to distribution networks. This includes the balancing of demand and supply. As the energy landscape currently changes rapidly as a result of a growing share of renewables in the energy grid, this transmission network faces limits of its current capacity. Transmission System

Operator (TSO) are responsible for balancing injections and withdrawals in the grid, the management of the transmission network and the management of import capacity. In the Dutch case Tennet is the TSO (De Vries and Correlje, n.d.).

Distribution networks used to be owned by the major utilities. After the unbundling and liberalization of the energy market, several of them are managed by independent companies such as Liander and Enexis. All distribution companies in The Netherlands are owned by local governments, as full privatizations is prohibited by law (De Vries and Correlje, n.d.), due to security of supply.

The *retailing* of electricity is the administrative interaction between retailing companies and consumers. Retailing companies purchase electricity and consequently sell it to their clients. This includes billing and customer acquisition. It is worth mentioning that decentralized generation of electricity can result in a bi-directional transactions between retailing companies and so called ‘’prosumers’’.

2.5 BACKGROUND CONCLUSION

In the past decade, the global photovoltaic industry has grown at an unprecedented pace, which is primarily the result of attractive feed-in-tariff schemes in which governments guarantee a price per produced kilowatt-hour that is generated by mostly large scale photovoltaic installations. Parallel with this policy instrument deployment, the costs of installed photovoltaic capacity came down dramatically as a result of large scale production which primarily takes place in China.

Although there are some challenges ahead, it is expected that this grow will continue and photovoltaic electricity will play an increasingly important role in the electricity system. The Dutch photovoltaic downstream market has been dominated by the residential segment as there is a netmetering scheme in place an electricity tax is regressive. However, recently the share of PV projects in the SDE+ subsidy scheme for large projects has grown significantly which results in a strong growth of annual installed capacity. The Netherlands is expected to be one of the leading photovoltaic markets of Europe in the coming years.

A total of ten policy instruments has been identified in this chapter, including the most important for the current Dutch market which are net-metering and the SDE+ feed-in-tarrif. These policy instruments provide a basis for the further research on how they relate to the success of specific business models in the market.

As done with the policy instruments, an overview of the most important quality and design aspects of photovoltaic plans has been made. As there are hardly any moving parts in photovoltaic systems and they do not require any fuel, the operational and variable costs of PV generated electricity are among the lowest of all electricity generation methods. The design of the system can have impact on the reliability and performance of the system. One of the most common breakdowns is the failure of inverters which can lead to downtime and component replacement. In the analysis in chapter 5 and 6, the design considerations are related to different business models.

The final topic that deserves background information is the historic and current role of photovoltaic for utilities. So far, utilities in The Netherlands and many other countries have not heavily been involved in the upraise of photovoltaic electricity generation. Photovoltaic electricity generation strongly differs from more conventional generation techniques as it is decentralized, does not require fuels, is low on maintenance costs, are weather depended and can be build on a small scale. This provides major challenges for utilities which might have to shift business models in order to successfully integrate this innovation and benefit from the market opportunities.

3. BUSINESS MODELS FOR PV: THEORY AND STATE OF THE ART

This chapter describes the exploration of theoretical frameworks that can be used to provide answer to the research questions.

Companies tend to invest extensively in new ideas and technologies, but their ability to innovate their business model is often very small (Chesbrough, 2010). A technology itself does not have any economic value until it is commercialized through a business model. The innovation of business models can have at least as much impact as the innovation of a product or process. Nespresso is an interesting example of a brand that succeeded to break the status quo in a market. Until the introduction of Nespresso, coffee was often considered as a commodity and was traded by import companies and distributors who sold it to consumers. By innovating the coffee business model Nespresso has been able to couple espresso-machines with their own coffee brand, and by doing this, increasing the transaction costs of switching to different coffee brands. This resulted in high customer loyalty and significant higher margins on consumer coffee. Other strong examples of business model innovation are Xerox, Google, Booking.com and free newspapers.

3.1 ORIGIN AND DEFINITION OF THE BUSINESS MODEL CONCEPT

The term business model was first used in academic publications in 1957 (DaSilva and Trkman, 2014.), but has not gained much attraction in the subsequent decades.

The business model is often referred to as a tool to describe and understand elements of how an organization is creating and capturing value. The strong emergence of the business model concept started in the mid 1990's and is strongly driven by the development of internet. During the last two decades the term has become increasingly popular among consultants, managers, scientist, scholars and popular media.

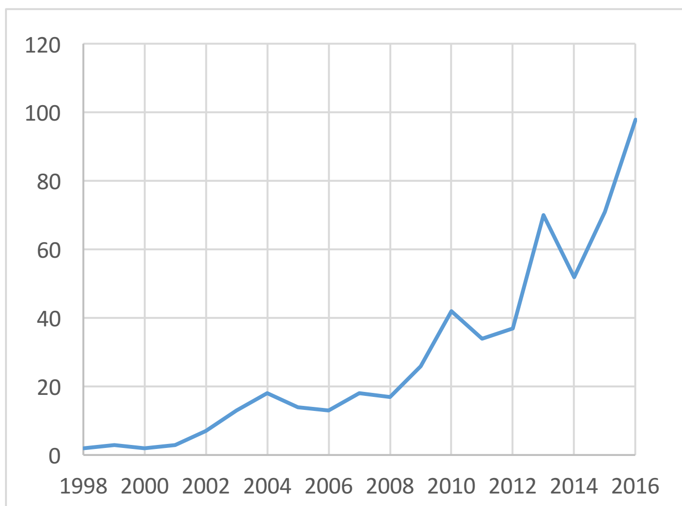


Figure 3.1 Search results for "business model" in title at Sciencedirect.com

The concept's popularity also raised voices of sceptics, amongst whom was economist Michael E. Porter who stated ''The definition of a business model is murky at best. Most often, it seems to refer to a loose conception of how a company does business and generates revenue. Yet simply having a business model is an exceedingly low bar set for building a company. [....] The business model approach to management becomes an invitation for faulty thinking and self-delusion'' (Wirtz et al., 2016).

The topic of business models is often used superficially and in many cases its roots, role and potential is not properly understood (Osterwalder et al., 2005). Different definitions of business models can be found in literature, and it has become a buzzword that is used by journalist academics and managers for nothing and everything that is related to the term of ‘’the new economy’’ that is driven by ICT’s (Osterwalder, 2004). This new economy is often described as vague as the term of business model itself. The lack of a common conceptual base (Zott et al., 2011) can lead to confusion and misunderstanding among researchers and practitioners.

Building on Osterwalder,)2004) and Richter, (2012a), this study uses business model uses the following definition of business models: **‘’the rationale of how an organization creates, delivers, and captures value**’’ This definition is widely used in practice and known by many scientists, business leaders and consultants. According to (Richter, 2012a) the Osterwalder & Pigneur framework has successfully been applied in the field of renewable energies, which provides sufficient ground to use this definition for the scope of this research.

3.2 BUSINESS MODEL LITERATURE REVIEW

In the wide variety of definitions that can be found in scientific literature, business models are referred to as a statement, a description, a representations, an architecture, a conceptual tool/model, a structural template, a concept, a method, framework, a pattern and a set (Zott et al., 2011). According a study conducted by Zott et. al. out of 103 publications on business models over one third did not define the concept in the paper at all.

Several studies on business model literature recognize a discrepancy between the popularity of business models and the lack of clarity on its definition and components (DaSilva and Trkman, 2014; Osterwalder et al., 2005; Richter, 2012a). Recent descriptions in the scientific literature on business models appear to have at least two prevalent aspects:

- The business model describes how a firm is doing its business
- The business model describes how value is created and captured by a firm

According to Chesbrough, (2010), the business model fulfils a number of functions:

- Articulation of the value proposition
- Identification of market segment and revenue generation
- Defines the value chain
- Details the revenue mechanism that generates income for the organization
- Estimates cost structure and profitability
- Description of firm within the network of itself, it’s suppliers and customers
- Formulation of competitive strategy and advantage

The work of (Wirtz, 2011) provides an comprehensive overview of the business model literature, and its development over time, which is illustrated by figure 3.2. In his research on business model definitions two categories are clearly distinguished. The first group of definitions comprises a theoretical, illustrative approach that describes how business is done. The second category is a more instrumental perspective that is also used for active management of a company’s core logic (Wirtz, 2011).

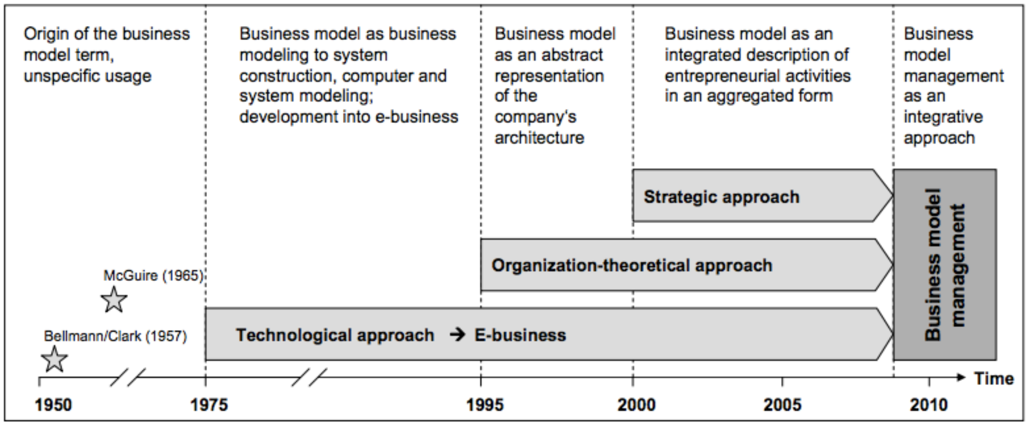


Figure 3.2 development of the business model literature (adapted from: Wirtz, 2011)

In summary, the business model literature is often focused on how business is done, identifying the underlying elements at a firm level (Mason and Spring, 2011). The earlier components clearly show parallels with the description of strategy by Porter which is ´´how all elements of what a company does fit together´´(DaSilva and Trkman, 2014). However, Dasilva and Trkman argue that ´´strategy sets up dynamic capabilities which then constrain possible business models to face either upcoming or existing contingencies.´´ In other words; a strategy can be considered as something a company is pursuing to achieve, whilst a business model describes what a company does at a certain time.

The white paper of (Pateli, 2002) comprises an broad review of the business model literature. It examines the different approaches that authors use to define and describe business models. Building on this (Osterwalder, 2004) describes the different approaches from the following perspectives:

- Definition
- Taxonomy
- Components
- Representation tool
- Ontological modelling
- Change methodology
- Evaluation measures

By researching these perspectives, Osterwalder aimed to deliver a so-called business model ontology. This ontology describes what business models are and how they can be visualized.

The core categories of elements, referred to as pillars of a business model are:

1. **Product (sometimes referred to as value proposition)**
   What business the company is in, the products and the value propositions offered to market
2. **Customer interface**
   Who the company target customers are, how it delivers them products and services, and how it builds a strong relationship with them

3. **Infrastructure management**
   How the company efficiently performs infrastructural or logistical issues, with whom, and as what kind of network enterprise
4. **Financial aspects / revenue model**
   What is the revenue model. The cost structure and the business model's sustainability
   Adapted from (Osterwalder, 2004)

In addition, Osterwalder adds detail to the business model approach by dividing these categories in nine so-called building blocks, which are a synthesis of the business model literature that he has researched.

Table 3.3 shows these nine building blocks form the core of the business model ontology as proposed in 2004 by Osterwalder:

Table 3.3 Building blocks of the Business Model Ontology (Osterwalder, 2004) (Osterwalder et al., 2005)

Pillar	**Building block**	**Description**
Product	Value Proposition	A Value Proposition is an overall view of a company's bundle of products and services that are of value to the customer.
Customer interface	Target Customer	The Target Customer is a segment of customers a company wants to offer value to.
	Distribution channel	A Distribution Channel is a means of getting in touch with the customer.
	Relationship	The Relationship describes the kind of link a company establishes between itself and the customer.
Infrastructure management	Value configuration	The Value Configuration describes the arrangement of activities and resources that are necessary to create value for the customer.
	Capability (sometimes referred to as core competency)	A capability is the ability to execute a repeatable pattern of actions that is necessary in order to create value for the customer.
	Partnership or Partner Network	A Partnership is a voluntarily initiated cooperative Agreement between two or more companies in order to create value for the customer.
Financial aspect	Cost structure	The Cost Structure is the representation in money of all the means employed in the business model.
	Revenue Model	The Revenue Model describes the way a company makes money through a variety of revenue flows.

The described nine building blocks are the roots of the popular business model canvas, which is used among many consultants and large corporates. It is worth mentioning that this framework does not include externalities such as competition and capital environments. Osterwalder recognizes the importance of these factors for the success of a business but considers them as not part of the internal part of the business model.

3.3 SUSTAINABLE BUSINESS MODELS

In the past decade sustainable innovation has gained traction among entrepreneurs, researchers and governments. As the world is facing major challenges such as climate change, aging population, population growth and resource scarcity, innovations that can help societies be more resource efficient and sustainable have become an important field of research and provide business opportunities. According to (Montalvo et al., 2011) in 2020 a cumulative $10 trillion worldwide investment in eco-innovation can be expected. Recent research shows that the business model approach can be a valuable tool to understand how sustainable innovations can be implemented successfully (Boons et al., 2013). As discussed earlier, innovation of business models can contribute to radical change in the performance of companies, and even an industry as a whole.

Based on the four pillars of Osterwalders business model framework, Boons and Lüdeke-Freund, (2013) propose a set of normative requirements that sustainable innovation need to be successfully marketed:

- Measurable ecological and/or social value as the *value proposition*
- Responsibility during procurement, as an organization actively persuades it's suppliers into sustainable supply chain management as *supply chain or infrastructure management*
- Motivation of customers for responsible consumption is part of the *value proposition*
- Appropriate distribution of economic costs and benefits among actors as *financial aspects* (Boons and Lüdeke-Freund 2013)

In Bocken et al., 2014a a set of sustainable business model archetypes is proposed, to create a unifying platform of possible sustainable business model innovations. This paper provides an overview of green, social and closed loop business models (Bocken et al., 2016).

Building on Boons et al., 2013; Osterwalder et al., 2005 and a range of eco-innovation and business model literature Bocken et al. describes a range of sustainable business model archetypes. Although this model is relatively new and not used extensively in other research yet, it provides a basis to assess whether specific business model innovations contribute to sustainability.

In this article business model innovation for sustainability is defined as ''innovations that create significant positive and/or significantly reduce negative impact for society, through changes in the way the organization and it's value-network create, deliver value and capture value or change their value propositions'' (Bocken et al., 2014a).

Bocken et. al. frame sustainable business models by using existing business model theory. They define business models by using three core components: value proposition, value creation and delivery and value capture.

Table 3.4 Conceptual business model framework. Adapted from Bocken et al, (2014) based on Richardson (2008), Osterwalder and Pigneur (2005)

Value proposition	Value creation & delivery	Value capture
Product/service, customer segments and relationships	*Key activities, resources, channels, partners, technology*	*Cost structure & revenue streams*

According to Bocken et al. the value proposition comprises several elements including customer segment and customer relationships. This view does not correspond with the Osterwalder framework as this addresses these elements as part of the customer interface pillar, which is not a part of the value proposition (Osterwalder, 2004 p43; Osterwalder et al., 2005). This contradiction once again shows that there is still no consensus about precise terminology of the business model concept.

The sustainable business model archetypes that are described by Bocken et al. are categorized in technological, social and organizational innovations. This approach is based on the work of (Boons et al., 2013), which is represented in figure 3.5. Although the archetypes are not explicitly proposed to be used as a framework, they are very well suited, and meant, to categorize and explain business model innovations for sustainability.

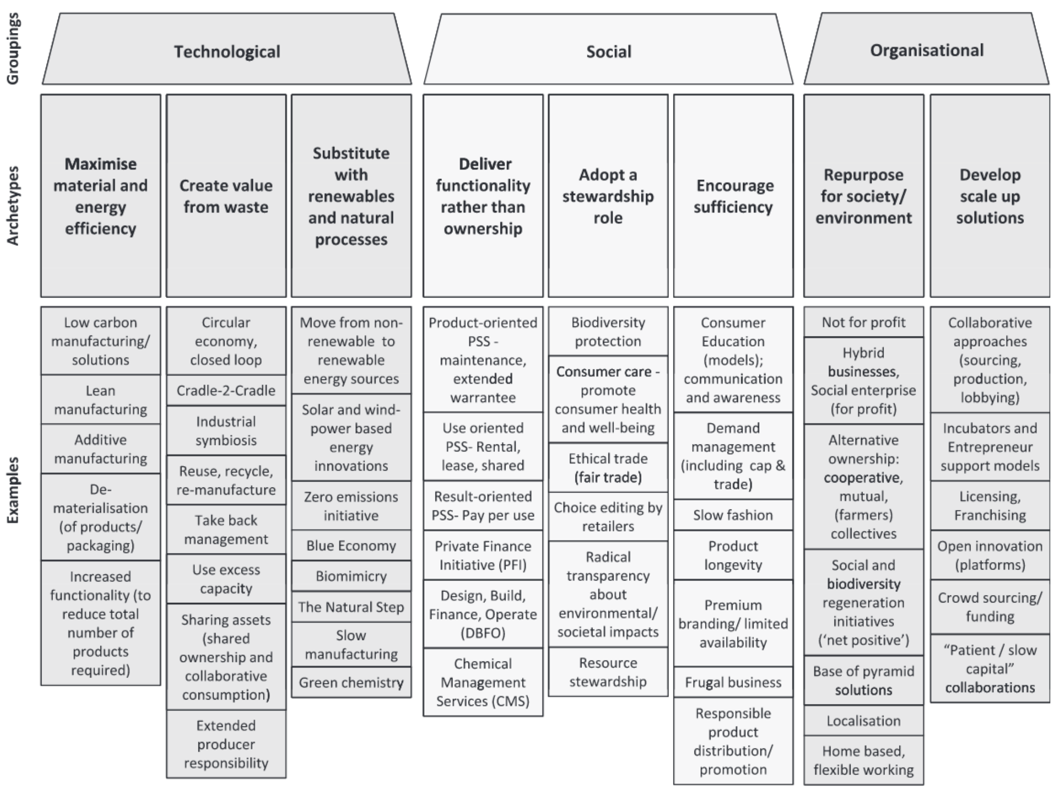


Figure 3.5 Sustainable business model archetypes adapted from (Adapted from: Bocken et al., 2014b)

In the work of A. Tukker, (2004) a set of eight product service systems are identified and discussed. These comply with the service-rather-than-product archetype that Bocken et al., (2014) describe. According to Tukker, product service systems are often seen as more competitive and foster sustainability. However, his research clearly shows that introducing product service systems on itself doesn't not necessarily lead to increased sustainability, and can even lead to decreased performance. In the discussion chapter, the approach of Tukker is reflected on the case studies.

3.4 PHOTOVOLTAIC BUSINESS MODEL LITERATURE REVIEW

Although limited, studies on business models for PV are available in scientific literature. The concept seemed to have gained traction among academics recently. Several novel business models are currently introduced in the Dutch market, and recently the first experiments have been researched by (J.C.C.M. Huijben and Verbong, 2013). This research has identified three categories of PV business models: Customer-Owned, Community Shares and Third party owned. Important conclusion of this research is that the viability of business models heavily depends on net metering regulations. The three categories of photovoltaic business models identified are:

- **Customer owned** business models are straight forward, as consumers purchase a PV systems and use or sell back the electricity that is generated
- **Community solar/solar shares** is a concept that is described as: multiple users can draw from a single solar PV array, or a series of arrays on different buildings, but operated as a single system, supplying clean electricity to community institutions (fire station, community centers, etc.) as well as residents that lacked good solar exposure on their own rooftops (Asmus, 2008). This means in essence that utility scale PV system ownership is contractually broken up into pieces. This often gives the shareholders energy credits that accrue to their energy bill. In The Netherlands there is regulation that allows community solar generated electricity within a postal-code range to be discounted (Hier Opgewekt, n.d.).
- **Third party PV business models** are rapidly growing in the United States. In this concept commercial party's own PV systems that are situated on the roofs of customers (Drury et al., 2012). By leasing out the system or selling the electricity to the roof owner, the companies take away the upfront investment for the consumers. According to Drury et al. the growth success of this business model is likely to increase total PV demand rather than gaining market share entirely at the expense of existing customer owned PV demand

In all these categories, the electricity is either directly used by the user of the grid connection, or it is injected in the electricity grid. By doing the latter, the utility company that manages the grid-connection either purchases the surplus electricity for an agreed price, known as a power purchasing agreement or discounts the kWh's with the owner of the PV system, known net-metering. It is often argued that net-metering is an unsustainable model, as the reward for surplus kWh's is not coupled to any temporal dimension. This means that utility companies buy surplus electricity at relatively high rates when market prices are low due to the high supply.

