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Lessons and Recommendations for the Dutch BIPV Ecosystem

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PREFACE

This internship project was carried out at Berenschot group, division Strategy, Funding and Innovation. Berenschot is a management consulting firm, serving both the public and private sector. Their work covers a wide range of themes, including Energy and Sustainability. Within this field, Berenschot is involved at many levels, e.g. changes in the energy market, the development of new business models as well as the implementation of new energy technologies such as BIPV. The internship is part of the Energy Science Master program and has been conducted over a period of five months.

I would like to thank the following people, without whose help and support this research would not have been possible. I would like to show my gratitude to Linda van den Hurk, consultant and my supervisor at Berenschot; Erik Teunissen, senior consultant and my second supervisor at Berenschot; and dr. Wilfried van Sark, Associate Professor and my supervisor at Utrecht University, for their valuable insights and directions throughout this research. I would also like to thank all persons and organizations that have cooperated in my research for sharing their information and knowledge in this field. Special thanks to Martje van Horrik and the participants of the Starters International Business workshops organised by Berenschot.

EXECUTIVE SUMMARY

Building integrated photovoltaics (BIPV) is one of the most promising solutions to generate renewable electricity in the built environment. BIPV applications can replace regular building components into prefab integrated components that at the same time generate electricity (Ritzen, Van Horrik, & Vroon, 2014). This contributes to the aesthetic value of a building. The concept is distinctive from regular solar energy applications, since the PV function is integrated into the building envelope instead of placing the solar panel on the roof (Building Adapted PV, BAPV).

BIPV is currently positioned primarily as a niche-product, making up about 1-3% of the total PV market with a total installed capacity worldwide of 1.0 GWp (Ritzen et al., 2014). Berenschot (2015) published a roadmap for BIPV that identifies eleven challenges in the field of technology, market and ecosystem to achieve a 5% BIPV share of total PV capacity in the Netherlands by 2020. This study has continued on these outcomes by reviewing the international situation for BIPV and the role of the Netherlands in this. The purpose of this research was twofold, to determine what the Netherlands can learn from the situation for BIPV in other European countries and to assess which countries show interesting opportunities for Dutch BIPV companies. Apart from the Netherlands, the focus countries that were studied in this research are France, Germany, Switzerland and the United Kingdom.

BIPV applications can replace regular building components into prefab integrated components that at the same time generate electricity.

(Ritzen et al., 2014)

Stakeholder and ecosystem analyses

A thorough review was done on the existing BIPV stakeholders, the BIPV ecosystem and policy and legislation for BIPV in all focus countries. The stakeholder analysis provided insight in which parties are active per country, by reviewing the Triple Helix of academia, industry and government. The most important research institutes can be found in Switzerland (SUPSI and the Swiss BIPV Competence Centre), the Netherlands (SEAC, Solliance and Hogeschool Zuyd) and Germany (Fraunhofer ISE). The amount of BIPV manufacturers and suppliers was found to be growing in all countries. Differences were found in the role of architects and contractors in the focus countries. In the Netherlands architects do not have a decisive role, the contractor makes the final decisions and bears responsibility. In Switzerland architects are the most important during the preliminary design phase and make strategic decisions about what renewable energy technologies can be used, whereas a German architect faces far reaching liabilities and remains responsible until the building is completed. In all countries, the construction industry was found to be relatively conservative, making it difficult to achieve intensive collaboration with the PV sector. Industry associations, legislation and consumers were found to play an important role in stimulating this.

The most important outcomes from the BIPV ecosystem analysis are summarized in Figure 1.

Environmental legislation and building requirements were found to be similar, as all countries have the Energy Performance of Buildings Directive (EPBD) in common. This offers the unique opportunity to incorporate renewable energy technologies, such as BIPV, into buildings. However, it differs per country how the objectives of the EPBD are to be achieved and what support schemes are used. First of all, support schemes in the Netherlands are highly focused on innovation for entrepreneurs and companies, but the focus on BIPV was found to be insufficient. Secondly, France and Switzerland make a clear distinction between regular PV and BIPV in their legislation. This way, the advantages of BIPV are clearly stated and acknowledged. Furthermore, all focus countries except for the Netherlands provide feed-in tariffs for solar energy, the Netherlands uses the concept of net metering. In the Netherlands, Germany and the UK, the subsidy schemes do not reflect the higher cost for BIPV. A last finding is the lack of harmonised building codes with the current developments in the field of domestic energy generation.

Demographic	Ecological	Socio-cultural	Technological	Economic	Political-legal
▪ 0.4% population growth per year until 2020 ▪ Number of single households increasing ▪ Unemployment rate decreasing ▪ 67% of households are homeowners	▪ 11 tonnes CO_2-emissions per capita per year ▪ Increasing temperature trend ▪ Annually 1,521 solar hours and 1,000 kWh/m^2 solar radiation	▪ Adequate level of environmental concern ▪ ~23% of expenditures to Energy & Housing ▪ Transition relationship citizens - government	Technological trends were found to be similar for all focus countries: ▪ Further automation of processes; ▪ Digitalization of information; ▪ Evolution of digitally connected customers, leading to different dynamics in relationships and transactions. Marketing channels are becoming more and more digital ▪ New internet revolution: more appliances and machines are interconnected to communicate and exchange data ▪ The lack of people with a strong IT background is a serious problem for many industries. This inhibits them to make the right techno-logical decisions and to harness the right emerging disruptive technologies at the right time.	▪ Recovery from economic crisis; 0.9% economic growth in 2014 ▪ Growth is projected for export, overall investments and expenditures of consumers ▪ Increasing trend house prices	▪ Decentralization of tasks and responsibilities ▪ Energy Agreement ▪ Focus on energy performance built environment ▪ Design Review Committee ▪ SolarEnergy Application Centre
▪ 0.4% population growth / year ▪ 65% of households are homeowners ▪ Unemployment rate increasing; currently 10.3% ▪ Recent increase building permits issued	▪ 5.6 tonnes CO_2-emissions per capita per year. Low due to large nuclear energy share ▪ Largest surface area; high solar radiation in the South ▪ In 2014 14.6% renewable energy share; 5.5 TWh from PV	▪ Strong focus BIPV to distinguish from Germany ▪ Strong support base for environmental measures and PV ▪ ~27% of expenditures to Energy & Housing		▪ Part of G7 ▪ Slow recovery economic crisis; 2014 economic growth 0.2% ▪ Unstable housing market, decreasing house prices ▪ Low electricity price due to nuclear energy share	▪ 19% citizens trust government ▪ Energy transition for Green Growth Act ▪ Building renovation policy ▪ 30% energy renovation cost refund ▪ Specific BIPV feed-in tariff
▪ Fluctuating population growth ▪ 53% households are homeowners ▪ Unemployment rate only 5% ▪ Building permit requests increasing	▪ 9.1 tonnes CO_2-emissions per capita per year ▪ Increasing temperature trend ▪ 1,100 kWh/m^2 solar radiation ▪ In 2014 26% renewable electricity; 5.9% PV electricity.	▪ ~30% of expenditures to Energy & Housing ▪ Strong support Energiewende, many domestic energy projects		▪ Part of G7 ▪ Economic growth (1.6% 2014) ▪ Increasing house prices ▪ Increasing electricity price due to grid fees (EEG-anlage) ▪ Domestic PV production declining	▪ 50% citizens trust government ▪ Renewable Energy Act (EEG) and Energiewende ▪ Focus on energy performance built environment ▪ Feed-in tariff for renewable energy
▪ 4 official languages: German, French, Italian, Romansh ▪ 1.2% population growth / year ▪ Unemployment rate only 3.16% ▪ High house prices, only 44% households are homeowners ▪ Construction sector declining	▪ 5.0 tonnes CO_2-emissions per capita per year. Low due to large hydropower capacity. ▪ Annually 1,700 solar hours and 1,250 kWh/m^2 solar radiation ▪ Snowfall can cover PV panels ▪ In 2014 842 GWh from PV	▪ Swiss have high level of environmental concern ▪ ~27% of expenditures to Energy & Housing ▪ Large share of energy demand fulfilled by electricity		▪ Not part of EU and Economic and Monetary Union (EMU) ▪ Currency Swiss Franc (CHF) ▪ High(er) import duties ▪ Open and innovating economy ▪ Economic growth (1.9% 2013)	▪ 80% citizens trust government ▪ CO_2 law; Energy Strategy 2050 ▪ Focus on building renovation; directive for BIPV ▪ Specific BIPV feed-in tariff ▪ Swiss BIPV Competence Centre
▪ 0.75% population growth / year ▪ 20% households ≥ 4 people ▪ 64% households are homeowners ▪ Decreasing unemployment rate; currently 5.4% ▪ Stable construction sector	▪ 7.93 tonnes CO_2-emissions per capita per year ▪ 1,300 solar hours per year ▪ 900 kWh/m2 solar radiation ▪ 7% renewable energy in 2014; 15% planned for 2020	▪ ~20% of expenditures to Energy & Housing ▪ Strong level of support for environmental-friendly measures ▪ Consumer behaviour to reduce energy use can be improved		▪ Not part of the Economic and Monetary Union (EMU) ▪ Recovery from economic crisis ▪ Moderate increase house prices will lead to more rental ▪ Relatively low energy taxes	▪ Climate Change Act: 80% GHG reduction in 2050 ▪ Electricity Market Reform towards competition for low-carbon energy ▪ All new homes carbon neutral by 2016

Figure 1: Summary of relevant impact factors on the ecosystem of the Netherlands in each category of the DESTEP-model.

Which countries show interesting opportunities for Dutch BIPV companies?

A multicriteria analysis (MCA) was performed on the focus countries, based on the information that was acquired in the stakeholder and ecosystem analyses and indicated preferences of Dutch BIPV companies. Switzerland and Germany show the most interesting opportunities for Dutch BIPV companies. Main drivers in this are their clear renewable energy targets and strategies. Both countries offer interesting support schemes for PV, Switzerland even provides legislation and incentive schemes specifically for BIPV. Companies indicated that political stability and a high level of trust in the government could be an important factor, on which Switzerland worldwide scores very high. Also, the level of environmental concern in society appears to be higher in both Switzerland and Germany, bringing opportunities for BIPV implementation. It has to be stated that this research merely provides an insight based on limited selection criteria on which the alternatives were scored relative to each other. Individual companies will need to reflect on their personal values and assets, which could lead to different outcomes. The information delivered throughout this report can provide guidance in this.

What are the lessons and recommendations for the (Dutch) BIPV ecosystem?

In addition, the situation for BIPV in the Netherlands was compared to the other focus countries. The Netherlands was found to stand out in the following points:

- Interesting support schemes are provided to stimulate SME companies to collaborate in the field of innovation, sustainability and renewable energy, e.g. IPC, SIB and PIB.
- All homes require an energy label and this information is openly accessible.
- Most municipalities have a Design Review Committee (*Federatie Ruimtelijke Kwaliteit*), showing that aesthetics in the built environment is valued high.
- The Dutch research institutes conducts valuable research on BIPV, making pioneering at an international level possible.

The main lessons for the (Dutch) BIPV sector that can be drawn from the comparative review are summarized in Table 1. Some of these recommendations have an international character. The recommendations are clustered according to the Triple Helix to provide information on the main responsible parties.

Table 1: Lessons and recommendations for the (Dutch) BIPV sector

Responsible parties	Lessons and recommendations
	Government
European and national governments	Governmental regulations and financial incentive schemes need to provide security for the future, and reflect the higher cost of BIPV systems compared to regular PV. Harmonisation of building codes with energy performance requirements and aesthetics is necessary for BIPV to gain ground.
CENELEC and IEC, EU and national governments	General standardization and certification for BIPV needs to be developed, as well as a generally accepted definition. Legislation needs to provide a clear distinction from PV.
	Industry
Manufacturers, suppliers and construction industry	Given the shifting regulatory regimes, business models are required that survive without the need of subsidies or that optimally capture subsidies offered in the current regime.
Suppliers, wholesale, construction industry, architects	BIPV needs to follow requirements and developments in the construction sector. This means among others that prices should be expressed per m^2 and not per Wp, aesthetics and materials comply with current standards and the added value of BIPV is understood.

Manufacturers, construction industry	In manufacturing, further automation of processes and digitalization of information needs to be adopted. This should simplify the integration process.
Existing PV industry associations, BIPV industry	An industry association specifically for BIPV needs to be developed at an international level, bringing together BIPV stakeholders to find complementary products and activities and collectively prepare market approaches.
Manufacturers, suppliers, media	The advantages and possibilities of BIPV and outcomes of projects need to be clearly communicated to the public, the government and the construction industry.
Academia	
Universities; educational institutions	Education specifically for BIPV needs to be provided at all stakeholder levels, e.g. construction, design and technological development.
Research institutes	Internationally coordinated research and development

The information that was provided throughout this research and the conclusions that were drawn should be taken into account by the government, academia and the BIPV industry when further designing the BIPV (export) strategy for the Netherlands. It has become clear that the BIPV sector crosses national boundaries, and should therefore be reviewed and developed from an international perspective.

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LIST OF ABBREVIATIONS

BAPV	Building Applied Photovoltaics
BIPV	Building Integrated Photovoltaics
CENELEC	European Committee for Electrotechnical Standardization
CHF	Swiss Franc
COICOP	Classification of Individual Consumption According to Purpose
Country codes	BE (Belgium), DE (Germany), FR (France), NL (Netherlands), CH (Switzerland), UK (United Kingdom)
C-Si	Crystalline Silicon
DESTEP	Demographic Ecological Socio-cultural Technological Economical Political
DIN	Deutsche Institut für Normung
EC	European Commission
EEG	Erneuerbare Energien Gesetz
EERA	European Energy Research Alliance
EnEV	Energieeinspaarverordnung
EPC	Energy Performance Certificate / Coefficient
EU	European Union
EU PV TP	European Photovoltaic Technology Platform
EU-EPBD	European Union Energy Performance of Buildings Directive
EU-ETS	EU Emission Trading System
EU-RED	European Union Renewable Energy Directive
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse gas
GWp	gigawatt peak
IEA	International Energy Agency
IEA PVPS	International Energy Agency Photovoltaic Power Systems
IEC	International Electrotechnical Commission
IoT	Internet of Things
(k)Wh	(kilo)watt hour
(k)Wp	(kilo)watt peak
MCA	Multicriteria analysis
MWh	megawatt hour
NBSO	Netherlands Business Support Office
NREAP	National Renewable Energy Action Plan
nZEB	net zero energy building
PPP	Purchasing Power Parity
PV	Photovoltaics
RVO	Rijksdienst voor Ondernemend Nederland
SEAC	Solar Energy Application Centre
SET-Plan	Strategic Energy Technology Plan
SIB	Starters International Business
SME	Small and Medium Enterprises
TFSC	Thin film solar cell
UNDP	United Nations Development Programme

INTRODUCTION

Decreasing the amount of emissions caused by fossil fuels is an important method to mitigate climate change, which is considered to be one of the greatest challenges of the current age. Both national and European policies steer towards emission reductions by promoting the use of renewable energy sources. The European Union Renewable Energy Directive (EU-RED) states that 20% of the total European energy consumption needs to be obtained from renewable energy sources by 2020 (European Parliament and Council, 2009). Globally, the building sector contributes to 30% of global greenhouse gas (GHG) emissions and 40% of total energy consumption (UNEP SBCI, 2009). Therefore, mitigation of GHG emissions from the building sector is very important to address in climate strategies. In this light, the European Union Energy Performance of Buildings Directive (EU-EPBD) states that as of 2019 new buildings occupied and owned by public authorities have to be net zero energy buildings (nZEB), and as of 2021 all new buildings have to be nZEB (European Parliament and Council, 2010). A nZEB should be energy-efficient and produce as much energy as it consumes over one year (European Parliament and Council, 2010).

One solution to achieve nZEB is the generation of renewable electricity on-site. Photovoltaics (PV), solar cells that produce electricity, is a technology that is particularly interesting to realize this (Lee et al., 2014). PV can nowadays be integrated into the building envelope, a concept called building integrated photovoltaics (BIPV). BIPV applications offer the possibility to replace regular building envelope components into prefab integrated components that at the same time generate electricity (Ritzen et al., 2014). BIPV applications are flexible in size, shape and appearance and can be combined with materials commonly used in construction, such as glass or metal (Frontini et al., 2015). This contributes to the aesthetic value of a building. This concept is distinctive from regular PV applications, since the PV function is integrated in the building envelope instead of placing the solar panel on the roof (Building Adapted PV, BAPV).

> ***BIPV applications can replace regular building components into prefab integrated components that at the same time generate electricity.***
>
> *(Ritzen et al., 2014)*

BIPV is currently positioned primarily as a niche-product, making up about 1-3% of the total PV market with a total installed capacity worldwide of 1.0 GWp (Ritzen et al., 2014). Berenschot (2015) published a roadmap for BIPV that identifies eleven challenges in the field of technology, market and ecosystem to achieve a 5% BIPV share of total PV capacity in the Netherlands by 2020. This research continues on these outcomes, by reviewing the international situation for BIPV and the role of the Netherlands in this. The aim is to identify ways to address the challenges that exist for BIPV in the Netherlands and to provide information for both the government and the industry to take into account when further designing the BIPV (export) strategy for the Netherlands.

The purpose of this research is therefore twofold, to determine what the Netherlands can learn from the situation for BIPV in other European countries and to assess which countries show interesting opportunities for Dutch BIPV companies. Therefore, the following two research questions are posed:

1. ***What can the Netherlands learn from the situation for BIPV in other countries?***
2. ***Which countries could be interesting markets for Dutch BIPV companies to explore?***

Apart from the Netherlands, the focus countries that are studied in this research are France, Germany, Switzerland and the United Kingdom. For these countries the existing BIPV stakeholders, the BIPV ecosystem and policy and legislation for BIPV are thoroughly reviewed. Additionally, some information is provided for Belgium, since due to geographical reasons this is an interesting country for Dutch entrepreneurs. No conclusions will however be drawn upon this.

This report is organized as follows. Section 1 introduces a theoretical framework that reflects on the state-of-the-art of the BIPV sector and its technological systems. This section also reflects on the definitions that exist for BIPV in the focus countries. Section 2 elaborates on the methodology that is used to gather and analyse data. Section 3 provides a stakeholder and ecosystem analysis on the situation for BIPV in the focus countries. These results are discussed and recommendations are provided in section 4. Finally, Section 5 presents the conclusions of this study by answering the research questions.

1. THEORETICAL FRAMEWORK

1.1 BIPV Definitions

What definitions are used to describe BIPV?

Since BIPV is currently positioned primarily as a niche-product, definitions of what is and what is not included in BIPV differ per country. The term ‘integrated’ can be used in different ways;

- aesthetical integration (does it look good? Does it match the environment?)
- functional integration (is it water- and wind proof? Is it resistant to low and high temperatures? Is it soundproof? Does it include solar heating solutions?)
- integration in the building envelope (does it replace regular building components? Can it be delivered as a prefabricated module?) (Van den Donker & De Jong, 2015).

For each of the focus countries it is determined what definition of BIPV they have adopted in their policies, or what definition is generally accepted in the country.

The Netherlands

“BIPV is part of the building envelope; it has a ‘structural’ building function, e.g. water proofing. Building Integrated PV system means that PV is integrated in the (energetic) building design and thus is a structural part of the construction of a building. It replaces regular building components.” (Agentschap NL, 2011)

“BIPV modules are building elements providing at least one additional functionality to the building envelope beside electricity generation. (Weather proofing, Aesthetical integration, Shadowing/sun protection, Thermal insulation, Noise protection, Safety)” (Folkerts, 2013)

“We consider Building Integrated PhotoVoltaics, or BIPV, in this roadmap process as the aesthetic and functional integration of solar power generation functions into regular building components.

These building components include at least one functionality in the building envelope in addition to electricity generation. Also, the objective is to obtain full integration. Aesthetical integration mostly means that the PV-function cannot be traced from the elevation of the building, or it becomes a component that particularly serves the aesthetic character.” (Berenschot, 2015)

France

“A photovoltaic system meets the criteria of integration into the building if and only if it meets all the following conditions:

1.1 The photovoltaic system is installed on the roof of a closed and covered building (on all the sides), ensuring the protection of persons, animals, property or activities. …
1.2 The photovoltaic system replaces building elements that have a closing and covering function, and ensure the waterproofing function. After installation, the dismantling of the photovoltaic module of film cannot be made without affecting the waterproofing function provided by the photovoltaic system or making the building unsuitable for use.
1.3 For photovoltaic systems consisting of rigid modules, the modules are the systems main waterproofing elements.
1.4 For photovoltaic systems consisting of flexible films, the assembly is carried out in the factory or on site. The assembly on site is carried out under a single work contract.” (Gouvernement Français, 2015)

Germany

"In new buildings photovoltaic modules can also take over the function of the roof, in addition to electricity production they then also offer the function of weather protection for the house, this is referred to as building integrated photovoltaics. … Photovoltaic modules can also be used as façade components or as canopies." (Weyres-Borchert, 2015)

"BIPV is a multifunctional building component: Electricity generation, Shading systems, Weather protection, Noise protection, Heat insulation and Sunlight modification." (Ferrara, Kuhn, Wilson, & Schindler, 2012)

"GTM Research characterizes BIPV as building integrated photovoltaics, which requires the cooperation of stakeholders along the value chain. Architects, engineers, owners and electricity suppliers have to cooperate accordingly in order to design and implement the integrated photovoltaics from the beginning as a part of the building envelope." (SolarServer, 2010)

Switzerland

"The acronym BIPV refers to systems and concepts in which the building element has an additional function, namely producing electricity. … At the building scale two main types of integration can be identified.

A *functional integration* refers to the role of the PV modules in the building. For this reason we can speak about multi-functionality or double function criteria. Photovoltaic modules are considered to be building integrated, if they represent a component of the building envelope providing a function as defined in the European Construction Product Regulation CPR 305/2011. Thus the building performance of the BIPV module is required for the integrity of the building's functionality.

The *aesthetical integration,* on the other hand, refers to the architectural concept, its appearance, these are harder to define in a unique way. The aesthetical integration has to be understood as capability of the PV solution to define the linguistic/morphological rules governing the signs, the structure and the composition of the building's architectural language. In contemporary architecture the appearance is one of the first factors of recognisability. In order for "Solar Architecture" to be successful it has to comply with the architectural standards of today." (Frontini et al., 2015)

"PV systems are considered 'integrated' if they are integrated into the building and serve, in addition to electricity production, as protection against bad weather, thermal protection or protection against rainfall … The criteria for 'building integration' and the double function (protection against bad weather, thermal protection or protection against rainfall) must both be met (cumulatively), before an installation is considered integrated. Double function means the following: if the integrated PV module is disassembled, the original function of the structure is no longer in place and replacement becomes unavoidable." (Schweizerische Bundesamt für Energie BFE, 2014)

United Kingdom

"Building Integrated PV (BIPV) refers to photovoltaic systems that generate electricity and function as part of the building. Products such as windows, walls, façades and roofs can be designed as BIPV (e.g. solar shingles/tiles) and architects can use these products to provide both function and style." (Department of Energy & Climate Change, 2013b)

"As the name suggests, the solar photovoltaic panel is integrated into the building fabric rather than a 'tack-on' addition. The PV panel replaces conventional building cladding materials with a multifunctional building material. Delivering the functional weatherproofing of glass but with the added benefit of renewable electricity." (Polysolar, 2015)

Belgium

"We speak of BIPV when solar panels are integrated in conventional building components or materials. BIPV can be found e.g. in the form of tiles, blinds or cladding. Those building components then have an extra functionality: they generate energy." (Bruynseraede, 2013)

"BIPV … products achieve a double function. They produce electricity and are used to replace conventional building materials in parts of the building envelope." (Issol, 2015)

"Building Integrated Photovoltaics: photovoltaic panel that is an alternative building component that can be used instead of and with the same structural function as a traditional building component. PV systems that are integrated into street furniture or transport infrastructure (shelters, roofs for platforms or car parks, covering of sports field) are also considered to be BIPV. " (Vlaamse Regering, n.d.)

From the above definitions it is clear that there is no consensus about which requirements a system should at least meet to be regarded as BIPV. Not every country includes the contribution to the aesthetics of the building in its definition, neither the requirement to be weather proofing. In this report BIPV is referred to as a system that includes at least one functionality in the building envelope in addition to electricity generation. This definition still leaves room for interpretation, which makes it possible to evaluate the situation for BIPV in all focus countries without further limitations.

In this report, BIPV is referred to as a system that includes at least one functionality in the building envelope in addition to electricity generation.

1.2 State-of-the-art of BIPV

What are the latest developments in the field of BIPV?

1.2.1 Market share and expectations for growth

At the end of 2014, the cumulative installed PV capacity worldwide was 183 GWp (Fraunhofer Institute for Solar Energy Systems ISE, 2015). BIPV is currently positioned primarily as a niche-product, making up about 1-3% of the total PV market (Ritzen et al., 2014). Both the PV and BIPV industry are expected to grow in the upcoming years. A roadmap study by Berenschot (2015) shows that in 2020 the global PV capacity is expected to exceed 800 GWp.

The BIPV industry is expected to reach 11.1 GWp by 2020.

(Global Industry Analysts Inc., 2015)

The BIPV industry is expected to reach 11.1 GWp by 2020, with Europe being the largest market (Global Industry Analysts Inc., 2015). These numbers indicate that both markets are subject to uniform growth.

1.2.2 PV technology

The growth of the BIPV market is to a large extent based on the progress that has been made in PV technology over the last decades, which has led to better performance and lower costs (Frontini et al., 2015). PV technology is still under development.

In evaluating the performance of PV elements, the following parameters are considered to be important (Twidell & Weir, 2015).

- *Power conversion efficiency* (η_c) is defined as the ratio between the peak power generated by the solar cell (power output, P_{max}) and the amount of solar radiation received (power input), $\eta_c = \frac{P_{max}}{E \times A_c}$, where η_c is the power conversion efficiency of the solar cell [%], P_{max} is the installed maximum power [Watt-peak, W_p], E is the solar irradiance [W/m^2] and A_c is the surface area of the solar cell [m^2]. Maximum power is defined at so-called Standard Test Conditions (STC): E = 1000 W/m^2, air-mass ratio is AM1.5 and temperature of the solar cell is T = 25˚C (Cerón, Caamaño-Martín, & Neila, 2013).
- *Open-circuit voltage* (V_{oc}) is the output voltage of a solar cell at STC when the circuit is not closed (Tripathy & Sadhu, 2015).
- *Short-circuit current* (I_{sc}) is the current through the solar cell when the voltage across the solar cell is zero.
- *Maximum or peak power* is given by $P_{max} = (V \times I)_{max}$.
- *Fill factor (FF)* is defined as the ratio between the maximum power and the product of the open-circuit voltage and the short-circuit current, $FF = \frac{P_{max}}{(V_{oc} \times I_{sc})} = \frac{(V \times I)_{max}}{(V_{oc} \times I_{sc})}$. A high fill factor means low internal losses.
- *Band gap*, E_g, is the energy gap between the conduction and valence band of the semiconductor material of which the solar cell is made.

Usually, a distinction is made between two types of PV technology (Cerón et al., 2013; Jelle, Breivik, & Drolsum Røkenes, 2012), see also Figure 1-1.

1) Crystalline Silicon (c-Si): PV elements of this kind consist of interconnected Si-wafers. The main advantages are a relatively high efficiency and a high reliability. Specific efficiencies are dependent upon the composition of the cells in the module. Mono-crystalline silicon cells (mono-Si) have a high purity and therefore a relatively high efficiency of typically 14-19%. The efficiency of poly-crystalline silicon (poly-Si) is typically 12-15%, due to lower silicon purity since a range of Si-materials is mixed (Twidell & Weir, 2015).
2) Thin-film (TFSC): These PV elements make up about 5% of the installed PV capacity (Fraunhofer Institute for Solar Energy Systems ISE, 2015). They consist of thin layers of semiconductor material (not necessarily

silicon), providing a thin PV element that can be either rigid or flexible. The main advantages are a lower thickness, lightweight and a high flexibility (offering various integration possibilities with deposit materials). TFSC modules have efficiencies of 10-20%, depending on the specific cell technology. Different types of TFSC are Amorphous silicon (a-Si), Cadmium telluride (CdTe) and Copper indium gallium selenide (CIS/CIGS).

It needs to be mentioned that a higher degree of integration of PV within the building envelope generally decreases the efficiency of the system. This can be the result of various causes, such as a complex geometry, higher temperatures, loss of solar gain area, the use of TFSC instead of c-Si or the requirement of transparency reducing the module density (Cerón et al., 2013). For both technologies the efficiency will therefore likely be lower in practice and when used as BIPV.

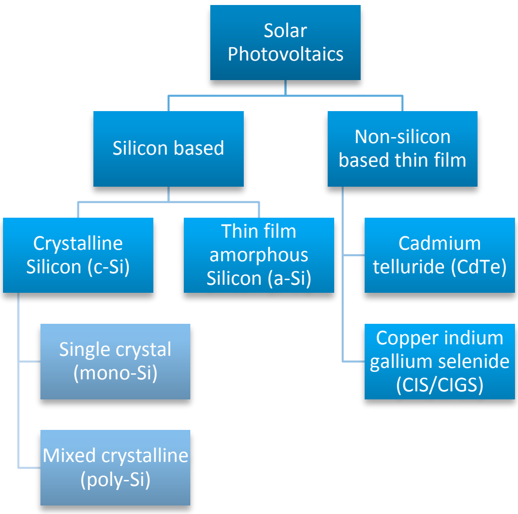

Figure 1-1: Classification of PV technologies. Based on (Jelle et al., 2012)**.**

1.2.3 *BIPV Pricing*

The learning curve for both PV technologies is shown in Figure 1-2. Each time the cumulative production doubled, the price went down by about 20% and even faster in the last few years. This results in the learning rates displayed in the figure.

