STUDY IV

STUDY ON DYNAMICS OF PHOTOVOLTAIC BUSINESS: INTEGRATION AND COMPETITIVENESS IN ENERGY SECTOR

THE CIRCA GROUP EUROPE

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1.1 Study IV: Dynamics of photovoltaic business: integration and competitiveness in energy sector

1.1.1 Study goals and objectives

The aim of this study is to provide an analysis of the dynamics of business in PV sector and to develop and describe scenarios for Lithuanian PV industry development.

This is Study number 4.

This study provides the analysis the value chain of PV industry, its dynamics, the reasons and the consequences of integration in the context of the diminishingPV incentives. The scenarios for possible evolving of Lithuanian Photovoltaic industry in the global environment profoundly analysed in other studies are developed.

The other studies are:

- Mid-term and long-term trends of global photovoltaic industry development (Study I)
- State of art and next generation photovoltaic (Study II)
- Present and prospective PV applications and challenges for the PV industry (Study III)
- State of the art analysis of Lithuanian PV technology cluster and potential for its development (Study V)

This study is aimed at audience of PV manufacturers, PV installers, researchers, policy makers and other interested stakeholders.

1.1.2 Reasons for the doing this study

Lithuania has an active photovoltaic technology cluster (PTC). It has 26 members, which include both commercial companies and research institutes. It was founded in 2008 with the aim to establish systematic background for international competitiveness and development of PTC members and a Lithuanian PV industry. The main PTC objective is to increase the added value produced by PTC members and Lithuanian PV technology and enhance companies' competitiveness by integrating RTD into the business model. The main PTC activity areas are (i) photovoltaic RTD and industry development and (ii) development of interface between photovoltaic and other areas of research and industry, where the achieved results in PV technology could be deployed.

PTC became a member of the European Photovoltaic Industry Association (EPIA) in 2009, and is the representative of Lithuania in European Photovoltaic Technology platform "Mirror" and "Research and Technology" working groups.

But the Lithuanian PV industry is currently only at an early stage of development and evolution. This study and its related studies are important contributions to the PTC's further development and the sustainable development of the Lithuanian PV industry by preparing the long-term development strategy and optimising the synergy of business and research and technological innovation (RTI) from both Lithuanian research centres and the research area of the European Union.

1.1.3 Scope

The scope of this report is twofold. The first part is dedicated to the analysis of the dynamics of business of PV sector. The second part is dedicated to the PV sector foresight, which is the overall process of creating an understanding and appreciation of information generated in other Studies. Foresight includes qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when directly linked to the analysis of policy implications. Foresight is dedicated to prepare Lithuanian PV sector to meet the needs and opportunities of the future. Foresight cannot define concrete action plan and policy, but it can help condition strategies to be more appropriate, more flexible, and more robust in their implementation, as times and circumstances change. Foresight is, therefore, closely tied to planning. It is not planning – merely a step in planning.

The main objective of the PV sector foresight is to propose strategic recommendations for development of Lithuanian PV sector competitiveness viable across different future environmental scenarios.

1.1.4 Methodology and Information sources

The study is based on two different methods. The extensive range of secondary sources, gathered from the specialised portals on the web and industry publications, were used for the analysis of the business dynamics of PV sector. The key sources:

- Bloomberg New Energy Finance – a source of research, forecasts, data and news in clean energy, including PV;
- Factiva – a business information and research tool aggregating news and financial reports from most of newspapers, magazines and market analysis reports;
- PHOTON International, the main industry magazine for the PV industry;
- Publications by the European Photovoltaic Industry Association (EPIA);
- Reports by the US National Renewable Energy Laboratory (Denver, Colorado);
- Market-related reports from the leading consultancy companies (McKinsey & Partners, Ernst & Young);
- Market overviews from the major market research service providers (IHS Solar);
- Research articles from Science Direct and other repositories of scholarly journals.

The methodology for development of the future scenarios of PV sector in Lithuania towards 2025 is mainly based on explorative, qualitative approach. Scenarios are not prognosis or forecasts or prediction of the future trends or events, but rather stories (or statements) about possible future explorative contexts that will possibly surround PV sector in Lithuania. The steps for the whole process of the PV foresight were as follows: (i) presenting the results of Studies I-IV (firs part) and the Studies to the selected experts, (ii) analysis of results of the survey and *interviews*, (iii) definition of the main trends and driving forces for PV sector, (iv) identification of main uncertainties and polarities and (v) development of scenarios. The detailed methodology of this process is presented in the sub-section 4.1 made in Annex II: Minutes of Expert Panel.