By using a value network perspective, (Frantzis et al., 2008) identifies three generations of photovoltaic business models. A zeroth generation where the end-user is the owner and controller of the installation. This is the model that is currently most common, and can be found both on a residential as a commercial scale. In first generation business models the plant is owned and controlled by a third party, and electricity is either sold to the end-user or an price is agreed for leasing the installation. This model reduces risk for the end-customer and the third party can take away hassle of finding financing solutions. In this model the utility company plays a larger role and acts as a facilitator (Frantzis et al., 2008; J. C. C. M. Huijben and Verbong, 2013). The second generation of photovoltaic business models is not seen on a big scale yet, but is expected to grow in the future. In the second generation business model utility companies are heavily involved as the plant is fully integrated in the electricity grid. This is often combined with storage and utility control.

By linking positions in the downstream photovoltaic value chain, and thus the required competencies to be successful in specific activities, to business models a number of generic business models is identified (Schoettl and Lehmann-Ortega, 2011). This research provides insight in relation between the competencies of an actor and how these relate to a business model that fits a natural role in the value chain.

In this research six generic photovoltaic business models are identified:

- *Turnkey project provider for residential and commercial (customer owned)*
  This is the most common and straight-forward business model as most consumers know it. The player provides the engineering, procurement and construction of the project and delivers a turnkey solution for either individual or commercial customers who do not have sufficient competencies or knowledge to install the system themselves. In some countries storage is involved as electricity outages can be a strong driver to invest in micro-generation. After the installation the actor has no role, other than providing the agreed warranty's on the installation.
- *Build-own-operate rooftop PV (third party)*
  In this model the player builds and owns the PV system and thus becomes an energy seller. This means that electricity is sold to the owner of the rooftop and the involved utility through a PPA. Additional revenues are generated from green trade certificates.
- *Value added service provider*
  By providing services such as consultancy, writing project requirements and developing the project this player is an orchestrator for the project, but does not own the plant.
- *Construction and installation service provider*

This player provides the service of the actual installation and construction to the final customer. This player has local project management as an important competency and makes money from margins on labor and materials.

- *Utility scale power producer (customer owned/third party/solar shares)*
  In this model a large plant is used to sell electricity to a utility, often through a PPA. Important competencies are being able to deal with large projects and having access to financing.
- *Virtual power plant*
  In this model the player is a virtual operator that controls supply and demand

Adapted from: (Schoettl and Lehmann-Ortega, 2011)

This set of generic business model covers and structures almost all photovoltaic business models and provides guidance for the final framework

3.5 PHOTOVOLTAIC VALUE CHAIN

In addition, analyzing photovoltaic business models, it is important to understand the value chain of downstream photovoltaic electricity generation. This provides focus in the research and helps to understand what activities actors can incorporate in their model. The comprehensive work of Kaplinksy and Morris provides guidance to structural value chain research and clearly describes the value of the concept. In this book the value chain is defined as:

‘’*The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use*.’’ (Kaplinsky and Morris, 2001).

Although the value chain approach is not often combined with the business model approach, it makes sense as describing a market’s value chain helps to understand the activities and competencies of an organization. These aspects are referred to by Osterwalder as ‘key activities and key resources’.

In terms of both investment and operations the characteristics of PV generated electricity strongly differs from more conventional generation methods:

- Harvesting energy from solar radiation vs. constant supply of fuel. The fact that there are no moving parts in a photovoltaic installation and no fuel is needed during the operational phase results in low operational expenses compared to fossil fuels and even windmills
- Production curves that fluctuate over the day and season as a result of constantly changing solar radiation vs. controlled or fixed generation
- Photovoltaic plants can be small scaled and often have a distributed character vs. large scale centralized generation

This inherently means that the value chain of PV has different characteristics. As upstream and downstream parts of the value chain are strongly divided by geographical and system boundaries, this research does not focus on the upstream part. Downstream, ownership & operation is what is close to grid impact and thus more relevant for utility companies. The upstream manufacturing process is further away from utilities' business (Schoettl and Lehmann-Ortega, 2011). Depending on the characteristics of a PV system, the activity of certain actors in specific parts of the value chain can strongly vary. This will become clear in following chapters.

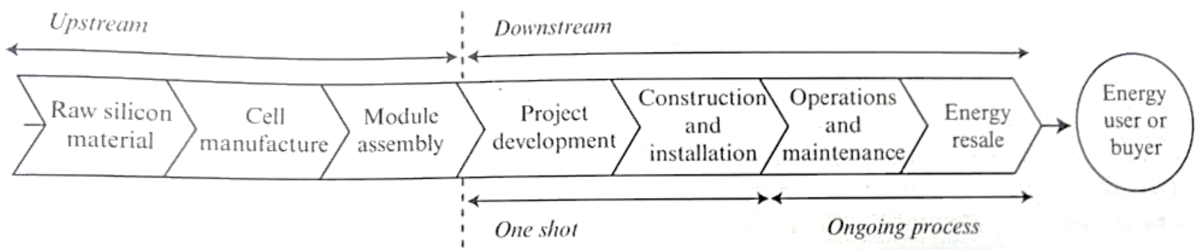


Figure 3.6 PV industry value chain (adapted from: Frantzis et al., 2008; Schoettl and Lehmann-Ortega, 2011)

As mentioned earlier this research has a focus on the downstream part of the photovoltaic value chain, which can be divided in the initiation- and operational stage, show in figure 3.6. The initiation stage comprises two segments:

- Project development stage in which the photovoltaic project is initiated, preliminary financial projections are made, access to financing is created (often in larger projects) and negotiations with actors as the roof owner, grid operator, energy buyer and governments are started. No physical materials are aqcuired in this stage and thus all value that is added is service-based.
- The construction and installation stage covers a more in depth technical feasabiltity study and the final engineering. After this the components are procured and installed on the installation site.

After the initation stage the operational stage of the project starts. This stage is often referred to as asset management, which includes all operations, maintanance, energy resale, accounting, billing etc.

Although (Schoettl and Lehmann-Ortega, 2011) state that asset management this is not a standalone activity in the PV industry, as scale of projects and asset portoflios grow it can be expected that companies will start specializing in this field. At a recent Solar Asset Management conferencte in Japan (June 2016) several multinational asset companies such have been observerd, these companies mainly operate in mature markets with relatively large projects such as Japan, United States, Germany, Spain and Italy. The activities include maintaining the installation, cleaning the panels, securing the plant (larger projects) and monitoring the performance. In business models that strongly rely on the performance of the project, e.g. when a PPA contract is present, this stage gains importance for the investor of the system.

- The energy resale stage is parralel to the O&M stage and comprises negotiations with utilities or other actors that are interested in purchasing the generated electricity.

Schoettl and Lehmann-Ortega have researched the photovoltaic value chain and it's relation with business models and competencies of actors in the industry. This research provides insights what position in the value chain relates naturally to the historic or current activities of specific actors.

Building on the research of (Schoettl and Lehmann-Ortega, 2011) and the conducted interviews an overview is made of the downstream photovoltaic value chain and the required competencies:

Table 3.7 Required competencies of each step of the downstream PV industry value chain building on (Schoettl and Lehmann-Ortega, 2011)

	Development phase		*Operational phase*	
Stage	**Project development**	**EPC**	**Asset management**	**Energy control**
Activities	(pre-) Engineering, selecting EPC partner, setting up financing, subsidiy and permit applications, negotiations with land-owner and grid operator	Engineering, purchasing components, planning, constructing the plant	Panel cleaning, cutting grass, maintanance, monitoring, reporting, improving performance	Electricity trading, obeying curtailment rules
Required competencies	Engineering, access to cash, lobbying and nogatioation with local athorities = value added services	Bargaining power, local project management	Knowledge on PV operations,	Information systems, trading skills

3.6 LITERATURE CONCLUSION

In brief summary there is no consensus on the precise definition and value of business models. However, most approaches that are identified have many similarities and are compatible with the umbrella definition of ‘’the rationale of how an organization creates, delivers, and captures value’’. This definition is based on an ontology of many different approaches in the business model literature and is widely the academic and business world (Osterwalder, 2004).

The most prevalent components of business models are product, customer interface, infrastructure management and the financial aspect. The framework provided by Osterwalders is based on this, and goes more into detail by mapping business models in 9 building blocks. The arguing behind this is described in the business model ontology (Osterwalder, 2004), which provided the cornerstone of the popular business book ‘’business model generation’’. Fundamental in this approach is that external factors such as market conditions, government regulations and environmental impact are not part of the business model itself. The building block approach has successfully been used to assess business models in the energy industry (Richter, 2012b)which provides an argument to use it as the basis of this research.

As this thesis is part of the Industrial Ecology master program, the sustainability of business models and the way in which they create environmental and social value, is taken into account as well. For this a literature review of sustainable business models is conducted as well. The bottom line of this is that there are multiple approaches that to a certain extend are based on the earlier discussed business model literature.

The business model approach is not sufficient to answer all the research questions, as not all policy measures, design and sustainability considerations are part of ‘internal business models’. For this reason, in the following chapter the business model framework is extended

4. FRAMEWORK AND METHODOLOGY

In order to provide answers to the research questions, several additional aspects need to be added or integrated to business model framework that is provided by Osterwalder:

- Design criteria
- Institutional environment
- Utility involvement

These three factors are interconnected as show in figure 4.1 and play an important role in the success of specific photovoltaic business models, and are taken into account in the analysis. Although specific means of design, institutional environment and utility involvement can be part of the business model itself, each represents a broader context rather just being a part of the internal business model.

The previous chapter describes various perspectives on photovoltaic business models. In order to provide satisfactory answers to the research questions, these perspectives are combined.

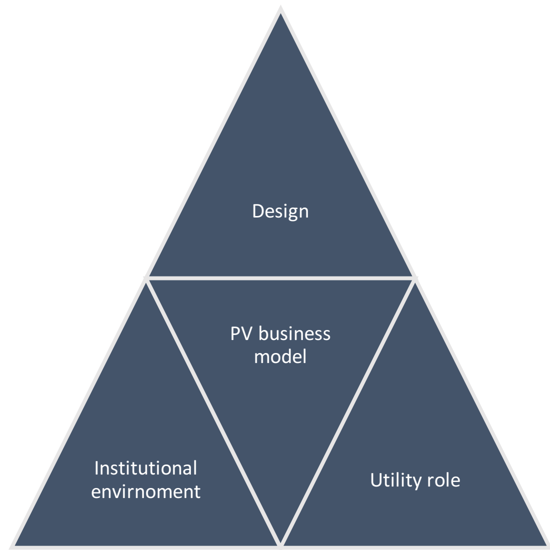


Figure 4.1 PV business model external factors

4.1 FRAMEWORK SELECTION

The Osterwalder approach as described in the business model ontology (Osterwalder, 2004) and more popular business book (Osterwalder and Pigneur, 2010), provides the cornerstone of many popular and scientific articles on business model. As described in 3.2, the ontology and framework provided by (Osterwalder, 2004; Osterwalder et al., 2005; Osterwalder and Pigneur, 2010) builds on existing scientific literature on business models. The framework is widely accepted and used both in academic and business environments and is extensively tested in practice. (Richter, 2012a). More specifically it has been used in the sustainable energy sector with success (Lüdeke-Freund, 2013; Okkonen and Suhonen, 2010; Richter, 2012a). According to Osterwalder the framework comprises all elements that are part of the way a company creates and captures value. This provides sufficient reasoning to use the approach as the fundament of this research.

Table 4.2 Business model building blocks as descibed in (Osterwalder, 2005)

Pillar	Building block	Description
Product	Value Proposition	A Value Proposition is an overall view of a company's bundle of products and services that are of value to the customer.
Customer interface	Target Customer	The Target Customer is a segment of customers a company wants to offer value to.
	Distribution channel	The distribution channel is the connection between a firm´s value proposition and the target customer. It is the way in which a firm delivers it´s value
	Relationship	The Relationship describes the kind of link a company establishes between itself and the target customer segment (Osterwalder, 2004).
Infrastructure management	Value configuration	The Value Configuration describes the arrangement of activities and resources that are necessary to create value for the customer.
	Capability (sometimes referred to as core competency)	A capability is the ability to execute a repeatable pattern of actions that is necessary in order to create value for the customer.
	Partnership or Partner Network	A Partnership is a voluntarily initiated cooperative Agreement between two or more companies in order to create value for the customer.
Financial aspect	Cost structure	The Cost Structure is the representation in money of all the means employed in the business model.
	Revenue Model	The Revenue Model describes the way a company makes money through a variety of revenue flows.

As paragraph 3.4 shows, different methods of PV business model categorization are observed in the literature. J.C.C.M. Huijben and Verbong, (2013) show a perspective with a focus on ownership of the photovoltaic installation. This approach is sensible when researching this specific topic, but lacks comprehensiveness when analyzing PV business model with a broader scope.

Richter, (2012a) provides an overview of photovoltaic business models for utilities, with a focus on Germany. By using the Osterwalder framework, Richter shows the potential of this method to frame, describe, analyze and categorize photovoltaic business model.

4.2 EXTENSION OF THE BUSINESS MODEL FRAMEWORK

DESIGN CRITEREA

Manufacturer bankability and component quality are decisive factors for the return rate on the investment. Although recently discussions have started in introducing additional KPI's for photovoltaic plants (DNV-GL, 2016), kWh generation or the Performance Ratio (PR) are the most commonly used performance indicators. However, bankability of manufacturers, durability, warranty conditions and panel shading have proven to be important factors in the long term success rate of plants as well. This research aims to provide insight in the difference between design qualities among different business models. It can be expected that business models where the professional engineering or development firms are accountable throughout the operational phase of the plant, lead to better design considerations and performance. From a business model perspective, design considerations and the results of this are part of the value configuration and revenue streams.

INSTITUTIONAL ENVIRONMENT

In chapter 2.2 nine generic components of institutional conditions in a photovoltaic market are identified. As most specific policy measures consist of financial or tax rewards, they form an integral part of a photovoltaic business model, and can be integrated in the proposed framework.

Table 4.3 Overview of general support scheme for PV deployment

Support scheme	**Brief description**	**Business model building block**	**Stage**
FiT (Feed in tariff)	Financial reward for electricity generated by renewable resources	Revenue model	Operational (based on actual generated electricity)
TGC's (Tradable green certificates)	Certificates for renewable generated electricity. Can be used by utilities to sell green electricity	Revenue model	Operational (based on actual generated electricity)
RPS (Renewable portfolio standard)	Obligation for utilities to produce a portion of their generated electricity from renewable resources	Value configuration	Operational (Based on actual generated electricity)
Low interest loans	Special interest rates provided by governments to stimulate	Cost structure	Project development

	renewable electricity production		
Investment subsidies	Upfront financial reward based on the installed capacity	Revenue model	Project development
Net metering	The right to discount generated electricity with the electricity that is taken from the grid during times where there is no production (seasonal and daily)	Capability	Operational
Tax credits	Tax benefit to stimulate the installation of renewable electricity resources	Revenue model	Project development
Energy assessment (new construction)	Obligation to have a certain energy performance level for a (new) building). Can be reached by all kind of sustainability measures, of which PV is one.	Depending on the business model (can be value configuration, revenue mode etc.)	Project development
Virtual net metering	Similar to net-metering, but the accounting comprises multiple grid-connections	Capability	Operational

UTILITY INVOLVEMENT

As this research has only grid-connected photovoltaic plants in it's scope, utilities always play a role in PVBM's. Owners of photovoltaic plants often can negotiate prices for their excess of electricity, these are often PPA's between the owner and the utility. In this case the utility company is an important partner in the business model. This partnership can be referred to as key partnership in the business model canvas.

In addition to this, it is interesting to analyze the key competencies of PVBM's. In utility scale IPP models, the generated electricity can be offered to the spot market. This means that electricity trading becomes an important competency for the PVBM executer. Competencies such as electricity trading and asset management have been natural for utilities for decades. This competency approach is based on the PVBM value chain research of (Schoettl and Lehmann-Ortega, 2011)

Table 4.4 Utility involvement in PV business models

Topic	Brief description	Business model building block	Stage
PPA	Agreement between electricity producer and utility or other party in which is agreed that the produced electricity will be traded for an agreed price.	Key partner, Revenue model	Development and operational stage. PPA's have typical duration of 15 years.
Grid connection	Utilities and grid operators play an important role when new or additional grid connections are required for a PV project	Key partner	Development stage
Utilities' competencies	Utilities often have core competencies such as asset management, customer services, system operations. Having these can provide them a competitive advantage.	Core competencies, Value configuration	Development/Operational

4.3 METHODOLOGY

4.3.1 DATA ACQUISITION

A combination of semi-structured interviews, conference attending and detailed literature study on academic and non-academic sources is carried out to map the most common and relevant photovoltaic business models in The Netherlands. For each business model category present in The Netherlands at least one experienced practitioner is interviewed. In addition to this several industry-experts from the academic and commercial field are enquired. Most interviews are semi-structured and lasted around 1 hour. With permission of the interviewees, all interviews are recorded and transcribed afterwards. The transcripts are available upon request.

The interviews consists of several parts: first some general questions about the organization are asked to map out what the current activities and long term goals are in terms of market segmentation and general company targets. After this, questions on photovoltaic business model innovation in the other countries are asked, including what the most important differences with the Dutch market are. The concluding part of the interview consists of a description of the organization's business model and the sensibility of them with regard to external conditions such as policy changes. The business model description is based on the business model canvas by Osterwalder (Osterwalder and Pigneur, 2010).

In addition to the interviews, the author has conducted dozens of meetings, phone calls and conference meetings with industry experts around the world. These were primarily organized as part of his job as a project manager at an EPC company and later as a project manager at one of the largest conference organizers on solar energy.

All case study data is sourced from interviews, author's daily interaction with industry professionals, scientific articles, conferences and industry specific media. The broad range of sources and continuous cross-check helps improving the data quality base on the data triangulation concept as shown in figure 4.5

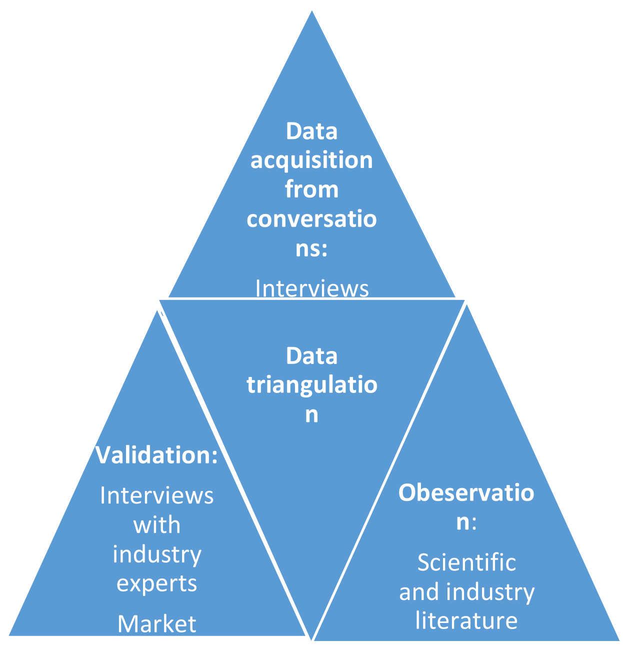


Figure 4.5 Data triangulation

4.3.2 CASE SELECTION

Each of the six photovoltaic business model categories from (Schoettl and Lehmann-Ortega, 2011) are identified and analyzed in the context of The Netherlands. Although it is possible that not all categories have activities in the Dutch market, a mix of interviews with business model practitioners, industry experts and industry literature provides a solid base to study all the categories. The comprehensive categories are the basis of the case selection for this study:

Table 4.6 Generic photovoltaic business model categories as identified by (Schoettl and Lehmann-Ortega, 2011).

- *5.1 Turnkey project provider for residential and commercial (customer owned)*
- *5.2 Build-own-operate rooftop PV (third party)*
- *5.3 Value added service provider*
- *5.4 Construction and installation service provider*
- *5.5Utility scale power producer (customer owned/third party/solar shares)*
- *5.6 Virtual power plant*

4.3.2 RESULTS STRUCTURE

Each case study starts with a brief introduction that shows the context, market size and developments that are discussed in the interviews. This starts at a global level and narrows down to the perspective of the Dutch market. As photovoltaic business model developments are rather heterogeneous among different countries, in most cases the developments in the most important markets for this category are described.