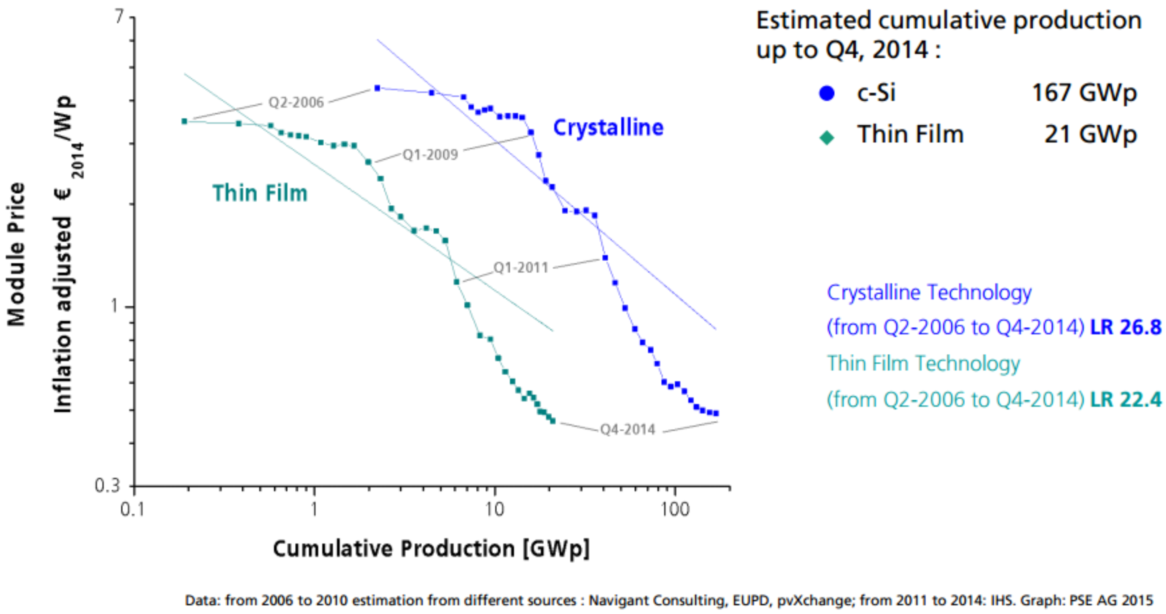

Figure 1-2: Price learning curve by PV technology for estimated cumulative production up to the fourth quarter of 2014 (Fraunhofer Institute for Solar Energy Systems ISE, 2015)**.**

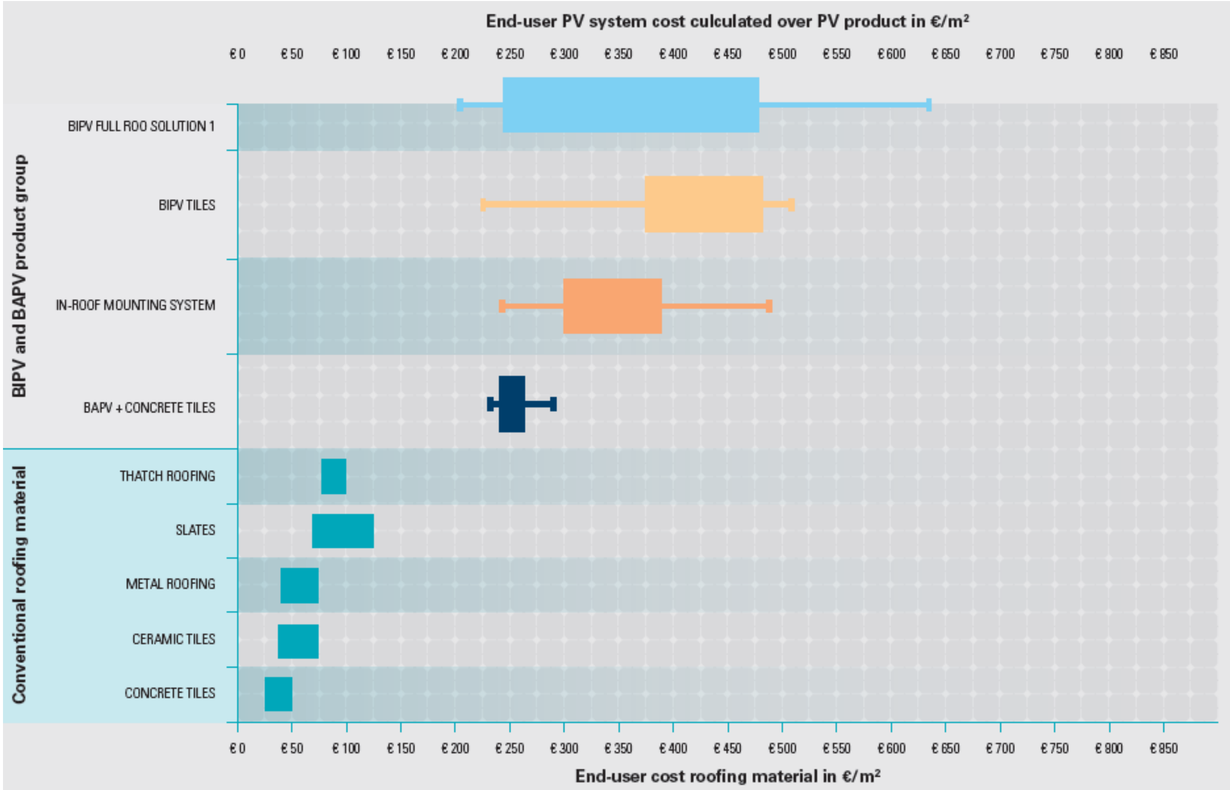

Figure 1-3: Cost comparison of conventional roofing materials with BAPV and BIPV roofing solutions. The price is defined as the end-user price in €/m^2. Adapted by Berenschot from (Frontini et al., 2015)**.**

Since PV technology is still under development, the prices are expected to decrease further in the future. For BIPV specifically, prices are expected to drop once production can take place at a larger scale (Berenschot, 2015). The BIPV prices relative to BAPV and regular building components are displayed in Figure 1-3 (Frontini et al., 2015). The various BIPV solutions are discussed in the next paragraph.

BIPV prices are expected to drop once production can take place at larger scale

(Berenschot, 2015)

1.2.4 BIPV implementation

Architectural aspects

In the design of BIPV structures site conditions play an important role. External parameters such as wind speed, rainfall and temperature influence the choice of material. In moist environments it is essential to use galvanized materials to prevent corrosion and allow for a longer lifetime. In windy areas, the potential uplifting force of the wind should be taken into account when mounting the BIPV into the building to prevent the structure from being blown away. Also the choice of material determines the strength and durability of the structure, as well as the weight (Tripathy & Sadhu, 2015). This can be an important factor for flat roofs that can only bear small extra weight (BIPV SME Workshops, 2015).

BIPV systems provide opportunities for aesthetical architectural design.

Apart from considering these practical issues, BIPV systems provide opportunities for aesthetical architectural design. By using BIPV tiles, a roof can look similar to a standard tiled roof. However, by using semi-transparent modules one can create an opaque façade or glass ceiling. Other options for BIPV are to use it as a shading device, or to create visual effects in the building (Tripathy & Sadhu, 2015).

BIPV applications

Basically any building component can be replaced by BIPV (Berenschot, 2015). The most preferred place is usually the rooftop due to less shadowing and therefore generally more solar radiation. However, more often the façade surface of a building is an important place to integrate PV (Tripathy & Sadhu, 2015). Therefore, this research focus is divided over three common building elements, i.e. pitched/sloped roofs, flat & curved roofs and façades (Frontini et al., 2015). The BIPV applications that are generally used are BIPV foil or thin film, BIPV tiles, BIPV modules and solar glazing (Jelle et al., 2012). Various classifications exist. Figure 1-4, 1-5 and 1-6 provide an overview of which BIPV applications are used for which building elements, as classified in this research.

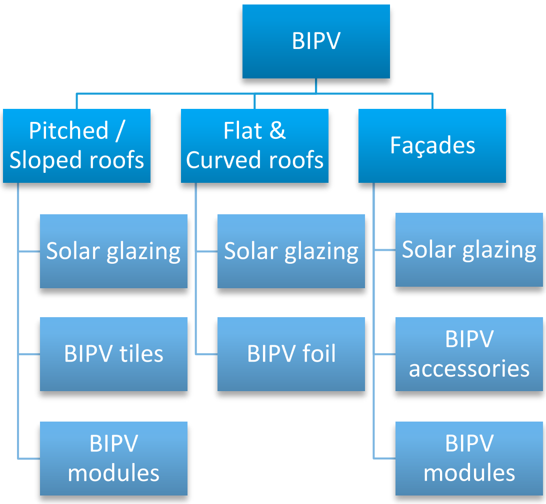

Figure 1-4: Classification of BIPV types and applications used in this research (Frontini et al., 2015; Jelle et al., 2012)**.**

Pitched/sloped roofs	Flat & curved roofs
▪ Found world-wide and can generally bear quite some extra weight (BIPV SME Workshops, 2015). ▪ Usually face only little shadowing, and are therefore a favourable place for solar power generation (Tripathy & Sadhu, 2015). South-facing pitched roofs are generally the most preferred option for (BI)PV systems in the Northern hemisphere, since they have a good angle with the sun (Jelle et al., 2012). ▪ Common BIPV applications are tiles, modules and sometimes solar glazing.	▪ Usually have little shadowing. ▪ Easily accessible which makes installation and maintenance easier. The BIPV elements can be flexibly oriented towards the sun (Tripathy & Sadhu, 2015). ▪ Many flat roofs cannot bear large extra weight, for example those made out of bitumen. Regular PV modules therefore are often not an option and BIPV needs to provide lightweight solutions (BIPV SME Workshops, 2015).

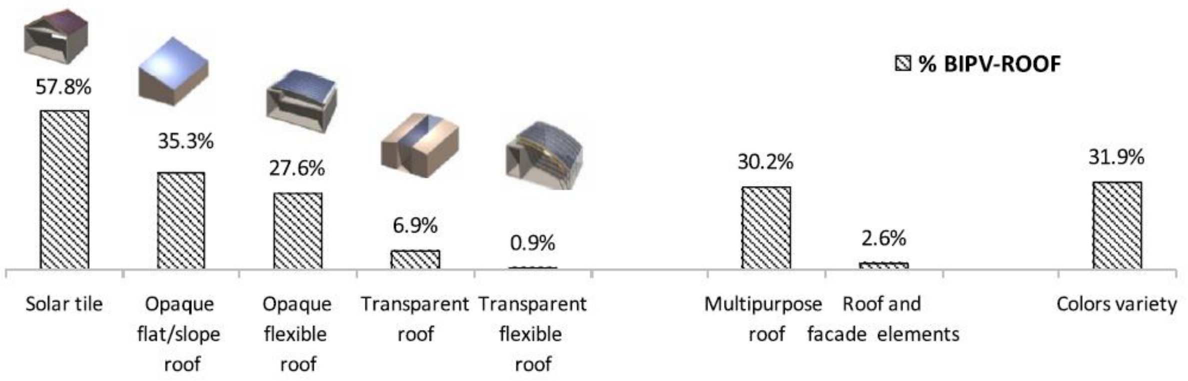

Figure 1-5: Overview of the (sub)division of different BIPV elements used on BIPV-roofs (Cerón et al., 2013)**.**

Façades

- Require thermal and noise insulation, load bearing and weather proofing (Frontini et al., 2015).
- Often large in size, small in thickness and have a high degree of transparency (Cerón et al., 2013).

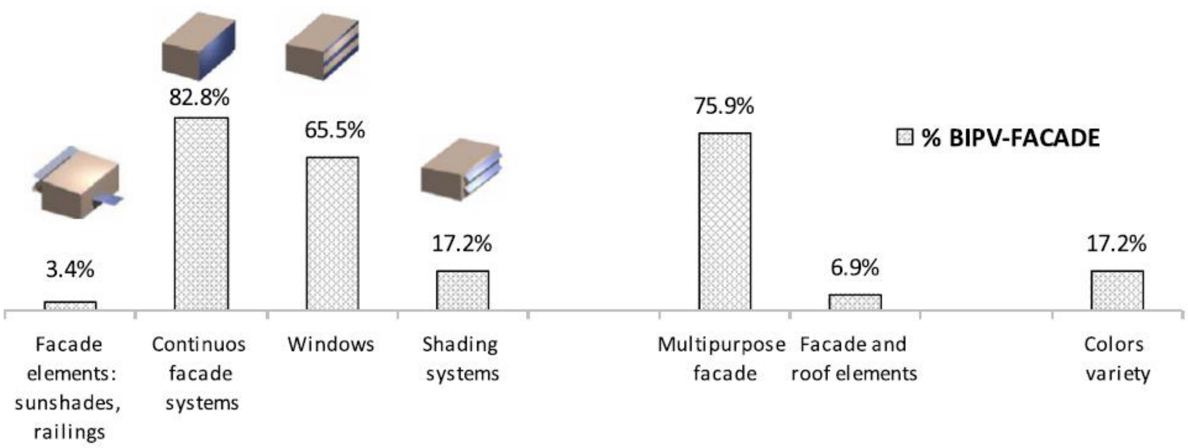

Figure 1-6: Overview of the (sub)division of various BIPV elements used in BIPV-façades (Cerón et al., 2013)**.**

BIPV tiles

As can be seen in Figure 1-5, BIPV tiles make up 57.8% of the BIPV roofing systems. The BIPV tiles are mostly designed to resemble conventional roof tiles and are therefore preferred to be homogenous dark in colour. They can be either flat or curved (Figure 1-7), with the latter one being generally more aesthetically pleasing but less efficient in catching solar radiation (Jelle et al., 2012). Commonly only part of the roof is covered by BIPV tiles, or the BIPV tiles blend with the conventional roof tiles (Frontini et al., 2015). The mono-Si technology is mostly used for these types of solar cells, providing relatively high efficiencies (Cerón et al., 2013).

Figure 1-7: Examples of flat BIPV tiles (Applied Solar) and curved BIPV tiles (SRS Energy) (Jelle et al., 2012)**.**

BIPV modules

BIPV modules are somewhat similar to conventional PV modules, sometimes leading to uncertainty whether they are BIPV or BAPV. The major difference is that BIPV modules are weatherproofing and installed using in-roof mounting systems, which increase the ease of installation (Jelle et al., 2012). Furthermore, the BIPV modules replace the conventional roofing material. They are mostly used in sloped roofs, covering only part of the roof (Frontini et al., 2015).

Figure 1-8: Example of BIPV modules in a sloped roof (RENUSOL INTERSOLE) (Frontini et al., 2015)**.**

BIPV foil

For BIPV foil or BIPV membranes, the TFSC technology is often used. Major advantages of BIPV foil are its flexibility and light weight (Jelle et al., 2012), which is why they are ideal for flat and curved roofs and façade accessories. Because the foil in itself is most of the times not weatherproofing, it is often attached to a building element or directly applied onto the complete roof (Frontini et al., 2015).

Figure 1-9: Examples of BIPV foil product (Alwitra GmbH & Co. (Jelle et al., 2012)**) and embedded in a flat roof (WEKA DAKSYSTEMEN** (Frontini et al., 2015)**).**

Solar glazing

As presented in Figure 1-4, solar glazing is used in all building elements. Figure 1-5 and Figure 1-6 also show that transparency is an important factor when it comes to BIPV in both roofs and façades. The level of transparency is determined by the distance between the cells (usually 3-50 mm). Since next to transparency also the colour of the glazing is flexible, solar glazing provides many opportunities for aesthetically pleasing design (Jelle et al., 2012). Both c-Si and TFSC technology can be used to create (semi)-transparent BIPV elements. When used in façades, load bearing and insulation requirements have to be taken into account (Frontini et al., 2015).

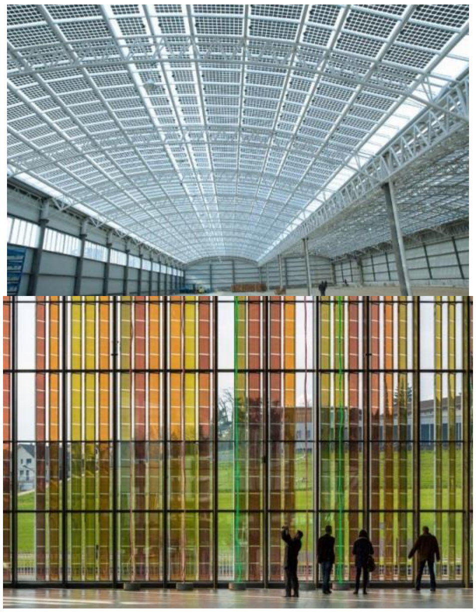

Figure 1-10: Examples of solar glazing (Weiku, 2011) and Swiss Tech Convention Centre.

BIPV accessories

This section includes all abovementioned BIPV types. Roofs and façades are often extended with accessories such as balconies, shading systems or decorating objects in which PV can be integrated. Shading systems provide the possibility of controlling the temperature and amount of natural light inside a building, and are therefore a popular accessory (Frontini et al., 2015). Another example is the product of Zigzagsolar, providing a BIPV add-on for façades which optimizes the amount of solar irradiance that can be caught, see Figure 1-11.

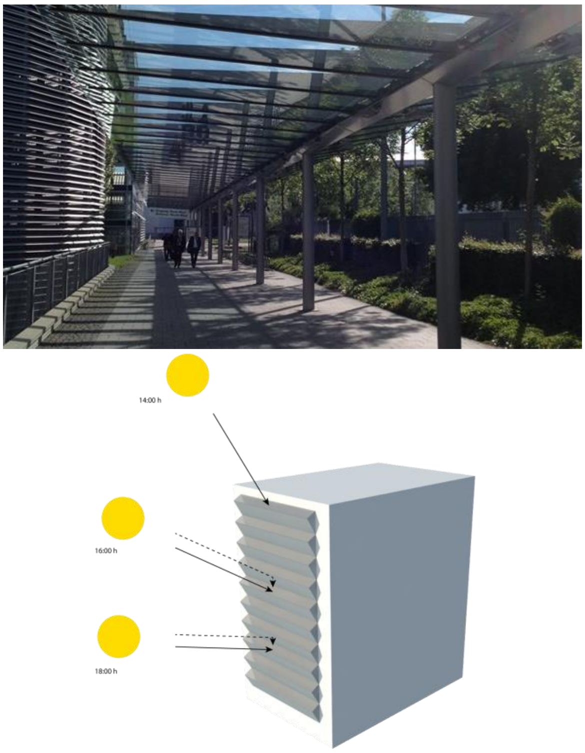

Figure 1-11: Example of BIPV accessory for roofs (shading system by SolarSwing**) and façades** (Zigzagsolar, 2015)**.**

2. METHODOLOGY

2.1 Selection of Focus Countries

In the first phase of this research, countries of interest that could serve as a benchmark for the Netherlands were identified in consultation with Berenschot. This selection was made based on prior knowledge about the specific countries, such as weather conditions, BIPV legislation or a positive attitude towards BIPV:

- Belgium: suppliers of construction industry are well represented; research center IMEC
- Denmark: aesthetics in the building envelope is valued high
- France: premium feed-in tariff is available for BIPV
- Germany: interest in PV is high
- Italy: favorable payback periods
- Spain: favorable payback periods
- Portugal: among the highest solar radiation levels in Europe
- Switzerland: interest in PV is high; Swiss BIPV Competence Centre, SUPSI
- United Kingdom: government highly involved in sustainability / incentives

These countries were briefly researched and evaluated and this list was proposed to two groups of BIPV stakeholders that are working in a consortium with Berenschot. Both groups expressed their ideas and preferences for the countries that should be included in the research (BIPV SME Workshops, 2015). In consensus a selection of five focus countries was made, resulting in the following shortlist. The country icons are used to refer to these countries throughout the report.

- The Netherlands
- France
- Germany
- Switzerland
- United Kingdom

The focus countries served as a benchmark for the Netherlands throughout the research. In addition, little research has been done on the situation in Belgium, since this might be an interesting export country for Dutch entrepreneurs due to its location. Belgium is however not considered as a focus country in this research, and therefore no conclusions will be drawn upon this information.

2.2 Ecosystem information

The establishment of an integrated and complete network is of great importance to provide a basis for future development of the sector. Figure 2-1 shows the steps that will be taken during the study. By using a Stakeholder analysis (2.2.1, Appendix A.I) and the DESTEP-analysis (2.2.2, Appendix A.II) it was assessed per country which parts of the ecosystem are already well established, and which gaps are still present. This information will be analysed in both an external (2.3.1) and internal analysis (2.3.2).

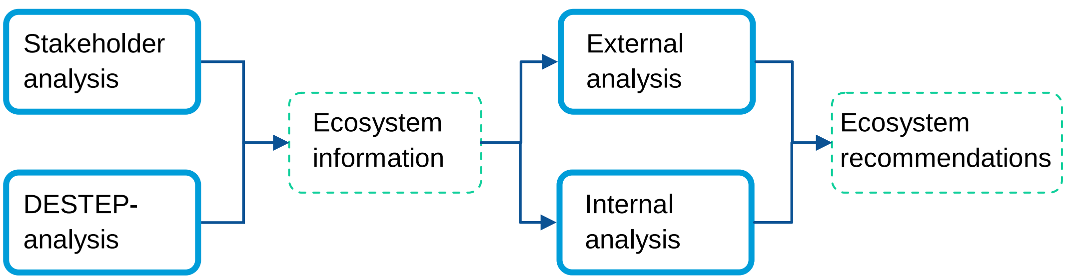

Figure 2-1: Schematic representation of the structure of this research

2.2.1 Stakeholder analysis

The first step in mapping the ecosystem is a Stakeholder analysis. The theory behind this analysis is discussed in *Appendix A.II*. This analysis consists of the following phases (RVO):

1. *Inventory of involved parties*

The inventory was made at the sectoral level. The parties have been identified in consultation with Berenschot according to the Triple Helix model (Government, Industry and Academia) (Leydesdorff & Etzkowitz, 1998). This inventory is presented and discussed in *section 3.1.1.*

2. *Define interest of each stakeholder*

For the stakeholders that were identified in the previous phase, market parties were identified and their interests as well as their perspective on BIPV were defined in *section 3.1.2*. Differences that were found between the focus countries were taken into account. Information was acquired from desk research and by contacting Netherlands Business Support Offices (NBSO) and Dutch Embassies in the focus countries.

3. *Determine relationship(s) between involved parties and their position within the ecosystem*

This step visualises how the stakeholders are related to each other within the BIPV sector. Points of differentiation are displayed in Figure 2-2, where the core represents primary stakeholders, the middle shell are secondary stakeholders and the outer shell tertiary stakeholders.

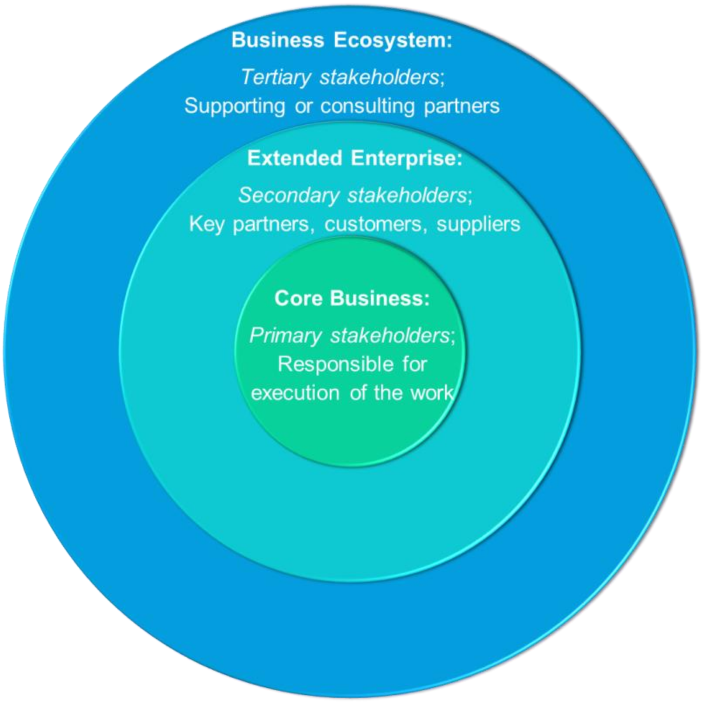

Figure 2-2: Stakeholder map, representing involvement and division of responsibilities

2.2.2 DESTEP-analysis

A DESTEP (demographic, ecological, socio-cultural, technological, economic and political-legal)-analysis gives an idea of the environment the BIPV sector is operating in and what developments, trends and uncertainties it faces. It provides a systematic analysis of the external factors the sector is subjected to (Berenschot, 2012). Further theory behind this analysis is discussed in *Appendix A.II*. By focussing on the six categories, a context was provided to prevent the research from becoming too broad (Peng, 2007). Each category was qualitatively described by means of desk research on all impacts that are applicable to the BIPV sector. Main sources for the desk research were the statistical databases of the focus countries, the Wold Bank and Eurostat, as well as scientific literature and reports from the International Energy Agency (IEA) and the United Nations Development Programme (UNDP). Where necessary, additional information was acquired by contacting NBSOs and Dutch Embassies. This analysis thereby contributes to the identification of all processes and developments that take place within a specific ecosystem.

2.3 Analysis of Results

The purpose of this study was twofold. To assess which countries show interesting opportunities for Dutch BIPV companies and to determine what the Netherlands can learn from the situation for BIPV in other countries. The analysis of the results from the Stakeholder and DEPEST analyses addresses these goals by making a distinction between an external and an internal analysis.

2.3.1 External analysis

The research question that was central to this part of the analysis of results is: Which countries show interesting opportunities for Dutch BIPV companies? Therefore, a comparative review was made between the focus countries. The following steps were undertaken:

1. Based on the outcomes of the Stakeholder and DESTEP analyses, fifteen criteria were identified that can influence the implementation potential of BIPV (section 4.1). For each of the countries it was known from the Stakeholder and DESTEP analyses how they score on each criteria.
2. These criteria were presented to 21 stakeholders that are active in the BIPV industry, mostly manufacturers and suppliers. This was done by a digital survey, distributed per e-mail. The stakeholders were asked to indicate what weight they would give to each of the criteria on a scale of 0 (no weight) to 3 (heavy), when determining market potential for BIPV.
3. From the responses to the survey, a weighting factor could be determined for each of the criteria.

These steps serve as a basis to compare the different countries by means of a Multi Criteria Analysis (MCA). The theory behind this analysis is discussed in *Appendix A.III*. An MCA provides the possibility of making decisions based on qualitative information. For this research, the focus countries were rated on the fifteen weighted criteria, based on the information that was acquired in the Stakeholder and DESTEP analyses. The scoring is not absolute, but relative. This provided information to further explore the research question.

2.3.2 Internal analysis

The research question that was central to this part of the analysis of results is: What can the Netherlands learn from the situation for BIPV in the focus countries? The results from the Stakeholder and DESTEP analyses for the different countries were now compared in a qualitative way. To frame this comparison, the eleven challenges that Berenschot (2015) has identified for the Dutch BIPV sector were used as a basis. The challenges were discussed separately by comparing the applicable information that was found for the focus countries. Based on this, recommendations were made for the Dutch BIPV ecosystem to address each challenge.

3. RESULTS

COUNTRY INFORMATION BIPV ECOSYSTEM

3.1 Stakeholder analysis

Which stakeholders are relevant for BIPV development and what is their role in the focus countries?

3.1.1 Inventory of involved parties

Firstly, a selection is made of all parties that are to a certain extent involved in the BIPV sector. The Triple Helix model (Government, Industry and Academia) (Leydesdorff & Etzkowitz, 1998) is used as a starting point to identify the parties. End users are classified as a separate party, outside the Triple Helix, see Figure 3-1. The parties are selected in consultation with Berenschot and checked with the preference of SMEs that are active in the BIPV consortium of the Netherlands (IPC, 2015).