The report was prepared by three very experienced senior consultants in close collaboration with Contract partner UAB "ProBaltic Consulting" (Lithuania). The team leader was Circa Group's Managing Director. The process used to prepare this report was that:

- An outline of the report was prepared by the team working together and initial research was undertaken. This formed the basis of the two monthly progress report submitted to VsI "Perspektyviniu technologiju taikomuju tyrimu institutas".
- The research was divided between the team members which allowed for a degree of overlap thus ensuring at least two of the team would cover the same ground.
- More detailed research was undertaken, then the team met to review the layout and develop a more detailed format. The writing was allocated to the team members.
- Detailed research was then undertaken and initial draft chapters were written.
- The methodology for scenario development discussed and prepared. The expert panel organised and the results summarised in the description of defined scenarios.
- These drafts were circulated and reviewed by the team.
- The chapters were redrafted and a final content and presentation agreed.
- The whole report was formally proofed and the final edits undertaken.

It was submitted to VsI "Perspektyviniu technologiju taikomuju tyrimu institutas" in September 2013.

1.2 Summary Layout

The layout of the report is outlined in the following paragraphs.

Chapter 1 includes the following sections:

- Introduction – which includes the study goals and objectives, reasons for the study, scope and format, methodology and information sources;

- Summary layout of the study;
- An overview of the content of the study.

Chapter 2 covers the overview of the value chain of PV industry, the reasons and consequences of integration. It includes the following sections:

- Detailed description of PV value chain: downstream channel structure and volumes, upstream channel structure and volumes and the profiles of the main players;
- Description of the reasons for integration in PV value chain and existing and foreseen consequences: models of vertical integration and the consequences of the integration of PV value chain;
- Detailed description of possibilities and analysis of barriers for market entrance: possibilities and main barriers, differences in importance of barriers for SMEs and large companies, upstream / downstream success factors and non-financial drivers.

Chapter 3 covers the analysis and prognosis of short-term (in 2 – 4 years) situation, when the PV incentives (especially Feed-in Tarif, FiT schemes) are over. It includes the following sections:

- Overview of PV incentive programmes, trends in development and foreseen deadlines and the latest status on PV funding policy and programs;
- Prognosis for PV competitiveness;
- Prognosis of the situation after closure of PV incentives and impact assessment of recent and planned policy changes on the market;
- Risk Factors.

Chapter 4 covers the presentation of scenarios for development of Lithuanian PV industry. It includes the following sections:

- Methodology: main uncertainties, main evidences, the potential opportunities and main statements form the expert panel;
- Presentation of Scenarios: Scenario "Sunny Tomorrow", Scenario "Broken Walls", Scenario "Step by Step" and Scenario "Formula 1";
- Key results of Lithuanian PV industry development scenarios.

Chapter 5 provides the conclusions to the study.

Finally the annexes include the Glossary, list of references and minutes of Expert Panel.

1.3 Overview

1.3.1 Background

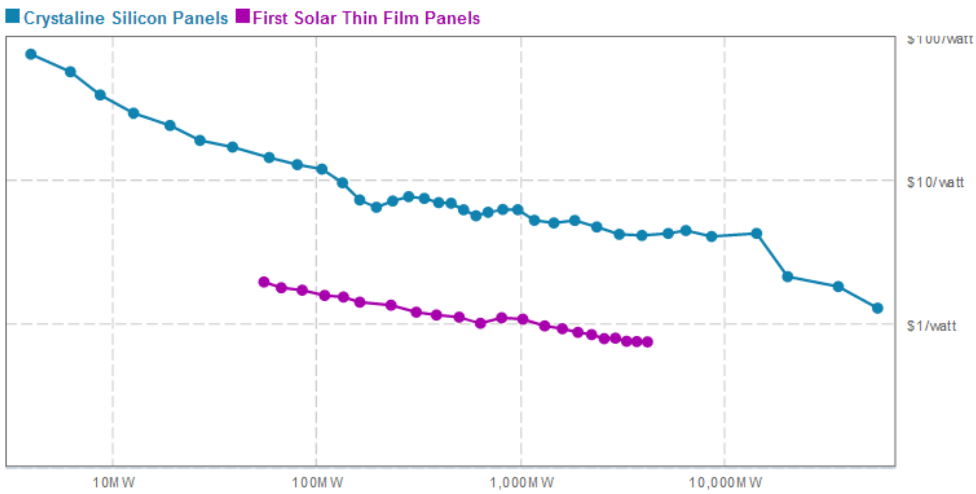
Trend: *price drop accelerates as installed capacity increases*

Over the past few years the solar industry has undergone a major market shake-up. The price of PV modules dropped from more than \$4 per W_p in 2008 to just under \$1 per W_p by January 2012, while market penetration in terms of installed capacity has increased globally from 4.5 GW in 2005 to more than 65 GW in 2012.[1]

The industry is entering a period of maturation that is likely to set the conditions for more stable and expansive growth after 2015. The analysis of McKinsey & Company suggests that the cost of a commercial-scale rooftop system could be reduced by 40 percent by 2015, to \$1.70 per W_p from roughly \$2.90 per W_p, and by approximately another 30 percent by 2020—to nearly \$1.20 per W_p.