Using the Osterwalder framework and current literature on photovoltaic business models provides a fundament to describe and frame generic photovoltaic business models. Based on industry literature and the semi-structured interviews with field practitioners and industry expert, generic photovoltaic business models are identified, framed and described. These descriptions are made by the framework as discussed earlier and will reveal insights on design considerations, value chain position required competencies and the relation with externalities such as institutional environment and electricity price levels. These results build on the generic business models that are already identified by (Schoettl and Lehmann-Ortega, 2011). Any additional relevant business models found are described in the same way.

In addition to the description based on the discussed framework, additional analysis is done on aspects that are relevant to answer the research questions. This includes the integration of sustainability, utility involvement, ownership, financing models and design considerations. As a final part of the analysis, a cross case analysis is made in chapter 6 to identify similarities and differences among the business models.

After the cross case analysis, the conclusions that can be drawn from the case studies and cross-case analysis are discussed. This part of the research provides direct answers to research questions RQ1, RQ1.1.

4.3.3 OVERVIEW OF CONDUCTED INTERVIEWS AND ATTENDED CONFERENCES

In order to provide sufficient data, the methodological target of this thesis is to interview at least one practitioner of each business model category. As the activities of virtual power plants that integrate solar assets are limited or even non-existent in The Netherlands, no suitable interviewee has been found. In addition to the business model practitioners a range of PV industry experts have been interviewed.

All interviews are anonymized as they can contain sensitive and strategic information that can not be published. Full transcripts of the interviews can be requested by contacting the author of this thesis. The full names of the interviewees and the organizations are part of the appendix and have been made available to the thesis committee.

Table 4.7 Overview of conducted interviews with business model practitioners

#	Postition	Organization description	Business model type
1	CEO/Founder	Leading global solar information platform	General/industry expert Former: 5.1 Turnkey project provider
2	Investment Manager	Major bank in The Netherlands that has activities in utility scale PV projects	5.5 Utility scale solar producer
3	Project Manager	Community shares solar organization	5.2 Build own operate rooftop-PV
4	Project developer	Major Dutch utility company involved in different business models	5.2 Build own operate rooftop-PV/5.5 Utility scale solar producer
5	COO	Solar lease company in The Netherlands	5.2 Build own operate rooftop-PV
6	Secretary	Initiator of one of the first community solar projects in The Netherlands	5.2 Build own operate rooftop-PV

Table 4.7B non-transcribed interviews with industry experts

7	Professor photovoltaic energy conversion	University	General/industry expert
8	Teamleader Technology	Housing cooperation involved in Solar	General/industry expert
9	Associate Professor	Technical University	General/industry expert

As part of the author's professional activities and in addition to the interviews and literature sources, several conferences have been attended throughout the world. During these conferences, dozens of industry leaders and experts have been interviewed in a non-formal way. Take-a-ways and insights that are relevant for this thesis are processed in the researched.

Table 4.8 Attended conferences that have been relevant for this research

Conference:	Date	Place	Topics/summary
Solar Asset Management Asia	June 2016	Tokyo	Major conference on operational phase of solar. >70 speakers on solar energy including O&M, business models, Asset Management, design quality etc.
Intersolar Munich	June 2016	Munich	Major tradeshow on European solar energy industry
Solar Power International	September 2016	Las Vegas	Major tradeshow on US solar energy industry
Solar Asset Management Europe	November 2016	Milano	Major conference on operational phase of solar. >70 speakers on solar energy including O&M, business models, Asset Management, design quality etc.
Solar Asset Management North America	March 2017	San Francisco	Major conference on operational phase of solar. >70 speakers on solar energy including O&M, business models, Asset Management, design quality etc.
The Solar Future Netherlands	May 2017	Baarn	Major high level conference on the Dutch solar PV market (>150 attendee's)
Intersolar Munich	May 2018	Munich	Major tradeshow on European solar energy industry

5 RESULTS

Based on the conducted interviews and scientific and industry-specific literature, each of the generic photovoltaic business models (Schoettl and Lehmann-Ortega, 2011) are described in this chapter. Before going into depth, is is valeable to assess the global and national market size of the business model category as well as examples of business model practitioners. In addition to the business model description, the additional perspectives that are described in chapter 4 are analyzed using the proposed framework.

5.1 TURNKEY PROJECT PROVIDER FOR RESIDENTIAL AND COMMERCIAL (CUSTOMER OWNED)

This model can be considered as the classic solar model. Many construction companies have been able to add solar to their business portfolio as the model has been known to the construction industry for many years. In the United States this model is commonly known as the 'cash model' in which the customer pays for the photovoltaic installation when it is installed. The revenues generated throughout the operational phase will return to the end customer. After several years of rapid growth of the residential TPO (third party ownership) market in the United States, some expect a rise of residential solar ownership (PWC, 2015)

MARKET SIZE AND DEVELOPMENT

Although there are no official numbers on ownership of photovoltaic plants in The Netherlands, all industry experts say that this business model accounts for the far majority of the solar market (Interview project developer utility, 2015) (Interview CEO solar media platform, 2016). The main reasons for that are the large share of residential solar, as observed in figure 5.1, which is in contrast with other markets. In comparison with the US market, Dutch residential seems to be reluctant to sign up for lease constructions and prefer to pay the installation upfront (Interview CEO solar media platform, 2016, Interview COO solar lease company, 2015, Interview project developer utility, 2015). A different factor can be the lack of utility- and large rooftop projects. Generally, larger projects attract dedicated solar investors and allows more financial structures to be set up.

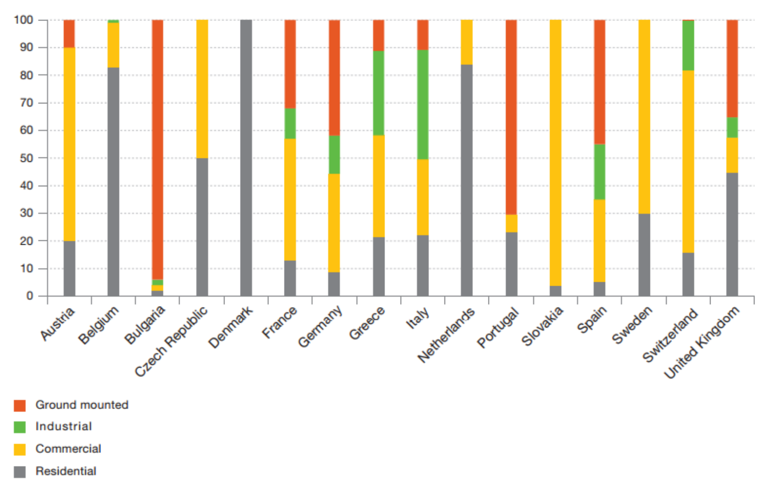


Figure 5.1 Breakdown of PV industry segments per country. (Adapted from :EPIA, 2013)

ACTIVITY AND PRACTITIONERS IN THE NETHERLANDS

The activity of this business model in The Netherlands is rather large. 813 companies were active in May 2013 as an installer of solar systems in The Netherlands (Segaar, 2013). One of the main reasons why this model is most apparent might be the combination of the of the in 2.1 discussed high share of residential systems in the PV market demand and the relatively high overhead costs that financing brings with these systems (Interview COO solar lease company, 2015). Some sources recently reported that there is a relationship between system prices and third party market share (PWC, 2015),

BUSINESS MODEL

Value proposition

Increased revenues or savings on electricity bills (Schoettl and Lehmann-Ortega, 2011) is the most obvious value proposition for this model. However, depending on the customer there can be additional value propositions:

- Resilience towards electricity price changes (residential and commercial)
- Improved green image (commercial)
- Low carbon and locally generated electricity (residential and commercial)

Target Customer

The target customer in this model are mostly owners of roofs that are planning to retain ownership of if for on the long term. These roofs can be residential or commercial scale (Schoettl and Lehmann-Ortega, 2011. It is important that the potential investor of the system is both the owner of the roof and the entity that pays energy bills. In the case of sub lending the property, the owner might not have an interest in lowering energy consumption and prices which makes it more difficult to find profitable business model for the investment in a PV-system.

Distribution channels

Distribution channels of this model in the The Netherlands are rather direct and straightforward. After the sale has been completed the procurement and installation is done by the business model practitioner. The delivery of the components and the actual installation is done by construction teams that work for the company or are sourced externally.

Relationship

The relationship with the customer in this model is limited as the long term commitments by the business model executor are limited to obeying warranties. Although some models with long term performance warranties are observed in the market recently, there is often no incentive for the business model practitioner to maintain or increase performance of the system and once the system in online and performs well, there is no strong relationship anymore. So far maintenance activities of rooftop systems in The Netherlands are limited.

Value configuration/key activities

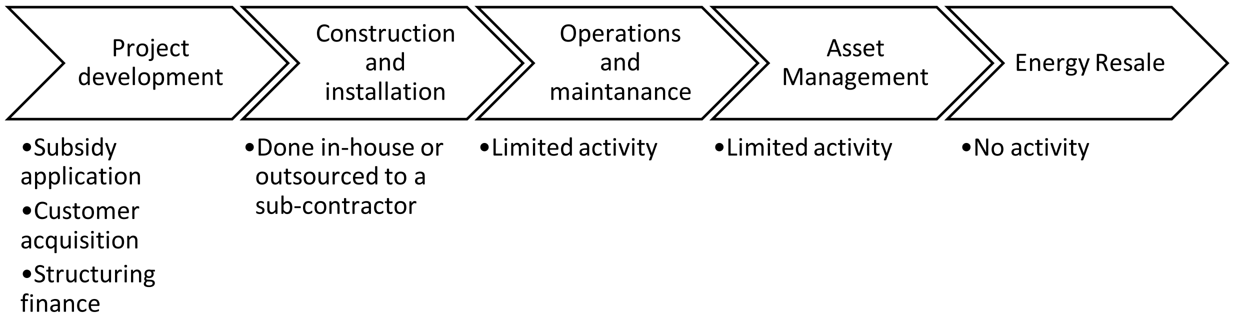


Figure 5.2 Value configuration of business model category 5.1

Core competency/Key resources

In this model the most important competency is access to (semi) mass market, which can be rephrased to customer acquisition ability (Schoettl and Lehmann-Ortega, 2011). As this industry space is highly competitive due to the number of active players, price is an important factor, and thus procurement and negotiation skills are important. When dealing with sloped roofs that are often owned by residential home owners, esthetics and building integration are important competencies as well (Gieselaar, 2013).

Partner network

In The Netherlands there have been several successful collective purchasing initiatives, where associations such as 'Vereniging Eigen Huis' and 'Natuur & Milieu' aggregated home-owners and tendered a collective purchase order for residential PV projects (Financieel Dagblad, 2012). There are also similar examples on a much smaller scale where local associations or sports clubs are important partners for the business model practitioners.

Depending on the purchasing scale, system components are often procured through distributors that specialize in importing solar components such as modules and inverters. Depending on the expertise of the business model practitioner, these suppliers can also take care of the project engineering and component selection (4Blue, 2017; Libra Energy, 2017). This model makes most sense for electrical installers or rooftop companies with limited solar expertise.

Cost structure

The EPC costs, including material procurement represent the majority of the PV capital expenses (Interview project developer utility 2015)). A more detailed overview of the costs that are additional to the inverter and the modules is provided in figure 5.3As the PV system is not owned by business model practitioner, the operational costs are not represented in the cost structure. Hardware costs have declined rapidly over the last years and are expected to continue to do so, resulting in the fact that so called soft costs represent a larger portion of the total system price and are often considered as becoming increasingly important to remain competitive in the market. This development supports the thesis that collective purchasing and online customer acquisition through innovative remote design software plays an increasingly important role in the residential and C&I segments (Renewable Energy World, 2016).

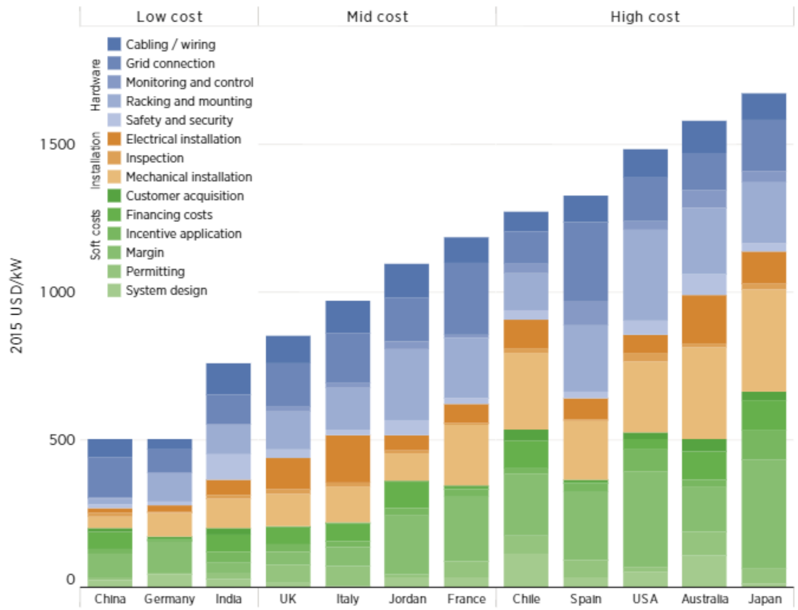


Figure 5.3 Detailed breakdown of Solar PV BoS costs by country, 2015 (Adapted from: IRENA, 2016b)

Revenue model

In this model the most obvious revenue stream is the sale of new installed PV systems. In addition to this installers can offer an O&M-contract to the end user to ensure that the modules are cleaned and the system is checked on a regular basis.

INSTITUTIONAL ENVIRONMENT

As grid parity has not been achieved in The Netherlands (Huijben et al., 2014), all market segments are economically depended on policy instruments("Interview COO solar lease company," 2015) . For the market segments targeted by this business model there are three prevalent policy instruments that stimulate the market:

- Obliged net metering that utilities have to provide for small scale grid connections (<3*80A) (Rijksoverheid, 2013).
- 15 year SDE+ subsidy feed in tariff for large scale connections (>3*80A)
- Energy investment tax reduction (EIA) for enterprises. This tax reduction can not be combined with the SDE+ subsidy scheme(RVO, 2016)

DESIGN

The relationship between the customer and the business model practitioner remains only limited after the commissioning of the system. In contrast with third party business models, underperforming or defective systems outside the warranty conditions affect the customer rather than the business model practitioner. The same counts for O&M costs and performance optimization.

For obvious reasons no company or interviewee that works with this business model will state that they design their systems sub-optimal. Based on heavily price driven market segments, incentives for all the stakeholders in both the initiation and operational stage and the authors experience in the Dutch PV industry, it can be assumed that design considerations are at least different than for business models where the practitioner is accountable for O&M costs and actual performance.

At this moment there is no sign of any turnkey project provider that incorporates end-of-life of components in their business model.

Utility involvement

The business model practitioner does not have a direct relationship with the utility.

BUSINESS MODEL CANVAS

Pillar	Building block	Description	Institutional environment	Design
Product	Value Proposition	• Electricity bill savings • Resilience towards electricity price changes • Improved green image Low carbon and locally green generated electricity	Tax credits for end-customer (EIA) (C&I) 15 Year feed in tariff for end-customer (SDE+) (C&I)	
Customer interface	Target Customer	Residential and C&I rooftop owners		
	Distribution channel	Delivery and installation by construction teams		
	Relationship	• Short-term • Limited Maintaining warranties		
	Value configuration	See value chain diagram	Net metering program for residential market(<3*80A)	

Infrastructure management	Capability (sometimes referred to as core competency)	• Access to (semi) mass market • Procurement and negotiation skills Building integration		
	Partnership or Partner Network	• Purchasing collectives Component distributors		
Financial aspect	Cost structure	• Components costs • Installation costs Customer acquisition		Competitive low-costs market
	Revenue Model	Sales of PV installation		Designed for direct (short term) revenues

5.2 BUILD-OWN-OPERATE ROOFTOP PV (THIRD PARTY)

In this model, project developers or utility companies aim to develop projects on roofs that they do not own themselves. An example is a utility company that builds a photovoltaic plant on an office building and sells the electricity to the end-user or real estate owner (ESCO Netwerk project database, 2017). The business model executer is the builder and retains the ownership of the photovoltaic facility during the operation phase. This makes the player an electricity producer(Schoettl and Lehmann-Ortega, 2011). This means that the player is often vertically integrated in the downstream photovoltaic value chain. The revenues are mainly based on PPA's with the utility and/or building owner and additional subsidies or tax credits.

GLOBAL MARKET SIZE AND DEVELOPMENT

In the past years, the concept of third party ownership of photovoltaic plants has become very popular in the US solar market, where residential solar leases and power purchase agreements (PPA's) gain popularity every year, as illustrated in figure 5.4. More than half of all new installed residential PV systems in most US markets is third party owned now, with Arizona topping the chart with 90% (GTM Research and Solar Energy Industries Association, 2013). GTM Research forecasts that third party ownership for residential installations will grow to $5.7 billion by 2016. This expected growth can be explained by the different value propositions that a consumer faces when using third party PV ownership. Drury et al. distinguishes three PV adaptation barriers for the consumer that are taken away by third party ownership. (Drury et al., 2012)

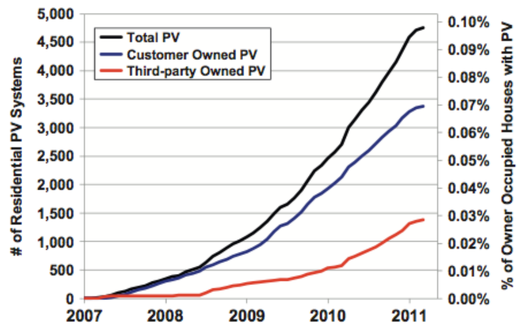


Figure 5.4 Deployment of third party and customer owned PV in the US residential market (Drury et al., 2012)

- Removing the upfront investment
- Reducing technology risk and complexity
- Repacking PV value by showing electricity savings in the first month, rather than defining PV value in terms of payback time

According to one of the interviewees there is a strong cultural difference among countries when it comes to taking a credit to procure materials. ''In the us people are used to buy materials on a credit. This is a cultural difference compared to other countries. The US also has a strong financial infrastructure that provides easy access to financing.'' (Interview CEO solar media platform, 2016). The interviewee adds that other countries such as South Africa have promising market conditions, but access to financing is limited.

SolarCity corp, Vivint Solar, Sunedison and Sunrun are examples of the 'game changers' in the US PV industry. Some of them offers fully integrated PV service including financing, maintenance, design and even the installation of charging stations for electric vehicles. Ownership of the panels can either remain among the company, the roof owner or is being re-sold to investors. Being founded in 2006, Solar City corp. was founded in 2006 and has grown at a high pace, representing a market capitalization of $1.98B by October 6th 2016. Recently Solarcity has been acquired by Tesla, and SunEdison has filed for Chapter 11 bankruptcy. These two developments show that this part of the industry is fairly dynamic.

ACTIVITY AND PRACTICIONERS IN THE NETHERLANDS

The number of project developers that offer a turnkey solution for commercial scale projects and remain financial and legal owner of the system is limited. There are several companies that offer lease or similar proposition to residential home-owners or housing corporations.

An important one is Eneco, which is one of the major utility companies. Based on the described business model of third party ownership, Eneco has realized several projects such as: Kyocera stadium (725 kWp), Sunport Blijdorp (518 kWp) (Solarplaza, n.d.) and The Edge Amsterdam (165 kWp). In addition to this, Nuon owns several large scale PV projects on third party roofs. However, the precise business model of these is unknown.

Apart from the two large utilities, hardly any commercial scale third party projects are known. Other commercial scale rooftop projects where the roof-owner is not the owner of the PV installation are often developed with solar share models such as 1Miljoenwatt and Solargreenpint (Solarplaza, n.d.). These are often SPV's that raise money through crowdfunding.

BUSINESS MODEL

Value proposition

For this business model, several value propositions towards the customer (mostly residential or C&I) are identified. In most cases, it is largely financially driven and the proposition consists of savings on the electricity bill.

The business model executer offers their customer a rooftop photovoltaic installation without any upfront costs. As long as the savings are larger than the costs of the installation and financing, the customer starts saving money from the first month onwards. In addition to this, the customer is protected from rising electricity prices and can agree on a fixed long-term kWh tariff. As the electricity is sold on a kWh-basis, the customer is not exposed to operational risks such as inverter failure or manufacturer bankruptcy. In some cases the customer can purchase or obtain the installation for free after the contract period (Interview project developer utility, 2015). During the development of the project a fee for renting out the roof can be negotiated as well.