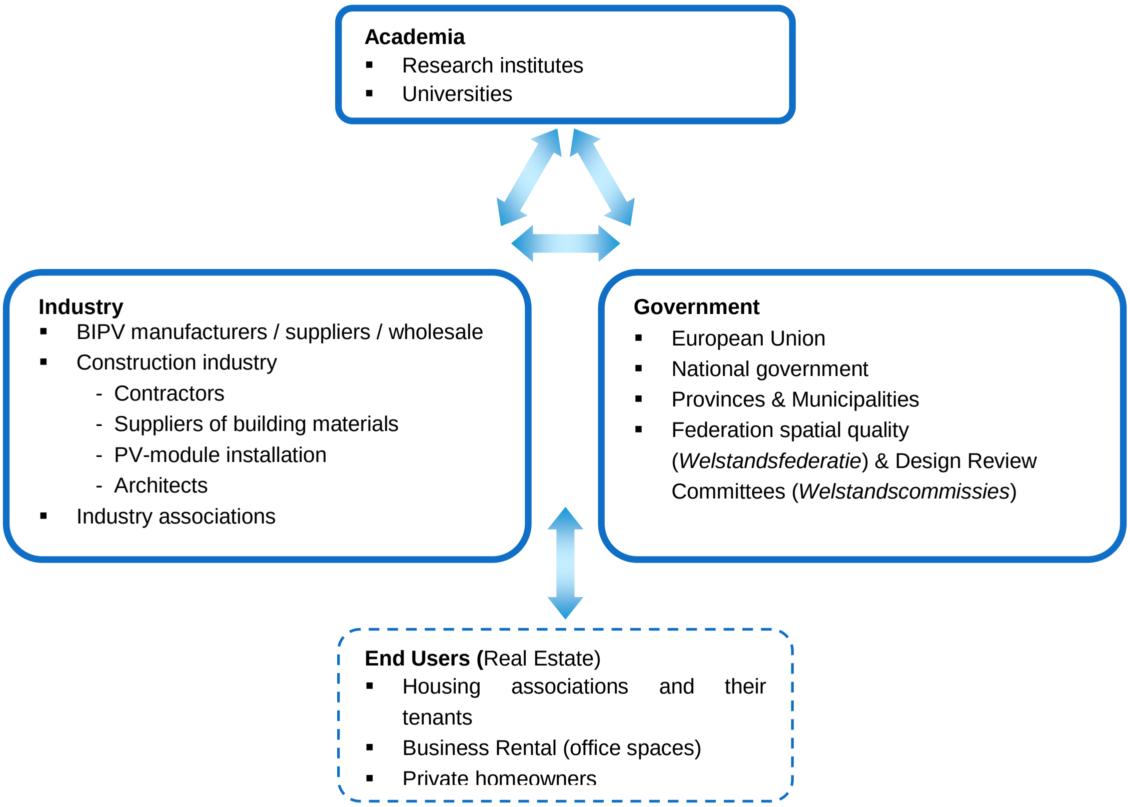

Figure 3-1: Inventory of parties that are involved in the BIPV sector, classified according to the Triple Helix model (Leydesdorff & Etzkowitz, 1998)**.**

3.1.2 *Interests of involved parties*

The second step is to define the interests of each stakeholder, as well as their perspective on BIPV. This is summarized in the table below. As for most stakeholders the situation will be relatively similar in the various countries, a distinction is made between general findings and, if applicable, country-specific findings.

Stakeholder	Interests, Perspective and Challenges	Netherlands	France	Germany	Switzerland	United Kingdom
Academia						
Universities	Universities serve as a supporting party within the BIPV ecosystem. They hold and develop extensive knowledge on technological developments for (BI)PV and sustainable construction by conducting independent research. This can be valuable input for the BIPV industry. Furthermore, they provide education on (BI)PV technology and applications to provide the necessary skills for future (BI)PV professionals. Regarding the relatively small scale on which BIPV is currently implemented, it remains a challenge to give sufficient attention to BIPV within study, education and training programmes (Berenschot, 2015). Utrecht University therefore has started an Erasmus+ project, together with institutions from Austria, Germany and Cyprus, to develop an innovative and multidisciplinary, high quality course for BIPV (Van Sark et al., 2015). This illustrates the growing interest in BIPV in the academic world. No guarantee can be given that this overview of universities that are involved with BIPV is complete.	▪ Avans Hogeschool ▪ Hogeschool Zuyd ▪ Technical Universities of Delft, Eindhoven and Twente ▪ Utrecht University	Universities of: ▪ Bordeaux ▪ Lille ▪ Lorraine ▪ Montpellier ▪ Nantes ▪ Paris-Est Créteil ▪ Savoie ▪ Strasbourg (SOLER, 2014)	▪ University of Stuttgart ▪ University of Technology Darmstadt	▪ SUPSI (University of Applied Sciences and Arts of Southern Switzerland)	▪ University of Bath ▪ University of Bristol ▪ University of Derby ▪ Loughborough University ▪ University of Southampton
Research Institutes	Research institutes have a position similar to universities. They conduct independent research projects that are often commissioned by external parties, e.g. government or industry. Therefore they are very important for the creation and maintenance of a strong (national) knowledge base. Subsidy schemes are an important driving force behind the research. This provides a challenge to continuously secure funding to support	▪ Solar Energy Application Centre (SEAC) ▪ TNO ▪ ECN ▪ Solliance	▪ INES (French National Solar Institute) ▪ IRDEP (Research and development institute for	▪ Fraunhofer ISE ▪ Batelle Institute	▪ ISAAC (Institute for Applied Sustainability to the Built Environment) ▪ Swiss BIPV	▪ SISER (Scottish Institute for Solar Energy Research) ▪ Sustainable Product

Stakeholder	Interests, Perspective and Challenges	Netherlands	France	Germany	Switzerland	United Kingdom
	parties in their research activities. No guarantee can be given that this overview of research institutes that are involved with BIPV is complete, the most important and most cited institutes are included.		photovoltaic energy)		Competence Centre	Engineering Centre for Innovative Functional Industrial Coatings (SPECIFIC)
Industry						
Manu-facturers & Suppliers	The amount of BIPV manufacturers is growing. This mostly concerns existing companies that are originally either solar panel manufacturers or manufacturers of building parts (e.g. roofs and façades). The BIPV suppliers work closely together with the manufacturers or sometimes comprise even the same entity. Currently, suppliers are mostly SMEs that provide a full solar roofing or solar façade solution. This overview of BIPV manufacturers and suppliers is far from complete (Frontini et al., 2015). Since BIPV is a fast developing field, the number of parties involved is changing rapidly as well. .	▪ AERspire ▪ BEAUsolar ▪ Centrosolar ▪ EXASUN ▪ Linesolar ▪ Orange Solar ▪ Stafier Solar Systems ▪ Scheuten ▪ SCX solar ▪ SolarSwing ▪ Solinso ▪ Synroof ▪ Tulipps ▪ Unidek ▪ Zep BV. ▪ ZigZagSolar ▪ Zonnepanelen-Parkstad	▪ Bosch Solar Energy ▪ Fonroche ▪ Francewatts ▪ Imerys ▪ Mecosun ▪ Systovi ▪ SUNIntegration SAS ▪ Sunpower ▪ Voltec Solar (SOLER, 2014)	▪ Abakus Solar ▪ Asola Technologies ▪ FATH Solar ▪ Galaxy Energy ▪ NaturHaus Solar ▪ Schletter Solarmontagesysteme ▪ SolteQ Group ▪ Solarwatt ▪ SolarWorld ▪ Soltech ▪ SUNOVATION ▪ Sunways	▪ Büro Dach & Wand ▪ ClickCon & Co ▪ Colt International ▪ Electro-sol ▪ Fornace Fonti ▪ Helvetic Energy ▪ Jansen/Schüco ▪ Megasol Energie ▪ Meyer Burger ▪ Panotron ▪ Rheinzink ▪ Société d'Energie Solaire SES ▪ Solstis ▪ SOLTERRA ▪ Star Unity ▪ SUNAGE ▪ Tritec	▪ Oxford Photovoltaics ▪ PolySolar ▪ Romag ▪ Solarcentury ▪ Suntech

Stakeholder	Interests, Perspective and Challenges	Netherlands	France	Germany	Switzerland	United Kingdom
Wholesale	For regular PV components the wholesale market is already well established. For example in the Netherlands, the turnover of PV-wholesalers has already increased with 87% in the first three quarters of 2015 (Solar Magazine, 2015). For BIPV components large-scale production is yet limited, since it is currently often designed per specific purpose (Ritzen et al., 2014). This implies that the share of BIPV in total PV wholesale is yet relatively small. To increase the awareness of BIPV it is important that the product is easily accessible, BIPV should therefore become standard stock in PV wholesale. The wholesalers presented in the columns on the right trade mostly in regular PV system components. This overview of BIPV wholesalers is far from complete. Since BIPV is a fast developing field, the number of parties involved is changing rapidly as well.	▪ 4BestSolar ▪ IBC Solar ▪ IkBenRa ▪ Klimaatgarant Solar ▪ Mijn Energie-fabriek ▪ Novasole ▪ ProfiNRG ▪ Sirius Solar Solutions ▪ Zonel Energy Systems	▪ Activ Eco ▪ ALMA Solar ▪ Atacama Solar ▪ Capenergie ▪ EOLANE Solar ▪ KDI Solar ▪ Krannich Solar ▪ Portail-Solaire ▪ PVG (Photovoltaïque Grossiste) ▪ Solaris Store ▪ Solar Trade ▪ SolarWorld ▪ Tritec	▪ AEET Energy ▪ Antaris Solar ▪ BayWa r.e. Solarsysteme ▪ Conergy Deutschland ▪ Energetik Solartechno-logie Vertriebs ▪ IBC Solar ▪ Krannich Solar ▪ Schmitt und Zerreissen ▪ SEN Solare Energie-systeme Nord	▪ bbsolar ▪ EME Solar ▪ ILB Helios AG ▪ IWS Solar ▪ PVMarkt ▪ RAH Kraft ▪ Solar Swiss ▪ Sumatrix ▪ Tritec	▪ Baywa R.E. Solar Systems ▪ Buy PV Direct ▪ Krannich Solar ▪ Metgen ▪ Midsummer Solar PV ▪ Segen ▪ Solar NI ▪ Solarvis Energy ▪ Rexel Energy Solutions ▪ Zenex Solar
Building energy consultant	In utility building projects, consultants provide advice on criteria such as energy regulation and performance, noise isolation, material saving procedures et cetera. More and more buildings have to comply with BREEAM, LEED, other certification procedures and requirements (Van Horrik, 2015). This stakeholder can recommend the use of BIPV in the building. It is therefore important that building consultants are familiar with the opportunities of BIPV in (utility) buildings and collaborate with architects.	Dutch Green Building Council (DGBC)	France Green Building Council (France GBC)	German Sustainable Building Council (DGNB)	Swiss Sustainable Building Council (SGNI)	UK Green Building Council (UKGBC)
Architects	An architect designs a building or building component in consultation with the client and a contractor. In this phase decisions are made on the energy neutrality goals of a building and the application of solar energy. It is therefore very important that these parties are familiar with the concept of BIPV and promote its implementation (Berenschot,	Architects do not have a decisive role in the Netherlands. Apart from the general design they mainly provide recommendations and ideas, but the final decision is made by the client or the contractor (Van Horrik, 2015). In France, planning applications larger than 170m^2 are required to be produced by an architect (Harris, 2014). Also , projects are experienced to be more cost and resource efficient, as well as of				

Stakeholder	Interests, Perspective and Challenges	Netherlands / France / Germany / Switzerland / United Kingdom
	2015). Costs of (BI)PV are often expressed as €/Wp. For architects this is not an interesting figure, especially not when the component has a building function. Therefore, expressing costs as €/m^2 has to become the standard for BIPV (BIPV SME Workshops, 2015; Ferrara et al., 2012). The role of an architect varies in different countries. Differences can be found in liability, obligation to be registered, scope of responsibilities and the role of other parties in the field, such as contractors (Royal Institute of British Architects, 2008).	higher quality (French Property, 2011). German architects have far reaching liabilities when compared to other countries. The architect is responsible for the project until the building is completed. This includes artistic as well as technological aspects of the building, in compliance with building laws and regulations (Hackel, 2007). In Switzerland, the situation is different for small buildings, such as single family houses, and large buildings, such as office or public buildings (Frontini, 2016). In the first case, the architect plays a strategic role and is, together with the client, the main driver behind renewable energy technologies. Therefore it is important that the architect is aware of BIPV. The second case however is more complex. The architect is responsible for the project, but can also leave this responsibility to the general contractor. Therefore, the architect is very important in the preliminary design phase, but choosing the right contractor that is involved with BIPV is essential for the rest of the project (Frontini, 2016). Overall, the main driver behind BIPV implementation in Switzerland seems to be the energy policy in the form of the building code. Frontini (2016) identifies this as the main stimulation for BIPV to increase its market. In the United Kingdom, the education programme for architects is intense. To be able to work in the UK, architects require a registration at the Royal Institute for British Architects (RIBA), for which strict requirements are in force. More in-depth information about the specific role of architects in the UK could not be found within the time-span of this research.
Contractors	The contractor usually coordinates a project after the design phase and is responsible for realisation of the building. It is therefore important that the contractor is familiar with the BIPV industry, regarding collaboration with sub-contractors and suppliers of building material (Berenschot, 2015). The main bottleneck is often the availability of sufficient financing to establish the design of an architect. In most cases, when the client and/or contractor are not familiar with the advantages of BIPV, this will be one of the first components that is replaced by a cheaper alternative (Van Horrik, 2015). This emphasizes the need of awareness creation.	The main differences between the countries, other than those mentioned in the Architects section, can be found in building techniques. In the Netherlands, bricks are commonly used and prefab is becoming more and more common. For Belgium prefab components are not common to be used at all, construction is more considered as craftsmanship. In Germany, wood is a commonly used building material. The importance of aesthetical details is viewed different as well. In the United Kingdom water pipes often are visible in the bathroom, whereas this would not be acceptable in the Netherlands (BIPV SME Workshops, 2015).

Stakeholder	Interests, Perspective and Challenges	Netherlands	France	Germany	Switzerland	United Kingdom
	For the contractors it is also important that BIPV costs are expressed as €/m² instead of €/Wp.					
Suppliers of building material	The proximity of suppliers of building materials is important for a value chain, in order to function as efficient as possible. These suppliers are mostly contacted through (sub-) contractors. This however holds for any type of value chain, not specifically for BIPV. What is important in the BIPV market, is that the standard building materials can be integrated with the BIPV components, both practically and aesthetically. This can for example also concern the sustainability of the building materials. Acquiring aesthetical and sustainable materials at a suitable price level can be a challenge.					
PV-module installation	The installation of BIPV-modules in a building requires electricians who have expert knowledge in PV-connections as well as in construction. Compared to regular PV, the installation costs for BIPV increase because a larger number of usually smaller components needs to be installed at a relatively larger area. This requires more interconnections and electrical wiring (James, Goodrich, Woodhouse, Margolis, & Ong, 2011). Furthermore, the roof is not only required to produce electricity, but also to be weatherproofing. On the other hand, the efforts for covering a traditional roof are diminished. It depends on the BIPV supplier whether they are limited to delivery of the BIPV modules or also include the installation.					
Industry associations	Organizations that cover specific branches exist in most countries, but mostly cover the entire solar industry, or at least multiple niches. The European industry association for PV and BIPV is Solar Power Europe, led by the industry, and the European Photovoltaic Technology Platform (EU PV TP), led by the industry and academic and research institutes.	▪ Duurzame Energie Koepel ▪ Ned.Vereniging Duurzame Energie ▪ Holland Solar ▪ Uneto- Vni	▪ ENF Solar ▪ France Solar Industry ▪ SES (Syndicat des Energies Renouvelables)	▪ BSW Solar ▪ Bundesverband Erneuerbare Energien ▪ Bundesverband Bausysteme	▪ Swissolar	▪ BPVA (British Photovoltaic Association) ▪ Solar Trade Association
Government						
European Union; Government; Provinces & Municipalities	The role of the government, including their influence on all other parties in the ecosystem, will be thoroughly discussed in section *3.2.6 Political-legal factors*. Therefore no introduction to the different governmental levels is given here, except that their role will be mainly supportive and to serve as an example.					
Federation spatial quality	The federation of spatial quality has the goal to promote and improve the quality of the built environment. This quality can be expressed in terms of safety, health and attractiveness of the surroundings. In most countries this concept is merely incorporated in the building code and not further addressed by a specific body. This is reflected upon in	Federatie Ruimtelijke Kwaliteit	n.a.	Landesdenkmal-schutzämter	Some regulations available on the municipal level	n.a.

Stakeholder	Interests, Perspective and Challenges	Netherlands	France	Germany	Switzerland	United Kingdom
	section *3.2.6 Political-legal factors*, under Building requirements.					
End users						
Housing associations + tenants	Housing associations can decide themselves to implement BIPV in their buildings, but can also be influenced by the wishes of their tenants or the municipality. Housing associations are responsible for energy supply being sustainable and affordable, which can be realized by investments in the real estate to decentralize electricity production (Van Haeften, 2015). Furthermore, housing associations have a social role since other buildings within the residential environment can be influenced by their decisions. In the Netherlands, both private rental and rental organized by housing associations is abundant. Housing associations in the Netherlands can almost be seen as a governmental body with specific rights and duties (Van Horrik, 2015). In other countries, the rental sector is not regulated that much. Housing associations are not as abundant, and rental is mostly organized by private investors (Van Horrik, 2015). These are less influential in (BI)PV implementation.					
Business rental (office spaces)	Buildings that are rented for business purposes can be important initiators of BIPV projects. The building can have various purposes, e.g. office spaces for both private companies and the government, parking area, shopping area or a venue for events. The building can also be an indication of how much attention a business has for green activities. BIPV can therefore contribute to the message a business wants to convey (Elkington, 1994).					
Private homeowners	Various reasons exist for private individuals to invest in renewable energy projects (Kollmuss & Agyeman, 2002). Homeowners can for example be interested in the technology, want to produce electricity themselves, have the wish to become self-sufficient, want to demonstrate a green or dedicated image to their environment et cetera. Through these visible investments, they can influence their direct environment. The amount of private homeowners that implements (BI)PV in their home is growing in the Netherlands (Jongsma, 2014).					

3.1.3 *Relationships between involved parties and their position within the ecosystem*

The third step is to determine the relationships between the involved parties by visualizing their position within the ecosystem. The primary stakeholders are the ones who initiate the main activities and are responsible for execution of the work. They are displayed in the centre of Figure 3-2. The second shell represents the secondary stakeholders, who are the key partners without whom operations would not be possible, e.g. direct suppliers or customers. The tertiary stakeholders have a mainly supporting role and are positioned in the outer shell. Some stakeholders show overlap between the shells, e.g. contractors are a customer in the first place but also highly influence the product output.

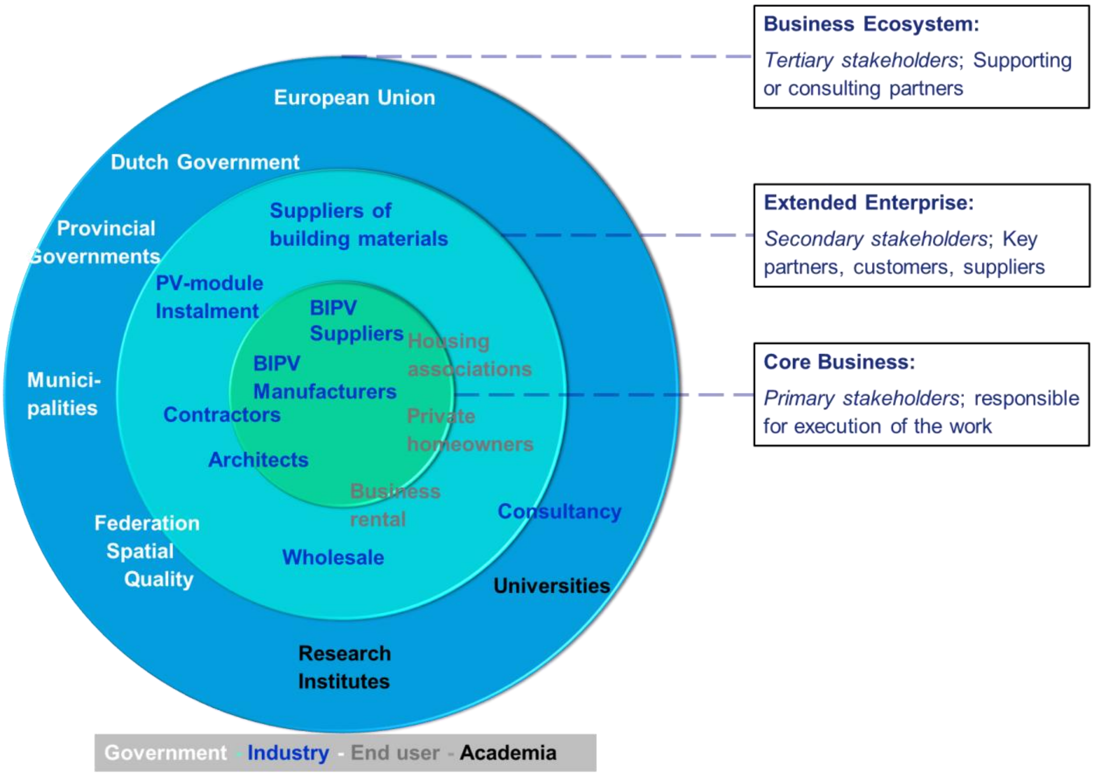

Figure 3-2: Stakeholder map for the BIPV ecosystem.

3.2 DESTEP analysis

What factors in the ecosystems of the focus countries are relevant for BIPV development?

This analysis addresses the demographic, ecological, socio-cultural, technological, economic and political-legal characteristics of the BIPV ecosystem in each focus country. For each factor, it is described which parameters are considered and what these values mean. The political-legal findings are thoroughly discussed at the end of this section, the parameters of the other impact factors are elaborated on per focus country in *Appendix B*. This detailed outline provides the ability to make a qualitative comparison between the focus countries.

The findings of this analysis are summarized on the next page in Figure 3-3.

A DESTEP analysis addresses the demographic, ecological, socio-cultural, technological, economic and political-legal characteristics an ecosystem

(Berenschot, 2015)

Demographic	Ecological	Socio-cultural	Technological	Economic	Political-legal
▪ 0.4% population growth per year until 2020 ▪ Number of single households increasing ▪ Unemployment rate decreasing ▪ 67% of households are homeowners	▪ 11 tonnes CO_2-emissions per capita per year ▪ Increasing temperature trend ▪ Annually 1,521 solar hours and 1,000 kWh/m^2 solar radiation	▪ Adequate level of environmental concern ▪ ~23% of expenditures to Energy & Housing ▪ Transition relationship citizens - government	Technological trends were found to be similar for all focus countries: ▪ Further automation of processes; ▪ Digitalization of information; ▪ Evolution of digitally connected customers, leading to different dynamics in relationships and transactions. Marketing channels are becoming more and more digital ▪ New internet revolution: more appliances and machines are interconnected to communicate and exchange data ▪ The lack of people with a strong IT background is a serious problem for many industries. This inhibits them to make the right techno-logical decisions and to harness the right emerging disruptive technologies at the right time.	▪ Recovery from economic crisis; 0.9% economic growth in 2014 ▪ Growth is projected for export, overall investments and expenditures of consumers ▪ Increasing trend house prices	▪ Decentralization of tasks and responsibilities ▪ Energy Agreement ▪ Focus on energy performance built environment ▪ Design Review Committee ▪ SolarEnergy Application Centre
▪ 0.4% population growth / year ▪ 65% of households are homeowners ▪ Unemployment rate increasing; currently 10.3% ▪ Recent increase building permits issued	▪ 5.6 tonnes CO_2-emissions per capita per year. Low due to large nuclear energy share ▪ Largest surface area; high solar radiation in the South ▪ In 2014 14.6% renewable energy share; 5.5 TWh from PV	▪ Strong focus BIPV to distinguish from Germany ▪ Strong support base for environmental measures and PV ▪ ~27% of expenditures to Energy & Housing		▪ Part of G7 ▪ Slow recovery economic crisis; 2014 economic growth 0.2% ▪ Unstable housing market, decreasing house prices ▪ Low electricity price due to nuclear energy share	▪ 19% citizens trust government ▪ Energy transition for Green Growth Act ▪ Building renovation policy ▪ 30% energy renovation cost refund ▪ Specific BIPV feed-in tariff
▪ Fluctuating population growth ▪ 53% households are homeowners ▪ Unemployment rate only 5% ▪ Building permit requests increasing	▪ 9.1 tonnes CO_2-emissions per capita per year ▪ Increasing temperature trend ▪ 1,100 kWh/m^2 solar radiation ▪ In 2014 26% renewable electricity; 5.9% PV electricity.	▪ ~30% of expenditures to Energy & Housing ▪ Strong support Energiewende, many domestic energy projects		▪ Part of G7 ▪ Economic growth (1.6% 2014) ▪ Increasing house prices ▪ Increasing electricity price due to grid fees (EEG-anlage) ▪ Domestic PV production declining	▪ 50% citizens trust government ▪ Renewable Energy Act (EEG) and Energiewende ▪ Focus on energy performance built environment ▪ Feed-in tariff for renewable energy
▪ 4 official languages: German, French, Italian, Romansh ▪ 1.2% population growth / year ▪ Unemployment rate only 3.16% ▪ High house prices, only 44% households are homeowners ▪ Construction sector declining	▪ 5.0 tonnes CO_2-emissions per capita per year. Low due to large hydropower capacity. ▪ Annually 1,700 solar hours and 1,250 kWh/m^2 solar radiation ▪ Snowfall can cover PV panels ▪ In 2014 842 GWh from PV	▪ Swiss have high level of environmental concern ▪ ~27% of expenditures to Energy & Housing ▪ Large share of energy demand fulfilled by electricity		▪ Not part of EU and Economic and Monetary Union (EMU) ▪ Currency Swiss Franc (CHF) ▪ High(er) import duties ▪ Open and innovating economy ▪ Economic growth (1.9% 2013)	▪ 80% citizens trust government ▪ CO_2 law; Energy Strategy 2050 ▪ Focus on building renovation; directive for BIPV ▪ Specific BIPV feed-in tariff ▪ Swiss BIPV Competence Centre
▪ 0.75% population growth / year ▪ 20% households ≥ 4 people ▪ 64% households are homeowners ▪ Decreasing unemployment rate; currently 5.4% ▪ Stable construction sector	▪ 7.93 tonnes CO_2-emissions per capita per year ▪ 1,300 solar hours per year ▪ 900 kWh/m2 solar radiation ▪ 7% renewable energy in 2014; 15% planned for 2020	▪ ~20% of expenditures to Energy & Housing ▪ Strong level of support for environmental-friendly measures in politics ▪ Consumer behaviour to reduce energy use can be improved		▪ Not part of the Economic and Monetary Union (EMU) ▪ Recovery from economic crisis ▪ Moderate increase house prices will lead to more rental ▪ Relatively low energy taxes	▪ Climate Change Act: 80% GHG reduction in 2050 ▪ Electricity Market Reform towards competition for low-carbon energy ▪ All new homes carbon neutral by 2016

Figure 3-3: Summary of relevant impact factors on the ecosystem of the Netherlands in each category of the DESTEP-model

3.2.1 *Demographic factors*

Demographic factors can influence the adoption of BIPV within a country. First of all, the size of the population, and more important the growth rate, are important factors. A growing population generally is equivalent to an increase in energy consumption. BIPV could be part of the solution to meet this increase in energy demand. Furthermore, a high population density and a high percentage of the total population that lives in urban areas often increase the need of renewable energy generation. Decentralized renewable energy generation increases energy security and improves the air quality in the built environment. The amount and size of households also are an indication of the implementation potential of BIPV, since more households generally mean a larger implementation potential for BIPV. If more people have jobs, the unemployment rate is lower. This is generally an indication of economic welfare, which often leads to more people buying a house or at least investing in housing. This also increases the potential of investments in renewable energy solutions for housing, including BIPV. Lastly, the activity of the construction sector can amongst others be seen in the amount of buildings with planning permission. This is an opportunity to implement BIPV in newly designed buildings as well as buildings that are under construction.

These demographic factors are summarized for all focus countries in Table 3-1. Subsequently, additional information about current demographic trends is provided per country.

Table 3-1: Key demographic statistics for the focus countries

Subject	Quantity						Unit	Source
	NL	*FR*	*DE*	*CH*	*UK*	*BE*		
Population (2014)	16,829,289	66,206,930	80,889,505	8,190,229	64,596,800	11,225,207	Persons	NL (CBS, 2015) UK (ONS, 2015) (World Bank, 2015)
Population density (2014)	501	121	232	207	267	371	Persons /km^2	(World Bank, 2015)
Urban housing (2014)	83.97	86.88	74.81	73.83	79.88	97.55	% of population	(UNDP, 2015)
Households (2014)	7,592,400	28,090,500	39,713,000	3,532,600	28,076,000	4,651,800	House-holds	(Eurostat, 2014) CH (Swiss Statistics, 2015)
Average house-hold size (2014)	2.2	2.2	2.0	2.3	2.3	2.3	Persons	(Eurostat, 2015a) UK (ONS, 2014)
Labour force (2013)	7,939,000	30,030,773	41,981,485	4,700,905	42.3 million	4,955,976	Persons	NL (CBS, 2014) UK (ONS, 2015)
Unemployment rate (2014)	7.4	10.3	5.0	3.16	5.4	8.5	% of labour force	(Eurostat, 2015a) CH (Statista, 2015) UK (ONS, 2015)
Installed PV capacity per habitant (2013)	40	71	436	92	53	268	Watt/capita	(Gaëtan, Sinead, & Manoël, 2014)
Share residential PV capacity (2013)	70	22	14	10	22	61	% of total PV capacity	(Gaëtan et al., 2014)

3.2.2 Ecological factors

Ecological factors give an indication of the physical potential of BIPV. The amount of electricity that can potentially be generated is dependent on the available surface area, orientation and tilt of the BIPV element and the way it is integrated in the building. The intensity of the solar radiation in the specific country is also of interest. Furthermore, the need of renewable electricity generation depends on the current emissions and temperature trends in the focus country. In order to limit climate change, emissions have to be reduced by among others shifting to renewable energy resources. BIPV could be part of the solution to renewable energy production.