Bloomberg New Energy Finance has established the following solar industry's learning curve: for conventional panels the price drops 24 percent for every doubling of total installation. For thin-film panels the cost falls 13 percent when capacity doubles.

Figure 1: Solar industry's learning curve[2]

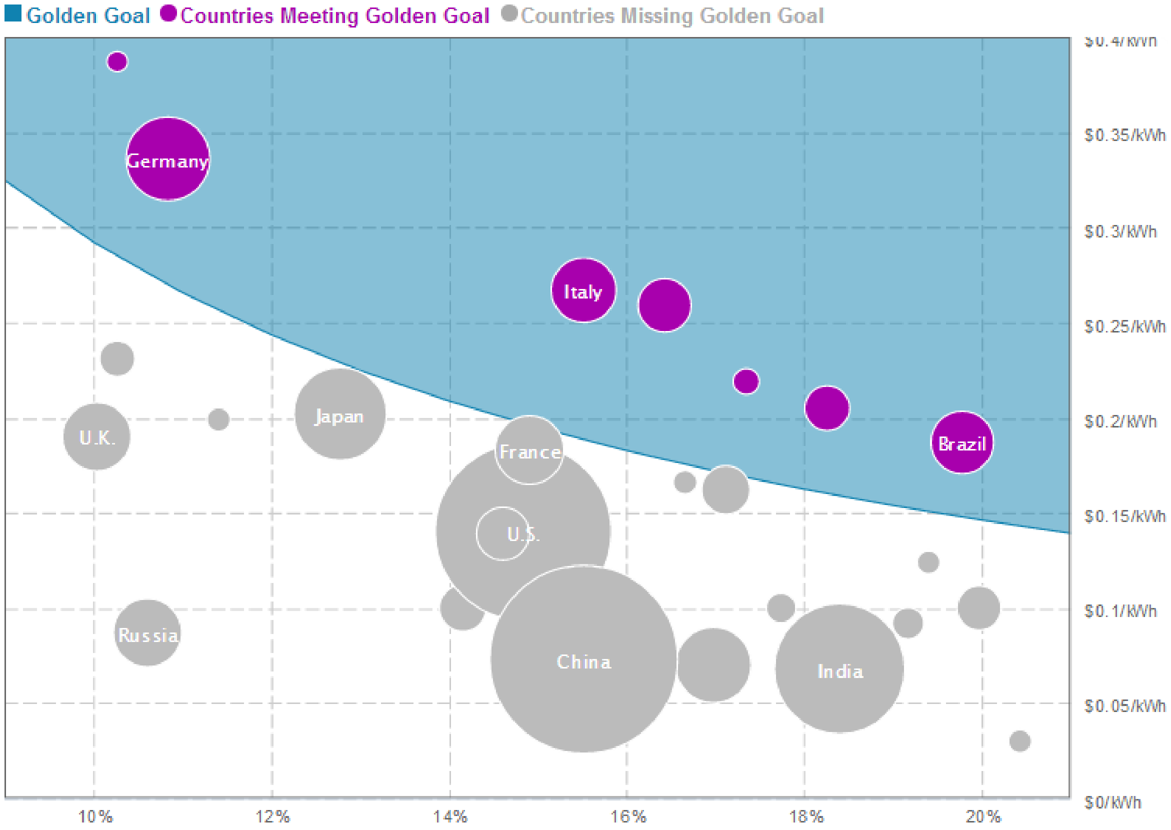


Trend: *industry is approaching a grid parity in major economies*

Due to the increase in electricity prices solar electricity has reached a grid parity (the so-called "golden goal") in several countries, including Germany, Denmark, Portugal, Spain and Australia. Japan, France, Greece and Turkey are expected to reach a grid parity by 2015.In 2012 an average annual return on investment (a weighted average cost of capital) was 6 percent. Bloomberg New Energy Finance estimates that by 2020 the US electricity prices will be high enough to justify investment in solar electricity, even without the 30 percent investment tax credit subsidy.

[1] McKinsey on Sustainability & Resource Productivity, 2012
[2]Bloomberg New Energy Finance, 2012

Figure 2: Levels of grid parity in different countries[3]