Depending on the precise characteristics the value propositions can be:

- A photovoltaic installation without upfront costs, which can be used for green marketing or improving the environmental performance of a building
- The customer benefits from lower electricity costs from the commissioning onwards (Interview project developer utility, 2015)
- Free or inexpensive photovoltaic installation after agreed contract period
- Fixed electricity prices for long period, through a PPA or performance guarantee
- Reduced technological and financial risk and complexity as a enterprise is responsible for the functioning and performance of the system(Schoettl and Lehmann-Ortega, 2011)
- Providing additional income from roof-rental for building owner (Schoettl and Lehmann-Ortega, 2011)

Target Customer

In this model the target customer are in most cases real estate owners. One of the interviewees distinguished retail and non-retail customer, where the latter consists of e.g. institutions and housing cooperation's (Interview project developer utility, 2015). The latter one provides opportunities for scaling up the project. For commercial-scale projects the target customers can be large real estate owners, (semi-)public organizations and SME's (Interview project developer utility, 2015). Depending on the precise value configuration, the electricity usage and pricing of the customer can be important for the success of the business model (Gieselaar, 2013). It is important for the business model executer that the electricity will be consumed or feed into the grid for the full contract duration. Targeting long-term real estate owners/developers such as housing corporations and real estate investors can reduce the risk of contract termination because of moving or bankruptcy of the user of the building. In summary the most important target customers for this model can be:

- Roof owners that have an electricity usage profile that fits the supply profile of PV
- Retail customers (home owners, small and medium enterprises)
- Housing corporations
- Real estate investors/developers
- Organizations with significant of roof space surface (Interview project developer utility, 2015)

Distribution channels

This model targets residential and commercial rooftops. These target customers can be divided in retail (individual customers) and corporate (housing corporations, real estate developers and SME's). Retail customers are relatively expensive to acquire, and are thus often targeted through direct sales, utility companies or other third parties that have access to large groups of retail customers (interview #4 and #7). Commercial scale projects are often acquired through direct sales, using account managers or project developers (Interview project developer utility, 2015)

Relationship

In this model the business model executor and customer enter into a long lasting contract. The executor has an interest in a well-performing installation. In almost all cases the installations are monitored through an monitoring platform that is provided by the inverter manufacturer or a third party (Deege, 2015). Whenever something appears to be wrong with the plant, the executor will contact the roof-owner. Regular cleaning and maintenance appointments make sure that the plant performs well (ISSO, 2012). Billing and accounting often takes place on a annual basis.

Value configuration/Key activities

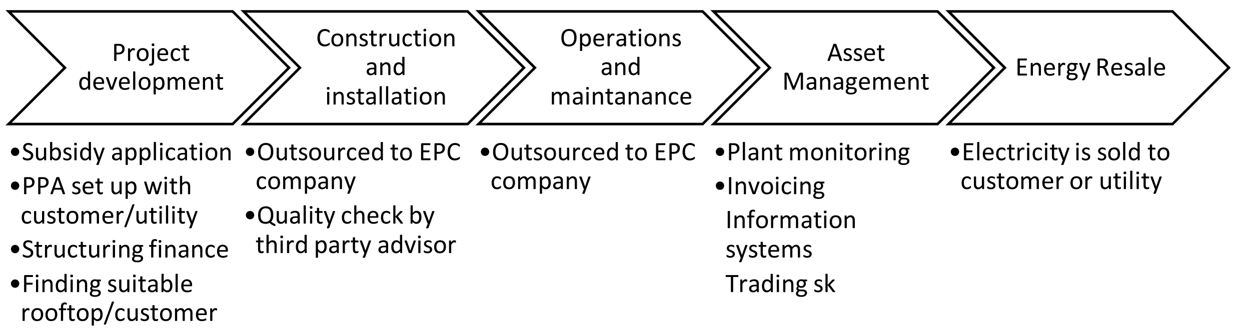


Figure 5.5 Value configuration of business model category 5.2

Financing

Depending on the business model executor, various financing mechanisms can be used for this business model. In the studied case of the interview utility the plant investment is done by the business model player itself. With a multi billion annual revenue in 2015 the few solar projects that are built using this business models do not have a large financial impact on the company. The utility does not have dedicated financing mechanisms for solar projects and invests in the projects themselves (Interview project developer utility, 2015). It is thus likely that these projects are financed by using debt financing.

Although they are not often seen yet in The Netherlands, other financing mechanisms such as crowdfunding, equity investors and solar bonds can work with this model as well. However, financial due diligence and financing costs are often too high for medium scale projects. Most equity investors are only able to make satisfactory returns on projects that are at least 3 megawatts (Interview investment manager Bank, 2015). In many cases the size of rooftops are at limiting factor for these financing constructions.

Core competency/Key resources

Practicing this model requires execution of several parts of the downstream value chain. It is important to have access to the local market to serve the customers, as well as being able to develop, operate and finance the project (Schoettl and Lehmann-Ortega, 2011). During the development stage the executor needs to be able to acquire legal roof access, subsidies and financing (Gieselaar, 2013). This requires local legal and market knowledge. During the operational stage, the electricity can be sold to the energy market on a spot-price basis. This requires energy trading skills.

Partner network

In this model the business model executor has a coordinating role. Engineering, construction and installation are an important determiner for the long term performance of the installation. ''The EPC company is thus an important partner and delivers a functioning system with warranties''(Interview project developer utility, 2015). The external advisor or consultant that performs the technical due diligence of the plant can be an important partner as well. In the case of the studied utility company, in-house engineers assess the plans of the EPC company. In many cases strong relationships with only a limited number of EPC companies are established to enhance trust. Although price remains an important issue, there are other important topics to address as the system needs to perform over a timespan of 15 years. In the case of attracting external financing, the financier is an important partner as well.

Cost structure

The downstream photovoltaic industry is known to be capital intensive. Thus EPC costs represent the majority of the total cost structure. In the case of revenue streams from SDE+ subsidies, additional certified kWh-metering devices are required. As in this specific business model the ownership of the plant differs from the energy user and rooftop owner, there are significant legal costs included. Other important costs that are indicated by the interviewees are several insurances, maintenance costs and interest. As the projects that result from this business model are executed by solar professionals, it is important that the forecasted energy production is achieved. This means that every kWh counts and downtime is undesirable. (Interview project developer utility, 2015) (Gieselaar, 2013).

Revenue model

This model is mainly driven by the SDE+ subsidy scheme and the negotiated PPA with the customer that uses the electricity (Interview project developer utility, 2015). In addition to this a electricity surplus can be sold to the utility. Some business cases are known with this business model where no SDE+ subsidy is used, but the EIA tax extension(Gieselaar, 2013). This is a tax deduction for renewable energy generation and energy efficiency measures. In practice this results in a 14% discount on the initial price (RVO, 2016) . This measure cannot be combined with the SDE+ subsidy.

INSTITUTIONAL ENVIRONMENT

Multiple interviewees stated that the institutional environment plays an important role in the success of third party solar market penetration. This model has a high level of sensitivity to the institutional environment(Interview COO solar lease company, 2015). There are several prevalent aspects of government regulation that have impact on this model in The Netherlands:

- SDE+ subsidy scheme which is a FiT policy measure that increases the revenues from a projects (Interview project developer utility, 2015).

- As mentioned in chapter 2, energy tax is regressive in The Netherlands. This results in a significantly lower electricity price for customers with a large electricity demand up to a factor of 4 (Rijksoverheid, n.d.). This directly results in a differentiation of the competitiveness of PV toward grid electricity. To execute this business model in a successful way, it is thus important to find the sweet spot where the right regulated electricity price and subsidized revenue streams match
- When this model is applied to the residential industry, the availability and continuation of net-metering is essential. This stability can be considered as a cornerstone of the model (Interview COO solar lease company, 2015) .
- As in most cases the electricity is sold by the third party through an PPA, as the production risk is at the business model executor, they are considered as an electricity trader and consequently have to pay energy tax. However, some case are known where the government provided rulings that state that this model is not subject to energy tax (Groene Courant, 2014).

DESIGN

In this model there is a clear incentive for the business model executor to create a high performance installation, as they benefit from a higher annual electricity production (Interview CEO solar media platform, 2016). One of the case studies showed that in this model there is not only more attention for component and design quality, but the bankability of the suppliers is taken into consideration as well. By doing this, the risk that bankruptcy of supplies can cause problems when warranty claims are filed is reduced (Interview COO solar lease company, 2015).

The interviews show that already in the initial financial projection the removal and/or recycling of the modules are taken into account from a financial perspective. However, at this moment of time the attention in the market for recycling of modules is limited. The interviewed practitioners expect this to gain traction in the coming years. The interviews also show that the sustainability of upstream manufacturing is not a big issue for the customers. In the current industry, this will only become a more important issue once the customer requires their supplier to pay attention to sustainable manufacturing (Interview project developer utility, 2015).

UTILITY INVOLVEMENT

This third party model is often very reliant on a negotiated PPA with a utility company. In one of the studied cases, a major utility executes the business model themselves, allowing them to engage on the long term with their customer. When a utility is heavily involved in this model, it can trade the generated electricity on the spot market or retail electricity market, providing them a competitive advantage over other companies. In other cases, a project developer needs to negotiate a PPA with the utility themselves, or make sure that the rooftop owner is able to consumer all generated electricity throughout the operational phase.

In the studied case on residential solar lease one of the major utilities in The Netherlands served as a partner and distribution channel, as they have access to mass market.

BUSINESS MODEL CANVAS

Pillar	Building block	Description	Institutional environment	Utility involvement	Design
Product	Value Proposition	• PV installation without upfront costs • Fixed electricity price • Free/inexpensive PV installation after contract • Reduced technology and financial risk and complexity • Removing upfront investment			
Customer interface	Target Customer	• Roof owners • Retail electricity customers • Housing corporations • Real estate investors/developers • Organizations with significant amount of roof space			
	Distribution channel	• Residential through third party client base (utility) • Direct sales • Account managers • Project developers		Utility can serve as a distribution channel	
	Relationship	• PV monitoring platform • Cleaning/maintenance interval • Invoicing/billing • Utility company			
Infrastructure management	Value configuration	See value chain diagram			Maintenance costs are for the BM practitioner
	Capability (sometimes referred to as core competency)	• Local market access • Financing access and knowledge • Legal knowledge • Asset management • Energy trading skills	Dependency on net-metering		
	Partnership or Partner Network	• Technical advisor • EPC company			

		• Financier			
Financial aspect	Cost structure	• EPC Costs • Legal costs of using roof • Certified meters • Insurance • Maintenance costs	In the case of variable kWh contracts, energy tax might be applicable		
	Revenue Model	• SDE+ subsidy • Negotiated PPA with customer • Surplus PPA with utility • EIA	High dependency on FiT	Long term PPA with utility in large projects	

5.3 VALUE ADDED SERVICE PROVIDER

By providing services such as consultancy, writing project requirements and developing photovoltaic plants this player is an orchestrator for the project, but does not own the plant. This business model category can address specific parts of the photovoltaic value chain and covers a broad range of business models. Several activities and executing companies are listed below

- Module quality testing (DNV-GL, Frauenhofer institute, Eternal Sun)
- Independent engineering services (3E, DNV-GL, Clean Energy Associates)

MARKET SIZE AND DEVELOPMENT

As this business model category contains all kind of services that are offered to players throughout the photovoltaic value chain it is virtually impossible to demarcate it and the market size of it. However, it can reasonably be stated that a more mature and professional market requires organizations that are able to provide specific knowledge that can be used to increase performance, reduce project risks and speed up processes.

This hypothesis implies that activity of PV consultancy firms increases as project and market sizes do so. Based on the author's experience in the PV industry in different market such as The Netherlands, Japan, Germany, Italy and The United States it is indeed the case that larger project attract dedicated service providers. Examples of these companies are DNV-GL and 3E, which are consultancy firms that provide technical knowledge and due diligence to stakeholders in the industry. Other segments include companies that focus on third party O&M and asset management services, such as 3Megawatt, Powerhub, Maxgen, BD4BS, which are currently hardly seen in the Dutch residential market but are growing rapidly in utility scale driven markets.

As the demarcation of the activities for this business model category is not set, no numbers on market size can be provided.

ACTIVITY AND PRACTICIONERS IN THE NETHERLANDS

With the current shift in the Dutch PV market from residential driven to a more C&I and even utility scale market, mainly driven by the €8 billion SDE+ feed in tariff provided by the government (Energeia, 2015). The recently announced utility scale ground mounted projects (Financieel Dagblad, 2017) involve multi millions of financing which requires intensive financial and technical due diligence of the installation and components. It is for this reason that it can be expected that value added service providers will increasingly be present in the Dutch PV market. An upcoming conference on the Dutch solar future is sponsored by Eversheds and DNV-GL, which companies that focus on large scale project services (Solarplaza, 2017).

BUSINESS MODEL

Value proposition

As discussed, the range of services in this business model category is rather large. When looking at the commercial activities of the most common players in this field, which are primarily independent engineers, the value proposition can best be summarized as reducing risk and optimizing performance in all phases of the PV value chain.

Target Customer

In this business model category the target customer can be any organization that is active in the downstream or upstream photovoltaic industry (Frantzis et al., 2008). Primarily the focus is on utility scale PV facility owners. There are some cases where the service provider targets residential customers for specific assignments such as financing brokerage or assistance with paperwork. (Schoettl and Lehmann-Ortega, 2011)

Distribution channels

As the out of this business model category are services, this is either done by providing labor force by the means of consultancy or providing data-based analysis through a monitoring or asset management software platform (3E Solar, 2017; DNV-GL, 2016).

Relationship

Depending on the kind of service that is provided, the relationship with the target customer can be maintained on a regular basis. Especially in the case of services that are provided in the operational part of the value chain such as: data performance analysis, monitoring, billing, asset management, strong relationships and dependencies can be in place.

Value configuration/key activities

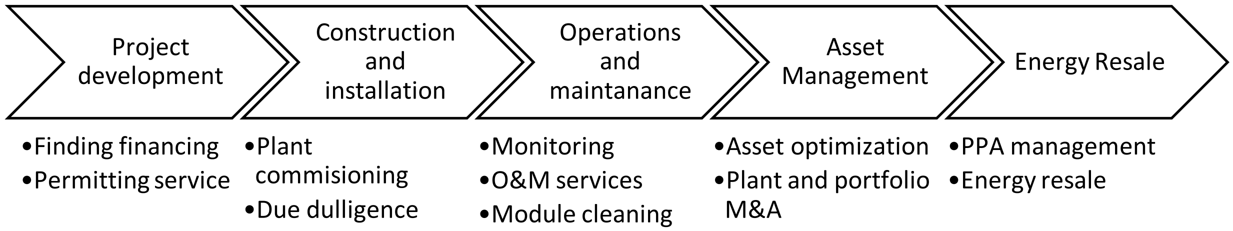


Figure 5.6 Value configuration of business model category 5.3

Core competency/Key resources

The core competencies in this business model are in many cases competencies that end-customers or system owners do not sufficiently have. This can be very specific data analysis on operating data that allow the owner to take O&M action, upfront module testing to determine the quality of the component or due diligence for commissioning or trading of plants.(3E Solar, 2017). These activities require in-depth knowledge of the components, financial knowledge or physical facilities such as PV module testing equipment.

Partner network

In order to maintain the competitive advantage of advanced knowledge on specific topics, value added service providers often form strong partnerships with (inter)governmental organizations and knowledge institutes. An example is the Belgium renewables consultant 3E that is involved in the European Solar Bankability program(Solar Bankability, 2017).

Cost structure

Most service providers in the downstream photovoltaic industry are primarily consultancy firms. This implies that the most important costs is the salaries of consultants and the investments in knowledge on a company level. In the case of test facility providers there can be significant investments in machinery. An example of this is Eternal Sun that provides accelerated solar radiation tests that can assess the longevity of solar modules.

Revenue model

The revenue model of value added service providers is usually charging for services as soon as they take place. This hold for both consultancy and testing services. At recent conferences and workgroups on best practices, the concept of upside sharing has been discussed extensively as well (Balfour and Klise, 2015). In this model, a bonus is provided to the value added service provider when actual performance is above an agreed level. This can be done by choosing an adequate KPI such as MWh/annum production or plant availability rate as a percentage. By agreeing on upside sharing there is more of an incentive for the service provider to increase the quality of their work as this translates in monetary value.

INSTITUTIONAL ENVIRONMENT

As stated earlier, the business model category of value added service provider is rather broad, but it is reasonable to assume that this space in the industry flourishes when large scale projects are built and operated. In the case of The Netherlands, larger scale projects are mainly driven by the following policy instruments:

- 15 year SDE+ subsidy feed in tariff for large scale connections (>3*80A)
- Energy investment tax reduction (EIA) for enterprises. This tax reduction can not be combined with the SDE+ subsidy scheme(RVO, 2016)

DESIGN

As this business model category is very broad it is difficult to make an analysis on the design aspects of it. In the interviews and literature, quite a few technical independent engineers have been found in this business model category. In business models with large projects or external financing involved, these independent engineers often provide technical due diligence. This leads to a better design of the plant, in order to decrease the performance risk in the operational phase.

UTILITY INVOLVEMENT

Other that consultancy firms that deal with grid-related solar topics such as net-interaction, grid-compliance and cybersecurity, there is no relationship with the utility in this business model category.

BUSINESS MODEL CANVAS

Pillar	Building block	Description	Institutional environment	Utility involvement	Design
Product	Value Proposition	• Reduced risk in PV projects • Increased performance	Not applicable		Not applicable
Customer interface	Target Customer	PV system owners Mainly utility scale			
	Distribution channel	Consultancy Software platforms			
	Relationship	• Strong relationship in services in the operational phase		Limited	
Infrastructure management	Value configuration	See value chain diagram			
	Capability (sometimes referred to as core competency)	• Technical knowledge • Financial knowledge • Testing facilities • etc			
	Partnership or Partner Network	• Knowledge institutes • (inter)governmental organizations			
Financial aspect	Cost structure	• Consultant salaries • Machinery			
	Revenue Model	• Sales of services • Upside sharing			

5.4 CONSTRUCTION AND INSTALLATION SERVICE PROVIDER

This business model category represents the activity of actual installation of the photovoltaic system. The category is similar to 5.1 but is limited to the construction and explicitly excludes all kind of project development or operational activities. The business model category can cover residential, C&I and utility scale projects (Schoettl and Lehmann-Ortega, 2011).

GLOBAL MARKET SIZE AND DEVELOPMENT

Numbers on which organizations are active in which part of the downstream photovoltaic value chain are not widely available. Market research shows that in the US market the vast majority of the large projects are contracted by dedicated EPC companies, rather than vertically integrated project developers that are described in the other business model categories.

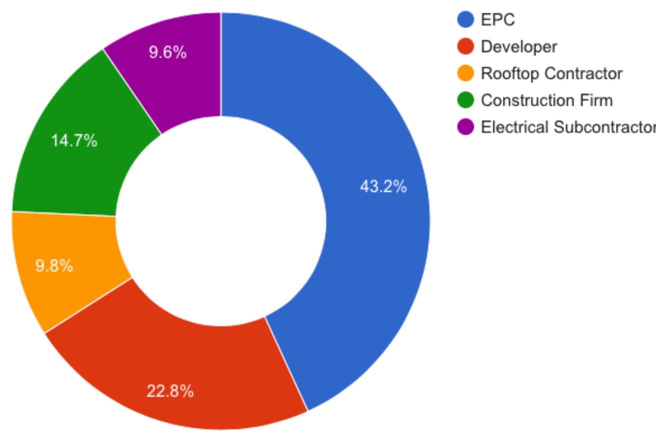


Figure 5.7 North American Solar contractors market share 2015 (total 15.24GW. Raw data from: (adapted from: Solar Power World, 2017))

As the US is one of the most mature PV markets and has relatively many vertically integrated project developers such as First Solar and Sunpower, the percentage of dedicated EPC contractors in the construction market is reasonable to project on other markets. According to Solar Power World about 23% of the added PV capacity in 2015 was constructed by developers (Solar Power World, 2017). The rest is either built by the EPC or an aggregation of subcontractors that work for the EPC. As rooftop, construction firms and electrical subcontractors often only fulfil a part of the installation the total installed capacity in these datasets can exceed the actual installed capacity. This is the result of double allocating installed capacity to both EPC's and their subcontractors.