BIPV could be part of the solution to reduce emissions and limit climate change

This section also displays to what extent renewable energy is part of the electricity mix of the focus countries, and what role solar energy plays in this.

Table 3-2: Key ecological and geographical statistics for the focus countries

Subject	Quantity						Unit	Source
	NL	*FR*	*DE*	*CH*	*UK*	*BE*		
Surface area	41,500	549,087	357,170	41,285	243,610	30,530	km^2	(World Bank, 2015)
Average solar hours	1,521	~1,700 (N) - 2,500 (S)	~1,500	~1,700	~1,300	1,546 (Brussels)	Hours /year	NL (Zonuren.nl, 2015) Rest (Current Results, 2015)
Average annual solar radiation	~1,000	~1,300	~1,100	~1,250	~900	~1,040	kWh/m^2	(SolarGIS, 2014)
Emissions per year (2012)	191,668.7	490,299.38	939,083.31	51,492.66	582,860.32	116,520.32	x1000 tonne CO_2-eq	(Eurostat, 2015a)
Annual CO_2 emissions per capita (2014)	10.96	5.56	9.11	4.95	7.93	10	Tonnes / year	(UNDP, 2015)
Renewable Energy in final energy consumption (2015)	5.6	14.2 (2013)	26	21.4	7.0 (2014)	7.9 (2013)	%	NL (CBS, 2015) BE, FR (Eurostat, 2015b) DE (EnBW, 2015) CH (Schweizerische Bundesamt für Energie BFE, 2015b) UK (Department of Energy & Climate Change, 2014)
Total installed solar capacity (2013)	665	4,673	35,715	737	3,375	2,983	MW	(Gaëtan et al., 2014)
Solar collectors' surface (2013)	880	1,916	17,222		5,545	577	X1000 m^2	(Eurostat, 2015a)

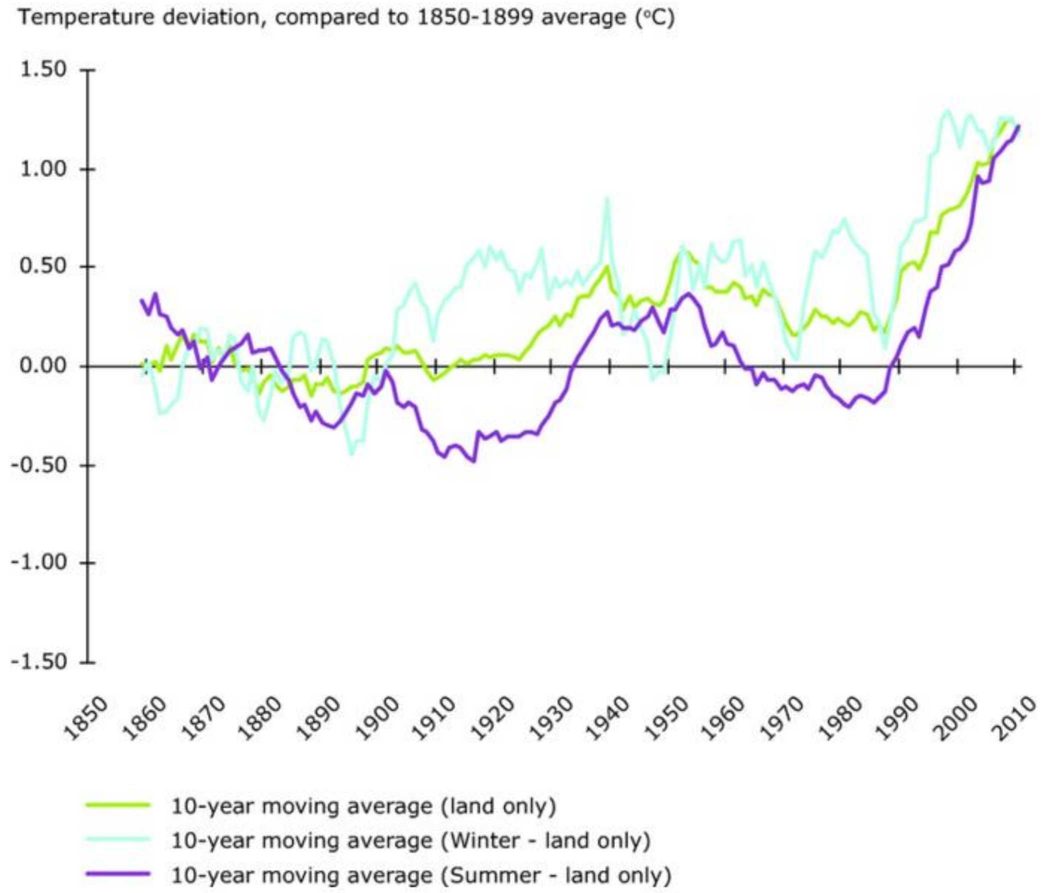

Figure 3-4: Temperature deviations for annual, winter and summer averages on European land, showing a trend from 1850 to 2010 in ˚C (European Environment Agency, 2010a)**.**

3.2.3 Socio-cultural factors

Empirical research has shown that in general, higher educated people express a higher level of environmental concern. This is often associated with environment-friendly behaviour, but this is not necessarily the case (Olli, Grendstad, & Wollebaek, 2001). However, many more factors exist that influence environmental behaviour. The size of the support base is also influenced by the environmental awareness of the society, the willingness to contribute to a better environment and how people value the aesthetics of their homes. Research has shown that economic factors are very important in peoples purchasing decisions. If a person can decide between two products, one being environmental-friendly, the person will only choose for the environmental-friendly product if the payback time is not too long (or most ideally shorter) (Kollmuss & Agyeman, 2002). Consumers thus generally balance the costs and benefits for all their purchases. This is also what plays a role in incentive schemes. Financial incentives can either stimulate or withhold people from buying a product or service. The way people interpret these incentives is influenced by their level of prior knowledge and their willingness to pay for the product or service. This has to do with psychological factors such as environmental awareness, the impact people expect to have and their sensitivity to peer pressure (Snellen, 2014).

BIPV can be financially beneficial to consumers, but benefits can also arise from improved aesthetics or doing something good to the environment

For BIPV this means that consumers will evaluate if the benefits outweigh the costs they have to make. These benefits can be financial, but can also be the improved aesthetics of their building or doing something good to the environment. For every country it is determined which part of the expenditures of households is allocated to energy and housing. When calculating payback-times for BIPV, the reference case should be the costs for both a regular roof or façade (housing) and regular BAPV or electricity expenses (energy) (BIPV SME Workshops, 2015).

Table 3-3: Key socio-cultural statistics for the focus countries

Subject	Quantity						Unit	Source
	NL	*FR*	*DE*	*CH*	*UK*	*BE*		
Educational level people from 15-64 years (2014)								
Low (lower secondary)	28.8	28.8	19.7	18.1	20.9	29.5		(Eurostat, 2015a)
Middle (upper secondary)	41.4	41.4	57.1	47.5	42.5	37.8	%	
High (tertiary)	29.7	29.7	23.2	34.4	36.6	32.6		
Expenditures by COICOP level[1]								NL (CBS, 2015) CH (Swiss Statistics, 2015) Rest (Eurostat, 2015a)
Food and stimulants	14.9	18.4	13.2	13.8	15.4	15.3		
Durable goods	14.8	8.9	9.1	9.0	13.1	10.8	%	
Energy & Housing	23.3	26.8	30.3	27.7	18.0	26.7		
Energy use per household (2014)								(World Energy Council, 2015)
Electricity	3,155	5,036	3,132	5,180[2]	3,941	3,874	kWh	(CBS, 2015)
Natural gas	1,600	906.5		958[3]	1,013.9[4]		m^3	(Lakhani & Williams, 2015)

[1] Durable goods comprise the COICOP (Classification of Individual Consumption According to Purpose) categories *Clothing and Footwear* and *Furnishings, household equipment and routine household maintenance*.

[2] Total natural gas consumption was 43.6 billion m^3 in 2010, represented for 55% by the residential sector (IEA, 2012c). Dividing by the total number of households gives the natural gas use per household in m^3.

[2] Total electricity consumption of households was 18.3 billion kWh in 2014 (Bundesamt für Energie BFE, 2015c). Dividing by the total number of households gives the electricity use per household in kWh.

[3] Total natural gas use in Switzerland was 107.1 PJ in 2014 (Schweizerische Bundesamt für Energie BFE, 2015a). One petajoule equals 31.6 million m^3 of natural gas (CBS, 2015). Multiplying these figures and dividing by the total number of households gives the natural gas use per household in m^3.

[4] The total domestic natural gas consumption in the UK over 2014 was 278,100 GWh (Lakhani & Williams, 2015). Natural gas typically has an energy content of 35.17 MJ per m^3 and 1 kWh equals 3.6 MJ. This gives a domestic natural gas consumption of 28.5 billion m^3. This figure is divided by the total number of households to give the natural gas use per household in m^3.

3.2.4 Technological factors

Specifically for BIPV the technological developments have been discussed in section *1 Theoretical Framework*. Progress is made in flexibility of size, shape and colour of BIPV elements, as well as upscaling of production processes (Berenschot, 2015). These developments do not differ much between the focus countries. This section will therefore focus on general global technological trends that potentially influence BIPV technology. Technological developments become more important in all facets of life. Trends in the field of internet, big data and social media influence the way challenges are handled and opportunities are realized.

Over the last decades, major developments have been made in the field of information- and communication technologies (Ministerie van Binnenlandse Zaken, 2015b). Current technological trends are:

- further automation of processes, leading to a shift in job types (NCOI, 2015). The costs of BIPV products will be reduced if the market can be further automated.
- digitalization of information, causing increased flexibility and shorter lead times (NCOI, 2015). All relevant information is digitally available in the cloud. This reduces costs and complexity of information availability and improves response speeds (Deloitte, 2015).
- evolution of digitally connected customers, leading to different dynamics in relationships and transactions. This also affects through which channels marketing is performed, being more and more digital (Deloitte, 2015). Table 3-4 shows the percentage of the population in the focus countries that makes use of an internet connection.
- a new internet revolution, where more and more appliances and machines are interconnected and can communicate and exchange data. This is called the Internet of Things (IoT) (Deloitte, 2015; NCOI, 2015). This will have a supporting effect on BIPV technology, since the application becomes more flexible to use in for example smart grids.
- improved analytical techniques, giving organizations the opportunity to perform predictive modelling and analysing large and complex data sets. This is also referred to as artificial intelligence, leading to more efficient decision making (Deloitte, 2015).

For a sustainable business strategy, it is important to harness emerging disruptive technologies. Many businesses now have incorporated the position chief integration officer (CIO), who has the responsibility to balance future needs with today's operational realities (Deloitte, 2015). A serious problem for many industries, however, is the lack of people with a strong IT background. This inhibits these industries to make the right technological decisions and to harness the right emerging disruptive technologies at the right time.

Table 3-4: Key technological trends in the focus countries

Subject	Quantity						Unit	Source
	NL	*FR*	*DE*	*CH*	*UK*	*BE*		
Internet users (2014)	93	83	84	85.2	87.02	82	% of population	(UNDP, 2015)

3.2.5 Economic factors

The state of the economy in a country strongly influences the developments within all industries. It is therefore important to know how the economy is evolving, and what factors affect this. First of all, the gross domestic product (GDP) says something about the size of an economy by measuring its added value. GDP is calculated by summing consumption (*C*), investments (*I*), government expenditures (*G*) and export (*X*), and subtracting imports (*M*); $C+I+G+(X-M)$. Economic growth of a country is defined as the change of the GDP compared to the previous year (World Bank, 2015). Furthermore, the purchasing power parity (PPP) is a measure of how much value people can buy with a certain amount of money. Table 3-5 displays the PPP of the focus countries relative to the mean PPP of the EU28. A higher PPP means that people can buy relatively more products with the same amount of money (Eurostat, 2015a). The table also displays international trade, the sum of imports and exports, as a share of the GDP. Since imports are subtracted when calculating the GDP, the share of international trade can be more than 100% (UNDP, 2015). Another indicator is the house price index, showing how the house prices have evolved since a certain moment in time, in this case 2010 (Eurostat, 2015a). Rising prices generally mean that the economy is doing well, as more people are buying houses, which drives up the price. Lastly, for domestic energy measures specifically it is interesting to determine how much regular energy (electricity and natural gas) costs per kWh. This is an important indicator that consumers take into account when making decisions on implementing their own energy system (Kollmuss & Agyeman, 2002).

The BIPV industry can profit from the recovering economies of the focus countries

A general trend that can be seen in Figure 3-5 for European countries, is recovery from the economic crisis that happened in 2008. The figure also shows that Switzerland and the United Kingdom, who are not in the Economic and Monetary Union (EMU), recovered relatively faster than the other focus countries (World Bank, 2015). The BIPV industry can profit from the recovering economy. It will become more likely that investments are made in housing and buildings, by both the public and private sector.

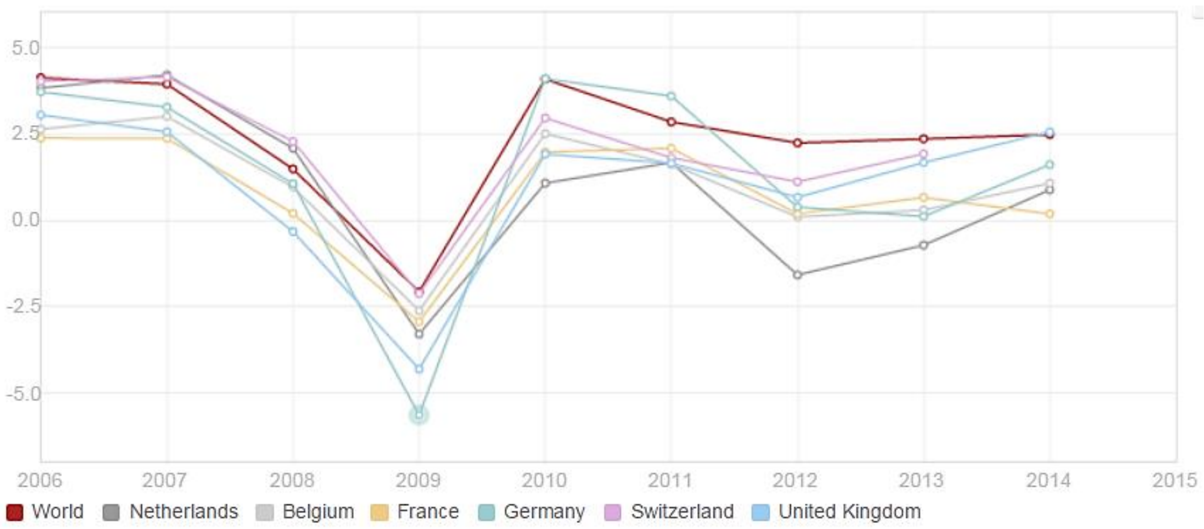

Figure 3-5: Annual GDP growth rate at market prices, based on constant local currency (World Bank, 2015).

Table 3-5: Key economic statistics for the focus countries

Subject	Quantity						Unit	Source
	NL	*FR*	*DE*	*CH*	*UK*	*BE*		
Gross Domestic Product (2012)	662,770	2,132,449	2,915,650	528,780	2,253,311	400,643	Mio €	(Eurostat, 2015a)
Economic growth (2014)	0.9	0.2	1.6	1.9 (2013)	2.6	1.1	% of GDP	(World Bank, 2015)
Disposable income people from 15-64 years (2014)	23.9	24.8	23.4	49.7 (2013)	23.0	24.6	x1000 €	(Eurostat, 2015a)
Purchasing Power Parity (2014)	1.092	1.098	1.042	1.814	0.938	1.110	EU28=1	(Eurostat, 2015a)
International Trade (2014)	165.88	57.09	97.57	91.64	65.72	168.4	% of GDP	(UNDP, 2015)
House price index (2014)	86.65	101.59	113.15	117.1	114.66	107.05	2010 =100	(Eurostat, 2015a) CH (The Economist, 2015)
Domestic energy prices[1]								(Eurostat, 2015a) CH (Schweizerische Bundesamt für Energie BFE, 2015a)
Electricity (2.5-5 MWh) (2015)	0.2231	0.1688	0.2799	0.177[2]	0.2243	0.2113	€ / kWh	
Natural gas (<20 GJ)[3] (2015)	0.1072	0.1273	0.1088	0.0950[2]	0.0807	0.0794	€ / kWh	

[1] Including VAT and taxes

[2] 1 Swiss franc (CHF) = 0.922574413 euro (€) at 24 November 2015

[3] Natural gas typically has an energy content of 35.17 MJ per m^3 and 1 kWh equals 3.6 MJ.1m^3 therefore equals 35,17 MJ/3,6 MJ= 9,769 kWh. Calculated gasprices for household consumers (<20GJ) in €/m^3 including VAT and taxes would then respectively be 1.047; 1,244; 1.063; 0.928; 0.788 and 0.776 €/m^3.

3.2.6 Political-legal factors

European Union

Environmental Legislation

Renewable Energy Directive

Climate and energy are important topics in the policy of the European Union (EU). Three key objectives are (international) security of energy supply, availability of affordable energy, and sustainability. To achieve these objectives, binding targets have been set for 2020 in the Renewable Energy Directive 2009/28/EC (European Parliament and Council, 2009):

- 20% reduction of greenhouse gas (GHG) emissions below 1990 levels;
- 20% of the total EU energy consumption has to be renewable;
- 10% share of renewable energy in transport;
- 20% energy efficiency improvement.

Security of energy supply, availability of affordable energy and sustainability are three key objectives of the European energy policy

The European Strategic Energy Technology Plan (SET-Plan) outlines long-term energy research priorities including concrete strategic milestones to be achieved. It is performed by representatives of the Member States governments and coordinated by the European Commission. Within this plan, European Industrial Initiatives are designed at the sectoral level. Solar is one of the industries that has officially launched a Joint Statement in 2010, including a technology roadmap and an implementation plan (Photovoltaic Technology Platform, 2015). According to this roadmap, 12% of all EU electricity is to be generated by solar by 2020. Energy research in support of the SET-Plan comes under the European Energy Research Alliance (EERA), combining knowledge and resources from national research institutes in Europe (European Commisson, 2015b).

Energy Performance of Buildings Directive

More specifically for the construction industry, in May 2010 an agreement was reached on the energy performance of buildings in the Directive 2010/31/EU. Member States have to develop national plans for increasing the number of net zero-energy buildings (nZEB). They have to ensure that after 31 December 2018 new buildings occupied and owned by public authorities are nZEB, and by 31 December 2020 all new buildings are nZEB. Furthermore, policies and measurements should be developed that stimulate renovation of buildings into nZEB, for example building code requirements and subsidy schemes (Atanasiu et al., 2012). The national plans will be described for the focus countries in the next sections.

A nZEB is defined in Article 2.2 of the DIRECTIVE 2010/31/EU as "… a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (European Parliament and Council, 2010). Any building that is constructed, sold or rent out has to be issued with an Energy Performance Certificate (EPC). Consumers can use this information in their decision-making process and building owners become more aware of the energy performance of their buildings. The final goal is to increase energy efficiency standards and renewable energy use.

A study by Lee et al. (2014) evaluated BIPV for realization of a nZEB. He indicated that effective energy saving measures and the supply of renewable energy are the two most important aspects to achieve a nZEB. Of all available renewable energy techniques, such as wind, solar and fuel cells, currently only a photovoltaic system is suitable for implementation in small and medium-sized buildings. Lee concluded that the power generation performance of BIPV was sufficient to achieve energy self-sufficiency of the building because there even was an energy surplus measured in their modelled building (Lee et al., 2014).

Support Programmes

Application of PV is supported under various EU-wide programmes. Horizon 2020 is the most recent framework programme that provides a funding platform for research and innovation, technological development and demonstration activities (European Commisson, 2015b). A total budget of 80 billion euro is made available to businesses and academia for fundamental research, further development of technologies and societal challenges. Climate and renewable energy are two key areas in this programme (RVO, 2015e).

Eurostars Eureka is a European initiative to support SMEs that develop market-oriented innovative technologies. The goal is to reduce the time-to-market by addressing the technological risks that are involved in such a process. The total budget is 1,100 million euro which is divided among the Member States (RVO, 2015e).

The European subsidy scheme INTERREG stimulates sustainable and innovative collaboration projects within Europe. The main goals are to strengthen Europe, improve the natural environment and reduce the economical differences between regions and Member States (RVO, 2015e).

LIFE is a funding instrument for the environment and climate action of the European Union. The programme supports development, implementation, monitoring, evaluation and communication projects in the field of biodiversity, environment, efficient use of resources and adaptation to and mitigation of climate change (RVO, 2015e). An example of a LIFE project is PHOSTER (PHOtovoltaic STEel Roof), developing eco-designed BIPV roofing (Vignal, 2014).

PV standards

The International Electrotechnical Commission (IEC) sets international standards for electronic products, systems and services. Its headquarter is in Geneva, Switzerland. CENELEC is the European Committee for Electrotechnical Standardization, based in Brussels. The publications from the IEC and CENELEC generally serve as a basis for national standardizations. International standards for the photovoltaic energy systems are prepared by the IEC / CENELEC Technical Committee 82 (TC82). A photovoltaic energy system includes all processes from solar radiation input, to the electrical systems to which energy is supplied. In general, standards are set in the area of electric performance, environmental testing, quality assurance and assessment criteria. To date, TC82 has set standards for among others terms and symbols, qualification of design of c-Si (IEC 61215) and TFSC (IEC 61646) modules, mechanical resistance and safety (IEC 61730) and characteristic parameters of stand-alone systems. Standardization for how to handle photovoltaic waste, characteristic parameters of new PV technologies and grid-connected systems, storage systems and PV applications for special sites are still under development (European Committee for Electrotechnical Standardization, 2015; International Electrotechnical Commission, 2015).

(BI)PV Institutions

The International Energy Agency (IEA) has created the Photovoltaics Power Systems Programme (PVPS). This is a global programme, so not under the responsibility of the European Union. The most recent task, Task 15, is focused on integration of PV in the built environment. Subtasks are designed to develop a BIPV database, BIPV business models, BIPV specifications, environmental assessments of BIPV products and demonstration projects (Ritzen et al., 2014).

A second important party is Solar Power Europe. Solar Power Europe is led by its members, representing organizations from all over the value chain. The aim is to support business activities in Europe's solar industry, and influence policy developments in this field. The EU Photovoltaic Technology Platform (EU PV TP) is one of the initiatives, bringing together all stakeholders in the PV chain (Solar Power Europe, 2015). It is an independent body that collaborates with both industry and governmental parties. The goal is to develop a strategy and an implementation plan for research and development, innovation, education and market development of the photovoltaic industry. This way, it can serve as a key reference for policy makers (Photovoltaic Technology Platform, 2015). The last annual conference (2015) organized by the European Photovoltaic

Technology Platform was focused on BIPV. Discussions took place between architects, building industry, PV industry, real estate representatives, investors and policy makers. This should lead to further deployment and implementation of BIPV (TECNALIA, 2015).

Lastly, the European Energy Research Alliance (EERA) is an important party, covering energy research within the EU. EERA combines knowledge and resources from national research institutes in Europe through joint programmes. BIPV comes under the joint programme for Photovoltaic Solar Energy (European Commisson, 2015b).

The Netherlands

General Political Situation

A trend can be seen in an increasing amount of undecided voters in the Netherlands. In provincial and municipal elections a shift is taking place towards local political parties and at the national level the parliament becomes more fragmented. Also, the voter turnout is decreasing. The general trust in the government is historically low, but internationally the Netherlands still is a high trust society. Another important development is decentralisation of tasks and responsibilities towards the municipal level (Ministerie van Binnenlandse Zaken, 2015b). These transitions may influence how the government handles BIPV projects, as was also explained under the 'Social' pillar.

The Eurobarometer measures annually how residents in the EU view the economy, their government, the society et cetera. In 2015 55% and 51% of the Dutch citizens tend to trust respectively the National Parliament and Government. This is significantly higher than the average EU resident does, i.e. both 31% (European Commission, 2015c).

Environmental Legislation

Energy Agreement for Sustainable Growth

In 2013, the Netherlands reached an Energy Agreement for Sustainable Growth (*Energieakkoord*). The agreement provides a long-term strategy with the following key objectives:

- a saving in final energy consumption averaging 1.5% annually;
- a 100 petajoule (PJ) saving in the final energy consumption by 2020;
- an increase in the proportion of energy generated from renewable resources to 14% in 2020;
- a further increase in this proportion to 16% in 2023;
- at least 15,000 full-time jobs.

Within the Energy Agreement, ten basic components were identified that address these objectives. The basic components are 1) saving energy, 2) scaling up renewable energy generation, 3) decentralised energy generation, 4) energy transmission network, 5) EU Emission Trading System (ETS), 6) energy generation from fossil fuels and coal-fired power stations, 7) mobility and transport, 8) employment opportunities, 9) energy innovation and energy export, and 10) funding programme (SER, 2013). All basic components are at least to a certain extent relevant for the BIPV sector.

Building requirements

The built environment is discussed within the first basic component of the Energy Agreement, i.e. saving energy, and mainly follows the guidelines from the European EPBD. A national fund of 600 million euro was established in 2013 to support individual homeowners to improve their home's energy performance. An additional 400 million euro was made available for the subsidized rented sector to take these measures. This way individuals and businesses benefit themselves from energy savings in the built environment. Furthermore, it is stated that in 2014 and 2015 all homes would receive an indicative energy label. This will increase awareness on the energy performance of buildings and the related costs (SER, 2013).

All regulations related to the built environment are captured in the Building Code (*Bouwbesluit*) (Ministerie van Binnenlandse Zaken, 2015a). The building code requires buildings to be wind- and waterproofing, to be safe and fireproof, et cetera. Every building in the Netherlands has to be built conform these regulations. Guidelines for these standards are developed by the NEN, the Dutch version of the IEC and CENELEC. Specifically focused on the energy performance of buildings, the Energy Performance Standard was developed, i.e. NEN 7120. This standard sets the objective to improve the Energy Performance Coefficient (EPC) of buildings from 0.4 in 2015 to 0.0 in 2020. EPC is measured in MJ/m^2 (NEN, 2015).

Besides increasing the efficiency, on-site production of electricity is an important way to improve the energy performance of buildings. PV is a key technology that is already widely used to achieve this. However, nowadays more attention is paid to the aesthetics of the built environment, and regular PV is not always perceived as aesthetically pleasing. Most municipalities have Design Review Committees (*Welstandsfederatie*) that evaluate which modifications in the architectural components of buildings meet the requirements and fit with the existing architecture (Federatie Ruimtelijke Kwalitiet, 2015). BIPV provides a possible solution for on-site electricity production in the built environment that is at the same time aesthetically pleasing.

PV is widely used to improve the energy performance of buildings, but is not always perceived as aesthetically pleasing

Private electricity production and grid redelivery

Regular grid electricity costs about €0.07 per kWh, but due to VAT and other taxes consumers pay €0.22 per kWh. In 2012, self-generated power from a regular PV system cost between €0.15 and €0.22 per kWh, depending on the specific site and technology (Agentschap NL, 2012). No taxes are imposed on self-generated power by a PV system that is installed 'behind the meter'. When the producer can directly use the generated electricity, he saves the regular grid electricity costs. In the situation that more electricity is privately generated than used, the electricity can be redelivered to the grid (Agentschap NL, 2012). Electricity redelivered to the grid can be subtracted from the grid electricity that was delivered by the utility company to the consumer, following the principle of net metering (*salderingsregeling*) (Dutch Government, 1998). This provides the possibility for small consumers to generate their own renewable electricity in a profitable way. The regulation will remain in force until at least 2020.

The principle of net metering is used for on-site generated electricity that is redelivered to the grid

Another regulation is the Postcode Cluster (*Postcoderoosregeling*). Through this regulation, housing corporations and home owners associations that collectively own a renewable energy system can qualify for tax advantages on their generated renewable energy. The individual renters or home owners receive a tax advantage of 9 eurocents per kWh and the housing corporation receives a compensation for the electricity that is redelivered to the grid (Holland Solar, 2015).

Support programmes

Renewable energy

The support schemes specifically for solar energy in the Netherlands are arranged through TKI Urban Energy (previously TKI Solar, TKI Energo and TKI Switch2SmartGrids). *iDEEGO* is an integrated programme that covers innovation, integration, information and intelligence for renewable energy and energy saving in the built environment. This programme supports the development of new products and services in this field. The annually available budget is expected to be 40-50 million euro (TKI Solar Energy, 2015).

Renewable energy and thus PV is supported by the Dutch government under various programmes. SDE+ (*Stimulering Duurzame Energie*) is one of the most recent initiatives, providing a feed-in premium (FIP) subsidy for among others renewable electricity projects. The FIP covers the gap between the market price and the cost price of renewably generated electricity. The SDE+ programme prioritizes low-cost technologies, in order to drive cost-reductions and promote efficient cost-models. In 2015 the SDE+ budget was 3.5 billion euro. For PV, the SDE+ 2015 provided a subsidy for systems with a capacity equal to or higher than 15 kWp that have a major consumer connection (3*80 A) (RVO, 2015d). BIPV projects would however not likely be implemented at this scale.