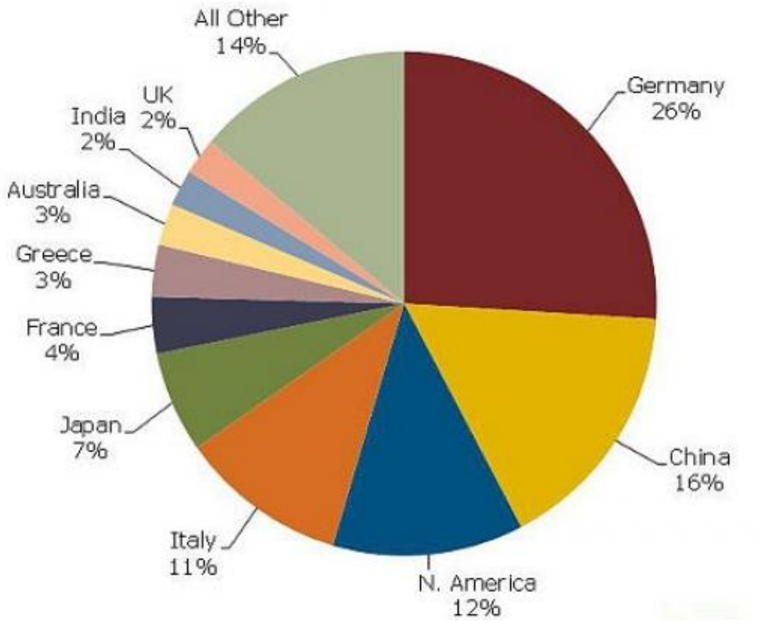
1.3.2 Regional PV distribution in the world

Trend: *Europe is losing a leading market position*

The regional PV distribution is rapidly changing in favour of China and other countries in the Far East. In 2010 Europe had accounted for more than 80% of solar demand, yet due to the financial crisis and the following cuts in feed-in tariffs the market contracted to 53% in 2012.[4]

[3]Bloomberg New Energy Finance, 2012
[4]Inverter, Storageand PV systemTechnology, IndustryGuide 2013

Figure 3: Top 10 PV Markets in 2012[5]



The EU demand will shrink further in 2013 to 39%, and Asia will then replace Europe as the world's largest solar market. Germany is predicted to be displaced by China in 2013 as the world's largest solar market—a position that Germany has held for the last seven years, with the sole exception occurring in 2008.

The United States is also forecast in 2013 to add more solar installations than Germany, which will drop down to third place, followed by Japan and Italy in fourth and fifth, respectively. This geographic shift presents a challenge in itself given that China is almost inaccessible to Western suppliers, with Japan proving equally challenging for non-domestic vendors, and the U.S. impacted by the recent anti-dumping trade case

The leading markets will include China, the United States, Germany, Japan, Italy, and India (Table 1).[6] This will create additional barriers for new manufacturers operating outside of the main solar markets.

Table 1: Top 5 Solar Markets

	2012 MW installed	2012 Rank	2013 MW installed	2013 Rank
Germany	8,000	1	5,000	3
China	5,100	2	6,300	1
USA	3,600	3	5,100	2
Italy	3,500	4	2,900	5
Japan	2,200	5	3,500	4

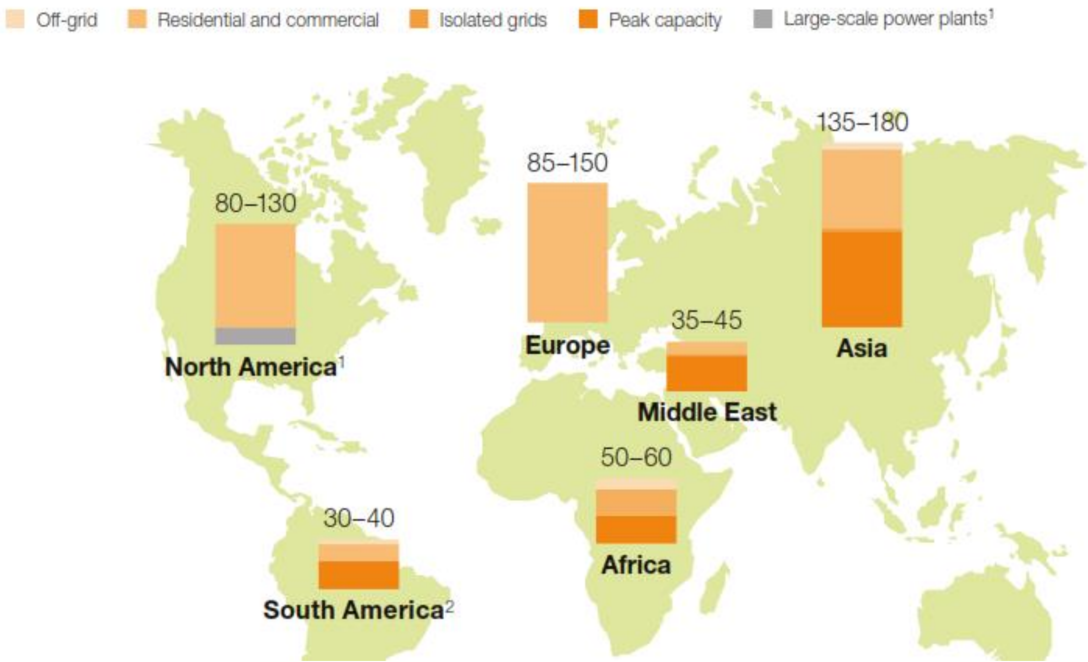
Trend: *Geographical defragmentation of global PV market increases*

A geographic fragmentation of global solar market is accelerating. While nearly three-quarters of total solar demand in 2012 came from the Top 5 end markets, the total portion will drop to 65% in 2013 as the market fragments. This is because of the

[5]JNPD Solarbuzz, Jan. 2013
[6]IHS Solar Research, 2012

increasing importance of “mid-sized” markets installing a few hundred megawatts per year.