ACTIVITY AND PRACTICIONERS IN THE NETHERLANDS

At this moment, the US appears to be the only market that is covered by solar media analysts on this level of detail, which makes it challenging to make estimates on market share of non-vertically integrated EPC companies. Focusing on The Netherlands, it is safe to assume that the construction market share of EPC is even larger than in the US, as the number of PV project developers is limited. Based on estimates the total Dutch installed capacity was 1.32GWp in 2016 (Energie Business, 2016) . As there are no numbers on annual added capacity in The Netherlands, the market size is virtually impossible to estimate

BUSINESS MODEL

Value proposition

In this business model category the business model practitioner installs the solar installation. The value proposition is providing a photovoltaic installation that meets the requirements of the customer. Depending on the business model of the end-customer, which can be residential, C&I or any type of project developer, additional elements such as warranties, bankability, performance guarantees ("Interview project developer utility," 2015) and VAT tax returns (Belastingdienst, n.d.) can be offered to the customers.

Target Customer

As described by (Schoettl and Lehmann-Ortega, 2011)the business model category aims at small, medium and large scale projects. This does not mean that the business model practitioner always targets these three end-customers. Based on the conducted interviews the target customers can be categorized as:

Small scale (residential):

- The construction contractor deals with the residential end-customer directly. In many cases plumbers or small electrical contractors work in this way (Schoettl and Lehmann-Ortega, 2011).
- The contractor works for large resellers that focus on more on customer acquisition than on the installation itself. Examples of these companies are Ikea, Solarcentury and Sungevity.
- The contracts is selected by large scale purchasing cooperatives and install the systems under the agreed conditions with these organizations (Financieel Dagblad, 2012).

Medium scale (commercial and industrial)

- In some cases contractors offer EPC services directly to building owners or renters. In most cases the company already has a long term relationship with the target customer as he is the general electrical service company.
- The contractor can work for project developers, energy cooperations or utilities that already have an relation with the end-customer. An example of a customer is Eneco, who offers SME's PV installations, but outsources the EPC work to a contractor ("Interview project developer utility," 2015)

Utility scale

- Although limited, recently some examples have shown up of mostly foreign utility scale PV project developers that enter the Dutch market. Examples of these are ib-vogt, BayWa-RE (PZC, 2016). As these companies have limited labor resources in The Netherlands, they are likely to outsource the EPC services to a local service provider.

Distribution channels

Construction and installation service providers deliver the components to the project site and send construction team that are able to do the installation.

Relationship

The relationship of the contractor with it's customer is mostly limited to the construction period. After completion of the project, there is no ongoing relationship other than maintaining the warranties.

Utility involvement

In this model, there is no involvement from the utility. All grid-related issues are done either by the project developer or end customer, which can be an energy cooperation, SME or residential customer.

Value configuration/Key activities

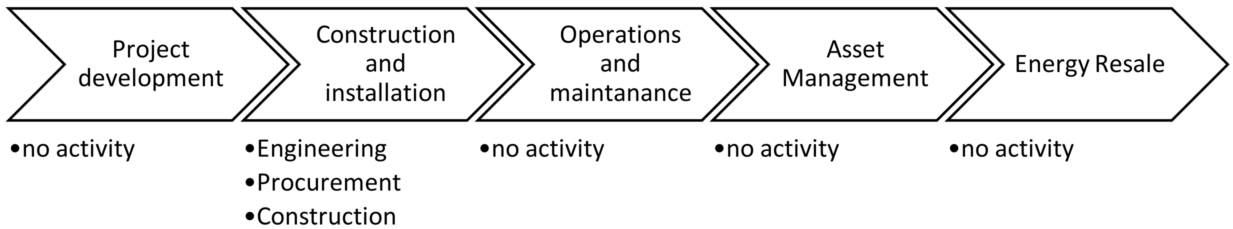


Figure 5.8 Value configuration of business model category 5.4

Core competency/Key resources

The primary skill set of this business model category is to build and manage solar projects (Schoettl and Lehmann-Ortega, 2011)

Partner network

The partner network activities of EPC contractors are relatively straight forward. On one side they need to remain in touch with the importers or distributors of the photovoltaic components. In addition to this there are all several organization types that have different positions in the development stage that are important for the contractor. Examples of this are crowdfunding platforms, energy cooperations (Lakemeijer, 2016) and cooperative purchasing organizations (Financieel Dagblad, 2012).

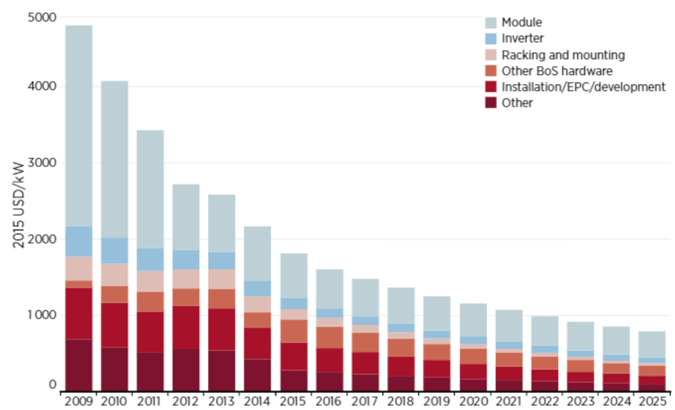


Figure 5.9 Global weighted average system costs breakdown of utility-scale solar PV systems, 2009-2025 (IRENA, 2016b)

Cost structure

EPC costs often account for the majority of capital expenses of photovoltaic projects. Figure 24shows how material and labor costs are structured and how they have developed over the years. As module and inverter prices have declined rapidly, their portion of the total costs has fallen as well. This, along with the increased competition of EPC's, resulted in an increased price pressure on the labor costs.

Revenue model

In this model all the revenues origin from the construction of the PV system. Usually the final payment is done after the commissioning and acceptance of the system by the owner or third party due diligence engineer.

INSTITUTIONAL ENVIRONMENT

As this business model addresses small, medium and large scale PV systems, there are no specific policy instruments that stimulate this model more than other. It benefits equally from all policy instruments that are favorable for the downstream photovoltaic market in The Netherlands:

Small scale:

- Obliged net metering that utilities have to provide for small scale grid connections (<3*80A) (Rijksoverheid, 2013).

Medium/Large scale:

- 15 year SDE+ subsidy feed in tariff for large scale connections (>3*80A)
- Energy investment tax reduction (EIA) for enterprises. This tax reduction can not be combined with the SDE+ subsidy scheme(RVO, 2016)

DESIGN

In most cases the practitioner of this business model has to comply to the project requirements as set up by the target customer. Depending on how professional this customer is or if they hired and independent engineer (5.3), the design requirements can differ. In most small installations the key performance indicators are often based on the initial installed capacity (kWp) with a warranty that typically lasts for one or two years ("Interview COO solar lease company," 2015). In projects where external financing is involved the KPI's are more focused on bankability and performance during the economic lifetime ("Interview COO solar lease company," 2015). In the latter case, an example is found where a solar lease company specifically requires specific inverters as they can have a 2 or 3 % higher efficiency. In larger systems or portfolio small performance increases can be vital to make the business model successful.

UTILITY INVOLVEMENT

No examples of utility involvement in this business model category are observed.

BUSINESS MODEL CANVAS

Pillar	Building block	Description	Institutional environment	Design
Product	Value Proposition	• PV installation • Warranty		Focus on initial project costs
Customer interface	Target Customer	• Residential end-customer • Energy cooperations • Project developers		
	Distribution channel	• Transportation to site		
	Relationship	• Mainly in EPC stage		
Infrastructure management	Value configuration	See value chain diagram		
	Capability (sometimes referred to as core competency)	• Building and management of solar projects	Indirectly depended on net-metering for small projects	
	Partnership or Partner Network	• Import company • Distributor • Energy cooperations, crowdfunding platforms etc.		
Financial aspect	Cost structure	• Labor • Components	Lower costs because of EIA tax return in some cases	Focus on low capital expenses
	Revenue Model	• Sales of construction of PV systems	SDE+ for large projects	

5.5 UTILITY SCALE POWER PRODUCER

Utility scale photovoltaic energy installations feed in electricity directly in to the grid. The major differences with the business model described in 5.2 are the project scale (often >1MWp), the lack of self-consumption of electricity and this category is almost exclusively ground-mounted, where self-consumption systems are often built on a rooftop.

The principle of this business model is the project execution by a project developer that raises, often externa, funding and operates the photovoltaic installation by receiving revenues from the electricity that is sold to the grid, in addition FiT’s or tax credits are often in place to increase the profitability of the project. After the successful development and once operational the plants are often traded on the secondary market and can be acquired by larger investment funds such as pension funds(Gieselaar, 2013) (Berg, 2016). However, the latter mentioned asset acquisitions have not been observed in The Netherlands yet.

GLOBAL MARKET SIZE AND DEVELOPMENT

As a result of a maturing solar industry and consequently falling component prices in the last decade, large-scale utility photovoltaic projects have gained attention from project developers and investors. As can be observed in figure 5.10, in 2015, the global utility-scale solar market was almost twice as large as the rooftop market. As an increasing number of countries face grid parity and component prices are expected to keep falling, both market segments are expected to grow in the coming years.

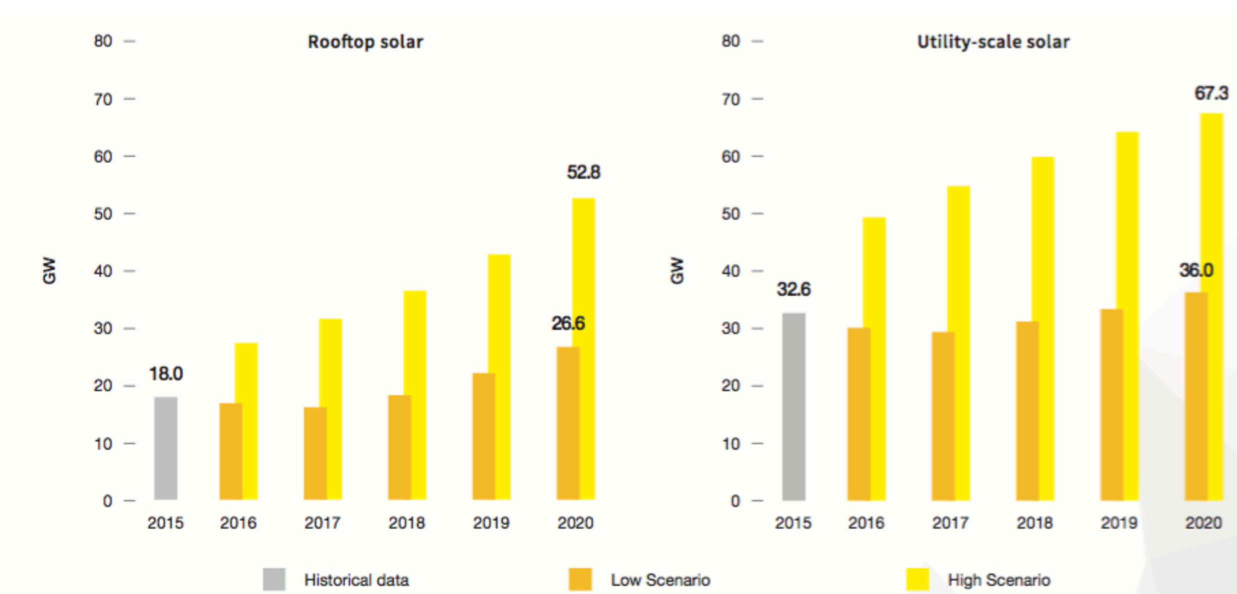


Figure 5.10 Rooftop and Utility scale market outlook for 2016 – 2020 (adapted from: Solar Power Europe, 2016)

ACTIVITY AND PRACTISIONERS IN THE NETHERLANDS

As discussed in chapter 2, The Dutch market is traditionally driven by residential and increasingly by commercial scale installations. Major cause for this is the net-metering scheme that is available for small grid connections. A detailed segment breakdown is shown in figure 5.11.

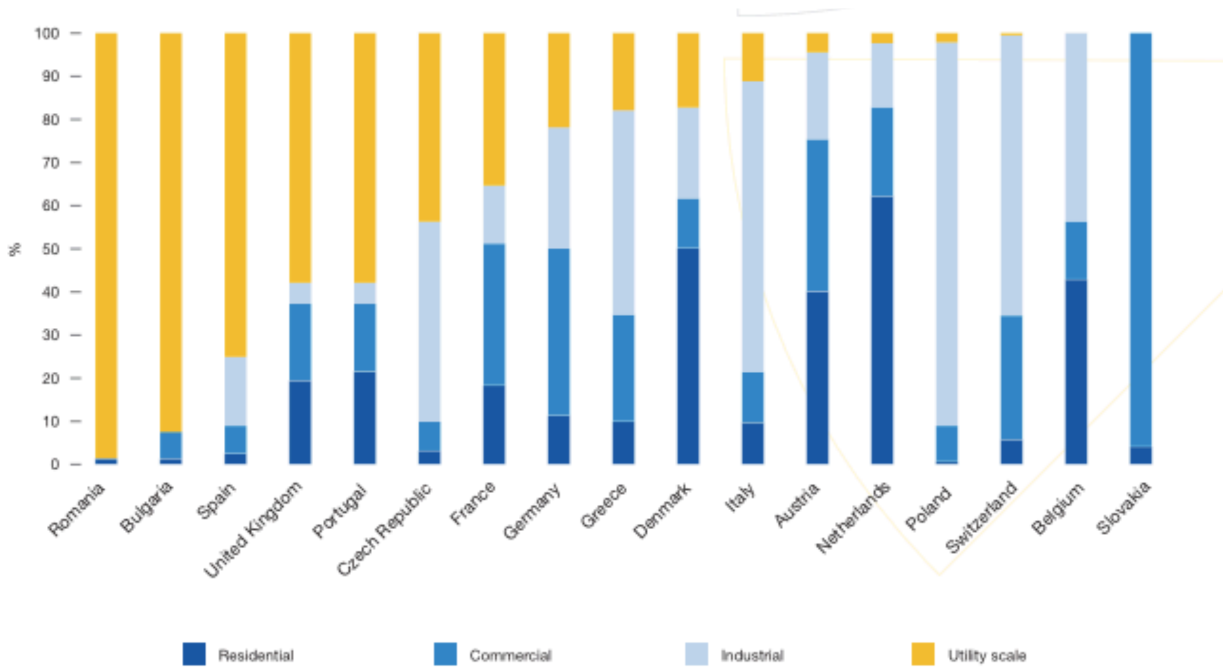


Figure 5.11 segmentation of European photovoltaic markets (adapted from: Solar Power Europe, 2016)

Only after recent SDE subsidy rounds, utility scale projects seemed to have gained traction. Currently 6 grid connected utility scale projects are known, varying in size from 675 kWp to 6 MWp (Solarplaza, 2016). However, various large scale ground-mounted projects are announced, have applied for subsidies or are currently tendered (Solarmagazine, 2016). Current market leaders in this segment are Eneco, Kieszon, Triodos bank and several local energy cooperatives.

BUSINESS MODEL

Value proposition

In an interview with a bank that manages a renewable energy portfolio, the interviewee stated that their value proposition is ''enabling their customers to invest in sustainable energy projects and contribute to a more sustainable environment, in addition they provide a good financial return on the investment''. This means that the fund manager considers that they serve their investors, and are not actively developing or operating any photovoltaic projects. This is somewhat arbitrary as these funds are often based on equity investment, which makes the investor legal owner of the assets. Detailed defining of legal and financial ownership is not within the scope of this research. Taking into account the other practitioners of the business model, equity investors that actively develop and operate utility scale photovoltaic installations are considered as practitioners of this business model as described by (Schoettl and Lehmann-Ortega, 2011). This means that the value proposition is sustainable electricity, for an agreed price. This results in an increase of the share of sustainable electricity in the generation portfolio of utilities, without having them to be involved in project development with the associated risk and investment requirements. When the model is operated by a utility, the value proposition is similar, but targeted on retail customers or third-party energy traders. It is worth mentioning that one of the interviewees at an US based utility stated that almost all of the developed projects include an external PPA, which means that the electricity is sold to a different utility company rather than to retail consumers within the customer base. This has to do with risk mitigation in the financing process.

Target Customer

One of the characteristics of this business model is the grid connection and lack of self-consumption or direct sales of the electricity to customer, such as described in 5.2. By this there is only one type of organization that is capable of purchasing the generated electricity, which is a utility company. However, recently a regulation has been introduced where retail customers in the surrounding areas of the plant can deduct the electricity tax from their bill (Elzenga and Schwenke, 2014). As the electricity itself is not sold to these customers, it is considered as a fiscal benefit, and not as a transaction of the electricity, and thus would the utility company that purchases the electricity still the customer of this business model. From the investment side the important partners are retail investors that are often combined in a certain fund. In the studied case, semi-institutionals and family offices are mentioned as specific partners

Distribution channels

As the number of projects and potential customers based on this business model can be counted on one hand, it is tempting to assume that direct sales is the most important distribution channel for practitioners of this business model. No data on distribution channel strategy of utility scale project developers is found in literature or in the conducted interviews.

Relationship

The relationship with the target customer is limited as there is often a long running PPA in place. It is sensible to have regular contact to report on plant performance, maintenance intervals and asset management.

Value configuration

Based on prior research this business model category consists of two sub-categories (Schoettl and Lehmann-Ortega, 2011):

- In this business model where a player virtually integrates the whole downstream value chain, and thus essentially is a project developer that remains owner of the installation during the operational phase. Although the organization controls and is responsible for all steps in the value chain, it does not exclude outsourcing of certain steps. This model is referred to as 'Utility scale power builder and producer'. Examples of this model are Eneco's large scale ground mounted systems.

- A business model where the executor is only owning and operating the plant. This is known in the market as an independent power producer (IPP) or 'Utility scale builder orchestrator and operator'. Although the author has been in contact with several IPP's throughout the US, there is no evidence of IPP solar activity in The Netherlands, and thus this sub-category is out of scope.

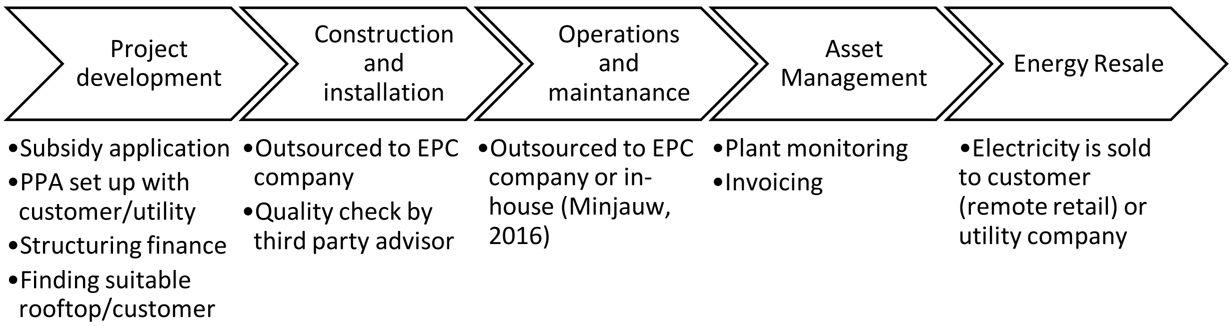


Figure 5.12 Utility scale builder and operator value configuration

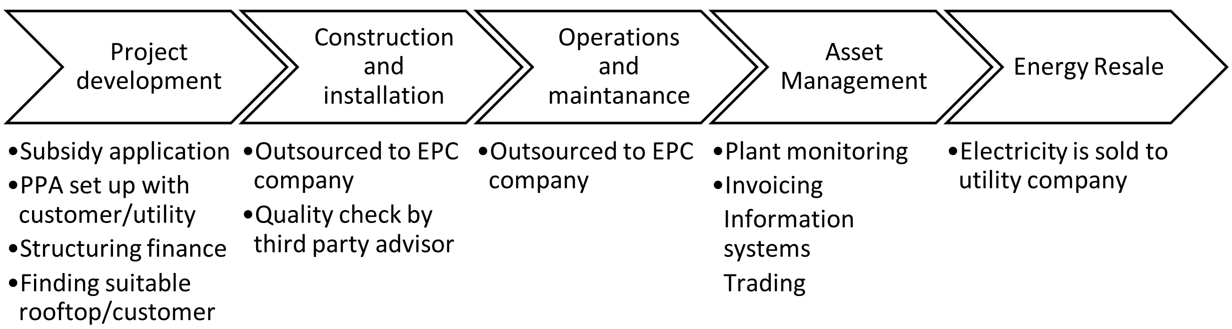


Figure 5.13 Utility scale power builder orchestrator and producer value configuration

Core competency

As this model comprises a rather large part of the development and operational stage, the required skillset is comprehensive. In contrast with rooftop solar, ground-mounted projects require government permits, which can result in longer and more complex development. In the development phase the most important competencies are access to finance, financial structuring, engineering, legal skills on permits, financing and subsidies. During the operational phase, it is key to have O&M and asset management skills including energy trading and potentially asset trading competencies.