Another example are the so-called *Green Deals*. A Green Deal is an arrangement between the Dutch Government and other parties, such as citizens, companies, foundations or other governmental parties. The deal will support the execution of their sustainable plans. The government can serve as a mediator, can adjust laws and regulations or can help to search financing. These actions are meant to facilitate the implementation of sustainable plans. Any party can apply with an initiative for a Green Deal (Rijksoverheid, 2013).

The *Milieu Investeringsaftrek* (MIA) and *the Willekeurige afschrijving milieu-investeringen* (Vamil) provide tax advantages for investments in environmentally friendly techniques. The *Energie Investeringsaftrek* (EIA) is a regulation that provides tax advantages specifically for investments in energy saving measures. In 2015 the budget for this regulation was € 106 million. On average a company will save respectively 36%, 75% and 10% of the investment costs, plus the financial advantage that results from the potential energy savings (RVO, 2015e).

The *Stimuleringsregeling Energieprestatie Huursector* (STEP) results from the Energy Agreement and supports landlords to improve the energy performance of their rental homes. The regulation is applicable to housing associations as well as registered private landlords. This way, investments take place to increase energy savings in existing buildings. The regulation will be in force until at least the end of 2017 (RVO, 2015e).

Innovation and export

Besides the programmes that are specifically designed to support sustainability and the development of renewable energy, many programmes exist that support innovation in general. PV also qualifies for these types of subsidies. A programme organized by RVO is Starters International Business (SIB). This programme supports businesses that have the ambition to go abroad, either individually or within a consortium (RVO, 2015c). Berenschot is currently facilitating a SIB project for a group of BIPV companies (BIPV SME Workshops, 2015). Partners for International Business (PIB) is another example of a regulation that develops a partnership with a group of companies to collectively approach other countries (RVO, 2015e).

InnovatiePrestatieContracten (IPC) is a subsidy scheme for collaborating SMEs that operate within the same region, branche or chain. The programme supports knowledge transfer, collaboration and innovation. In 2015, 3 million euro was made available by RVO (IPC, 2015).

The *Wet Bevordering Speur- & Ontwikkelingswerk* (WBSO) is a regulation that supports research and development, by providing tax advantages for labour costs and other expenses. The regulation is in force for businesses of any size. For 2016, a budget of 1,143 million euro is proposed (RVO, 2015e).

(BI)PV Institutions

An overview of (BI)PV institutions and their responsibilities can be found in Table 3-6.

Table 3-6: Important institutions in the Netherlands that are engaged with (BI)PV.

Institution	Description
Solar Energy Application Centre (SEAC)	SEAC was developed in 2012 and focuses solely on solar energy systems and applications. This was an initiative of the Ministry of Economic Affairs and the Ministry of National Affairs in collaboration with R&D institutes TNO, ECN and Holland Solar (SEAC, 2015). SEAC is an important partner in many BIPV projects.
Solliance	Solliance is a partnership of industrial and research oriented organizations from the Netherlands, Belgium and Germany that are active in PV. They share knowledge and facilities to accelerate development of the solar industry. The partners also collaborate in projects with governments, individual organizations or industrial consortia. Solliance's focus themes are TFSC, Copper Indium Gallium Selenide (CIGS/CZTS) and Organic PV, so not necessarily BIPV. Solliance is based in Eindhoven (Solliance, 2015).
Holland Solar	Holland Solar is the Dutch industry association for all stakeholders that are active in the solar industry, e.g. manufacturers, suppliers, advisors, architects. Holland Solar promotes the interests of its members by providing education, being involved in the political dialogue, collaborating with industry partners and consortia and organizing related events (Holland Solar, 2015).

Hogeschool Zuyd	Hogeschool Zuyd comprises both education and research activities. One of their lectureships is focused on solar energy in the built environment, of which Zeger Vroon is the lector. Research is done on the integration of solar panels in buildings as well as the use of innovative materials. The goal is to apply this knowledge together with companies in the South-East of the Netherlands. An example of a project is *'De Wijk van Morgen'*, a neighbourhood where experiments with all types of sustainable measures take place, among others a BIPV roof. Furthermore, Hogeschool Zuyd is the operating agent of Task 15, developed in the previously discussed IEA PVPS.

France

General Political Situation

France is a republic. The president, currently François Hollande, is the Head of State and appoints a prime minister, currently Manuel Valls, who is Head of Government. The Ministry of Ecology, Sustainable Development and Energy is currently chaired by Ségolène Royal (Gouvernement.fr, 2015).

The Eurobarometer measures annually how residents in the EU view the economy, their government, the society et cetera. In 2015 21% and 19% of the French citizens tend to trust respectively the National Parliament and Government. This is significantly lower than the average EU resident does (European Commission, 2015a).

Environmental Legislation

Energy Transition for Green Growth Act

At August 17 2015, the Energy Transition for Green Growth Act (*LOI n° 2015-992 relative à la transition énergétique pour la croissance verte*) came into force in France (Legifrance, 2015). With this Act, all sectors become subject to a long-term low carbon strategy to reduce GHG emissions. Every period of five years requires a new energy plan that is adjusted to the latest developments at that time. The objectives of the Act are (Ministry of Ecology Sustainable Development and Energy, 2015):

- 40% GHG emission reduction by 2030 compared to 1990 levels;
- 50% reduction of final energy consumption by 2050 compared to 2012 levels;
- 30% fossil fuel consumption reduction by 2030 compared to 2012 levels;
- 32% renewable energy share in final energy consumption and 40% in electricity generation by 2030;
- 50% less waste in landfill by 2025;
- Reduce the share of nuclear power to 50% by 2025.

The building sector is the biggest GHG emitter in France. It accounts for 44% of the energy consumption and yearly emits 123 million tons of CO_2 (Ministry of Ecology Sustainable Development and Energy, 2015). In this light, the government of France in particular focuses on energy savings in this sector by the introduction of financial incentives. This is elaborated on in the next paragraph. Furthermore, development of renewable energy is important to reach the 32% target. It is expected that about 100,000 new jobs are created to reach the objectives (Planete Energies, 2015).

Every period of five years requires a new energy plan that is adjusted to the latest developments

Building requirements

Already in the 2009 National Renewable Energy Action Plan, France indicated that the energy consumption of the existing building stock should be reduced by 38% by 2020 (République Française, 2009). In the 2015 Act, it is targeted to renovate 500,000 houses per year to become more energy efficient. Also, by 2050 all new buildings should comply to the low-energy building (LEB) standard. For optimal development of the building sector, the knowledge on energy renovation of buildings will be gathered by digital monitoring (Ministry of Ecology Sustainable Development and Energy, 2015). The financial incentives that are existent for homeowners to improve the energy performance of their dwelling will be discussed in the next paragraph.

The French planning regulations are set out in the *Code de l'Urbanisme*. Every new construction or building requires a building permit. Adjustments to existing buildings only require a permit when it changes the usage, the exterior view of the building or when extra levels are constructed (Angloinfo France, 2015). This is to ensure that the project is compatible with the local zoning rules (Fröding, 2010). Also (BI)PV projects require a permit (*déclaration préalable*) (French Property, 2011).

Support programmes

As a result of the 2015 Act, in France several financial incentives for homeowners exist to improve the energy performance of their dwelling. First of all, the energy transition tax credit (*Crédit d'impôt transition énergétique, CITE*) provides a refund of 30% of the energy renovation costs. For a single person this amounts to maximal €8,000, for a couple to €16,000. A second financial incentive for home owners is an interest-free loan of up to €30,000 to improve the energy performance of existing buildings (Ministry of Ecology Sustainable Development and Energy, 2015).

In the feed-in tariffs for solar energy, France makes a distinction between BIPV that is integrated in an aesthetic manner, simplified BIPV (*Intégration simplifiée au bâti, ISB*) and regular PV systems (Polo, 2015). What the exact differences are between BIPV and simplified BIPV remains unclear, so room is left for interpretation. Table 3-7 presents the FITs that were in force during the first quarter of 2015, for a duration of 20 years (Becquerel Institute, 2015).

Table 3-7: Feed-in tariffs for PV in France during the first quarter of 2015 (Becquerel Institute, 2015)**.**

Type	Installed capacity	Feed-in tariff (€/kWh)
BIPV	0-9 kW	0.2655
Simplified BIPV	0-36 kW 36-100 kW	0.1347 0.1279
Other PV	0-12 MW	0.0620

The FIT policy is funded by the fee that consumers of grid electricity pay, called the Contribution to Electricity Public Services (*CSPE*). Grid operators are obliged to buy PV electricity (Durand, 2013).

France distinguishes aesthetically integrated BIPV, simplified BIPV and regular PV systems

(BI)PV Institutions

An overview of (BI)PV institutions and their responsibilities can be found in Table 3-8.

Table 3-8: Important institutions in France that are engaged with (BI)PV.

Institution	Description
Agency for Environment and Energy management (ADEME)	ADEME plays an important role in the implementation of sustainable energy policies. ADEME advices companies, public authorities and the public. Furthermore, ADEME helps in financing projects (SOLER, 2014).
Syndicat des Énergies Renouvables (SER)	SER represents stakeholders that are active in the field of renewable energy. The goal is to promote the development of renewable energy in France (SOLER, 2014).
SOLER	SOLER is the industry association for French photovoltaic practitioners. Their goal is to stimulate research and development of PV applications (SOLER, 2014).
Alliance Qualité Photovoltaïque (AQPV)	AQPV ensures the quality of PV applications in France. The quality and performance of the specific PV application is assessed in one to four stars (SOLER, 2014).

Germany

General Political Situation

The German government consists of a federal government, which determines the primary legislation, and 16 federal states. Each of the federal states has its own government, complying with the laws and regulations of the central government. The representatives are chosen through democratic voting. Germany is led by a federal President (*Bundespräsident*) and a federal Chancellor (*Bundeskanzler*), currently represented by respectively Joachim Gauck and Angela Merkel. The federal President is the head of state, but has a merely ceremonial role. The federal Chancellor can be seen as the political leader of Germany (Duitsland Instituut, 2015).

The Eurobarometer measures annually how residents in the EU view the economy, their government, the society et cetera. In 2015 53% and 50% of the German citizens tend to trust respectively the National Parliament and Government. This is significantly higher than the average EU resident does. Furthermore, 86% of the Germans perceives their national economy as ‘good’, versus 38% for the average EU resident (European Commission, 2015b). This indicates that the German citizens have a positive opinion towards their government.

Environmental Legislation

Energiewende and Renewable Energy Act (EEG)

The German Renewable Energy Act (*Erneuerbare Energien Gesetz (EEG)*) regulates the use of renewable energy and stimulates cost reductions by improving energy efficiency. The act was first introduced in 2000, and has been revised multiple times. The last reform was in 2014 to stimulate the implementation of wind- and solar energy. This is done by guaranteed purchases against fixed prices and the priority for the renewable electricity to enter the market (BMWi, 2015a). This reform facilitates the implementation of the *Energiewende*, the national strategy for the transition of Germany’s energy system. The main objectives of this long-term policy are “to combat climate change, avoid nuclear risks, improve energy security, and guarantee competitiveness and growth” (Pescia, Graichen, & Jacobs, 2015).

Germany aims ‘to combat climate change, avoid nuclear risks, improve energy security, and guarantee competitiveness and growth’

(Pescia et al., 2015)

The policy sets several interrelated targets until 2050, these are visualized in Figure 3-6 (EnBW, 2015). The most important objectives are:

- to reach 35% renewable energy share in final electricity consumption in 2020, 40 to 45% in 2025, 55 to 60% in 2035 and 80% in 2050 (Morris & Pehnt, 2015). As described in chapter 2.2 Ecological factors, currently 26% of Germany’s electricity mix is generated renewably (Schuffelen, 2015).
- to reduce CO_2 emissions with 40% in 2020 and 80 to 95% in 2050, relative to 1990 levels. The binding EU target is a reduction in CO_2 emissions of 20% by 2020.
- the installed nuclear power capacity (11GW) is gradually reduced, in order to be totally phased out until the end of 2022. In 2004, nuclear power accounted for 27% of the electricity generation mix. In 2014, this share had already been reduced to 16% (Schuffelen, 2015). Conventional fuels such as oil and natural gas are gradually replaced by renewable energy resources.
- in terms of electricity demand, an efficiency improvement of 10% by 2020 and 25% by 2050 against 2008 levels is targeted (Agora Energiewende, 2013). This is among others elaborated on in Energy Conservation Ordinance (*Energieeinspaarverordnung, (EnEV)*) for the built environment of Germany.

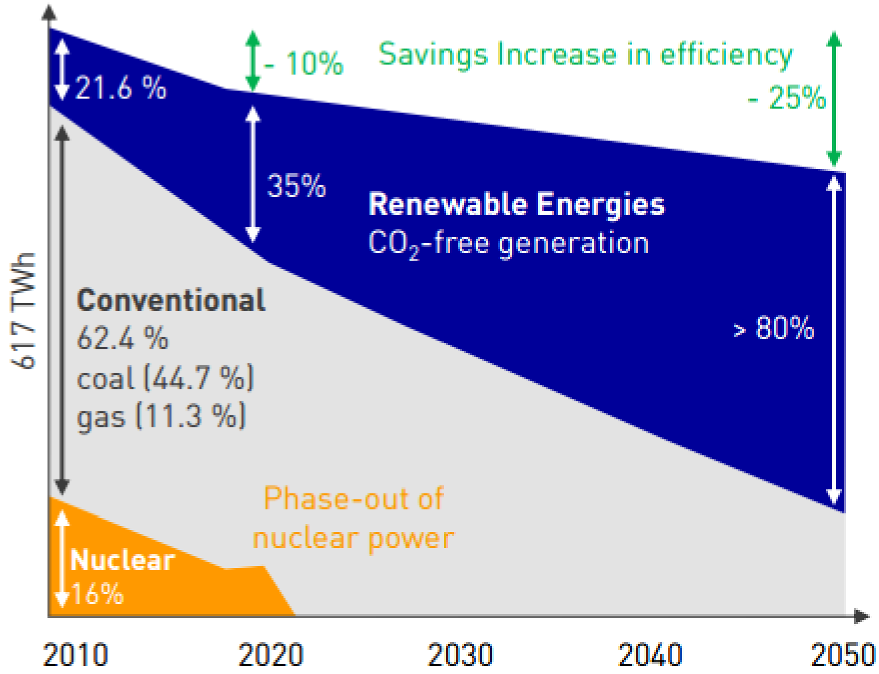

Figure 3-6: Graphical visualization of important targets in Germany's *Energiewende* (EnBW, 2015)**.**

This shift in electricity resources brings along challenges for Germany. The increased share of renewables imposes stress on the German grid, since electricity from renewables is generally subject to fluctuations in supply. The stability of the grid, as well as energy security therefore become relevant topics of discussion (BMWi, 2015a). Other than this, the electricity market needs to be re-designed and continuous development of cost-effective measures to reduce CO_2 emissions and integrate renewable energy sources are required. Another important challenge is the cooperation with surrounding European countries to make optimal use of the electricity grid (Pescia et al., 2015).

Renewable energy suffers from larger supply fluctuations, causing stress on the electricity grid

Building requirements

As mentioned before, the Energy Conservation Ordinance (*Energieeinspaarverordnung (EnEV)*) is the German regulation for energy use in the built environment. The EnEV among others serves to implement the European EPBD. The EnEV follows the guideluines of the DIN (Deutsche Institut für Normung), the German version of the IEC and CENELEC. The current policy focuses on the following points:

- to increase the renovation rate of German buildings from 1% per year to 2% per year. This means that all existing German buildings would be renewed within 40 years instead of 100 years (Morris & Pehnt, 2015);
- to reduce the heating requirement of the building stock by 20% by 2020 (Global Buildings Performance Network, 2015);
- to reduce the primary energy requirement of the building stock by 80% by 2050, resulting in an almost climate-neutral building stock where remaining energy demand is covered with renewable energy (Global Buildings Performance Network, 2015).

Germany issues Energy Performance Certificates (EPC) for both new and existing buildings. For new buildings, the EPC is mandatory. For existing buildings however, it is mandatory as soon as the purchaser or tenant requests such an energy label (Global Buildings Performance Network, 2015). The urge for improvement of the building stock is high, since over 90% of the German built environment was built before 1990 and these buildings generally do not meet the policy objectives (Partners for Innovation, 2008). This implies large potential for the building industry. The Passivhaus standard goes one step further then the EPC, this is a voluntary labelling scheme for which only buildings with an annual heating and cooling demand of maximal 15 kWh/m^2 qualify. This standard can be applied to residential, commercial as well as public buildings on a global scale (BRE, 2015). In 2010, German households already reduced their energy use per unit of floor area by about 13% compared to 2000 levels (Global Buildings Performance Network, 2015).

The building sector can significantly benefit from the required improvements in the building stock. Besides increasing the efficiency by using sustainable and efficient materials and techniques, on-site production of electricity is an important way to improve the energy performance of buildings as well as the share of renewable energy in the electricity mix. PV is a key technology that is already widely used to achieve this. Many German houses nowadays have their roof covered in PV. However, in many cases this does not benefit the aesthetics of the building. In Germany Design Review Committees do not exist. Guidelines for aesthetics in the built environment is arranged by the *Landesdenkmalschutzämter*. These are governmental bodies that issue permits for changes in the built environment, mainly when it comes to (national) monuments. PV systems on regular buildings usually do not need authorization (Wolff, 2015).

Guidelines for aesthetics in the built environment are arranged by the Landesdenkmalschutzämter

Building laws are defined in the *Bauordnungsrecht* at the federal level and in the *Bausatzungen* at the municipal level. Individual municipalities have the right to decide on the aesthetical aspects of building projects, this is not regulated at the federal level (Wolff, 2015). BIPV could then provide a solution for on-site electricity production that is at the same time aesthetically pleasing.

Support programmes

The major renewable energy support scheme comes under the EEG in the form of feed-in tariffs. This system brings two things. First of all, a fixed price is pay for every kWh that is produced for 20 years. The tariffs differ per type of renewable energy and according to the size of the installed capacity. The guaranteed prices decrease annually to compensate for technological development and natural price decreases. Secondly, grid operators are obliged to purchase electricity that is produced from renewable energy, so that renewable electricity has priority to enter the market. This provides a secured income for investors in renewable energy projects (Partners for Innovation, 2008). The most recent review of the EEG was in 2014. Solar PV is set to expand with 2.5 GW installed capacity annually, which includes BIPV investments. A large part of the EEG is financed through charges on grid electricity prices.

Furthermore, financial incentives are provided for investment in renewable energy solutions in buildings. Examples are passive houses, as explained earlier, and KfW-houses. Some cities in Germany, such as Frankfurt, require all new houses to have the Passivhaus Standard (Global Buildings Performance Network, 2015). The government-owned KfW bank provides low-interest loans for energy efficient renovations and construction of new buildings (Partners for Innovation, 2008). This happens under the KfW Renewable Energies Programme (*KfW-Programm Erneuerbare Energien*) (IEA & IRENA, 2015). Another support scheme by de KfW bank is the so-called *Energetische Stadtquartiere* that started in 2012. This scheme supports municipalities with financial incentives to implement heating networks, efficiency measures and installation of renewable energy capacity within specific districts (Morris & Pehnt, 2015). Lastly, Germany financially supports the use of batteries to store renewably generated energy for domestic use. This scheme is expected to be in force until at least 2018 (ten Brinck, 2015).

(BI)PV Institutions

An overview of (BI)PV institutions and their responsibilities can be found in Table 3-9.

Table 3-9: Important institutions in Germany that are engaged with (BI)PV.

Institution	Description
Deutsche Energie-Agentur GmbH (dena)	Dena is the German Energy Agency, and supports the energy transition in politics, business and society. Dena focuses on innovative energy systems, energy efficiency and renewable energy. Many sectors are involved, e.g. buildings, transport, electricity, energy generation, consumption and storage. A project that is particularly interesting for the BIPV industry is QUALITRAIN. This EU project focuses on training of the construction sector to work with and implement energy-efficient construction and renewable energy measures, such as PV. This project will run until June 2016 (dena, 2015).
Deutsche Gesellschaft für nachhaltiges Bauen, (DGNB)	DGNB is the German Sustainable Building Council. Members that are associated to the DGNB represent parties in the entire construction and real estate value chain, such as architects, constructors, investors, project developers and researchers. The main aim of the DGNB is to stimulate sustainability in the building sector (Partners for Innovation, 2008).
Bundesverband Solarwirtschaft (BSW) e.V.	BSW is the German Solar Industry Association, and represents the interests of about 1,000 organizations that are active in the solar industry. The association operates between politics, research and consumers and gives solar companies more security to their investments. Therefore, BSW is important of the development of the German solar industry (BSW e.V., 2015).
Fraunhofer-Institut für Solare Energiesysteme (Fraunhofer ISE)	Fraunhofer ISE does extensive research on solar energy systems, which is of global importance. Research is done on PV techniques, energy efficiency improvements and the development of all types of material components. For BIPV specifically, Fraunhofer ISE is running a research and development project together with partners (Fraunhofer ISE, 2015). This could be of significant importance for BIPV implementation in Germany.

Switzerland

General Political Situation

Switzerland is divided in 26 cantons with autonomous governments, overarched by a federal government. The country has a direct democratic system at all governmental levels (IEA, 2012b). Besides a separation of government, parliament and courts of justice, this means that citizens are encouraged to participate in the political process. When a number of citizens (100,000 at the federal level) support a certain proposal, it will be discussed by the parliament and a referendum is organized for the citizens to vote for an alternative plan. This system is not unknown to other democracies, but the frequency by which it is used is rather unique (The Federal Council, 2015).

The Organization for Economic Cooperation and Development (OECD) published a report on key indicators of governmental performance. Almost 80% of the Swiss citizens said to have confidence in their national government (OECD, 2015a). This is the highest trust rate of all OECD countries and emphasizes the stability of the Swiss political system.

Environmental Legislation

Action Plans 2008 for Energy Efficiency and Renewable Energy

In 2008 the Federal Council approved for two action plans to implement the energy policy for Switzerland. These action plans include stimulating measures, regulations and minimum standards.

- Energy efficiency action plan

Between 2010 and 2020, the use of fossil fuels should be reduced by 20% and the increase in electricity consumption is limited to maximum 5% (Bundesamt für Energie BFE, 2008a). This action plan also covers best-practice strategies for energy efficiency in appliances, vehicles and buildings.

Relevant measures for BIPV under this action plan are the renovation of buildings dating back to 1995 and earlier (1), reducing the fossil oil use from 9 L/m^2 to 4.8 L/m^2 (2), the introduction of an energy certificate for buildings to create transparency on the energy consumption (3), and the reduction of legal obstacles and introduction of tax incentives for building renovation (5) (Bundesamt für Energie BFE, 2008a).

- Renewable energy action plan

The share of renewable energy is set to increase to 50% of overall energy consumption (Bundesamt für Energie BFE, 2008b).

Relevant measures for BIPV under this action plan are feed-in tariffs for electricity produced from renewable energy (2), spatial planning and building permits for renewable energy production systems (3), supporting research in the field of renewable energies (5), acceleration of technology transfer by promoting pilot and demonstration plants and information activities for renewable energies (6), and introduction of education and training in the field of renewable energy, in the form of targeted courses, teaching material and support projects (7) (Bundesamt für Energie BFE, 2008b).

CO_2 law

Reduction of CO_2 emissions is regulated in the CO_2 law (Bundesamt für Energie BFE & Bundesamt für Umwelt BAFU, 2015) that came in force in 2000 and was revised in 2013 to cover all GHGs. The goal is to reduce GHG emissions by 20% by 2020 compared to 1990 levels. This equals 10.6 Mt CO_2-eq. Almost half of this reduction, 4.9 Mt CO_2-eq, is to be achieved by the building sector (IEA, 2012b). Financing of these objectives takes place by means of a CO_2 tax (*CO_2-Abgabe*) which is imposed on the use of fossil fuels.

Almost half of the envisioned GHG emission reductions are to be achieved by the building sector

Energy Strategy 2050

In 2011, it was agreed upon that nuclear energy has to be withdrawn from the Swiss energy mix. In order to achieve this, the five existing nuclear power plants have to be decommissioned on a step-by-step basis. 40% of Swiss electricity was provided by nuclear energy (IEA, 2012b). As a result of this, it is necessary to restructure the Swiss energy market to secure sustainable energy supply on the long term. The Energy Strategy 2050 is designed to address these issues. Hydropower capacity is projected to increase, and so is the use of other renewable energy resources. Furthermore, the focus is on energy efficiency potentials in buildings, appliances and transport (Swiss Federal Office of Energy, 2015a), according to the Energy Efficiency Action Plan 2008 (Bundesamt für Energie BFE, 2008a).

Solar energy is part of the renewable energy strategy of Switzerland. In a 2013 report by the *Bundesamt für Energie* (BFE), energy perspectives for 2050 are given for 3 scenarios. Scenario C assumes a situation in which fossil (gas) remains the central energy resource, scenario C&E assumes a combination of fossil and renewable energy, and scenario E assumes that renewables will become the central energy resource and remaining energy gaps are supplemented by electricity import. For these scenarios respectively, the produced electricity from photovoltaics in 2050 is projected to be 5,839; 11,036 and 11,036 GWh_{el}. PV is in all scenarios responsible for about half of the renewable energy production in the country (Bundesamt für Energie BFE, 2013).

About half of the renewable energy production in Switzerland in 2050 is projected to be from PV

(Bundesamt für Energie BFE, 2013)

The Federal Energy Act (*Energiegesetz*) has been revised to include legislation on renewable energies. For PV, the act says that operators with an installed capacity of minimal 10 kW and maximal 30 kW qualify for a feed-in tariff or a direct compensation for the investment (Art. 19). The compensation amounts to a maximum of 30% of the investment costs of a reference system (Art. 29) (Schweizerische Eidgenossenschaft, 2013).

Building requirements

Every canton has its own building law, so Switzerland knows 26 different building laws (Bürgi Nägeli Lawyers, 2015). The building sector is responsible for 40% of the CO_2 emissions in Switzerland (Bundesamt für Energie BFE & Bundesamt für Umwelt BAFU, 2015; IEA, 2012b). One of the programmes under the Energy Efficiency Action Plan (2008) therefore focuses on building refurbishment. In the whole country energy renovation of buildings is supported, however whether renewable energy systems are supported differs per canton (Bundesamt für Energie BFE & Bundesamt für Umwelt BAFU, 2015). For the period 2010-2020 yearly one third of the earnings from the CO_2 tax (300 million CHF) (Bundesamt für Energie BFE & Bundesamt für Umwelt BAFU, 2015), is made available by the Swiss parliament for energy improvement of buildings. By 2012 already 48,000 applications were received (IEA, 2012b). In 2014, a reduction of 3.9 Mt CO_2-eq was established (Bundesamt für Energie BFE & Bundesamt für Umwelt BAFU, 2015).

Switzerland knows a Spatial Planning Act that has been in force since 1979 and was last revised in 2014. Art. 18a specifies that sufficiently adapted PV applications for roofs do not require planning permission (Schweizerischen Eidgenossenschaft, 1979). PV applications are considered to be sufficiently adapted when they are maximum 20cm higher than the roof surface; do not protrude from the roof surface when viewed from the front or from above; are installed according to the state-of-the-art technology; and are connected as a compact area (Schweizerische Bundesrat, 2000). Each individual canton has more specific legislations.

Specifically for BIPV, a new directive was presented in 2014. In order to qualify as BIPV, the PV function must be integrated in the building and at the same time meet an additional function, e.g. weather-proofing or thermal insulation (Schweizerische Bundesamt für Energie BFE, 2014). These dual functions are clearly described in the directive to avoid ambiguity.

Support programmes

PV installations in Switzerland qualify for financial support measures. Most PV investments are for example tax deductible. This means that expenses that are associated with a PV system can be deducted from taxable income streams (IEA PVPS, 2015).

The most important financial support measure however, is yet mentioned under environmental legislation (Schweizerische Eidgenossenschaft, 2013). Distinctions are made between one-off compensations and a (sometimes additional) feed-in tariff. The amount of compensation differs per type of installation, and is specified in Table 3-10. It has to be mentioned that the waiting list for these support measures is very long (IEA PVPS, 2015).