Figure 4: Cumulative capacity additions, 2012-2020, gigawatts (source: McKinsey, 2012)



Trend: *Renewable energy attractiveness is ranked on a country-by-country base*

The geographical fragmentation of solar markets has led to the increasing segmentation on a country-based basis. According to latest rankings (November 2012) in the Ernst & Young Country Attractiveness in Long-term solar index which is based on a composite indicator derived from the solar PV index (85%) and the solar CSP index (15%). The ranking results are presented in the Table 2.

Table 2: Country-based ranking results

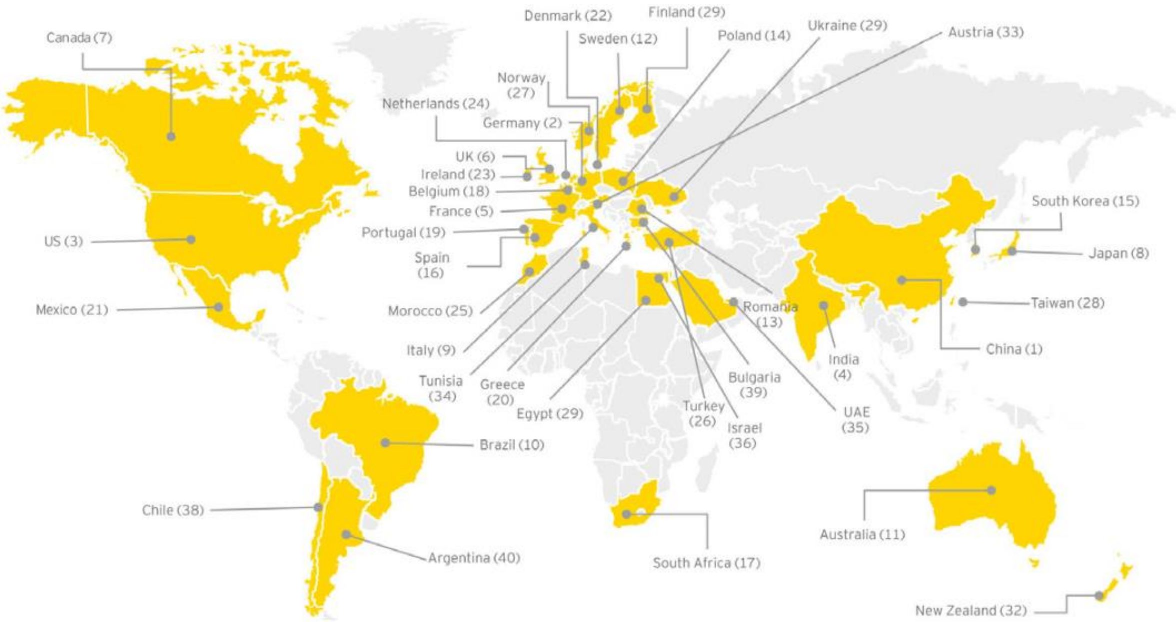
Rank		Country	All renewables	Wind index	Onshore wind	Offshore wind	Solar index	Solar PV	Solar CSP	Biomass/other	Geothermal	Infrastructure
1.	(1)	China	69.6	76	77	69	64	66	46	59	50	72
2.	(2)	Germany	65.6	68	65	79	61	70	0	68	58	73
3.	(2)	US	64.5	62	64	55	70	69	73	61	67	59
4.	(4)	India	63.5	63	69	40	66	68	53	60	44	63
5.	(6)	France	55.8	58	59	54	53	57	29	57	34	56
6.	(5)	UK	54.6	62	59	78	41	47	0	57	35	64
7.	(8)	Canada	53.6	63	66	46	40	46	0	50	36	66
8.	(9)	Japan	52.6	50	52	43	60	65	29	42	49	58
9.	(6)	Italy	52.4	53	54	45	53	56	37	49	57	44
10.	(10)	Brazil	50.5	52	55	40	48	50	33	54	24	51
11.	(11)	Australia	50.1	49	52	38	53	53	55	43	57	48
12.	(12)	Sweden	49.2	55	55	53	37	43	0	58	35	56
13.	(13)	Romania	48.2	54	57	39	40	46	0	45	42	47
14.	(15)	Poland	47.8	55	57	44	39	44	0	44	23	49
15.	(16)	South Korea	47.5	48	47	54	49	52	30	41	37	47
16.	(14)	Spain	47.0	45	48	35	52	52	56	43	26	37