Partner network

Grid operators and utilities are the technical counterparties of this business model executor, and thus form important partners. As the amount of electricity that is produced in these projects can be rather large, the grid connection provided by the grid operator forms a vital success factor. EPC contractors are another important partner, as they have a major stake in the actual installation quality.

Cost structure

The EPC costs of a project account for the majority of the project costs. As these projects are ground-mounted in many cases the land needs to be acquired by the project developer. Utility scale projects are financed by professional investors or utilities, this results in the requirement of professional asset management and accurate metering of the project.

Revenue model

From a portfolio or yieldco perspective the most important revenues are dividends from a variety of projects (Interview investment manager Bank, 2015). On a project level, the main revenues can consists of the generated electricity through a PPA or sold on the spot market. In addition to this several subsidy schemes can be in place such as the Dutch SDE+ feed in tariff ("Interview project developer utility," 2015). Certificates of origin might become an more important revenue stream, which can be beneficial for utilities specifically as they can use these certificates to sell green electricity on the retail market.

INSTITUTIONAL ENVIRONMENT

As discussed in the business model, this model is in most cases dependent on the SDE+ subsidy scheme, which has the characteristics of a feed in tariff. These feed in tariffs have been proven to be able to ramp up the utility scale PV market size in a very short timeframe. As it guarantees a 15 year long revenue stream for the project developer, the financial risk for the investor is limited. However, recently there have been some cases abroad where feed in tariffs have been cut retroactively (PV Magazine, 2017), these cases are currently discussed in court.

DESIGN

Utility scale projects are generally larger than commercial- and industrial rooftop projects. This implies that professional investors are on-board. In most cases these investors demand the involvement of an independent engineering company in the development process, which leads to better performance and durability. Utility scale projects are often debt financed, which involves banks. These banks generally ask for certifications and bankable project components. This bankability generally includes technical characteristics, manufacturing plant quality, certification and test procedures, track record, warranty conditions and financial position of the company (International Finance Corporation, 2015).

In contrast with other business models a major bank that advertises sustainability in their investments, does state that it prefers not to invest in utility scale solar plants that are built on fertile or valuable ground ("Interview investment manager Bank," 2015). This player also takes manufacturer sustainability into account. Most major panel manufacturers are ISO 14001 certified. However, this does not necessarily mean that the modules are produced in a sustainable way.

In the current state of the art of the solar industry, demounting solar modules on large scale is still rare. It is expected that at some point PV plants can be re-powered which might included large scale module replacement. At this point it is important that materials from PV-panels can be recovered by recycling a recycling process.

OWNERSHIP OF THE PLANT

Although this model is barely seen in The Netherlands, lessons can be learnt from more mature markets such as Japan and the United States. In the US the majority of the utility scale projects are developed and operated by dedicated renewable development companies or utilities. It is common that regulated utilities set up a legal entity to be able to develop PV projects in an unregulated environment. It is increasingly common that operational assets and portfolios are sold to utilities or institutional investors to raise additional capital. A different way to raise capital is setting up a so called yieldco which raises capital on the stock market. In summary, the legal ownership of the plant remains with the developer/IPP or utility if the plant is sold in the secondary market. In the US market there is a clear difference among developers, as some have the strategy to hold their assets for a long time, where others try to sell the assets after a few years of operations to be able to focus on developing new plants.

UTILITY INVOLVEMENT:

Utilities are getting increasingly involved in utility scale ground mounted solar projects. In the US PG&E invested in several project (Schoettl and Lehmann-Ortega, 2011) (Solarmagazine, 2015).

BUSINESS MODEL CANVAS

Pillar	**Building block**	**Description**	**Institutional environment**	**Utility involvement**	**Design**
Product	Value Proposition	• Sustainable electricity • Obeying RPS requirements		Contributes to RPS	
Customer interface	Target Customer	• Utility companies (through PPA) • Retail customers (in case the utility is the BM executor and in community solar case)			

	Distribution channel	• Direct sales			
	Relationship	• Monitoring reports • Service intervals • Asset management			
Infrastructure management	Value configuration	See value chain diagram			
	Capability (sometimes referred to as core competency)	• Financing access and knowledge • Legal knowledge (permit application) • Asset management • Energy trading skills • Asset trading			Institutional investors have higher requirements regarding compenencies
	Partnership or Partner Network	• Grid operator • EPC-contractor • Asset manager/O&M provider			
Financial aspect	Cost structure	• EPC Costs • Financing costs • Land acquisition • Certified meters • Insurance • Maintenance costs			
	Revenue Model	• SDE+ subsidy • Negotiated PPA with utility • Merchant solar • Tax credits	High dependency on FiT Potential for TGC's		

5.6 VIRTUAL POWER PLANT

The increasing share of the renewable energy generation in the electricity mix leads to a more unpredictable and weather dependent electricity supply. This consequently leads to challenges for grid-operators and utility companies. Expensive reserve capacity from partly-loaded fossil based electricity plants are currently used to manage electricity supply in the grid (Cheng et al., n.d.). The grid frequency shows the balance between electricity generation and demand, in The Netherlands the desirable frequency is 50 hertz. As a result of sudden changes in electricity supply or demand, this frequency can be disturbed. In order to avoid grid stability issues, system flexibility is crucial (BestRES, 2016). Virtual power plants are one of the concepts that can play an important role in the future electricity landscape. Virtual power plants can be defined as ‘’a system that relies on software and other technology to remotely and automatically dispatch and optimize distributed energy resources via an aggregation and optimization platform linking retail to wholesale markets’’ (BestRES, 2016). In practice this is a bundle of medium and small-scale electricity production and consumption units operated through a central operator. By doing this supply and demand can be managed and profitably electricity trade becomes available (Next Kraftwerke, n.d.).

GLOBAL MARKET SIZE AND DEVELOPMENT

When considering current shifts in the electricity landscape, two prevalent aspects need to be present in a market to enable virtual power plants to operate successfully and profitable:

- Mismatch of demand and supply of electricity, often caused by a high share of renewable generation in the electricity mix
- A liberated market where small and medium scale electricity demand and production can be traded

A pioneering company in the European VPP market, Next Kraftwerke, claims to have 2.400MW networked capacity, speak over 3820 units, acting as a virtual power plant. In total, the company has traded 9TWh of electricity in 2015 (Next Kraftwerke, n.d.). According to research the global installed capacity of VPP’s was 4.8GW in 2014 and is expected to quintuple to 28GW by 2023 (Navigant Research, 2014). Currently technology firms, utilities and regulators are in the early stage of figuring out market value and business models for virtual power plants, and there is still a large gap between developed technologies and profitable business cases at this stage (Gallucci, 2016).

ACTIVITY AND PRACTISIONERS IN THE NETHERLANDS

As the Dutch retail electricity market (<3*80A grid connection) allows net-metering, there is no financial incentive for the user of the grid connection to differentiate electricity consumption and production over time. At this moment there are only very few experimental projects known where virtual power plants are installed. Eneco’s subsidiary Agro-energy offers micro-CHP solutions that include power balancing in the business model. Recently Eneco started a partnership with Tesla, and currently sells residential scale battery storage systems that can serve as a virtual power plant. In 2015 Eneco invested in the Dutch start-up PEEEKS that connects real time electricity prices with demand response of buildings (Eneco, 2015). Although expectations are high and there is some development, no actual cases of commercial virtual power with solar PV are found in The Netherlands.

BUSINESS MODEL

Literature does not show any clear examples of stand-alone business models for PV-installations that are part of a virtual power plant. This paragraph will address the generic virtual power plant business model. The results of this will provide insights in core competencies and utility involvement in the model, and thus is relevant to answer the research questions.

Value proposition

Virtual power plants can reduce or eliminate imbalance in the grid in a relatively inexpensive manner. Grid stability and reserve capacity can be considered as a value proposition towards the grid operator, which is responsible for power quality. More specifically the flexibility of distributed generation can be translated to value propositions as:

- Rapid curtailment for grid balancing (PWC et al., 2015)
- Rapid curtailment for congestion management

Towards the retail market, the value proposition is an additional revenue stream on their solar-, storage- or other grid-connected installation.

Target Customer

In the limited cases where PV-installations are explicitly named as part of a virtual power plant, the installation is combined with decentralized storage (Deign, 2016; Eneco, 2016). The aggregated portfolio is monetized by offering flexibility on the power market, utility, DSO or TSO.

Distribution channels

As the name suggests, most value created by virtual power plants are services rather than hardware products. These services are delivered through the grid, which has special requirements to be able to facilitate virtual power plant services. Most important is a data connection that continuously delivers price information and can deliver commands to electrical equipment.

Relationship

Virtual power plants are aggregations of retail customers under one pricing, demand response or distributed energy resource program (Zurborg, 2010). This means that the ongoing relationship between the business model practitioner and the retail customer is vital to operate the virtual power plant.

Utility involvement

Involvement of utilities and grid operators in this business model category is key. The utility ultimately is the organization that is economically involved in the balancing of the grid. This means that mismatch between generation and demand of electricity is costly for them. In addition to this, utilities own and operate virtually all involved central generation power plants such as gas peakers and hydropower plants.

Value configuration/Key activities

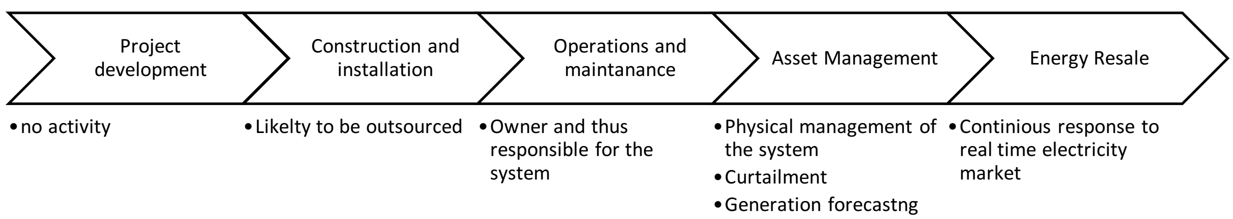


Figure 5.14 Value configuration of business category 5.6

Core competency/Key resources

Most important resources for the VPP operators is the access to the aggregated demand and generation capacity. By operating these devices on agreed conditions, the response can be monetized through the power exchange. It is extremely important to have energy trading skills, knowledge of the grid and access to mass market in order to set up the aggregation.

Partner network

The VPP operator heavily relies on its suppliers which are prosumers, which can be industrial or residential owners of photovoltaic systems. In addition to this the DSO and TSO can be important partners, as they will set up the request for curtailment or

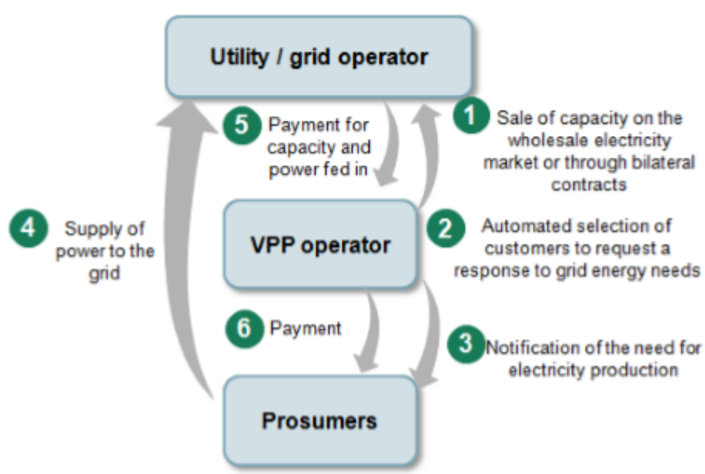


Figure 5.15 Partner network of VPP operator (adapted from: Boston Consultancy Group and Cuadernos Orkestra, 2015).

grid balancing (Boston Consultancy Group and Cuadernos Orkestra, 2015). Figure 5.15 provides an overview of of the partners relate to each other.

Cost structure

The costs of PV integration in virtual power plant can be split in capital- and operational expenses. Main capital expense is the smart converter/controller and gateway that needs to be installed to be able to a remotely monitor and control the PV system. In the operational phase there are potential costs for the curtailment of generation (PWC et al., 2015).

Revenue model

The revenue model is primarily based on the possible action of down-regulation (curtailment) of the photovoltaic energy production(PWC et al., 2015). In an aggregated system with storage, demand response and DER there are several other revenue streams including up-regulation, peak-shaving and battery (discharge).

INSTITUTIONAL ENVIRONMENT

In the current situation in The Netherlands, a net-metering scheme compels utilities to balance out the rates of electricity demand and generation for small grid connections (Rijksoverheid, 2013). This legislation clearly limits the potential for virtual power plant as no value can be created for the owner of small scale systems.

DESIGN

The design consideration of photovoltaic systems that are used for VPP aggregation do not necessarily differ from other business models. However, it is vital that there is a smart inverter or some other device emplaced that is able to monitor and control the electricity generation of the system. Reliability of the system is more important than in other business models as well, as not only the missed generation revenues will be lost in the case of downtime, but failing to comply to balancing mechanisms can result into significant economical penalties.

BUSINESS MODEL CANVAS

Pillar	Building block	Description	Institutional environment	Utility involvement	Design
Product	Value Proposition	• Curtailment for grid balancing • Curtailment for congestion management			
Customer interface	Target Customer	• Utility • DSO • TSO • Counterparty at power exchange		Utility can be target customer	
	Distribution channel	• Virtual distribution through communication channels			
	Relationship	• Vital to have a strong relationship with retail-customer		Strong relation needed with utility.	
Infrastructure management	Value configuration	See value chain diagram			
	Capability (sometimes referred to as core competency)	• Energy trading skills • Grid knowledge • Access to mass market			
	Partnership or Partner Network	• Partner with utility/grid operator			
Financial aspect	Cost structure	• PV system • Smart inverter/control device			• Smart inverter or control device leads to additional costs • Failing to grid balancing request can lead to penalties
	Revenue Model	• Sales of ability to curtail electricity supply			

6 CROSS CASE ANALYSIS

This chapter provides an overview the similarities and differences of the business model categories on a building block level. In addition to this, it provides an analysis of the relations between business models and design considerations and policy instruments.

6.1 PRODUCT

VALUE PROPOSITION

Defining the value proposition for the business model categories that are selected has a degree of complexity in it. Based on the studied cases there are three main value propositions observed:

- A photovoltaic installation that is owned by the end-customer (5.1 and 5.4). This is the most classical business model and is seen across many other industries. The risks of the operation is at the end-customer.
- Electricity produced by a PV installation. This electricity can be sold to a end-customer or a utility through a power purchasing agreement (5.2, 5.5, 5.6). In this category a third party finances and operates the asset, and carries the operational risk. The proposed value to the off-taker can be local electricity production without upfront investment or a hedge against potential rising electricity prices on the market.
- Ancillary services such as power quality, reserve capacity (5.6) can become increasingly valuable as the share of renewables in the electricity mix rises, resulting in higher fluctuations on the supply side. Several models are identified that offer value in a very specific niche, such as reduced project risk by due diligence.

Both the first and second bullet points are in some cases accompanied by side products such as an improved green image (mostly the case in the C&I market), compliance to regulations that oblige organizations to procure or produce sustainable electricity, or tradable green certificates.

Table 5.1 Comparison of business model categories on product level

Product	**5.1 Turnkey project provider R,C&I**	**5.2 Build-own-operate rooftop**	**5.3 Value added service provider**	**5.4 Construction and installation service provider**	**5.5 Utility scale power producer**	**5.6 Virtual power plant**
PV installation	X					
Electricity purchasing through PPA		X			X	
Resilience or hedge towards electricity price increase	X	X			X	
Improved green image	X	X				
Free or inexpensive		X				

installation after end of contract						
Risk reduction (technological and financial)		X	X		x	
Power quality						X

6.2 CUSTOMER INTERFACE

TARGET CUSTOMER

Within the different photovoltaic business models. Multiple target customer groups are identified. The most common are residential and commercial rooftop owners (5.1, 5.2). In most of the cases that the building owners utilize the building, they pay for the electricity bill as well. This implies a latent customer need of lower electricity costs, which can potentially be achieved by investing in a PV installation. In the case of rental real estate where the roof-owner and electricity bill payer can be different entities, it can be more challenging to convince all stakeholders to utilize the roof for a PV installation.

In the third party market (5.2, 5.4) target customer qualifications are different. As the third party often finances the photovoltaic installation, the financier is likely to set strict conditions to reduce the medium and long term risk of the project. Long term ownership of the real estate and bankability of the roof-owner and/or PPA-off taker need to be taken into consideration. It is rather obvious that a bankruptcy of the roof-owner or PPA-off taker are very likely to reduce project revenues to zero, while the interest and debt still need to be paid.

It is precisely the risk that is described in the prior paragraph that is assessed and potentially reduced by some of the Value added service providers (5.3). Services can include asset management, project due diligence and data analysis.

In the case of utility scale projects, the customer is a utility that purchases the electricity through a PPA (Presentation Davidts, 2012).

It is interesting to see that most business models serve their own specific target customers, that each have specific needs or benefits for the business model practitioner. Most notable requirement is the long term commitment and bankability of the customer in the case of third party ownership.

Table 6.2 Comparison of business model categories on target customer level

Target customer	5.1 Turnkey project provider R,C&I	5.2 Build-own-operate rooftop	5.3 Value added service provider	5.4 Construction and installation service provider	5.5 Utility scale power producer	5.6 Virtual power plant
Rooftop owners with intention to keep the asset in the medium-long term	**X**	**X**				
Utility scale installation owners/project developers			**X**	**X**		
Residential end-customers	X			X		
Utilities				X	X	X
Large PV system resellers/				X		
Grid Operator						X
Purchasing cooperatives	**X**			X		

DISTRIBUTION CHANNELS

As explained in paragraph 3.2, the distribution channel represents the means by which the practitioner delivers the value to the customer. It is the connection between the target customer and the value proposition. This comprises both the way a organization gets in touch with their customer and the way the value is physically delivered on site.

The interviews and analysis show that utilities generally have a large database of potential customers for rooftop solar in the residential and C&I segments, whereas regular solar installers need to find these customers in a different way. In some cases the customer actively reaches out to their utility to ask if they can provide solar solutions on their roof (Interview project developer utility, 2015). For this reason it can be a benefit to partner with a utility when targeting residential and commercial customers, which is done by one of the interviewed companies (Interview COO solar lease company, 2015).

Table 6.3 Comparison of business model categories on distribution channel level

Distribution channels	**5.1 Turnkey project provider R,C&I**	**5.2 Build-own-operate rooftop**	**5.3 Value added service provider**	**5.4 Construction and installation service provider**	**5.5 Utility scale power producer**	**5.6 Virtual power plant**
Direct sales	X	X			X	
Through third parties that have mass market access (utility)		X				
Delivery through EPC companies		X				
Though consultancy			**X**			
Material and labor delivery on site				X		
Virtual distribution through IT						**X**

RELATIONSHIP

Analysis on the relationship with the customer shows that this strongly relates on the activities of the value chain that are representented in the value configuration of the business model. In the more classical business model that strongly focus on project development (5.1), customer acquisition and the construction of the installation, the customer relation is concentrated in the (pre)-construction period and is often relatively short.

In the third party models, there is a stronger ongoing customer relation. In the studied cases the residential customers are contacted on an annual basis, and the system performance is continiously monitored (Interview COO solar lease company, 2015). For utility scale projects there is often an monthly report to the investor and large plantes are continiously monitored and operated in cooperation with the grid operator and utility (First solar operation center visit). In third party there is an intensive for the practitioner to maintain or increase the performance of the plant, which in some cases is done by cleaning the modules (ISSO, 2012)

In the case of the studied utility, the practitioner is continiously in contact with their potential customers in the residential and C&I segment. When customers are interested in solar energy they naturally contact their utility (Interview project developer utility, 2015).