Table 3-10: Compensations for PV installations after October 1st 2015 (EnergieSchweiz, 2015)**. 1 Swiss franc (CHF) = 0.922574413 euro (€) at 24 November 2015.**

Installation type	Financial support options		
PV (< 2kWp)	*No compensation*		
Small BAPV (2 - 9.9 kWp)	*Basic contribution (CHF)*	1,400	Small BAPV installations receive a basic contribution of CHF 1400,- and an additional CHF 500,- for every kWp installed. Surpluses in electricity production can be sold to the grid against a fair market price (on average 0.10 CHF/kWh) (EnergieSchweiz, 2015).
	+ *One-off compensation (CHF/kWp)*	500	
Small BIPV (2 - 9.9 kWp)	*Basic contribution (CHF)*	1,800	Small BIPV installations receive a basic contribution of CHF 1800,- and an additional CHF 600,- for every kWp installed. Surpluses in electricity production can be sold to the grid against a fair market price (on average 0.10 CHF/kWh) (EnergieSchweiz, 2015).
	+ *One-off compensation (CHF/kWp)*	610	
Medium Installation (10 - 29.9 kWp)	*One-off compensation (Einmalvergütung)*		The compensation amounts to maximal 30% of the investment costs of a reference system. As soon as the system is used, the total compensation will be paid.
	or *Feed-in tariff (Kostendeckende Einspeisevergütung, KEV) (CHF/MWh)*	44.53	The feed-in tariff is provided for a period of 20 years and is determined according to performance of reference PV systems. The tariff can be adjusted according to technological progress that is made (Bundesamt für Energie BFE, 2015a). In 2014, the average compensation per MWh produced was 44.35 CHF (Bundesamt für Energie BFE, 2015b).
Large Installation (>30 kWp)	*Feed-in tariff (Kostendeckende Einspeisevergütung, KEV) (CHF/MWh)*	44.53	The feed-in tariff is provided for a period of 20 years and is determined according to performance of reference PV systems. The tariff can be adjusted according to technological progress that is made (Bundesamt für Energie BFE, 2015a). In 2014, the average compensation per MWh produced was 44.35 CHF (Bundesamt für Energie BFE, 2015b). Surpluses in electricity production can be sold to the grid against a fair market price (on average 0.10 CHF/kWh) (EnergieSchweiz, 2015).

(BI)PV Institutions

Switzerland is rich in (BI)PV institutions. An overview of their responsibilities can be found in Table 3-11.

Table 3-11: Important institutions in Switzerland that are engaged in (BI)PV.

Institution	Description
International Energy Agency Photovoltaic Power Systems programme (IEA PVPS)	The IEA PVPS is very important at the international level and is located in Ursen, Switzerland. It is a collaborative research and development agreement, formed by 29 member countries under the International Energy Agency (IEA) (IEA PVPS, 2015). The most recent task, Task 15, is focused on integration of PV in the built environment. Subtasks are designed to develop a BIPV database, BIPV business models, BIPV specifications, environmental assessments of BIPV products and demonstration projects (Ritzen et al., 2014).
Swiss BIPV Competence Centre	The Swiss BIPV Competence Centre is a joint effort of the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) and the Institute for Applied Sustainability to the Built Environment (ISAAC). Together with SwissEnergy, supported by BFE, they aim to provide applied research, training and professional advice in the field of BIPV specifically (Swiss BIPV Competence Centre, 2015). The Swiss BIPV Competence Centre has influence at an international level.
SwisSolar	SwisSolar is the Swiss industry association for all stakeholders that are active in the solar industry, e.g. manufacturers, suppliers, advisors, architects. SwisSolar promotes the interests of its members in the field of politics and at regulatory authorities, supporting the increase of solar energy (Swissolar, 2015).

United Kingdom

General Political Situation

The government of the UK is formed according to a democratic system. The UK government is led by the Prime Minister, currently represented by David Cameron. The rest of the 118 chairs in the Parliament is occupied by the Cabinet and other ministers. The total government is divided in Departments and Agencies, which are ultimately responsible for implementation of the policy (GOV.UK, 2015). (BI)PV is covered by the Department of Energy & Climate Change (DECC), as will be further discussed below.

The Eurobarometer measures annually how residents in the EU view the economy, their government, the society et cetera. In 2015 38% and 37% of the British citizens tend to trust respectively the National Parliament and Government. This is slightly higher than the average EU resident does. Also, the trust in the UK institutions has increased since 2010, when respectively 24% and 26% tended to trust the National Parliament and Government (European Commisson, 2015a).

Environmental legislation

The Department of Energy and Climate Change (DECC) is responsible for the energy and climate change mitigation policy of the British government, including energy security, renewable energy and energy efficiency measures. Energy efficiency of existing buildings is the responsibility of DECC, but the Department for Communities and Local Government (DCLG) is responsible for the energy performance of new buildings (IEA, 2012a).

Climate Change Act 2008

The United Kingdom was the first country worldwide to legislate their goal to reduce GHG emissions in the Climate Change Act in 2008. The act consists of four parts, with the following main goals (UK Parliament, 2008):

- In 2050 there should be at least 80% reduction in GHG emissions relative to the 1990 baseline;
- A carbon budget is set for each period of five years, which cannot be exceeded within this period;
- A Committee on Climate Change is formed, that advises the government on the level of the carbon budgets and reports the progress that has been made and the further progress that is needed to meet the targets;
- The government has to periodically report on the impact that climate change might have and propose programmes for adaptation to climate change.

The act applies to all sectors. Apart from these goals, items on waste reduction schemes, renewable transport fuel obligations et cetera are also covered in the act (UK Parliament, 2008).

Electricity Market Reform (EMR)

As a response to the Climate Change Act, the British government recognised that more influence in the electricity market is necessary to achieve enough clean production capacity for the future. Therefore, the Electricity Market Reform (EMR) entered into force in 2014. The EMR will facilitate the transition towards a new market (Boot, 2015). This would be a more liberalised market with competition among low-carbon electricity generation technologies to produce electricity against the lowest cost. The EMR should therefore be viewed as an interim measure (IEA, 2012a).

A more liberalised electricity market is necessary to achieve enough clean production capacity in the future

(Boot, 2015)

In a progress report the Committee on Climate Change is relatively positive about the EMR. However, they indicate that the strategy after 2020 is currently highly uncertain and this can be a threat for the future functioning of the EMR. Furthermore, they strive for a legal target for the carbon intensity in 2030 of 50 gCO_2/kWh (Committee on Climate Change, 2013).

Building requirements

The quality of the British housing stock is very poor. According to the IEA (2012), an average new dwelling requires about half the energy that existing homes require per square meter. This has to do with the revised building regulations, setting stricter requirements to housing since 2010. By 2016 all new homes have to be carbon-neutral.

The main focus of the UK building policy is on insulation to increase the energy efficiency of buildings. Consumers are supported to take these measures under the Green Deal. This framework enables private firms to recover the investments they make to improve the energy efficiency of their consumers' homes through a charge in instalments on the electricity bill. Furthermore, the energy performance certificate (EPC) scheme of the EU is fully implemented, requiring a rating for every building that is sold, rented or under construction. By 2018 landlords have to make sure their dwellings have at least EPC rating 'E' before they can be rented out (IEA, 2012a).

Support programmes

Contract for Difference (CFD) and Emissions Performance Standard (EPS)

A relevant regulation under the EMR is the contract for difference feed-in tariff (CFD). Producers of clean electricity are guaranteed a fixed price for their energy for the duration of the contract. Since the producers do not depend on volatile wholesale prices, their revenues will be more stable. On the other hand consumers are protected from paying for these potentially higher support costs (Department of Energy & Climate Change, 2015b). Currently, only a CFD is in force for a new nuclear power plant. After 2017 CFDs will be also issued to large-scale renewable energy projects. Technologies that are well covered are nuclear, (off-shore) wind and carbon capture and storage (CCS). For PV projects, uncertainties are still relatively large (Boot, 2015). Another regulation is the emissions performance standard (EPS), setting a maximum amount of CO_2 per kWh that new power plants are allowed to emit. Under the current EPS no new coal power plants can be built due to their emissions being too high, gas power plants are still within the allowed emission range (Boot, 2015). BIPV projects are most likely to small in scale to qualify for these schemes.

Green Deal

As mentioned under Building Requirements, the Green Deal supports consumers to increase the energy efficiency of existing buildings. This can either be in the form of energy saving measures, such as insulation or double glazing, or by renewable energy generation, e.g. heat pumps or solar panels. This framework enables private firms to recover the investments they make to improve the energy efficiency of their consumers' homes through a charge in instalments on the electricity bill (IEA, 2012a). An important requirement for energy performance measures is that they pay for themselves over the lifetime of the Green Deal, therefore advise will be given on which measures are most appropriate for a certain property. This way, households can benefit from their efficiency measures and savings on the electricity bill, without having to make the up-front investment. Furthermore, the Green Deal is bound to the building, so if consumers move to another building the charge will not move with them (DECC, DWP, & DCLG, 2015).

Feed-in Tariffs (FiTs)

The UK has introduced feed-in tariffs (FiTs) to financially support small-scale (<5MW) low-carbon electricity technologies, such as small hydro and wind and solar PV. The programme ensures that payments are made to the renewable electricity generators according to the amount of kWh they generate. Furthermore, unused electricity can be exported to the grid to receive an additional guaranteed tariff (Department of Energy & Climate Change, 2014). In 2011/2012 just over one fifth of the generated electricity was exported to the grid, of which 79% (82,459 MWh) concerned solar PV (Department of Energy & Climate Change, 2013a).

79% of domestically generated electricity that was delivered to the grid in 2011/2012 was from PV

(Department of Energy & Climate Change, 2013a)

Installed PV capacity increased rapidly when the FiT scheme was introduced (Department of Energy & Climate Change, 2014). In 2011/2012 PV installations accounted for 52% (259,198 MWh) of the total electricity generation under the

FiT scheme (Department of Energy & Climate Change, 2013a). However, after a review of the FiT programme at the end of 2012 the tariffs were reduced, which led to a significantly lower rate of increase in new PV installations. The PV tariffs now are reduced every three months, only affecting new entrants of the scheme (Department of Energy & Climate Change, 2014).

For the period April 2014 to March 2015, 69,460 PV installations of 0-4 kW were installed, 2,216 installations of 4-10 kW and 2,375 with a capacity of 10-50 kW. October 30th 2015 the new tariffs for the period 1 January 2016 - 30 March 2016 were published. The middle rate tariffs are respectively 10.83, 9.81 and 9.81 pence per kWh electricity generated and the rate for electricity delivered to the grid is 4.85 pence per kWh, as displayed in Figure 3-7 (ofgem, 2015).

Description	*2015/16*							
	For Eligible Installations with an Eligibility Date on or after 1 April 2015 and before 1 July 2015 *(p/kWh)*		For Eligible Installations with an Eligibility Date on or after 1 July 2015 and before 1 October 2015 *(p/kWh)*		For Eligible Installations with an Eligibility Date on or after 1 October 2015 and before 1 January 2016 *(p/kWh)*		For Eligible Installations with an Eligibility Date on or after 1 January 2016 and before 1 April 2016 *(p/kWh)*	
Solar photovoltaic with Total Installed Capacity of 4kW or less, where attached to or wired to provide electricity to a new building before first occupation	Higher rate	13.39	Higher rate	12.92	Higher rate	12.47	Higher rate	12.03
	Middle rate	12.05	Middle rate	11.63	Middle rate	11.22	Middle rate	10.83
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic with Total Installed Capacity of 4kW or less, where attached to or wired to provide electricity to a building which is already occupied	Higher rate	13.39	Higher rate	12.92	Higher rate	12.47	Higher rate	12.03
	Middle rate	12.05	Middle rate	11.63	Middle rate	11.22	Middle rate	10.83
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 4kW but not exceeding 10kW	Higher rate	12.13	Higher rate	11.71	Higher rate	11.30	Higher rate	10.90
	Middle rate	10.92	Middle rate	10.54	Middle rate	10.17	Middle rate	9.81
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 10kW but not exceeding 50kW	Higher rate	11.71	Higher rate	11.71	Higher rate	11.30	Higher rate	10.90*
	Middle rate	10.54	Middle rate	10.54	Middle rate	10.17	Middle rate	9.81*
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 50kW but not exceeding 100kW	Higher rate	9.98	Higher rate	9.63	Higher rate	9.63	Higher rate	9.29
	Middle rate	8.98	Middle rate	8.67	Middle rate	8.67	Middle rate	8.36
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 100kW but not exceeding 150kW	Higher rate	9.98	Higher rate	9.63	Higher rate	9.63	Higher rate	9.29
	Middle rate	8.98	Middle rate	8.67	Middle rate	8.67	Middle rate	8.36
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 150kW but not exceeding 250kW	Higher rate	9.54	Higher rate	9.21	Higher rate	9.21	Higher rate	8.89
	Middle rate	8.59	Middle rate	8.29	Middle rate	8.29	Middle rate	8.00
	Lower rate	6.16	Lower rate	5.94	Lower rate	5.94	Lower rate	5.73
Solar photovoltaic (other than stand-alone) with Total Installed Capacity greater than 250kW	6.16		5.94		5.94		5.73	
Stand-alone	6.16		4.44		4.28		3.08	
Export Tariff	4.85		4.85		4.85		4.85	

Figure 3-7: Feed-in tariff (FiT) payment rate table in pence per kWh for photovoltaic eligible installations (1 January 2016 - 31 March 2016) (ofgem, 2015)**. At January 26th 2016, 1 British Pound equalled 1.31532 Euros.**

(BI)PV Institutions

An overview of (BI)PV institutions can be found in Table 3-12.

Table 3-12: Important institutions in the UK that are engaged in (BI)PV.

Institution	Description
Energy UK	Energy UK is the trade association of the UK energy sector. The association represents suppliers of oil and gas, as well as renewable and nuclear energy sources and provides them with advice (UK, 2015).
Solar Trade Association (STA)	The Solar Trade Association (STA) represents practitioners of PV applications in the UK. Their goal is to empower the solar transformation in the country by participating in policy developments and conveying the appropriate message in the media (STA, 2015).
SISER	SISER is the Scottish solar research institute. BIPV is one of their focus areas. Current research is done on the range in forms and colours of BIPV products (SISER, 2015).

4. DISCUSSION AND RECOMMENDATIONS

INTERNAL AND EXTERNAL EVALUATION OF COUNTRY INFORMATION

4.1 External analysis

Which focus countries show interesting opportunities for Dutch BIPV companies?

The first part of the analysis of the results is a comparative review between the focus countries. Based on the outcomes of the Stakeholder and DESTEP analyses, fifteen criteria have been identified that potentially influence the implementation potential of BIPV. This serves as a basis to compare the different countries by means of a multicriteria analysis (MCA). The scoring of the focus countries on these criteria is presented in *Appendix C.I*. The weighting of the criteria is determined through a survey among eighteen stakeholders in the BIPV industry, as shown in *Appendix C.II*.

Table 4-1: Criteria for MCA of focus countries

#	Criteria	Reference DESTEP-analysis
1.	Large amount of established BIPV companies, indicating a flourishing but high entry market	Section *3.1 Stakeholder inventory and interests*
2.	Availability of (BI)PV research centre(s), indicating research potential and knowledge transfer	Section *3.1 Stakeholder inventory and interests*
3.	Low unemployment rate, indicating a more stable economy	Section *3.2.1 Demographic factors*
4.	High share of homeowners vs. renters, indicating a larger potential market	Section *3.2.1 Demographic factors*
5.	Large established PV capacity per capita, indicating interest in PV but at the same time a possibly high entry market	Section *3.2.1 Demographic factors*
6.	Large amount of solar radiation	Section *3.2.2 Ecological factors*
7.	High level of environmental concern, indicating willingness to implement environmental friendly measures	Section *3.2.3 Socio-cultural factors*
8.	High share of expenditures to Energy & Housing, indicating willingness to reduce the electricity bill	Section *3.2.3 Socio-cultural factors*
9.	Economic welfare	Section *3.2.5 Economic factors*
10.	Flourishing housing market	Section *3.2.5 Economic factors*
11.	Part of Eurozone (EMU), indicating no risk of losses due to currency changes	Section *3.2.5 Economic factors*
12.	High degree of trust in government, indicating a politically stable environment	Section *3.2.6 Political-legal factors*
13.	Clear renewable energy strategy and targets	Section *3.2.6 Political-legal factors*
14.	Clear policy on energy performance of buildings	Section *3.2.6 Political-legal factors*
15.	Availability of feed-in tariff schemes (or other specific financial support)	Section *3.2.6 Political-legal factors*

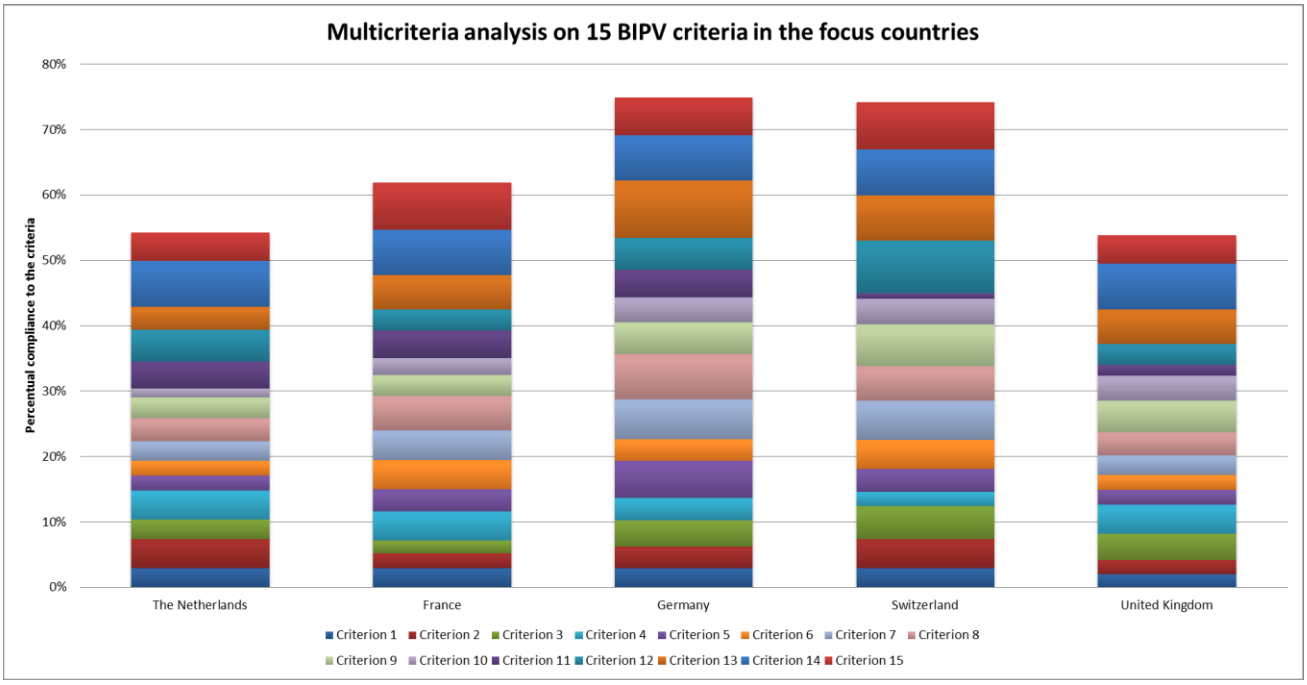

Figure 4-1: MCA of the focus countries, providing a quantitative comparison of their relative compliance to 15 criteria that possibly influence BIPV implementation.

The outcomes of the MCA are presented in Figure 4-1, showing the results when weighting is applied. Germany and Switzerland score best when it comes to opportunities for Dutch BIPV companies, with respectively 75% and 74%. The United Kingdom and the Netherlands score the lowest, i.e. 54%. France is in the middle with 62%. When no weighting would be applied Germany scores best, with 75%, closely followed by Switzerland with 72%. The United Kingdom then has the lowest score, i.e. 53%. The Netherlands and France respectively score 56% and 63%.

Stakeholder criteria (1 and 2), show the main differences for the availability of research centres for BIPV. Demographic criteria (3,4 and 5) show little difference between the focus countries. Germany has a significantly higher established PV capacity per capita, indicating interest in the technology. In Switzerland the unemployment rate is considerably higher than in the other focus countries, indicating a more stable economy. Low influence can be seen from the ecological factor for large amount of solar radiation (Criterion 6). This is expected to be of minor importance compared to the efficiency and orientation of PV applications. Socio-cultural criteria (7 and 8) show average to high influence on the attractiveness of a country to implement BIPV. Especially criterion 8, high share of expenditures to energy and housing, is weighted with 2.48 out of 3. This indicates a willingness to reduce the electricity bill by potentially using BIPV. The impact of economic criteria (9, 10 and 11) is minor to average. Criterion 11, relating to differences in currency, was weighted as the least important, i.e. 1.19 out of 3. The fact that Switzerland and the United Kingdom do not have the Euro as a currency, is therefore not regarded as a potential threat. The highest weighting was given to political-legal criteria 13 and 14, relating to the renewable energy and building performance strategy of countries, i.e. 2.48 out of 3. Commonalities between the ecosystems of the focus countries stem from the fact that they all have to comply with the same EU directives. Therefore, the basis of their building performance and renewable energy strategies are similar. However, the way each country has interpreted and translated these directives into a national strategy differs, as is clear from section *3.2.6 Political-legal factors*.

4.2 Internal analysis

What can the Netherlands learn from the situation in the focus countries?

The second part of the analysis of the results is aimed at identifying lessons and recommendations for the Dutch BIPV ecosystem. The developments in the BIPV market are dependent on market drivers and market restraints. Market drivers that are applicable to PV in general are the rising energy demand, the increasing costs of fossil fuels, the increasing need to differentiate the energy mix to enhance security of supply, the increasing environmental concerns about conventional energy, and government subsidies and financial incentives. Examples of market restraints are the high reliance on government subsidies and incentives, relatively high PV electricity costs and high administrative barriers in some countries (Ferrara et al., 2012).

Berenschot (2015) has presented a Roadmap for BIPV that evaluates the market drivers and restraints for the Netherlands. This roadmap has identified eleven challenges in the field of technology, market and ecosystem to achieve a 5% BIPV share of total PV capacity in the Netherlands by 2020. These challenges are summarized in Figure 4-2.

For BIPV specifically, it was found throughout this research that market drivers could be found in the perceived aesthetic benefits of BIPV and the need for energy efficiency and renewables in the built environment to achieve nZEB. Market restraints however are the higher costs compared to regular PV, low awareness of the public, the government and the construction industry, the limited collaboration between the PV- and construction industry, and the compatibility with existing buildings and building practices. This section proposes ways to deal with these challenges, by assessing how other countries act upon them. This is based on the information that was acquired in the Stakeholder- and DESTEP analysis and some additional sources.

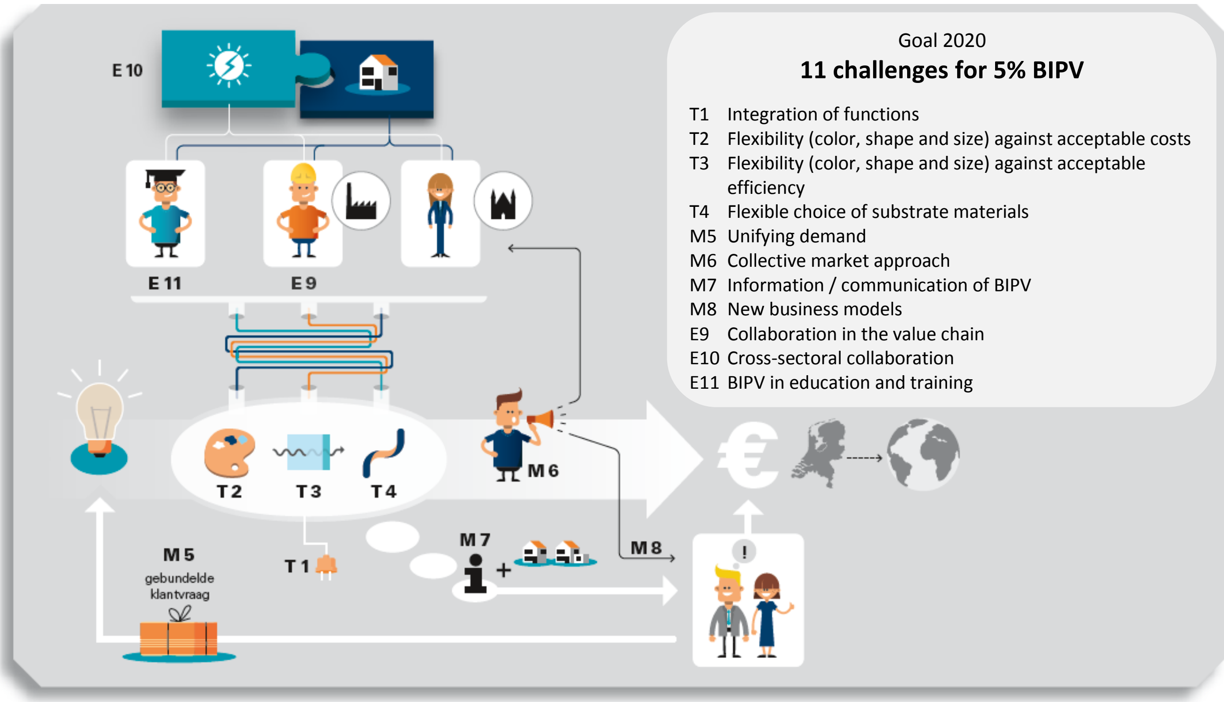

Figure 4-2: Visualization of 11 challenges for BIPV technology (T), market (M) and ecosystem (E) to achieve a 5% BIPV share of total PV capacity in the Netherlands by 2020. Adapted from (Berenschot, 2015)**.**

(T1) Integration of functions; (T2) Flexibility (color, shape and size) against acceptable costs; (T3) Flexibility (color, shape and size) against acceptable efficiency; (T4) Flexible choice of substrate materials

The technical challenges have not been addressed for BIPV specifically throughout this research. This would be a study in itself. Therefore the first four challenges are discussed together, by focussing on general technological trends that have been identified in the DESTEP analysis.

The technological challenges have to ensure the compatibility of BIPV with existing buildings and building practices. This not only by complying with the aesthetics and materials of components that are used in the built environment, but also with the costs of these components. At the moment, BIPV is still found to be too expensive for mass-market adoption. Therefore, a major challenge is to simplify the process of integration in order to be able to upscale production to factory-based installation and reduce the costs per unit. Technological trends that were identified are further automation of processes and digitalization of information (NCOI, 2015), causing increased flexibility and shorter lead times. These trends can positively affect the development of BIPV production lines. Another technological trend can be found in digitally connected customers and interconnection of appliances (Deloitte, 2015; NCOI, 2015), which enables data exchange. This provides the possibility to flexibly use BIPV systems to for example match electricity production and demand.

A technical aspect that involves the design of the BIPV modules within the building, is shading due to trees, other buildings or the building itself. This lowers the potential electricity production, meaning that BIPV is possibly not suitable for use at all sides of a building (Ikedi, Okoroh, Dean, & Omer, 2010). Other than that, the mode of installation can highly influence the performance of BIPV modules, for example when considering the degree and mode of ventilation under the roof (Ikedi et al., 2010). These two aspects that can lower the performance of BIPV should be subject to certification, as is currently being developed at the European level by the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardization (CENELEC) (European Committee for Electrotechnical Standardization, 2015; International Electrotechnical Commission, 2015).

Technological Recommendations and responsible stakeholders	
R1	More coordinated research and development.
	Research institutes from all countries, including: Fraunhofer ISE, SEAC, SISER, Swiss BIPV Competence Centre.
R2	Develop BIPV modules in compliance with the aesthetics and materials of building components.
	BIPV industry: manufacturers and suppliers together with research institutes, architects and contractors
R3	Adopt further automation of processes and digitalization of information.
	BIPV industry: manufacturers and suppliers together with research institutes
R4	Development of general standardization and certification for BIPV.
	IEC and CENELEC, together with EU and national governments and industry associations

(M5) Unifying demand

When looking at the demand side for BIPV, the building industry is the primary customer. This can relate to both private and commercial buildings. The application does not differ much between the two, the main differences can be found in the size of the projects (Ikedi et al., 2010). To be able to offer a comprehensive selection of BIPV products, it is important that the expectations from the market side are aligned. Berenschot (2015) proposes to yearly monitor the market demand and give stakeholders the possibility to indicate what they find important, in order to achieve this.

BIPV components need to follow the characteristics of the building market, to meet the wishes of its primary customer. A very important development to facilitate this, is the incorporation of a globally, or at least Europe-wide, accepted definition of BIPV. In section *1.1 BIPV Definitions*, definitions were provided for each country, showing some differences in the perception of BIPV between the focus countries. IEA PVPS is in the process of developing a definition for BIPV that is applicable in the associated countries (Van Horrik, 2015), which will be similar to the definition used in this study. This will facilitate adoption of BIPV as perceptions become more unified.

Unifying demand Recommendations and responsible stakeholders	
R5	BIPV components should follow characteristics of building market.
	BIPV industry: manufacturers and suppliers together with research institutes
R6	Develop one definition for BIPV
	IEA PVPS together with manufacturers, suppliers, architects, contractors

(M6) Collective market approach; and (E9) Collaboration in the value chain

Since BIPV is a niche market within the PV industry, more can be achieved if stakeholders collaborate, most ideally in an international context. Referring to the stakeholder analysis in section *3.1*, this is particularly interesting for research institutes and BIPV manufacturers and suppliers. Research institutes can collaborate through knowledge transfer, creating an open environment in which technological developments can take place faster. BIPV manufacturers and suppliers can be complementary to each other, regarding the different types of BIPV products that exist.

In section *3.2.6 Political-legal factors*, governmental schemes for the Netherlands were discussed that support collaboration of SME companies, e.g. Starters International Business, Innovatie-PrestatieContracten and Partners for International Business (IPC, 2015; RVO, 2015c).