Rank		Country	All renewables	Wind index	Onshore wind	Offshore wind	Solar index	Solar PV	Solar CSP	Biomass/other	Geothermal	Infrastructure
17.	(17)	South Africa	46.5	50	54	37	44	43	51	37	35	51
18.	(19)	Belgium	45.0	51	50	58	37	43	0	39	28	52
19.	(20)	Portugal	44.6	46	58	35	46	47	36	38	26	39
20.	(18)	Greece	44.1	45	48	33	47	49	33	34	25	32
21.	(21)	Mexico	44.0	45	46	40	44	44	40	39	55	41
22.	(22)	Denmark	43.1	48	45	58	35	40	0	46	33	53
23.	(24)	Ireland	42.7	52	53	51	27	31	0	43	24	49
24.	(23)	Netherlands	42.6	48	49	47	36	41	0	37	21	41
25.	(25)	Morocco	42.4	40	43	26	49	48	56	38	21	43
26.	(26)	Turkey	41.6	43	45	33	41	43	29	36	42	39
27.	(28)	Norway	40.4	48	49	46	26	30	0	45	31	52
28.	(27)	Taiwan	40.3	43	44	38	37	42	0	37	38	43
29.	(30)	Egypt	39.8	42	44	32	39	38	45	35	24	33
30.	(29)	Ukraine	39.8	39	41	27	40	46	0	46	32	41
31.	(31)	Finland	39.8	46	48	39	25	28	0	54	26	47
32.	(32)	New Zwaland	39.5	47	50	37	27	31	0	34	51	47
33.	(33)	Austria	38.8	33	40	0	45	51	0	51	34	52
34.	(34)	Tunisia	36.6	36	38	27	44	43	47	20	27	40
35.	na	UAE	36.5	34	37	22	48	47	50	18	18	44
36.	(35)	Israel	36.4	33	38	14	45	46	39	27	29	39
37.	na	Saudi Arabia	35.9	38	40	27	47	47	49	0	0	49
38.	(37)	Chile	35.4	36	39	24	36	37	31	29	38	42
39.	(36)	Bulgaria	35.0	35	38	23	35	40	0	34	34	39
40.	(38)	Argentina	34.7	37	40	22	33	35	17	32	27	33

A statistical analysis of the indices above has revealed that the solar attractiveness index correlates with wind attractiveness index which means that both wind and solar energy markets are complementary and not competing directly, while biomass and geothermal are direct challengers to the PV market.

In terms of overall rankings for renewable energy attractiveness based on a weighted compound indicator (55% of its value is taken from wind index, 32% from solar index and 13% - biomass and other resources, including small hydro, landfill gas and wave and tidal technologies, index) EU countries still lead globally which an exception of the US, China and India.

Figure 5: Map highlighting Country Attractiveness Index countries in renewable energy[7]

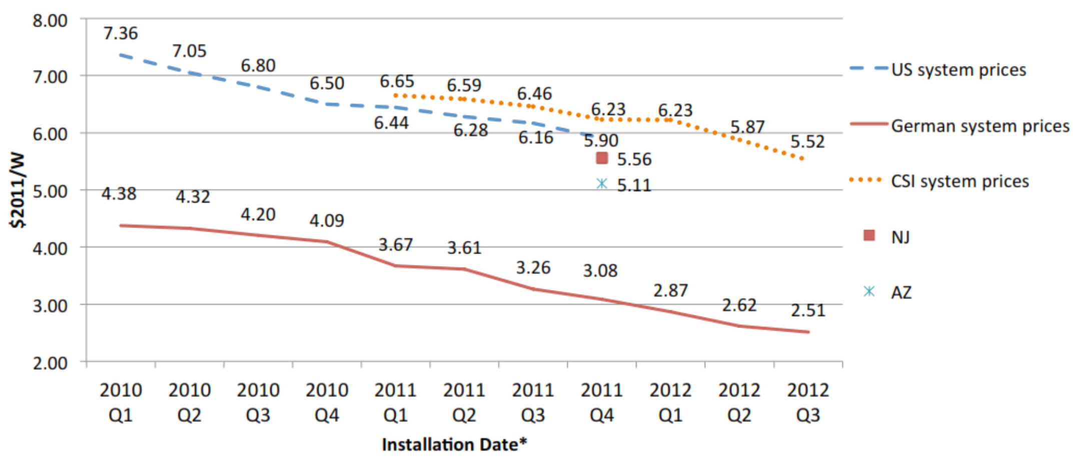


1.3.3 Cost disparities between the main markets

Trend: *System costs are driven down by economy of scale*

During the recent years a cost disparity in PV installation costs has emerged between the US and Europe (mainly, Germany). Though the price of PV systems in the US has dropped dramatically in recent years due to substantial reductions in global PV module market, system cost reductions were not realised by many customers, as confirmed by the NREL study (2012).[8] The comparison with the situation in Germany has showed that the main major contributors to a cost difference are 1) customer acquisition costs ($0.60); 2) shorter installation times leading to lower labour costs ($0.55); and 3) profit, overhead and residual soft costs" ($1.15/W).