Table 6.4 Comparison of business model categories on relationship level

Relationship	**5.1 Turnkey project provider R,C&I**	**5.2 Build-own-operate rooftop**	**5.3 Value added service provider**	**5.4 Construction and installation service provider**	**5.5 Utility scale power producer**	**5.6 Virtual power plant**
	Focus on early stage	Continuous monitoring	Strongly depends on offering	Mainly focused on early stage	Through long term PPA	Through smart meter and controlling devices
	Longer term relationship through warranties.	Annual contact (residential)	Strong relationship if active in operational phase	Maintaining warranties	Asset management and monitoring reports	Continuous interaction by operating devices
		Operation and maintenance		Operation and maintenance		

6.3 INFRASTRUCTURE MANAGEMENT

VALUE CONFIGURATION

In the value chain activities in the downstream photovoltaic industry a dinstinction can be made between pre- and post construction. All activities prior to commissioning can be considered as part of the development process, after which the operational phase begins. This development process consists of all the necessary stepts to build a proper project. Depending on the scale this can be permitting, customer acquisiton, financing, permitting etc. In some models the engineering, procurement and construction are completely sourced out, where others integrate these activities in their own business. In general the project development and EPC skill strongly differ as the first on is mainly legal and financial in the latter one requires more techincal copmetences.

The operational phases consists of O&M, asset management and energy resale. Although many definitions of asset management can be found in professional literature, in general it can be stated that asset management comprises the financial aspects in the operational phase and oversees the operation and maintanance activities.

In the analysis of chapter 5 it becomes clear that in third party solar business models (5.2 and 5.4) involve more activity in the operational phase. It can be argued that in conventional models the operational activities are done by dedicated service providers, but hardly any of them are observed in the Dutch market at this point. Hardly any of the exhibitors and attendee's on the visited European Solar Asset Management conference have operational activities in The Netherlands, which mainly has been a conventional market.

At this point the number of installations that are end-of-life and need to be decomissioned are neglatable. However, it is interesting to investigate how end-life and potential recycling can be integrated in downstream business models.

CAPABILITY/CORE COMPETENCIES

In Osterwalders framework the capabilities and core compentencies are defined as ''the ability to execute a repeatable pattern of actions that is required to create value for the customer'' (Osterwalder, 2004). When comparing these abilities, it becomes clear that the first party solar business models mainly require market access for customer acquisition and project management skills for the construction of the project. As clarified in the background chapter, this space in the solar market is very competative and crowded. This has lead to low margins and price pressure.

A more comprehensive skillset is required in the third party and utility scale projects. This is mainly due to the third party location which requires legal competencies and permits. In principle the third party sells electricity to the grid or real estate owner and thereby becomes a utility. This activity requires legal and financial complience which can include the requirement to pay electricty tax (H.G.J. Kamp, 2013). When large or aggregated projects lead to a surplus of electricity at certain moments of time, the owner can trade this electricity on the energy market, or sign a power purchasing agreement with a utility.

Table 6.5 Comparison of business model categories on capability level

Capability	5.1 Turnkey project provider R,C&I	5.2 Build-own-operate rooftop	5.3 Value added service provider	5.4 Construction and installation service provider	5.5 Utility scale power producer	5.6 Virtual power plant
	Access (semi) mass market	Access to local market	Specific skillset that end-customers or professionals lack	Construction skills	Development skills	Access to aggregated energy demand and supply systems
	Procurement and negotiation skills	Development skills (legal, subsidy acquisition)	Technical knowledge	Project management	Permits	Grid knowledge
	Ability to integrate panels in roof (residential)	Operations/asset management	Specific financial and legal skills		Access to finance	Energy trading skills
		Energy trading skills	Physical facilities such as module testing equipment		Development skills	
					Energy trading skills	
					O&M/Asset Management	

PARTNER NETWORK

In the partner networks large differences are observed among the business model categories. Utility scale projects are connected directly to the grid and can have a large impact on it. This means that the business model practitioner continuously works together with the grid operator and by that creates a strong partnership.

In terms of sales, both conventional and third party business models are observed that partner with utilities or association to gain access to a large customer database. An example is Nuon that offers a solar lease proposition to their retail customers by partnering with Sol-ease (Deege, 2015). This mass market access appears to be vital in the residential market.

Table 6.6 Comparison of business model categories on partner level

Capability	5.1 Turnkey project provider R,C&I	5.2 Build-own-operate rooftop	5.3 Value added service provider	5.4 Construction and installation service provider	5.5 Utility scale power producer	5.6 Virtual power plant
Utility		X			X	X
Sports and purchasing associations	X			X		
Distributors	X			X		
EPC company		X			X	
Financier		X			X	
Knowledge institutes			X			
Grid operator					X	X
Asset management/o&m provider					X	

6.4 FINANCIAL ASPECT

COST STRUCTURE

Although costs of photovoltaics systems have come down in the past decade, the costs of materials still represents the largest portion of the total cost structure (IRENA, 2016). In conventional solar business models, there are hardly other costs than customer acquisition and EPC.

In more complex third party models there is often external financing involved which increases the total costs and levelized costs of electricity. When this external financing structure is present, several costs need to be considered to reduce the exposed risk. Legal and insurance costs are required to ensure the long-term profitability and take away technical and financial risk of the project. External financiers tend to require specific components that have stronger warranties. In most cases the financial position of the manufacturer is taken into account as well, this is the so-called bankability of the components. In addition to this, often technical and financial due diligence is required.

When projects benefit from a feed in tariff, which is the case in the Dutch SDE+, a certified net production meter is required to tackle fraud. In relatively small projects these meters can represent a significant extra cost. In virtual power plants complex meters are supplemented by demand and supply controllers that can regulate generation and loads in order to comply with grid demand.

When comparing rooftop with utility scale ground mounted projects, there can be high costs of land acquisition or lease involved in the latter one. Especially in The Netherlands, where land costs are high this can be a major barrier for the profitability of utility scale projects.

Table 6.7 Comparison of business model categories on cost structure level

Cost structure	5.1 Turnkey project provider R,C&I	5.2 Build-own-operate rooftop	5.3 Value added service provider	5.4 Construction and installation service provider	5.5 Utility scale power producer	5.6 Virtual power plant
EPC Costs	X	**X**		**X**	**X**	
Customer acquisition	X					
Operational costs (O&M and asset management)		**X**			**X**	**X**
Certified meter/grid connection		**X**			**X**	**X**
Legal costs		**X**			**X**	

Financing costs		X			X	
Consultants			X			
Other hardware (test equipment, demand response controllers etc.)			X			X
Land Acquisition/lease					X	

REVENUE STREAMS

The cross case analysis shows that zeroth generation business models mostly rely on the sales of PV systems. This is

The revenue streams are one of the most important cornerstones of a sustainable business. In the analysis the major difference between first party and third party is that the latter receives revenues throughout the lifetime, rather than at the commissioning. These long term revenues can vary in terms of revenue security. In the case of a long-term power purchasing agreement with a credible off-taker or a feed in tariff, the risk of not receiving revenues is limited. These low risk projects are obviously easier to finance than projects that are exposed to the electricity market. As feed in tariffs are getting more and more scarce in modern markets, the revenue streams in future business models may become less secure.

Table 6.8 Comparison of business model categories on revenue stream level

Revenue streams	**5.1 Turnkey project provider R,C&I**	**5.2 Build-own-operate rooftop**	**5.3 Value added service provider**	**5.4 Construction and installation service provider**	**5.5 Utility scale power producer**	**5.6 Virtual power plant**
Sale of pv system	X		X	X		
Feed back in the grid (net-metering)						

SDE+ Subsidy / feed in tariff		**X (large projects)**			**X**	
Off-taker power purchasing agreement or lease agreement		**X**				
Utility PPA		**X (large projects)**			**X**	
O&M services	**X (limited activity)**		**X**	**X (limited activity)**		
Services			**X**			
Upside sharing			**X**			
Grid services (curtailment, power quality, demand response)						**X**
Tax benefits	**X**				**X**	

6.5 INSTITUTIONAL ENVIRONMENT AND POLICY INSTRUMENTS

Based on the policy instruments that are identified in 2.2, an analysis of the dependency of the business models on policy instruments is made. As most of the conducted interviews are with professionals in the Dutch market and so is the focus of this thesis, there are no dependencies discovered on policy instruments that are not available in The Netherlands.

As grid parity, which is the point where the costs of PV electricity matches the electricity prices on the grid, still has not been achieved in The Netherlands yet (Huijben et al., 2014), all market segments are economically depended on policy instruments (“Interview COO solar lease company,” 2015).

In the analysis, it becomes clear that there are three major policy instruments that stimulate the photovoltaic industry in The Netherlands; net-metering, investment tax reduction and a feed-in tariff.

Historically, the net-metering scheme has been beneficial for systems that are connected to a small grid connection (maximum 3*80A). The theoretical maximum of these systems are 55 kVA on the AC side of the inverter. In reality, this means that mainly small businesses and the residential benefit from this program. As this program has an assumption in it that electricity prices are equal throughout the year, it is considered as unsustainable on the long term. The net-metering economically makes the grid a free efficient storage solution. Physically, other ways of generation need to provide electricity in times of low supply of renewable energy.

With the current uncertainty of the continuation of the net-metering scheme (Solar Magazine, 2016) and expect continuation of electricity price decline(ECN, 2016), the profitability of these smaller systems on the long term becomes increasingly uncertain. It is worth mentioning that the net-metering scheme forms a barrier for successful integration of virtual power plants on the residential level.

The energy investment tax reduction has been a strong driver for energy efficiency and renewable energy measures in the past. With the increased budget for de SDE+ subsidy (feed in tarrif) combined with the higher share of PV in this subsidy scheme, the usage of the EIA in the different business models is limited.

As discussed earlier, the SDE+ subsidy scheme has become an increasingly important driver for the Dutch photovoltaic market. The 15 year guaranteed revenue stream from the government makes large scale solar investments attractive as the returns are high and risk is limited. All business models that focus on large grid connections benefit from this program.

Altogether, the analyzed policy instruments seem to be much more related to target customers than business models in general. The following discussion paragraph elaborates on this.

Table 6.9 Comparison of business model categories on policy instruments

Policy instrument	**5.1 Turnkey project provider R,C&I**	**5.2 Build-own-operate rooftop**	**5.3 Value added service provider**	**5.4 Construction and installation service provider**	**5.5 Utility scale power producer**	**5.6 Virtual power plant**
Feed in Tarrif	X (SDE+ for larger projects)	X (SDE+ for larger projects)	Indirect dependency: BM Benefits from industry growth. SDE+ subsidy	Indirect dependency	High dependency on SDE+	
Tradable green certificates	n/a in The Netherlands	-	-	-	Can be important, not mentioned in interviews	-
Renewable portfolio standards	n/a in The Netherlands	-	-	-	-	-

Low interest bank loans	X available for consumers	-	-	-	-	-
Investment subsidies	n/a in The Netherlands	-	-	-	-	-
Net metering	X (small grid connections)	X (small grid connections)	-	Indirect dependency	-	Net-metering forms a barrier for VPP's
Tax credits	X Energy Investment tax for SME's	-	Indirect dependency: BM Benefits from industry growth. Energy Investment tax for SME's	Indirect dependency	-	-
Energy assessment	X	-	-	-	-	-
Virtual net-metering	-	X Vital n postcode roos projects	-	-	-	-

6.6 CROSS CASE CONCLUSION

The business model canvas has shown to be a valuable tool to assess and compare different business models in the downstream photovoltaic industry. In this cross-case analysis, the identified business model categories have been compared at a building block level. After this analysis, the categories are compared on the level of design aspects and the institutional environment.

The results of this chapter provide a clear overview of how business model categories relate to available policy instruments, design characteristics, ownership, capabilities and other factors. This overview provides a tool for policy makers and entrepreneurs in the sense that they can asses what is required for the successful execution of business models in a market. An example of this is that utility companies have access to mass market and experience with the trading of electricity. This means that they are potentially well suited for operating virtual power plants, which require aggregation and trading skills.

For policy makers the cross case analysis can be used to choose specific policy instruments if they want specific market segments or business models to grow. The analysis clearly shows that third party ownership in the residential segment is extremely sensitive to the net-metering scheme, and can already be negatively affect by not providing clarity on the future of this scheme.

In chapter seven, the results of the business model study and cross case analysis are discussed in more detail, consequently leading conclusions and recommendations in chapter eight.

7 DISCUSSION

As PV system and installations costs have been coming down dramatically and are expected to continue to do so, more and more markets will face grid-parity which means that the costs of PV generated electricity is equal or lower than the grid electricity costs. With solar PV being already considered in some regions as the cheapest way of electricity production, the share of it in the global electricity mix is likely to increase significantly.

This increase of renewables in the electricity mix, leads to a much more intermittent supply of electricity with major challenges for the grid and grid operators. In places with high renewable penetrations such as Germany and California, negative electricity prices can be observed on a regular basis. Currently major developments are seen in the lithium-ion battery storage, but it is not economically viable to cover seasonal fluctuations with that.

As discussed in prior chapters, photovoltaic electricity generations not only differs from more conventional sources in a technological perspective, it also allows electricity to be generated in a distributed way and on a residential level. This leads to so-called prosumers, which are grid-connected retail customers that generate electricity and thereby participate actively on the generation market.

These major trends, including expected developments in blockchain and virtual power plants that can combine demand response and flexible generation, lead to unprecedented challenges for utilities (Richter, 2012a).

This research shows that the business model approach can lead to insights in what business models fit with the already available skills, customers or resources of organizations.

7.1 REFLECTION ON CASE SELECTION AND PV BUSINESS MODEL LITERATURE

The business model approach as used in this thesis has been a solid tool to describe the rationale of how a firm creates, delivers and captures value. As this tool is rather general and meant to be used across virtually all industries, there are some limitation for the downstream photovoltaic industry.

A main differentiation among the business models is the differences in products. In conventional business models (5.1 and 5.4), the photovoltaic installation is delivered to the end customer. This means that a physical product, that mainly consists of photovoltaic modules, inverter(s) and balance of system materials, is traded. This model is similar to the business model of many organizations in the construction industry and can be compared to the models that have been use for decades by plumbers, roofing companies, electrical installers and construction firms. In the photovoltaic business model literature these categories are referred to as customer owned (J. C. C. M. Huijben and Verbong, 2013) or the 0th generation (Frantzis et al., 2008).

In addition to the zeroth generation business models, activities in the first and second generation have been found as well. The studied case of residential and commercial build-own-and-operate business models (5.2) are clear examples of this generation as described by Frantzis et al. (2008). Although utility involvement and grid integration is still limited in these models, the operational and financial risk of the installations lies with a third party. It has become clear that these third party organizations are better able to assess the quality and risks of photovoltaic components and system.

The utility scale projects (5.5) and virtual power (5.6) plants represent the second generation of photovoltaic business models, and comprise a much larger involvement of utilities and grid operators. Although the activity in these segments are limited, most it is widely expected that these segments will grow as the market matures. Recently some utility scale projects have been announced, and once the grid penetration of renewables becomes larger, smart grids with controllable generation and loads are required which ultimately leads to virtual power plants.

When taking an ownership perspective (J.C.C.M. Huijben and Verbong, 2013) based on the existing literature, all three categories are identified. This approach is somewhat similar that the one by Frantzis et al., but has an even stronger focus on ownership.

In the analysis, all three ownership categories are identified: customer owned in 5.1 and 5.2, community solar in 5.2 and third party in both 5.2 and 5.5. Community solar is not specifically mentioned as a business model category in the theory on which the case selection is based. However, the interviews with the two community solar organizations show that the rationale of value creation, delivery and capturing is completely different than other business models that are described. It can be argued that community solar fits in the build-own-operate or utility scale power producer models, but several aspects of the business models differ strongly from other business models in this category; the financing is raised through a crowdfunding platform which consequently forms an entity that operates the installations. Fundamentally this concept does not differ strongly from a stock listed IPP (independent power producer) that operates in a similar way. However, in some models where the 'postcoderoos' policy scheme is used, the generated electricity can be net-metered virtually with surrounding grid connections.

The value added service provider category, has not proven to be very effective to answer the research questions of this thesis. In the photovoltaic industry, there are dozens of organizations that fulfil a very specific niche such as but not limited to: technical due diligence, monitoring, asset management, on site module tests and insurance. Each of these niche activities can represent a business model on itself, with strong varieties in each of the single building blocks from the business model framework.

Summarizing discussion on photovoltaic business models, the used categorization might have been a limiting factor, as there are modern models that are somewhat excluded and some models that hardly have any relevance for the research questions. However, this research provides a more in depth description of the business model categories that can be used to better understand the dynamics of them and how they function in specific environments.

7.2 REFLECTION ON SUSTAINABLE BUSINESS MODELS

In paragraph 3.3 two approaches on sustainable business models are discussed, each of them is compatible to a certain extend with the Osterwalder framework. When taking the earlier discussed normative requirements Boons and Lüdeke-Freund (2013) in to perspective, no positive matches have been identified in the analysis of this thesis. Although an increased share of photovoltaic electricity generation in the energy mix arguably leads to a more sustainable energy system, no business models have been found where the ecological or social value has specifically been mentioned as being value proposition. Although specifically asked for it, recyclability and component sustainability is not mentioned specifically in the interviews. After studying datasheets of the most commonly used modules, it can be stated that the vast majority of them complies with ISO14001, which is a certificate for environment management systems.

A different approach to assess business model innovations for sustainability is the sustainable business model archetypes approach as described in Bocken et al., (2014). Based on the analysis several sustainable business model archetypes are observed:

- In the discussed energy cooperations and crowdfunding initiatives, it can be argued that it fits in the 'shared assets' archetype. However, it is a virtual transaction as the installation is directly connected to the home-owners grid connection.
- The identified third party models (5.1) can be related to several social sustainable business models archetypes. These models clearly provide 'functionality rather than ownership'.

Until now there are no examples found of 'integration of recycling' or 'take back management'. This is likely because the vast majority of the installed capacity is well under a decade old and most components have a technical life expectancy of 25 years. At some attended conferences the concept of repowering has been discussed, which can include the replacement of aged modules with higher performing parts in order to increase profits of existing PPA's of feed-in-tariffs. This concept appears to be in a very early experimental phase, but could potentially lead to dismantling of large projects and can stimulate the market for module reuse or recycling. A side note needs to be made that although recycling of PV modules generates raw materials for the upstream photovoltaic industry, which currently primarily is based in Asia. This is likely to lead to relatively high transportation costs and potentially leads to opportunities for more vertically integrated companies in downstream markets.

In the case studies, several examples of product-service-systems are identified. As discussed by Tukker (2004), when firms make money on provided services and the involved products become costs factors, there is an incentive to prolong the service life of products for the firm. Although no quantitative research is conducted on this topic, the interviews show that in business models where electricity generation is provided as a service, there is a strong focus on the long term performance of the system. One of the interviewees stated that ''roofs with an east-west orientation are not performing well enough to make this model profitable'' and ''We design the system in a way that it will perform well for 20 years, whereas the local installer installs with two years of warranty. We don't just look at the efficiency and degradation of the modules but also at the company behind it.'' (Interview COO solar lease company, 2015). In this example there is an incentive for the firm for both high performance of the system and long lasting components with low operational costs. The work of Bocken et al., (2014b) states that implementing product services systems alone is not likely to enhance sustainability, but needs to be combined with increased efficiency. This is supporter by the fact that there are no examples of solar panels being shared by different users on a need basis, as observed in car sharing business models. It is rather obvious that solar panels are already utilized for the maximum amount of time regardless of the business model. However, these kind of business model can make sense in off-grid systems, which are beyond the scope of this research, such as development countries and islands where shared solar systems can be used to charge batteries of devices.

7.3 INSTITUTIONAL ENVIRONMENT AND POLICY INSTRUMETNS

Although the costs of PV generated have come down in a rapid pace over the past decade, the analysis makes it very clear that PV electricity in The Netherlands is in most cases still depend on government incentives. It is increasingly argued that solar is the most inexpensive way of electricity generation, this is often based on comparisons of levelized costs of electricity (Greentech Media, 2017). Even in The Netherlands this LCOE might be lower than prices that consumers currently pay for grid-electricity, which means that the so-called phenomenon grid-parity is reached. However, this grid parity is based on the assumption that available electricity has a fixed price regardless of the season, hour and tax regime. As the penetration of renewables, and by that the generation fluctuations in the electricity mix increases, this theory is not likely to sustain on the medium-long term.

In the current regime, the Dutch photovoltaic industry mainly relies on the SDE+ subsidy for large scale projects and the net-metering scheme for residential and small commercial projects. As there currently is no certainty on the continuation of the net-metering scheme, this can form a barrier for further market development. Third party business models in the residential market space heavily rely on net-metering (Interview COO solar lease company, 2015). According to one industry expert the stability of policy instruments is more important than the financial incentive level (Interview CEO Solar Media platform, 2016).