Collective market approach Recommendations and responsible stakeholders	
R7	Develop industry association specifically for BIPV
	Existing PV industry associations, including SolarPower Europe, the European Photovoltaic Technology Platform (EU PV TP), the Swiss BIPV competence centre and SISER
R8	Bring BIPV stakeholders together to find complementary products and activities, and collectively prepare market approaches
	Manufacturers and suppliers

(M7) Information / communication of BIPV

In order to increase awareness on BIPV, communication is important. Apart from informing stakeholders in the BIPV value chain, communication should be aimed at the public, government and construction industry. Lack of knowledge is one of the largest barriers for BIPV implementation. For the public, information should be easily accessible and understandable. Homeowners need to be able to make well-informed decisions and have to have knowledge of the advantages of BIPV. For the government, information is important in their decisions to design specific incentive schemes and relevant building policies. In Switzerland and France, the government even provides BIPV-specific subsidies. Specifically for the construction industry (e.g. building advisors, architects and contractors), it is important that BIPV components are priced in €/m^2 instead of in €/Wp (BIPV SME Workshops, 2015). BIPV components may be expensive compared to regular building components, but they generate electricity. This reduces the total energy consumption of a building and therefore the initial investment will ultimately be earned back (Ikedi et al., 2010)

Information/communication of BIPV Recommendations and responsible stakeholders	
R9	Price BIPV components in €/m^2 instead of in €/Wp
	BIPV suppliers, wholesale, construction industry
R10	Clear communication on advantages and possibilities of BIPV to public, government and construction industry
	Industry associations, and manufacturers and suppliers

(M8) New business models

This study has not addressed the development of new business models specifically for BIPV. This challenge was however deservedly identified by Berenschot (2015), as the lack of a suitable business model is a main barrier for many (BIPV) companies. Current business models are highly dependent on governmental support schemes. It would however be more sustainable to develop independent business models. Batey (2011) has identified a few potential alterations to regular business models. Figure 4-3 visualizes the old business model, as well as the new proposed joint-venture business model. Batey (2011) pledges for factory-based integration, by collaboration between the PV- and building element manufacturer. When electrical connections are included in the BIPV unit, no specialized PV installer is required to connect this to the building (Batey, 2011). Such integrations can be a relatively simple answer to gaining sustainable new business models.

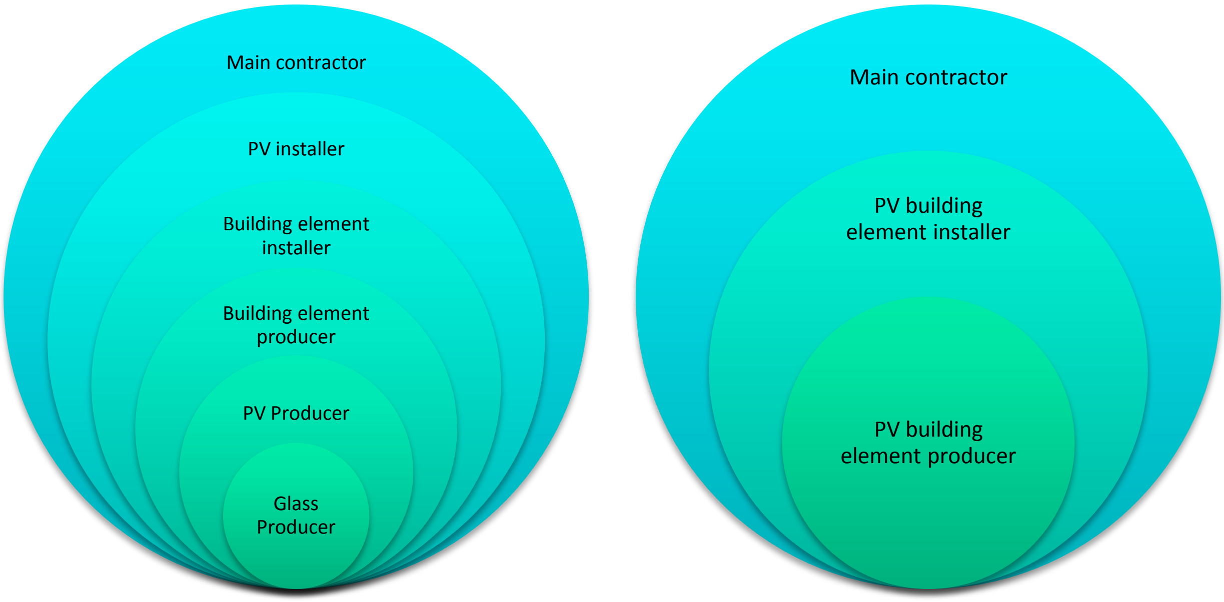

Figure 4-3: Old BIPV business model (left) and proposed new BIPV business model, showing collaboration between the parties in the form of joint-ventures (right). Adapted from (Batey, 2011)**.**

Huijben (2015) has done extensive research on suitable business models for PV under various regimes. Three types of business models were identified; customer-owned, community shares and third party PV (Huijben, 2015). In the first case, homeowners or companies own a PV-system, the second model has multiple owners of one PV-system that is installed on e.g. a public building, in the latter case PV is installed on the roof or property of a third party.

Several domains for further research on business models can be recommended:

New Business Models Recommendations and responsible stakeholders	
R11	Business models for optimal functioning under the current regime
	BIPV manufacturers and suppliers, construction industry
R12	Business models for a situation without subsidies or other forms of governmental support
	BIPV manufacturers and suppliers, construction industry
R13	Business models for self-sustainable houses with 100% renewable energy generation, both with and without deployment of a battery to store overproduced electricity for later use.
	BIPV manufacturers and suppliers, construction industry

(E10) Cross-sectoral collaboration

In all focus countries, building policies are developing towards nZEB. These are very efficient buildings that are highly insulated. They produce at least as much energy as they consume. Energy production should be renewable, so (BI)PV is a suitable technology that is already used to achieve this.

However, the construction industry views ‘integration’ often more as a problem than an advantage, which makes collaboration between the PV and construction industry difficult. At the moment, this can be seen as one of the most critical barriers for large-scale BIPV implementation. The planning and installation is a considerable cost factor. To improve this perception, the advantages for building performance and the related offset costs need to be understood. This was already mentioned in R10, regarding information/communication of BIPV. Collaboration between the PV and construction industry involves various stakeholders. As mentioned in section *3.1 Stakeholder Analysis*, architects are important to incorporate BIPV already in the design phase of buildings. Contractors need to be aware of the added value of BIPV, in order to have it implemented during the construction of a building. Lastly, building advisors play an important role in introducing BIPV, especially for utility buildings.

In order to prove the added value of BIPV to the construction industry, simplifying the process of integration is necessary, for example by introducing factory-based installation. This will facilitate collaboration between the industries.

Cross-sectoral collaboration Recommendations and responsible stakeholders	
R9+ R10	Make sure construction industry understands the added value of BIPV
	BIPV manufacturers and suppliers, industry associations, research institutes and construction industry
R14	Simplify integration process (e.g. by factory-based installation
	BIPV manufacturers and suppliers, construction industry

(E11) BIPV in education and training

The last challenge that Berenschot (2015) has identified is the incorporation of BIPV in education and training programmes. If architects, contractors and craftsmen were educated on the potential advantages of BIPV at an early stage, this would automatically solve the problem of unawareness in the construction industry. In order to achieve this, BIPV companies, research institutes, universities and construction training programmes need to closely collaborate.

This study identified some relevant examples of progress that is currently made. The Photovoltaic Technology Platform is developing a strategy and an implementation plan at the EU-level, for among others education in photovoltaics (Photovoltaic Technology Platform, 2015). Furthermore, Switzerland has incorporated the goal to introduce education and training in the field of renewable energy, in the form of targeted courses, teaching material and support projects in their renewable energy action plan (Bundesamt für Energie BFE, 2008b). To conclude, two practical examples. Firstly, Utrecht University has started an Erasmus+ project, together with institutions from Austria, Germany and Cyprus, to develop an innovative and multidisciplinary, high quality course for BIPV at the University of Cyprus (Van Sark et al., 2015). Secondly, the EU project QUALITRAIN focuses on training of the construction sector to work with and implement energy-efficient construction and renewable energy measures, such as PV (dena, 2015).

BIPV in education and training Recommendations and responsible stakeholders	
R15	Adopt education and training on (BI)PV in the renewable energy action plan and make financing available to establish this at all stakeholder levels
	Government, research institutes, universities and BIPV companies

(12) Governmental support for BIPV

Support for BIPV through governmental subsidies and incentives highly differs per focus country, and is therefore added as an extra challenge. Environmental legislation and building requirements are found to be similar, as all countries have the Energy Performance of Buildings Directive (EPBD) in common. This offers the unique opportunity to incorporate renewable energy technologies, such as BIPV, into buildings. However, it differs per country how the objectives of the EPBD are to be achieved. Only recently, it was recognized for the Netherlands that energy savings in the industry and energy performance of buildings need improvement in order to achieve the 2020 targets of the Energy Agreement (NOS, 2015).

In section *3.2.6 Political-legal factors*, a wide range of support and/or incentive programmes was identified for entrepreneurs and companies in the Netherlands, including iDEEGO, SDE+, Green Deals, MIA, Vamil and EIA. Green Deals can also be issued by private home-owners. For the rental sector, the STEP regulation exists to improve the energy performance of buildings (RVO, 2015e). Other, often specific, support programmes exist at the municipality level.

Different types of legislation and support were found in the other focus countries. First of all, France and Switzerland make a clear distinction between regular PV and BIPV in their legislation. This way, the advantages of BIPV are clearly stated and acknowledged. Secondly, all focus countries except for the Netherlands provide feed-in tariffs for solar energy. The Netherlands uses net metering. In France, a specific feed-in tariff exists for BIPV systems, providing a higher compensation per kWh. In Switzerland the basic contribution and the compensation per kWp installed are higher for BIPV systems. In the Netherlands, Germany and the UK, the subsidy schemes do not reflect the higher cost for BIPV. For solar energy in general, however, the British and German feed-in tariffs are clearly regulated, which also stimulates BIPV. Thirdly, the use of batteries to store renewably generated energy for domestic use is financially supported in Germany. This can stimulate households to become more and more self-sufficient, among others by using BIPV.

A general remark that can be made from the findings in this research, is the urge to harmonise building codes with the current developments in the field of domestic energy generation. (BI)PV is often not allowed on existing buildings, since it is perceived not to comply with architectural or cultural features. Therefore, permission is needed to alter or extend the building. BIPV provides the unique opportunity of integrating the electricity producing function aesthetically into the building. Most of the Dutch municipalities have a Design Review Committee, a body unique to the Netherlands that should be aware of the advantages of BIPV in the built environment when issuing these permits.

Lastly, some general recommendations can be made on the role the government can play in BIPV implementation. When projects turn out to be successful, this can reinforce political commitment. Therefore, the positive impacts on the energy behaviour of consumers or developments in the local economy need to be identified and communicated to decision makers. On the other hand, especially on the municipal level successful projects will stimulate other community members to do the same. The (local) government can play an important role in facilitating this.

Governmental support for BIPV Recommendations and responsible stakeholders	
R16	Make a clear distinction between regular PV and BIPV in legislation
	Government
R17	Provide a subsidy scheme that reflects the higher cost of BIPV systems
	Government
R18	Harmonise building codes with energy performance requirements and aesthetics
	Government
R19	Communication to and by (local) governments about successful community projects
	Government + society

4.3 General Discussion

This research focused on the Netherlands and four additional focus countries, i.e. Germany, France, Switzerland and the United Kingdom. This has provided many insights, however for a more complete image of the international situation for BIPV, additional research on other countries would be valuable. This study therefore mainly serves as a starting point.

The stakeholder analysis provides a rather complete overview of the parties that are involved in BIPV at the academic, industrial and governmental level at the time of writing. However, since BIPV is a rapidly changing market, it has to be acknowledged that this situation is subject to change as well. Shifting regulatory regimes highly influence the composition of the market and its active stakeholders. This has to be kept in mind when using this information. Furthermore, some information for the stakeholder analysis could not be easily acquired from literature, mainly information regarding the role or architects and contractors in the focus countries. In these cases, a combination of literature and expert opinions from various parties has been used. This could have led to subjective results. However, due to limited time and resources this was the best solution to address this discrepancy.

The DESTEP analysis provides an extensive overview of the recent dynamics in the demographic, ecological, socio-cultural, technological, economic and political-legal factors of the focus countries. In reality, many more parameters play a role in these factors, some more relevant than others. For the purposes of this report however, it can be said that the reviewed parameters are sufficient. If parties are interested to expand their business activities to one of the focus countries, it is recommended to conduct a more in-depth research on the DESTEP factors.

Due to limited time and resources, policy measures have been reviewed mainly at the federal level. For all renewable energy measures, including BIPV, it is expected that regulations at the regional or even municipal level are abundant and can be influential. Especially since many countries are subdivided in smaller regulatory provinces, further detailed research on such more locally oriented incentive schemes is recommended to parties who are interested to start business activities.

Lastly, a few things can be pointed out on the MCA. First of all, the number of respondents to the online survey was 21. More respondents would have led to more reliable results with less noise. However the opinions of respondents appeared to be relatively in line, so this is not expected to negatively impact the results. Secondly, the relative scoring of the focus countries on the fifteen criteria has been done based on qualitative information gathered throughout the research. This could have led to subjective scores, potentially influencing the outcomes of the MCA. Finally, the MCA showed that energy policy and building performance policy are main drivers for BIPV implementation. This study also identified the need for new innovative business models for BIPV, to provide the possibility to survive as an individual industry, without governmental support or mandatory regimes. If these business models find their way in the near future, this would alter the criteria that business developers regard as important and therefore change the outcomes of this analysis.

5. CONCLUSION

This research has continued on the roadmap for BIPV, published by Berenschot (2015), by placing the outcomes in an international context. The purpose of this research was twofold, to assess which countries show interesting opportunities for Dutch BIPV companies and to determine what the Netherlands can learn from the situation for BIPV in other countries. Apart from the Netherlands, the focus countries that were studied in this research are France, Germany, Switzerland and the United Kingdom. For these countries the existing BIPV stakeholders, the BIPV ecosystem and policy and legislation for BIPV were thoroughly reviewed.

Based on the fifteen criteria that were weighted by the preferences of Dutch BIPV stakeholders and evaluated for the focus countries in the MCA, Switzerland and Germany show the most interesting opportunities for Dutch BIPV companies. Main drivers in this are their clear renewable energy targets and strategies. Both countries offer interesting support schemes for PV, Switzerland even provides legislation and incentive schemes specifically for BIPV. Companies indicated that political stability and a high level of trust in the government could be an important factor, on which Switzerland worldwide scores very high. Also, the level of environmental concern in society appears to be higher in both Switzerland and Germany, bringing opportunities for BIPV implementation. It has to be stated that this research merely provides an insight based on limited selection criteria on which the alternatives were scored relative to each other. Individual companies will need to reflect on their personal values and assets, which could lead to different outcomes. The information delivered throughout this report can provide guidance in this.

In addition, the situation for BIPV in the Netherlands was compared to the other focus countries. The Netherlands was found to stand out in the following points:

- Interesting support schemes are provided to stimulate SME companies to collaborate in the field of innovation, sustainability and renewable energy, e.g. IPC, SIB and PIB.
- All homes require an energy label and this information is openly accessible.
- Most municipalities have a Design Review Committee (*Federatie Ruimtelijke Kwaliteit*), showing that aesthetics in the built environment is valued high.
- The Dutch research institutes (SEAC, Solliance and Hogeschool Zuyd) conduct valuable research on BIPV, making pioneering at an international level possible.

The main lessons for the (Dutch) BIPV sector that can be drawn from the comparative review are summarized in Table 5-1. Some of these have an international character. The recommendations are clustered according to the Triple Helix to provide information on the main responsible parties.

Table 5-1: Lessons and recommendations for the (Dutch) BIPV sector

Responsible parties	Lessons and recommendations	Reference section 4.2
	Government	
European and national governments	Governmental regulations and financial incentive schemes need to provide security for the future, and reflect the higher cost of BIPV systems compared to regular PV. Harmonisation of building codes with energy performance requirements and aesthetics is necessary for BIPV to gain ground.	R17, R18
CENELEC and IEC, EU and national governments	General standardization and certification for BIPV needs to be developed, as well as a generally accepted definition. Legislation needs to provide a clear distinction from PV.	R4, R6, R16

Industry		
Manufacturers, suppliers and construction industry	Given the shifting regulatory regimes, business models are required that survive without the need of subsidies or that optimally capture subsidies offered in the current regime.	R11, 12, 13
Suppliers, wholesale, construction industry, architects	BIPV needs to follow requirements and developments in the construction sector. This means among others that prices should be expressed per m^2 and not per Wp, aesthetics and materials comply with current standards and the added value of BIPV is understood.	R2, R5, R9
Manufacturers, construction industry	In manufacturing, further automation of processes and digitalization of information needs to be adopted. This should simplify the integration process.	R3, R14
Existing PV industry associations, BIPV industry	An industry association specifically for BIPV needs to be developed at an international level, bringing together BIPV stakeholders to find complementary products and activities and collectively prepare market approaches.	R7, R8
Manufacturers, suppliers, media	The advantages and possibilities of BIPV and outcomes of projects need to be clearly communicated to the public, the government and the construction industry.	R10, R19
Academia		
Universities; educational institutions	Education specifically for BIPV needs to be provided at all stakeholder levels, e.g. construction, design and technological development.	R15
Research institutes	Internationally coordinated research and development is already happening, but knowledge sharing remains important in this new and dynamic sector.	R1

The information that was provided throughout this research and the conclusions that were drawn should be taken into account by the government, academia and the BIPV industry when further designing the BIPV (export) strategy for the Netherlands. It has become clear that the BIPV sector crosses national boundaries, and should therefore be reviewed and developed from an international perspective.

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7. APPENDIXES

A. Business and Innovation Theories

I. *Stakeholder analysis*

A stakeholder analysis identifies and maps all groups that have a certain interest in an organization or sector. This serves to gain insight in potential collaborations between partners, stakeholders that participate in the decision-making process and stakeholders that do not have an active role but do influence the progress of the project. This way, already at an early stage it can be determined to what extent which stakeholders should be involved in the project. A distinction is usually made between stakeholders that will participate in the project as a partner (primary) and stakeholders that only play a passive role (secondary and tertiary) (RVO, n.d.).

A stakeholder analysis gives an organization or sector insight in (Berenschot, 2012):

- Which stakeholders play a dominant role (what is their interest, priority and power);
- What the drivers are for the various stakeholders in their relation with the organization or sector;
- How the various stakeholders are related to each other;
- Which stakeholders and interests (should) influence the decision-making process.

II. *DESTEP-model*

A DESTEP (demographic, ecological, socio-cultural, technological, economic and political-legal)-analysis provides insight in the most important impacts that are present in the direct environment of an organization or sector. These impacts are divided into the categories: demographic, ecological, socio-cultural, technological, economic and political-legal. The model focuses on the current situation as well as on the long term. DESTEP is a qualitative analysis, but, where possible, it is important to quantify developments and to use facts as a basis. This will give an idea of the environment an organization or sector is operating in and what developments, trends and uncertainties it faces. Every organization or sector will focus on different aspects, as will show from the analysis (Berenschot, 2012; Marketingmodellen.com, 2015).

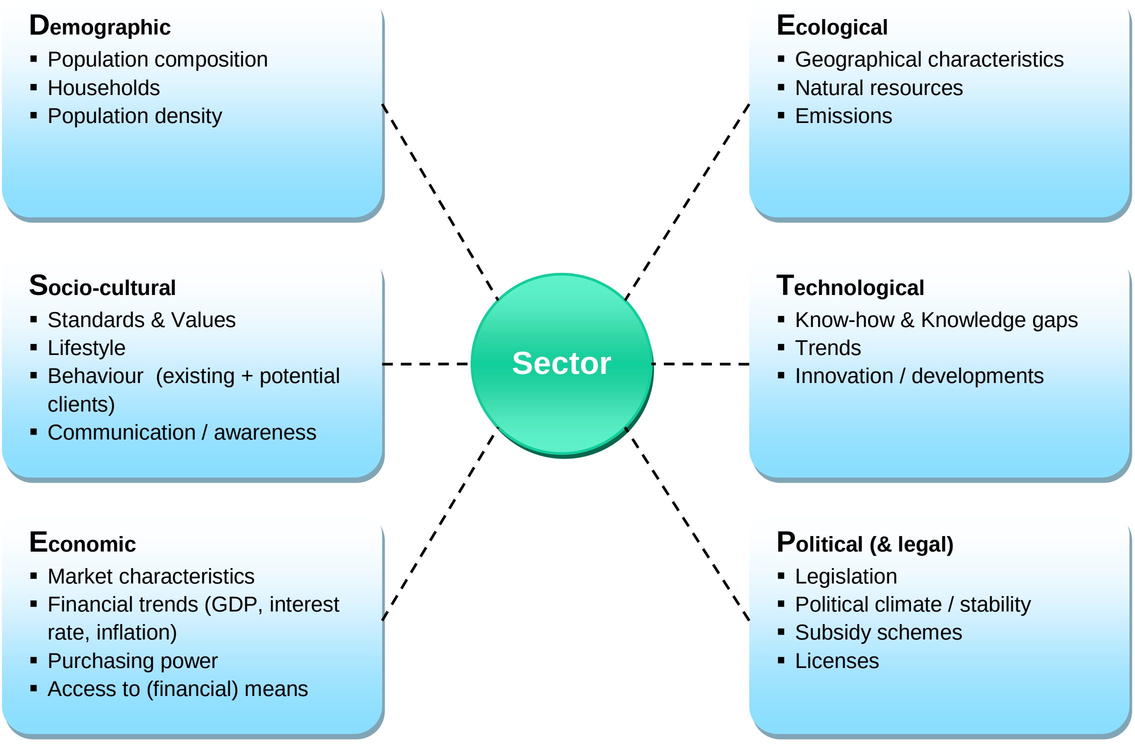

Figure 7-1: Examples of impact factors for each category in the DESTEP-model that can influence the decision-making process.

The DESTEP-analysis will contribute to the identification of all processes and developments that take place within a specific ecosystem. To further analyse the processes and stakeholders that are active within an ecosystem, a Stakeholder analysis may provide a solution.

III. *Multicriteria analysis*

Multicriteria analysis (MCA) is used to determine general preferences among alternatives. Desirable objectives are specified as qualitative criteria. The measurement is then based on a quantitative analysis of these criteria, through scoring, ranking and weighting of qualitative impact. The results are not absolute, but relative within the analysis. MCA provides the possibility to compare different qualitative outcomes in a quantitative manner (UNFCCC, 2014).

An MCA is of particular interest for decision-making and benchmarking based on non-monetary values, such as social, political, cultural and environmental criteria. These criteria can be weighted to show their relative impact on the results. Since this weighting can be subjective, it has to be done carefully and backed up by sufficient information.

B. Detailed discussion of DESTEP-factors

I. Demographic factors

The Netherlands

The population of the Netherlands is expected to grow with about 0.4% a year until 2020. The yearly relative population growth has been continuously declining over the last decade (CBS, 2015). The average household in the Netherlands consists of only 2.18 people and the number of single households is projected to increase (Ministerie van Binnenlandse Zaken, 2015b). In the upcoming ten years 500,000 new households are expected to be formed (ING Economisch Bureau, 2015). This does not directly imply more households where BIPV could be implemented, since a large part most likely concerns single person apartments. 67% of the households concern homeowners (Statista, 2015). Furthermore, from the table it can be seen that the population density is the highest in the Netherlands. The share of built area in the land area is significantly high, resulting in limited availability of land for wind or solar parks. Applying renewable electricity generation capacity on houses in the form of BIPV is therefore an interesting opportunity.

At the moment the unemployment rate is relatively high as a consequence of the economic crisis. Forecasts however show that more jobs will become available in the upcoming years and unemployment will consequently decrease (UWV, 2015). This positively affects the economy and therewith increases the amount of people that will buy a house rather than renting one. In general the potential of investments in renewable energy solutions for housing, including BIPV, will also increase.

In 2011, the Netherlands counted 166,614 houses with planning or renovation permission that were in the construction phase (CBS, 2012). Although this number might not be as recent, it does indicate that the construction sector is active.

France

The French population growth was 0.4% in 2014. This percentage has been relatively stable over the last five years (World Bank, 2015). The average household counts 2.2 persons. The homeownership rate of French households is about 65% (Statista, 2015), with over 80% having a long-term housing loan (INED, 2015). In 2010, the average age to buy a home in France was 37 (INED, 2015).

The unemployment rate in France is the highest of the focus countries, i.e. 10.3% (Eurostat, 2015a). This figure has been increasing over the past five years, whereas in other OECD countries a decreasing trend can be noticed (OECD, 2015b). When looking at other economic indicators, the French economy seems to be recovering. This will be reflected upon in section *3.2.5 Economic factors*.

Between October 2014 and October 2015, 366,900 building permits were issued in France. This is a reduction of about 3% compared to one year earlier. Of these permits, 350,600 projects have actually started construction. In the last few months an increase in issued building permits as well as projects in progress can be noticed (Commissariat Général au Développement Durable, 2015b). This indicates that the construction sector in France is doing well, showing opportunities for BIPV.

Germany

In 2014, the total population growth in Germany was 0.3%. Changes in German population have been fluctuating over the last five years, with even a decline of 1.7% in 2012 (World Bank, 2015). Germany has the highest population of the considered focus countries. The average German household counts 2 persons, which is the smallest of all focus countries. About 53% of the households are homeowners (Statista, 2015).

The unemployment rate in Germany is very low, i.e. 5%. When analysing the figures over the last two decades, it can be seen that the unemployment rate has not been as low as is currently the case. Around the year 2000 the unemployment rate varied around approximately 10%, and during the economic crisis an unemployment rate of about 8% was measured (Statista, 2015). These positive developments can also be seen in economic factors, as will be reflected upon later.

Most likely, a decreasing unemployment rate will lead to more people buying a house instead of renting one, further increasing the implementation potential of BIPV. Furthermore, this also often is an indicator for an increase in requests for planning permission. In 2014, about 111,000 permits were granted for construction of residential buildings, accounting for over 200,000 homes. This number has been significantly higher a few years ago, but shows an increasing trend again (Statista, 2015). Depending on the activity of the solar sector, which will be considered later, this can be an interesting opportunity for BIPV.

Switzerland

Switzerland knows four main languages. In 2013 63.5% of the Swiss residents had German (or Swiss-German) as their first language, 22.5% French, 8.1% Italian and 0.5% Romansh (Swiss Statistics, 2015).

In 2014, the Swiss population has grown 1.2%. This is similar to the annual growth over the last five years (World Bank, 2015). Switzerland has the lowest population as well as the lowest population density of the considered countries. The average household size is however similar to the other countries, with 35% of the households being single person households (Eurostat, 2015a; Statista, 2015). A relatively large share of the dwellings concern urban housing (UNDP, 2015). The home ownership rate of Swiss households is the lowest among OECD countries, with 44% of the dwellings being owner-occupied (Statista, 2015). This low share of homeowners is a result of the high house prices relative to household incomes in Switzerland. House prices are high because prices for land are high due to high degrees of conservation of environmental and urban heritage. Furthermore, owner-occupied homes are heavily taxed in Switzerland (Bourassa & Hoesli, 2010). Since long-term renting is considered normal in Switzerland, this will not be a limitation to BIPV implementation.

Switzerland's unemployment rate was only 3.16% in 2014, and has been relatively stable over the last few years. Projections until 2020 show that this stability will most likely continue to be the case. This indicates that the economic security in Switzerland is high and people are likely to invest in e.g. housing.

The housing construction sector has been declining over the last ten years and is the lowest since 2001. In 2015, about 47,000 dwellings were expected to be completed, of which the majority were rental apartments. This trend is expected to continue in 2016. The construction activity seems to shift back to urban center municipalities instead of in the agglomerations, but still 20% of rental apartments are built in rural areas (Credit Suisse, 2015).

United Kingdom

The population of the United Kingdom recently grows each year with 0.75% on average (ONS, 2015; World Bank, 2015). The average British household counts 2.45 people. In 2013 29% of the British households were one-person households, versus 20% households sheltering four or more people (ONS, 2014). Of the 26.4 million households in 2011, 64% was owner occupied and 36% of the households rented their home. Private and social renting are equally divided over the rental sector (ONS, 2011).

The unemployment rate has gone down from 6.0% in 2014 to 5.4% in June to August 2015. This is the lowest unemployment rate since the beginning of the economic crisis in 2008 (ONS, 2015). This trend indicates that more people have a job, which positively affects the economy and the housing market.

In the period 2014/2015, 474 thousand planning applications were received. 88% of these applications were granted, meaning 360 thousand houses or buildings received planning permission. These numbers have been quite stable over the last few years (ONS, 2015) and indicate that the construction sector is active.

II. *Ecological factors*

The Netherlands

The Netherlands is a relatively small country. This is part of the reason why upscaling of the BIPV sector can only be achieved by an international approach (Ritzen et al., 2014). In 2014 the total CO_2 emissions per capita in the Netherlands were 10.96 tonnes (UNDP, 2015), which is more than double the world average of 4.9 tonnes per capita (World Bank, 2015). The changing climate causes a rising sea level and can have consequences for the economic activities (Ministerie van Binnenlandse Zaken, 2015b).

The share of renewable energy in final energy consumption is increasing in the Netherlands. In 2013, 4.5% of energy consumption was fulfilled by renewable resources, in 2014 this was 5.6% (CBS, 2015). The 2020 target is 14% renewable energy share (SER, 2013), so there still is a long way to go. Solar energy represented only 3.5% of all renewable energy in 2014, with an installed capacity of about 1 GW. Biomass and wind energy are the largest renewable energy resources in the Netherlands, with respectively 71 and 17% in 2014 (CBS, 2015).