Figure 6: Median installed price of customer-owned PV systems ≤10 kW



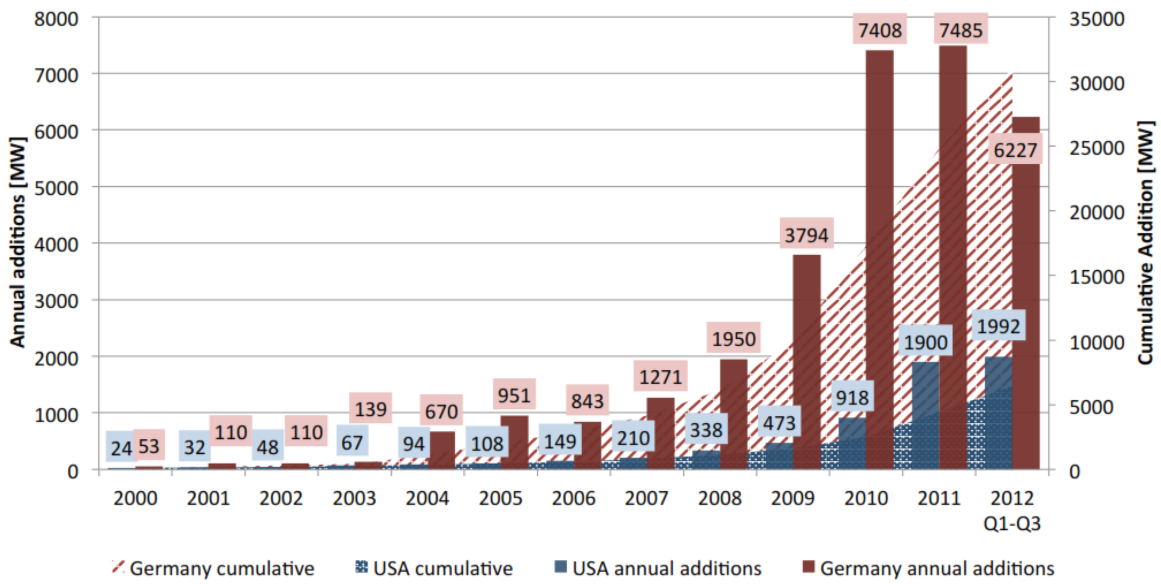
Data Sources: US: TTS, CSI working database of Dec 5th 2012; Germany: EuPD and BSW

7Ernst & Young, Nov. 2012

8 Renewable Electricity Futures Study, National Renewable Energy Laboratory, 2012

It was established that by the additional study conducted in 2013 by NREL into the cost differentiators between the US and Germany that economy of scale (cumulative additions of new systems per year) has an impact on system costs to the customer.

Figure 7: PV capacity additions (MW)



Trend: *System costs are driven down by market concentration*

Further, the following market drivers for soft cost differential in PV system costs have been established by NREL (2013):

- Greater market-wide deployment and longevity in Germany allow for cost reductions based on installer experience;
- Lower market fragmentation (one contiguous market and regulatory framework) and higher population density in Germany allow for lower overhead, transport, and supply chain costs;
- Larger and more concentrated markets in Germany (as well as cultural differences with the US) facilitate bandwagon effects and customer acquisition by word of mouth, leading to lower customer acquisition costs;
- Less onerous permitting-inspection-interconnection processes (e.g. online registration, no permitting fee or inspection by county officials) and installation practices (e.g. easier grounding, roof penetration) in Germany;
- Simpler, more certain and more lasting value proposition in Germany allow for both lower customer acquisition + overhead costs, and larger average system sizes:
    - FiT guaranteed for 20 years in Germany vs. varying value of net metering + state incentives + federal tax incentives in the US
- Regular declining FiT and high competition among installers yield pressure for price reductions and lower margins in Germany, while larger incentives,

opportunities for higher value-based pricing, and less installer competition allow for higher prices and margins in US.

1.3.4 Impact of cost on PV supply chain

Trend: *PV supply chains are getting vertically-integrated and based in China*

Due to the rapidly changing geographical markets PV supply chains are becoming more vertically integrated with upstream value chain actors competing for cost through new technological innovations.

Seven out of the top 10 PV module suppliers are public-listed vertically-integrated c-Si manufacturers located in China. First Solar (thin film), Sharp and SunPower are the only non-Chinese based suppliers in the rankings for 2012.[9]

Table 3: Top 10 PV Module Suppliers in 2012 (source: NPD Solarbuzz, Jan. 2013)

2012 Rank	Module Supplier	Change form 2011
1.	Yingli Green Energy	+1
2.	First Solar	+2
3.	Suntech	-2
4.	Trina Solar	-1
5.	Canadian Solar	-
6.	Sharp Solar	-
7.	Jinko Solar	+2
8.	JA Solar	+7
9.	SunPower	-1
10.	Hanwha SolarOne	-3