An additional important insight that can be distilled from this thesis is that the regressive electricity tax as discussed in chapter 2 certainly helps solar PV to reach grid parity for small grid connections. As the tax component comprises the majority of the retail electricity price, returns on solar investments are multiple times as high as they are for larger electricity users (not taking feed in tariffs in consideration). Although this is not a specific policy instrument for renewable energy and it has been in place for over two decades, it does have a strong impact in the profitability of small scale distributed generations.

Similar to the discussion on the photovoltaic business model literature, it can be argued that linking business models to policy instruments is a sub-optimal research foundation as in all studied cases the policy instruments are more related to the target customer group than to the general characteristics of the business model.

7.4 HOW BUSINESS MODELS RELATE TO DESIGN QUALITY

It has become clear that the third party models have a stronger focus on design optimization by several means. Several of the conducted interviews clearly show that third party business models lead to more financial and operational risk at the business model practicioner. In most cases reduced or increased performance directly impacts the profitablitly of the project. In the models where the practicioner is responsible for the yield of the system, the design quality is higher (Interview CEO solar media platform, 2016) and there is more focus on long term profitability rather than initial costs (Interview project developer utility, 2015).

As the Dutch market historically has been driven by residential installations under the net-metering scheme currently there is a major shift toward commercial and utility scale projects. The majority of the latter categories are developed and build by larger companies with more experience in the solar industry. It can thus be expected that the quality of installations and component selections will increase as a result of this market trend.

8 CONCLUSION

Based on the results that are presented in chapter 4 and 5 and the discussion in chapter 6, this chapter provides answers to the research questions as phrased in paragraph 1.5 and provides recommendations for scientific, business and policy professionals.

8.1 ANSWERS TO RESEARCH QUESTIONS

RQ 1.1: HOW CAN GENERIC PHOTOVOLTAIC BUSINESS MODELS BE DESCRIBED AND FRAMED?

Although this research has the limitations that are discussed in the prior chapter, it is clear that the business model canvas approach is a valuable tool to assess how organizations develop and perform under specific conditions. The conducted research clearly shows what specific business model categories require and what they deliver of what value they create. All internal aspects of the way a firm delivers, captures and monetizes value are clearly represented in the business model canvas as proposed by (Osterwalder, 2004).

From a business model perspective the most interesting difference among the models is the first party (customer owned) compared to the third party ownership of the installation. In the latter case the potential financial and operational benefits and risks of the installation are mainly the business model operator.

RQ 1.2: WHAT CAN BE LEARNED FROM THE (INTERNATIONAL) STATE OF THE ART REGARDING PHOTOVOLTAIC BUSINESS MODEL INNOVATION

In The Netherlands the photovoltaic market has been relatively small and mainly residential driven as a result of the net-metering scheme. In the past few year, billions of euros have been made available to stimulate renewable energy in The Netherlands (Energeia, 2015). This incentive consists of the SDE+ subsidy, which is very similar to the successful feed in tariffs that previously have been available in Germany, Spain and Italy. As a result of the economic crisis and the subsequent Spanish electricity reforms in 2013 and 2014, the feed in tariffs have been restructured and cut retroactively (PV Magazine, 2017). One of the interviewees has been affected by this, and emphasized that insecurity of these regulations are problematic for investors, which are usually risk-averse. (Interview investment manager Bank, 2015). Taking this into consideration it is easy to conclude that retroactively cutting feed in tariffs leads to a negative investment climate and therefore can slow down the market.

When looking at the feed in tariffs in Germany, the policy instrument has been very successful in terms of added capacity. However, this currently leads to major fluctuations in the electricity generation, which can lead to negative energy prices. When solar and wind become more abundant, fossil plants with higher variable costs will be challenging to operate in a profitable way, which can lead to significantly higher electricity peak prices and major write-offs for utility companies that have fossil assets. It is therefore an important to deploy flexible generation, demand response, storage, smart grids and virtual power plants, in order to be able to facilitate a higher share of renewables in the electricity mix.

The research results show that several factors influence the success of third party solar. Mainly in the United States this model has been very successful. It has been identified that his success mainly due to cultural difference and the quality of the financial infrastructure. Declining costs of PV and the lack of cultural affinity with credits, can be barriers for third part solar in The Netherlands.

A final lesson that is learned from the analysis is that larger projects and third party business models generally lead to a more mature and professional photovoltaic market. This professionalism can translate into better material selections, higher project bankability, higher safety standards and more ability to raise capital.

RQ 1.3 HOW DO SPECIFIC BUSINESS MODELS RELATE TO COMPETENCIES AND OTHER BUSINESS MODEL BUILDING BLOCKS OF PLAYERS IN THE DUTCH DOWNSTREAM PHOTOVOLTAIC MARKET?

Chapter 4 and 5 clearly show that each identified business model clearly show their own characteristics. Most important conclusions are:

- Business models that focus on residential and C&I segments require access to mass market
- Utility scale projects comprise long project duration and require a different skillset than most current players in the Dutch market have, such as: legal knowledge, access to financing
- Future business models that do not rely on FiT's anymore will require the business model player to have electricity trading skills
- Most current models heavily rely on policy instruments. In particular third party models require clarity about the future of these schemes

RQ 1.4: HOW DO POLICY INSTRUMENTS RELATE TO THE OPPORTUNITIES OF PRACTICING SPECIFIC PHOTOVOLTAIC BUSINESS MODELS?

All currently successful PV business models in The Netherlands rely on policy instruments. The models that mainly focus on the residential segment relies on the availability of the net-metering scheme of which the extension is currently discussed. Third party residential schemes rely even more on the stability of the program as professional financiers that are involved are not willing to take risk in future revenue streams.

The growing commercial, industrial and utility scale segments are often build on the availability of the 15 year SDE+ subsidy scheme that is guaranteed by the national government. Although similar schemes have been retroactively cut in other countries, the financial risk for these projects are relatively low as they provide clarity 15 years. It can be concluded that long term subsidy schemes attract institutional and commercial investors to the photovoltaic industry leading to larger and more professional projects.

Once the net-metering and SDE+ schemes are abandoned, the generated electricity is exposed to the electricity market. This provides barriers for existing models, but will create financial incentives for virtual power plants and more integrated services that can be coupled to PV project (storage, demand response etc.).

RQ 1.5: HOW DO PHOTOVOLTAIC BUSINESS MODEL CHARACTERISTICS RELATE TO THE DESIGN CONSIDERATIONS OF PV INSTALLATIONS?

The interviews show that building quality requirements of photovoltaic projects are higher when external financing is involved. Larger projects and lease propositions often include requirements for bankability of the manufacturer and component quality. In the models where the operational risk of the system performance and durability is at a third party, a more professional approach with regard to risk management is observed.

At this stage there are no examples observed where business models build on recycling or re-using components of the photovoltaic systems. As seen in other industries, this could lead to enhanced sustainability and cost reduction for new projects. However, most solar projects are relatively young and the technical lifetime of many components is over 2 decades. Once more projects reach the end of their lifetime, opportunities for recycling will arise. It is a fundamental problem that the recycling of modules and electronics leads to resources that can only be used in upstream processes, which primarily take place in Asia. It can be argued that vertically integrated solar companies such as First Solar can benefit from recycling at some point.

RQ 1Photovoltaic Business model challenges and opportunities in The Netherlands

In this research it has become clear that the photovoltaic industry both in The Netherlands and on a global level are relatively immature and are expected to keep growing in the coming decade. As the energy and electricity landscape are changing as fast as the PV industry, major challenges for policy makers and commercial organizations lie ahead.

The Dutch solar association expects a tremendous growth of the solar market, primarily driven by de SDE+ feed in tariff. Although the historically dominant residential market remains relatively stable, most of the growth is in large scale commercial systems and utility scale solar parks as illustrated in figure 8.1 (Holland Solar, 2017).

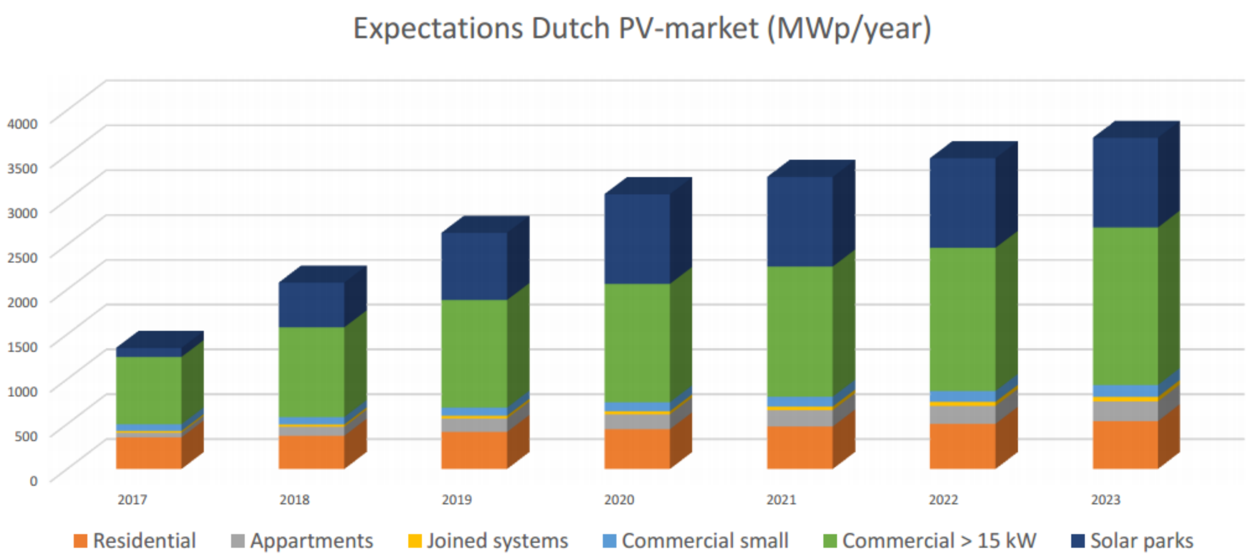


Figure 8.1 Dutch solar PV market outlook (adapted from: Holland Solar, 2017)

If these estimates are correct, the Dutch market will be one of the largest in Europe, mainly driven by new industry segments, which will create tremendous market volume opportunities in the coming years. Based on the studied business model categories, it can be expected that on the short term the build-own-operate (5.2) and utility scale power producer (5.5) business models can and will benefit from the bright market outlook, as they are the categories that primarily profit from this subsidy scheme.

The analysis in chapter five and six shows that both of these business model categories require access to finance, large scale project development and management skills and either sell the electricity to an organization through an PPA or trade the electricity directly on the market which requires trading skills. The cross case analysis makes it clear that virtually all aspects of the business model strongly differ from the business models that have been dominating the Dutch market in previous years (5.1). In conclusion, it can be expected that current players in the market need to adapt to the new environment they will operate and new players will enter the market.

Table 8.2 provides an overview of the change in paradigm that comes with the energy transition we are currently facing. This table illustrates that subsidizing solar and bringing it to the lowest levelized costs of electricity only will lead to a cap on the penetration of renewables in the future. At recent conferences, there have been discussions about the future of solar electricity in an era where there are no feed in tariffs anymore and PPA's tend to become much shorter. This reduced securitization of future revenue streams in solar projects, can form a barrier for future investments. Frantzis et al., (2008) supported that in a later stage, photovoltaic and energy business models become more complex. According to this paper, engineering, procurement and construction of photovoltaic installations becomes a commodity in more modern business model generations.

Table 8.2 Paragdigm shift in the electricity landscape (adapted from: IRENA, 2016b)

Old Paradigm	New Paradigm
Baseload	Variable renewable electricity
Controlled grids	Decentralized grids
Spinning reserve	Flexibility
Network planning	Big data
Energy-only markets	Energy and capacity markets
Must-run	Curtailment
Rising electricity costs	Falling electricity costs
Energy security	Domestic resources and interconnectors
Air pollution	NIMBY and environmental trade-offs

On the short term investements in the Dutch market are fairly secure as the SDE+ subsidy, which comprises the majority of the lifetime revenue, is guaranteed by the government for 15 years. However, based on experiences abroad and developments in the energy landscape, it can be proposed that the current business models will face challenges in terms of finding new long term revenue streams in an environment that is exposed to the electricity market.

In brief summary it is clear that the coming years provide unprecedented opportunities in The Netherlands for gigawatts of annual new installed capacity of PV, both on commercial roofs and utility scale fields. Both of these market segments have been served only limited in the past years and have their own requirements from a business model perspective. This generates opportunities for professional actors in the build-own-operate and utility scale power producer business model categories which are studied in depth in chapter five.

Taking more mature PV markets in consdiration, it is reasonable to expect that the SDE+ subsidy as well as the net-metering scheme will expire in the coming decade, with a probability of existing projects being grandfathered as done in the Californian netmetering 2.0 scheme (Greentech Media, 2016).

In this scenario where both policy instruments are phased out, PV generated electricity is fully exposed to the electricity market that is experiencing increased differences in price levels when renewable penetraion grows (Shayle Kann, 2017). The high uncertainty requires different business models that might include electricity trading skills, supply and demand aggregation and access to less risk-adverse capital. These models can be a major opportunity for vertically integrated utility companies as they have vast experience with these facets.

8.2 RECOMMENDATIONS

POLICY RECOMMENDATIONS

Several interviewees in this research have stressed the importance of consistent policies, and continuously changing policies are one of the largest frustration of industry professionals. It has been stated that the consistency of policies is more important that height of the incentive (Interview CEO solar media platform, 2016, Interview COO solar lease company, 2015). There for the main policy recommendation of this research is to provide stable policy measures, and communicate clearly how long they will last. This provides a foundation for all kinds of business models.

In this research, 10 policy instruments are identified that each have their own characteristics and stimulate different parts of the photovoltaic market in different ways. In The Netherlands, the most prevalent instruments are the SDE+ subsidy feed-in-tariff, net metering scheme for small grid connections and the regressive electricity tax that is not directly related to renewable energy goals but has a strong impact.

The net-metering scheme allows users of small grid connections to feed decentralized generated electricity back in the grid and obliges utilities to compensate them the kWh price that is equal to the price of electricity that is consumed. This scheme virtually creates a free battery for the consumers, which makes it attractive to invest in small scale PV installations. However, the assumption that electricity prices are not related to time and season, becomes increasingly outdated when renewables represent a higher share in the electricity mix. Some markets already face negative electricity prices on the spot markets in times of high renewable electricity production. The net-metering scheme is by that not a sustainable instrument, as some counterparty has to procure generated electricity in times of low prices and need to invest in batteries or flexible generations sources that only can run for a limited number of hours per year.

The Dutch net-metering scheme is likely to be reconsidered in the coming years (Solar Magazine, 2016). The uncertain future of this scheme obviously can lead to lower investments in the residential market, as customers don’t know what regulation to expect after 2020. In the state of California, the net-metering scheme has recently been revised and now includes time-of-use and clearly states that new users of this regulation have a guarantee for a fixed number of years (Greentech Media, 2016). Although this Californian net-metering 2.0 scheme is less favorable than the prior regulation, it is very clear to the market what the return on their investment will be, and takes away uncertainty. A similar scheme is recommended for the Dutch market.

The current SDE+ subsidy is expected to result in a vast new installed capacity of large scale solar projects. This feed-in-tariff secures long stream revenue streams for the investor, which is increasingly important as PPA’s tend to get shorter. So far, the number of granted applications of this subsidy scheme has been much higher than the number of projects that are actually build, this is mainly because there are only limited barriers for applications and no major penalties for not building projects that are approved in the subsidy scheme (Akbari, 2015). This means that a vast part of the SDE+ budget is not actually spent and carried over to next year's budget. This should be taken into consideration for future budget allocation. Increasing the entry barrier can lead to more projects that are granted to professional organizations that actually build the projects, which will lead to a faster growth of the market.

In summary, the main recommendations for Dutch central government policy makers are:

- Provide clarity on the future of the net-metering scheme, and take the Californian case as an example
- Take in consideration that clarity and stability is more important than the height of the policy scheme
- Facilitate legal structures that provide opportunities for long-term corporate PPA's
- Create a barrier for SDE+ projects, to make sure that approved projects are actually executed

RESEARCH RECOMMENDATIONS

This thesis shows that the business model approach is a valuable tool to assess business models in a dynamic environment as the photovoltaic industry is. However, during the research, some limitations to the existing literature and frameworks have been identified that require further research.

In paragraph 3.4, a selection of photovoltaic business models has been made based on the work of Schoettl and Lehmann-Ortega, (2011). As discussed in chapter 7, this set of categories has space for further improvement. An example of potential improvement is that the value added service provider category is very broad, and can have activities in very specific niches. This makes this category hard to compare in a systematic way.

Main research recommendation is to do more research on how the different PV business model frameworks or categorizations relate to each other. The approach by Huijben en Verbong (2013) is an example of a categorization that has a strong focus on the ownership of photovoltaic installations, including solar shares and community solar models. These models and the three different ownership business model generations as discussed in chapter 3 are inadequately covered in this research. The fact that photovoltaic business models become more complex supports the need of further research on framework comparison.

As this thesis is rather explorative, descriptive and quantitative, it would be valuable to follow up on the correlation between policy instruments and business model activities on a quantitative level. A significant part of the acquired data comes from the authors experience in the industry and conferences. Statistic significance of these correlations would provide information for policy makers to assess how successful certain policy instruments are or can be.

BUSINESS RECOMMENDATIONS

The downstream photovoltaic industry in The Netherlands faces rapid growth with in particular opportunities for larger projects in the commercial, industrial and utility scale segments. This inherently leads to the rise of new business models, such as the utility scale independent power producers and third party propositions towards medium and large enterprises. These modern business models are likely to make engineering, procurement and construction activities a commodity in the market. In other markets, the companies in these fields have started to focus on activities the operational phase such as O&M and asset management. These activities are typical for larger projects, and will provide major opportunities in the coming years.

In the long term, it can be expected that the net-metering and FiT schemes will disappear, leading to electricity market exposure for photovoltaic projects. In order to be able to successfully operate in these market conditions, it is required to be able to trade electricity directly of have partners that can do so. It is for this reason, that utility companies may be able to play a larger role in the PV industry. Corporate PPA's can provide a long-term secured revenue stream for project developers as well. These PPA's are increasingly. The generating assets in these PPA's can be either on-site or off-site which are so-called virtual PPA's. A PPA can either be build on a premium over the spot market price, or on a fixed price for a long term.

In general the recommendations for Dutch solar companies are:

- Explore new fields in the downstream market, such as asset management and O&M models, as EPC activities become commodities
- Prepare for new market dynamics in a post-subsidy era. Revenue streams will be less secure and will be focused on energy trading and PPA's

Dutch utility recommendations:

- Providing a lease proposition either through a partner or as a company can increase customer retention
- Trading capabilities and asset management will become more important skills in modern business models. This is an opportunity for utilities.

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APPENDIX I GENERAL INTERVIEW STRUCTURE

Introduction:

- Brief introduction of goal and research questions of thesis
- Mentioning duration of interview (30 minutes)
- Mentioning goal of interview
- Way of reporting (voice recorder)
- Ask for permission to publish (with or without name)

Interview

1. Beschrijf de activiteiten van uw bedrijf
2. In welke mate is PV op dit moment belangrijk voor uw bedrijf?
3. Waarom is uw bedrijf actief op het gebied van PV?
4. Hoe kan PV bijdragen aan de korte en lange termijn doelstellingen van uw bedrijf?
5. Wat zijn voor uw bedrijf de belangrijkste drijveren voor het investeren in PV?
6. In welke mate past PV in het huidige busisness model van uw bedrijf?
7. Hoe verhoudt de verhouding Residentieel/Utiliteit zich binnen jullie bedrijf?
8. Investeert u in installaties waarbij wordt afgerekend op kWh basis? Zo ja, beschrijf deze installaties
9. Hoe zien jullie garanties naar afnemers er uit in de verschillende segmenten (opbrengstgarantie, etc).
10. Hoe waarborgt u deze garanties, en wat zijn belangrijke selectiecriterea?
11. Wat zijn de selectiecriterea bij het uitkiezen van een EPC partij?
12. Hoe stemt u het ontwerp van de installatie af op de specifieke klan en het bijbehorende business model?
13. In hoeverre is uw huidige PV verdienmodel afhankelijk van specifieke regelgeving?
14. In hoeverre is uw model afhankelijk van net-interactie (heden en toekomst)
15. Verwacht u dat het huidige model bestand is tegen institutionele veranderingen?
16. Wat ziet u als bedreiging van het huidige model?
17. Wat heeft u als organisatie geleerd van de tot nu toe genomen stappen in PV

Closing:

Closing interview and summarizing the results

APPENDIX II INTERVIEW TRANSCRIPTS

The interview transcripts have been made available to the thesis committee.