France

France is one of the largest European countries, and the largest of the focus countries. This has as a consequence that the difference in solar energy potential between the North and the South of the country is significant (SolarGIS, 2014). Regarding both annual solar hours and solar radiation, France is a high potential country for PV.

It is notable that the total CO_2 emissions per capita in France are relatively low, i.e. 5.56 tonnes per year. This can be explained by the relatively high share of nuclear energy in the French electricity mix. In 2014 this share was 76.9% (Statista, 2015). This share however has to be reduced to 50% by 2025.

As a consequence, the share of renewables needs to increase. This share has increased from 9.1% in 2005 to 14.6% of the final energy consumption in 2014. Almost two third of the renewable energy was from solid biomass and hydropower (Commissariat Général au Développement Durable, 2015a). In 2014, PV systems in France produced 5.5 TWh, covering 1.2% of the total electricity consumption (Yaneva, 2015). The overall renewable target for 2030 is 32%. Merely for electricity this target is set at 40% (IEA & IRENA, 2015).

Germany

Germany is one of the largest European countries, with its main PV potential located in the south (SolarGIS, 2014). The CO_2 emissions per capita were 9.11 tonnes in 2014 (UNDP, 2015). Over the last decades, the average German monthly temperatures show an increasing trend (Glaser & Riemann, 2009).

Between 2004 and 2014, the share of renewables in the generated electricity has increased from 10 to 26% (Schuffelen, 2015). In 2014, 5.9% of the total generated electricity was from solar (EnBW, 2015). The total installed capacity of renewables could potentially account for 46% of the generated electricity, of which almost half (19.6%) is photovoltaics (Schuffelen, 2015). Wind is also a significant energy source in Germany, with a capacity similar to solar. In practice, the amount of electricity generated from the installed renewable capacity is however dependent on among others weather circumstances. The objective of the *Energiewende* is to reach 35% renewable energy share in final electricity consumption in 2020, 40 to 45% in 2025, 55 to 60% in 2035 and 80% in 2050 (Morris & Pehnt, 2015).

Switzerland

Switzerland is a relatively small country, but the amount of solar hours and solar radiation is relatively high (SolarGIS, 2014). Specific weather conditions, especially regarding temperature and snowfall, are however very dependent on the location within the country. The main outliers can be found in the mountainous areas in the south, i.e. the Alps (MeteoSwiss, 2015). Snowfall can cover PV panels and prevent energy production during certain times in the year. This is acknowledged by Haeberlin (2004), but did not cause any damage to the PV panels in his research. The electricity production was even relatively constant throughout the year (Haeberlin, 2004).

The CO_2-emissions per capita in Switzerland are extremely low for a Western country, i.e. 4.95 tonnes (UNDP, 2015). This figure has been declining over the last decade (European Environment Agency, 2010b). This is possible due to the high hydropower capacity of the country. Over 600 hydropower plants of about 300 kW each annually produce about 36,000 GWh electricity (Swiss Federal Office of Energy, 2015b).

In 2014, the renewable energy share in the final energy consumption in Switzerland was 21.4%. Merely for electricity use this share is 58.8%, almost completely generated by hydropower (54.9%). About one third of the remaining 3.9% renewable electricity (842 GWh in 2014) was from solar PV. This share has rapidly increased since 2000, towards an installed PV capacity of over 1 GWp in 2014 (Schweizerische Bundesamt für Energie BFE, 2015b).

United Kingdom

In the United Kingdom, the solar hours, solar radiation and temperatures are significantly higher in the south of the country (Current Results, 2015; Met Office, 2010; SolarGIS, 2014). Also, a vast majority of the built and urban area is located in the south of the country (Rogers, 2011). This automatically means that the potential for BIPV is higher in the south.

According to the UNDP (2015) the CO_2-emissions per capita in the United Kingdom are 7.93 tonnes, which is well over the world average of 4.9 tonnes per capita (World Bank, 2015).

The share of renewable energy in the final energy consumption UK has increased from 1.4% in 2005 to 4.9% in 2013 (Boot, 2015) and 7.0% in June 2014 (Department of Energy & Climate Change, 2014). Their 2020 target is 15% renewable energy share (Boot, 2015). The largest renewable energy sources are biofuels and waste, wind energy is the second most important source. The share of solar energy was almost negligible in 2010, with 0.04% (IEA, 2012a). However, installed solar capacity significantly increased in the past few years, among others through feed-in tariff schemes. At the end of the second quarter of 2015 the total installed capacity solar PV reached 8.3 GW, equal to 29.2% of the total renewable capacity in the UK (Department of Energy & Climate Change, 2015a).

III. Socio-cultural factors

The Netherlands

In the Netherlands, about 30% of the working population is highly educated and about 40% has a middle educational level (CBS, 2015). According to Olli (2011), this means there could be a large support base for environment-friendly measures.

The average expenditures listed in Table 3-3 reflect the buying behaviour of the Dutch population. About 20-25% of the average household expenditures are on energy and housing (CBS, 2015). BIPV covers both categories, since it are weatherproofing building components that generate electricity. This indicates that in combination with a certain degree of environmental concern there could be a relatively large support base for BIPV in the Dutch society.

The Dutch Consumers Association (*Consumentenbond*) carries out independent comparative analyses of various products, to assist consumers in their decision-making process. This potentially influences consumer behaviour. However, there was great criticism on the last rankings the *Consumentenbond* made of green energy suppliers. According to specialists and energy companies the products were evaluated against incorrect criteria and the conclusions were not realistic (Schootstra, 2015). These publications do influence the opinion of consumers and can impact their perception of among others BIPV, both positive and negative.

Lastly, in the Netherlands a transition is taking place in the relation between citizens and the government. Citizens have certain expectations of government performances but at the same time plead for less interference. Due to increasing societal differentiation and segmentation it becomes more complicated to respond in a way that meets the needs of the entire society (Ministerie van Binnenlandse Zaken, 2015b). This transition will also influence how the government will cope with for example the facilitation of BIPV projects. More on this is discussed in section *3.2.6 Political-legal factors*.

France

The focus on BIPV rather than regular PV emerged in France a long time ago, as a result of the search for a niche market to distinguish themselves from Germany within the PV industry (SER magazine, 2011). This can also be seen in special feed-in tariffs for BIPV, as will be further elaborated on in section *3.2.6 Political-legal factors*.

Educational levels of the French population are relatively similar to the other focus countries, i.e. about 40% has a middle educational level and 30% is highly educated (Eurostat, 2015a). According to a Eurobarometer research in 2014, 80% of the respondents expect to have a direct role in protecting the environment. The number one measure mentioned was reducing energy consumption, closely followed by waste separation (encycloEcolo, 2015). A research among French citizens conducted by Syndicat des Énergies Renouvelables (SER) in 2011, showed that 8 out of 10 respondents thinks climate change can be limited by adapting human behaviour. 75% considered photovoltaics to be the best source of renewable electricity generation, and indicated to be willing to pay extra for renewable electricity. The most proponents of solar energy in France can be found in the Mediterranean region (Syndicat des Énergies Renouvelables, 2011).

Furthermore, as a result of the economic crisis French consumers are very much focused on keeping costs down, while obtaining similar value. Popular trends are do it yourself activities, as well as the sharing economy (Euromonitor International, 2015). Self-sustaining is also part of this trend, showing interesting opportunities for (BI)PV.

The average expenditures of the French are similar to the other focus countries. Over a quarter of the household expenditures are on energy and housing (Eurostat, 2015a). Electricity consumption in France is significantly higher than in most other focus countries. Natural gas use however, is relatively low (IEA, 2012c). This indicates that most of the energy demand of households is fulfilled by electricity, which can positively stimulate BIPV implementation.

Germany

A significant majority of the German population has a middle education level, which does not necessarily indicate a high level of environmental concern according to Olli et al. (2001). Furthermore, whereas wholesale electricity prices go down due to overcapacity, the end consumer price keeps increasing because of remuneration and grid fees under the Renewable Energy Act (*Erneuerbare Energien Gesetz, EEG*) (AG Energiebilanzen e.V., 2015; Schuffelen, 2015). In August 2015, the end consumer electricity price for households (28.77 cents/kWh) was built up as follows: 25% supplier cost and profit margin, 23% grid fees, 21% renewable energy support fees, 16% sales tax, 7% ecological tax on electricity and 8% other levies (Thalman, 2015). The figures in Table 3-3 show that about 30% of the expenditures of German households is on energy and housing (Eurostat, 2015a).

Despite this, the general support of the German citizens for a transition to a low carbon economy is strong, in particular when compared to other European countries. To the question ‘What do you think are the two most important issues facing Germany at the moment?’, 12% of the German citizens answered ‘The environment, climate and energy issues’ (European Commission, 2015b). Over 90% of the German citizens are in favour of the objectives of the *Energiewende* (Pescia et al., 2015). In 2014, 46% of the installed bio-, photovoltaic and onshore wind energy systems in Germany (33GW) was from civil energy projects (Degenhart & Nestle, 2014). This study by the Leuphana University of Lüneburg (2014) also showed that the main motives for citizens to invest in private renewable energy projects were not financially-, but more ecologically and socially driven. The main reasons for citizens to participate in these projects are protection of the environment and stimulation of the *Energiewende*. The support base is high, since a large part of the German citizens has a stake in the renewable energy projects and therefore feels responsible for the transition (Fischedick, 2015).

The German consumers association, *Verbraucherzentrale Bundesverband* (VZBV), has energy, energy politics and environment incorporated as a specific theme. The importance of being environmentally friendly is again presented as a clear value of German consumers. The VZVB however also reflects that not all consumers are satisfied with the rising electricity costs due to the *Energiewende* (VZBV, 2015). The rising electricity prices stimulate people to generate their own electricity in decentralized systems. This however reduces the returns of the government from grid electricity fees, which leads to a further increase in grid and remuneration fees that drive up the end consumer electricity price (Schuffelen, 2015). This vicious circle reflects that the current system might not be preservable in the future.

Switzerland

In Switzerland, about 35 % of the working population is highly educated and about 48% has a middle educational level (Eurostat, 2015a). Compared to the other focus countries, the educational level of the Swiss is relatively high, which can mean a higher level of environmental concern (Brönnimann et al., 2014; Olli et al., 2001). In an international context surveys show that Swiss residents have a very high level of environmental concern. Studies however also illustrate that climate change is in Switzerland not necessarily perceived as a domestic issue, which is also the case in many other European countries (Brönnimann et al., 2014). Communication strategies to improve this environmental support base could possibly increase the implementation of domestic renewable energy projects.

Regarding household expenditures, the Swiss score quite average. About 27% of their consumption expenditures go to energy and housing (Swiss Statistics, 2015). The energy demand is to a relatively large extent fulfilled by electricity (Bundesamt für Energie BFE, 2015c), leading to a significantly higher electricity consumption per household than in most of the other focus countries. This is an opportunity for BIPV, since solar energy can mitigate part of the grid electricity consumption.

United Kingdom

In the UK, about 37% of the working population is highly educated and about 43% has a middle educational level (Eurostat, 2015a). The IEA (2012) indicated that the UK has invested in communication and explanation of energy and climate change. This has resulted in a strong level of support among stakeholders and within politics and the rise of local energy generation initiatives. However, consumer behaviour in reducing energy use is not yet widespread (IEA, 2012a). This indicates that the support base for environmental friendly measures, such as BIPV, is present but can still be improved.

The average expenditures listed in Table 3-3 reflect the buying behaviour of the British population. About 20% of the average household expenditures are on energy and housing (Eurostat, 2015a). This number is relatively low compared to the other focus countries.

IV. Economic factors

The Netherlands

The consequences of the economic crisis can still be noticed in the Netherlands, but recovery is taking place. The Dutch economy is expected to grow with 2.0% and with 2.4% in 2016. Inflation was 0.8% in August 2015 (CBS, 2015). Furthermore, according to the Budget Memorandum (*Miljoenennota*) for 2016 a growth is projected for export, overall investments and expenditures of consumers (Rijksoverheid, 2015).

This can also be seen in the increasing housing market (Ministerie van Binnenlandse Zaken, 2015b). The house price index however shows that house prices are still not back at the 2010 level. ING (2015) published a report about trends in the Dutch housing market for 2015-2015. They found that buying a house is no longer a worthwhile investment for the future, since house prices will only rise with about 2% a year. Furthermore, households become smaller and request smaller dwellings, also lowering the average house price (ING Economisch Bureau, 2015).

The average net income and PPP of Dutch citizens is relatively similar to the other focus countries, and so are the electricity and natural gas prices.

France

France is the fifth largest economy in the world (Pohlman, Morán, Ciccarelli, Aceves, & Torné, 2014) and also is part of the G7. France is still recovering from the economic crisis. The growth rate is low, but positive at the moment, and future predictions show an increasing trend (Pohlman et al., 2014). However, as a result of multiple terrorist attacks in Paris in 2015, expenses on defence are significantly increased. This impacts the budget that was proposed for 2016. Reduced income from tourism and recreational activities is another consequence from these attacks (Karaian, 2015).

The housing market in France is not stable and has been going down for several years now. This is shown in Figure 7-2 (French Property, 2015b). Rental prices however show a slightly increasing trend (French Property, 2015a).

Figure 7-2: Development of house prices in France. Similar trends can be seen for urban housing, apartments and family dwellings (French Property, 2015b)**.**

Compared to other European countries, the French electricity price is very low. This can be explained by the abundant production of cheap nuclear energy in France. Eurostat (2015) gives a price of € 0.1688 per kWh, but other sources even show prices around € 0.14 per kWh for private consumers (fournisseurs électricité, 2015).

Germany

Germany belongs to the most advanced economies in the world and is therefore part of the G7. As already briefly mentioned in 2.1 Demographic factors, the German economy shows a growing trend over the last few years. The employment has reached a new record and is expected to grow further (BMWi, 2015b). Table 3-5 shows a positive economic growth, and more important for the BIPV sector, an increasing trend in house prices relative to 2010. This indicates that people are willing to invest in housing.

As already touched upon in 2.3 Socio-cultural factors, Table 3-5 shows that the German electricity price is significantly higher than in the other focus countries. The *Energiewende* is a very important factor in this phenomenon, since renewable energy projects are mostly financed by the fees that are imposed on grid electricity (Schuffelen, 2015). These high electricity prices among other result in citizens investing in decentralized energy projects, which could be an interesting opportunity for BIPV.

Germany is the only European country with a relatively large PV production industry. A survey among employees active in manufacturing, planning or operation of the solar industry has shown that they perceive the economic development of the domestic solar production to be relatively low. Only 8% of the respondents observes the developments to be good or very good, versus 64% perceiving the economy of the German solar industry as bad or very bad. The remainder of the respondents thought the solar market was steady (Statista, 2015). This has to do with the influence of China, where solar power production is a fast growing industry.

Switzerland

Switzerland is not a Member state of the EU, which means that the country can impose high(er) import duties on particular groups of products. Energy and energy efficiency techniques are mentioned by RVO to be promising sectors in Switzerland (RVO, 2015b). Besides this, Switzerland is also not part of the Economic and Monetary Union (EMU). The currency is the Swiss Franc (CHF). This is very important to take into account when doing business with Switzerland, since fluctuations between the euro and the Swiss franc can cause companies to lose income. However, the country shows interesting locational advantages such as an open economy, high innovating companies, a stable political climate, a good infrastructure and competing taxes (RVO, 2015b).

Switzerland was hit by the economic crisis, but not as hard as the other European countries. This is illustrated in Figure 3-5, but can also be seen in the parameters for economic growth, net income and purchasing power parity (PPP) in Table 3-5. Especially the net income and PPP are significantly higher, indicating a higher level of welfare. Furthermore, energy prices, both electricity and natural gas, are lower than in the other focus countries. This has to do with tax differences.

United Kingdom

The United Kingdom is a Member State of the EU, but is not part of the Economic and Monetary Union (EMU). Their currency is therefore not the euro, but the British pound (£). This is very important to take into account when doing business in the United Kingdom, since fluctuations between the euro and the pound can cause companies to lose income (RVO, 2015a). Furthermore, the UK is also part of the G7, a group of the seven most advanced economies in the world.

A report by PWC (2015) shows that the economy of the UK is slowly growing again, inflation in 2015 was 0.3%, but is expected to be 1.7% in 2016. GDP growth was 2.6% in 2015 and is expected to be 2.4% in 2016. House price growth will be moderate, i.e. about 5% per year until 2020. This will however be higher than the average growth in income, which will result in an increased share of the rental sector. Lastly, the services sector is the most important driver of economic growth in the UK, also when it comes to international trade (PWC, 2015).

The investments made by venture capitalists in technology start-up companies in the UK reached a record in 2015, with $2.2 billion. The technology sector is expected to grow, and so are the investments (Potential VC, 2015). A benchmarking report on start-up ecosystems shows that London scores highest of the European Union and seventh in the world when it comes to active technology start-up companies (Compass, 2015). This is a positive trend for BIPV, being an innovative high-potential technology.

In the United Kingdom, the prices for domestic energy use are relatively low. The reason for this is that the quality of British houses has always been poor. For gas in particular, the energy taxes are low (Boot, 2015).

C. Multicriteria analysis

I. *Scoring*

Based on the information that was acquired in chapter 3. Results, the countries were scored on their compliance to the fifteen criteria, relative to each other. The results therefore are not absolute. No compliance to the criteria equals a scoring of 1, optimal compliance equals a scoring of 5. When no weighting would be applied Germany scores best, with 75%, closely followed by Switzerland with 72%. The United Kingdom then has the lowest score, i.e. 53%. The Netherlands and France respectively score 56% and 63%.

#	Criteria	NL	FR	DE	CH	UK
1.	Large amount of established BIPV companies, indicating a flourishing but high entry market	**3**	**3**	**3**	**3**	**2**
		Section *3.1 Stakeholder inventory and interests* BIPV suppliers, manufacturers and wholesale companies are present in all countries, and the amount is growing. The UK seems to lag a little behind the other focus countries.				
2.	Availability of (BI)PV research centre(s), indicating research potential and knowledge transfer	**4**	**2**	**3**	**4**	**2**
		Section *3.1 Stakeholder inventory and interests* Switzerland has a research centre specifically for BIPV. The Dutch PV research centre SEAC collaborates at a high level with the Swiss and has a major focus on BIPV. Germany's Fraunhofer ISE does specialised PV research, but BIPV expertise seems to be less abundant. The research institutes of France and the UK were found to be less specialised.				
3.	Low unemployment rate, indicating a more stable economy	**3**	**2**	**4**	**5**	**4**
		Section *3.2.1 Demographic factors* The unemployment rate in Switzerland was found to be very low, i.e. 3.36%. The UK and Germany score almost as good with respectively 5.4 and 5.0%. In the Netherlands, unemployment rate is 7.4% and France was found to have the highest unemployment rate, at 10.3%.				
4.	High share of homeowners vs. renters, indicating a larger potential market	**4**	**4**	**3**	**2**	**4**
		Section *3.2.1 Demographic factors, Appendix B.I Demographic factors* The share of homeowners in the Netherlands, France and the UK were found to be similar, respectively 67%, 65% and 64%. In Germany 53% of households owned their home, in Switzerland this was only 44%.				
5.	Large established PV capacity per capita, indicating interest in PV but at the same time a possibly high entry market	**2**	**3**	**5**	**3**	**2**
		Section *3.2.1 Demographic factors* Germany obviously has the highest share of PV capacity per capita, at 436 W/cap. France and Switzerland score significantly lower, at respectively 71 and 92 W/cap. The Netherlands and the UK only have an established PV capacity of respectively 40 and 53 W/cap.				
6.	Large amount of solar radiation	**2**	**4**	**3**	**4**	**2**

		Section *3.2.2 Ecological factors* France and Switzerland have the highest average solar radiation, at respectively 1,300 and 1,250 kWh/m^2. In Germany 1,100 kWh/m^2 is average, followed by the Netherlands and the UK (1,000 and 900 kWh/m^2).				
7.	High level of environmental concern, indicating willingness to implement environmental friendly measures	**2**	**3**	**4**	**4**	**2**
		Section *3.2.3 Socio-cultural factors, Appendix B.III Socio-cultural factors* In Switzerland and Germany, research shows that the average citizen is very willing to invest in renewable options to protect the environment. French also were found to be supportive of environmental friendly measures. For the Netherlands and the UK, no clear evidence for a high level of environmental concern could be found.				
8.	High share of expenditures to Energy & Housing, indicating willingness to reduce the electricity bill	**2**	**3**	**4**	**3**	**2**
		Section *3.2.3 Socio-cultural factors* The expenditures to Energy and Housing in Germany was found to be very high, i.e. 30.3%. France and Switzerland score almost as high with respectively 26.8 and 27.7%. In the Netherlands, energy and housing expenditures are 23.3% and the UK was found to have the lowest expenditures to this category, at 18.0%.				
9.	Economic welfare	**2**	**2**	**3**	**4**	**3**
		Section *3.2.5 Economic factors, Appendix B.IV Economic factors* The Swiss economy was found to perform best, with the highest disposable income and purchasing power, as all as significant economic growth. The situation for the UK and Germany was found to be relatively similar, with moderate economic growth and average purchasing power. In the Netherlands and France, purchasing power and disposable income were relatively average, however economic growth was found to be lower.				
10.	Flourishing housing market	**1**	**2**	**3**	**3**	**3**
		Section *3.2.5 Economic factors, Appendix B.IV Economic factors* In Germany, Switzerland and the UK, house prices are increasing again. In France house prices were found to be slowly deceasing over the last few years, but are still higher than 2010 levels. In the Netherlands, recovery seems to slowly be taking place, however house prices are still significantly lower than 2010 levels.				
11.	Part of Eurozone (EMU), indicating no risk of losses due to currency changes	**5**	**5**	**5**	**1**	**2**
		Appendix B.IV Economic factors The Netherlands, France and Germany are in the European Union and all have the Euro as a currency. The UK is part of the EU, but not part of the EMU. Switzerland is not in the EU and neither in the EMU.				
12.	High degree of trust in government, indicating a politically	**3**	**2**	**3**	**5**	**2**

	stable environment	Section *3.2.6 Political-legal factors* The Swiss have the highest trust in their government, i.e. 80%. In the Netherlands and Germany, respectively 51% and 50% trusts their government. For France and the UK, these numbers respectively are 19% and 37%.				
13.	Clear renewable energy strategy and targets	**2**	**3**	**5**	**4**	**3**
		Section *3.2.6 Political-legal factors* Germany is very clear and ambitious in their renewable energy strategy. Switzerland closely follows this example. France and the UK are less ambitious, but the targets are clearly defined in a renewable energy act. The Netherlands has a relatively clear and ambitious strategy, however these objectives are not defined in the form of a mandatory act.				
14.	Clear policy on energy performance of buildings	**4**	**4**	**4**	**4**	**4**
		Section *3.2.6 Political-legal factors* All countries have translated the European Building Performance Directive into their national strategies. However, not much difference in types of targets and level of ambitiousness can be found between them.				
15.	Availability of feed-in tariff schemes (or other specific financial support)	**3**	**5**	**4**	**5**	**3**
		Section *3.2.6 Political-legal factors* France and Switzerland have feed-in tariffs and support schemes specifically for BIPV. Germany also offers well-regulated feed-in tariffs for PV, but does not offer specific incentives for BIPV. The feed-in tariffs of the UK are also not specifically for BIPV and the Netherlands does not offer feed-in tariffs, but has a net metering principle. Less future security is provided for consumers in the last two countries.				

II. Weighting

The weight of each of the fifteen criteria was determined through a survey among 18 BIPV stakeholders. The survey was distributed by e-mail and consisted of three main questions. The questions and the answers are presented in Tables 7-1, 7-2 and 7-3.

Table 7-1: Answers of 18 respondents to *Question 1: In which country / countries are you active?* **Respondents could give more than one answer.**

Country	Number of times mentioned	Comments
Netherlands	15	
Belgium	2	
Germany	2	
France	2	
Switzerland	1	
United Kingdom	1	
Benelux	1	Not added to Netherlands and Belgium in this table
Europe	1	
Sweden	1	
Spain	1	
Italy	1	

EMEA	1	
EEUU, Latin America, Dubai, UAE, etc.	1	Outside scope of this research
1	1	Invalid answer

Table 7-2: Answers to *Question 2: The criteria below can be important in determining market potential for (BI)PV. Please select what weight you would give to each of the criteria.1 = normal, 2 = extra, 3 = heavy or 0 = not applicable (n.a.).* **The average weighting that results from these answers is also provided. Comments that were made are given in footnotes per criteria below the table.**

#	Criteria	Weighting				Total respondents	Average weighting
		Normal 1	Extra 2	Heavy 3	n.a. 0		
1	Large amount of established (BI)PV companies, indicating a flourishing but high entry market	9	7	2	3	21	**1,38**
2	Availability of (BI)PV research centre(s), indicating research potential and knowledge transfer [1]	6	9	3	3	21	**1,57**
3	Low unemployment rate, indicating a more stable economy [2]	13	4	3	1	21	**1,43**
4	High share of homeowners vs renters, indicating a larger potential market [3]	10	4	5	2	21	**1,57**
5	Large established PV capacity per capita, indicating interest in PV but at the same time a possibly high entry market [4]	7	9	3	2	21	**1,62**
6	Large amount of solar radiation [5]	9	6	4	2	21	**1,57**
7	High level of environmental concern, indicating willingness to implement environmental friendly measures [6]	5	8	8	0	21	**2,14**
8	High share of expenditures to Energy & Housing, indicating willingness to reduce the electricity bill	1	9	11	0	21	**2,48**
9	Economic welfare	4	7	10	0	21	**2,29**
10	Flourishing housing market [7]	8	6	6	1	21	**1,81**
11	Part of Eurozone (EMU), indicating no risk of losses due to currency changes [8]	11	4	2	4	21	**1,19**
12	High degree of trust in government, indicating a politically stable environment [9]	4	7	10	0	21	**2,29**
13	Clear renewable energy strategy and targets	2	7	12	0	21	**2,48**
14	Clear policy on energy performance of buildings [10]	1	6	13	1	21	**2,48**
15	Availability of feed-in tariff schemes (or other specific financial support)	3	8	8	2	21	**2,05**

[1] New science labs to compete with Silicon valley

[2] - Iets hogere werkloosheid kan ook een stimulans zijn om nieuwe businesses op te zetten;
- Irrelevant;
- Investment in 'durability' is more a question of timing. How/when to improve the efficiency of your home;

3 - As we provide solutions for BIPV highend PV low rates good indicator.
- Er zijn ook goede marktmodellen voor huurhuizen;
- irrelevant - but does depends on bcase for owners of rental appt;

4 - Home owners wish an individual approach, whilst they own an individual home. BIPV is a concept and generally not the cheapest solution. Bigger (initial) steps could be made by approaching corporations who own some stock of dwelling for rental
- yes, negative correlation;
- I think that PV is cheap enough nowadays and the economy of scale and better guarantees of performance will certainly enhance the business;
- Consumenten, bedrijven en overheid hoef je niets meer uit te leggen inzake PV. Het is bekend;

5 - BIPV willl always loose aginst PV if it comes only to the discussion about only solar issues.
- Dit is natuurlijk een factor mbt de kostprijs/kWh, maar niet de belangrijkste. Ook is opbrengst/kWh (oftewel de geldende kWh prijs) belangrijk;
- Regulation on renewable energy implementation creates the business case;
- bus case depends on legislation not radiation;
- Nowadays efficiency is better, also CGIS might be an option.

6 bcase more important I think

7 we prefer commercial buildings

8 - No currency changes;
- irrelevant.

9 This is important wrt regulations (heacy), but on the other hand in unstable countries, electricity supply is also unstable and people are more willing to invest in autonomy.

10 Only if this clear policy is towards near zero energy buildings. A clear policy that says: we do not do anything, will not help.

Table 7-3: Answers to *Question 3: Are there any other criteria of which you think they are important in this decision? Think about general criteria that are relevant for the BIPV sector. For example 'many personal contacts' is not applicable here.* **The answers have been clustered based on their similarity.**

Clusters	Comments
Demonstration projects / publicity	more publicity about how to bring bipv in practice, design and possibility's; to show end users , more in media; met veel en diverse demonstratieprojecten aan architecten en consumenten laten zien dat er ook mooie PV toepassingen zijn.
Policy	The most important criterium is - I think - a stable policy with ambitious targets on energy performance of buildings; regulations – laws; european harmonisation of the construction norms,....
Financial incentives	financial support for renovation projects of houses; financial support focussing on BIPV; subsidie van de overheid om de eerste kleinschalige projecten te ondersteunen.
Aesthetics	Aesthetical aspects of the product; sensitivity for design; Aesthetical preferences (importance of architecture and fashion)
Building industry	position of the architect/designer in design choices; stable and strong building industry; florishing market for refurbishing of buildings; education for the construction business, including architects
Other	Improvement of the 'second hand value' (e.g. when you sell your home); lack of land area/expensive land. BIPV competes with solar farms; redelijk betaalbare BIPV moeten beschikbaar zijn; Offering BIPVT; Offering Turn-key solutions; (BI)PV market is not only driven by FIT, but (like NL, DK) also on net metering. Incentive is a better wording; Early adopter behavior (early markets of e.g. iPhones or Teslas)