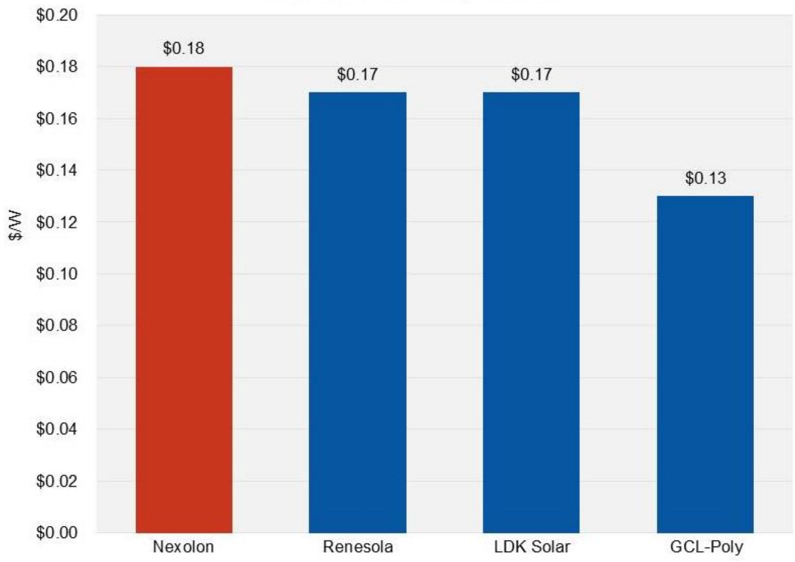
Historically, manufacturing costs for Chinese producers have been more than 15 percent lower than their closest competitors. Although this is attributed mostly to lower labour costs, in reality labour accounts for only a small portion of overall PV manufacturing costs. The real reason is the difference in the price of key consumables: the past three years have seen the emergence of a large domestic supply chain for materials such as steel wire, slurry, silver paste, glass and frames in mainland China. Firms in this supply chain (e.g., Xingda for steel sawing wires) have priced their offerings significantly below European and Japanese competitors (e.g., Bekaert), to the benefit of customers such as GCL-Poly and Yingli Green Energy.

Trend: *China competitors aim to lower wafer conversion costs*

In 2012 South Korean wafer manufacturer Nexolon reported a wafer conversion cost of $0.18 per watt, just one cent higher than Renesola and LDK.[10] Looking to Q3, the company guided continued conversion cost reductions to $0.16 per watt. If Nexolon achieved this cost reduction, it would remain on par with Renesola (Q3: $0.15 per watt) and would easily surpass LDK (Q3: $0.25 per watt, the result of lowered utilization rates). This compares to Q4 2011, when Nexolon reported a conversion cost of $0.25 per watt – 32 percent higher than Renesola.

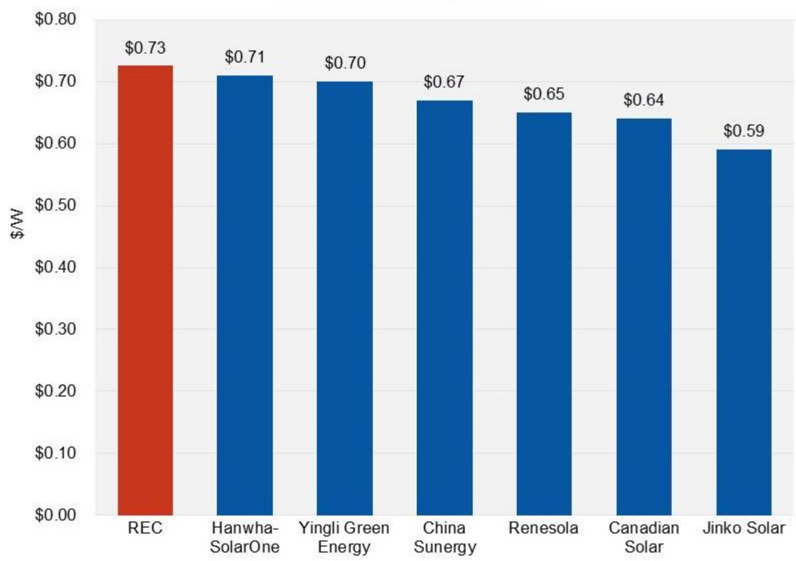
[9] 10 Key Trends for the PV Industry, Slarbuzz an NPD Group Company, January 2013
[10] Carolyn Campbell, Global PV Supply Chain: REC, Nexolon Lower Cost Gap with China, January 2013

Figure 8: Wafer conversion cost, Q2 2012



Similarly, REC has demonstrated an all-in module cost that is competitive with its Chinese peers. The company reported a cost of $0.73 per watt, less than 5 percent higher than its closest cost competitors, Hanwha-SolarOne and Yingli Green Energy. The company is calling for further cost reductions, targeting a Q1 2013 all-in cost of only $0.59 per watt.

Figure 9: All-in module cost, Q3 2012



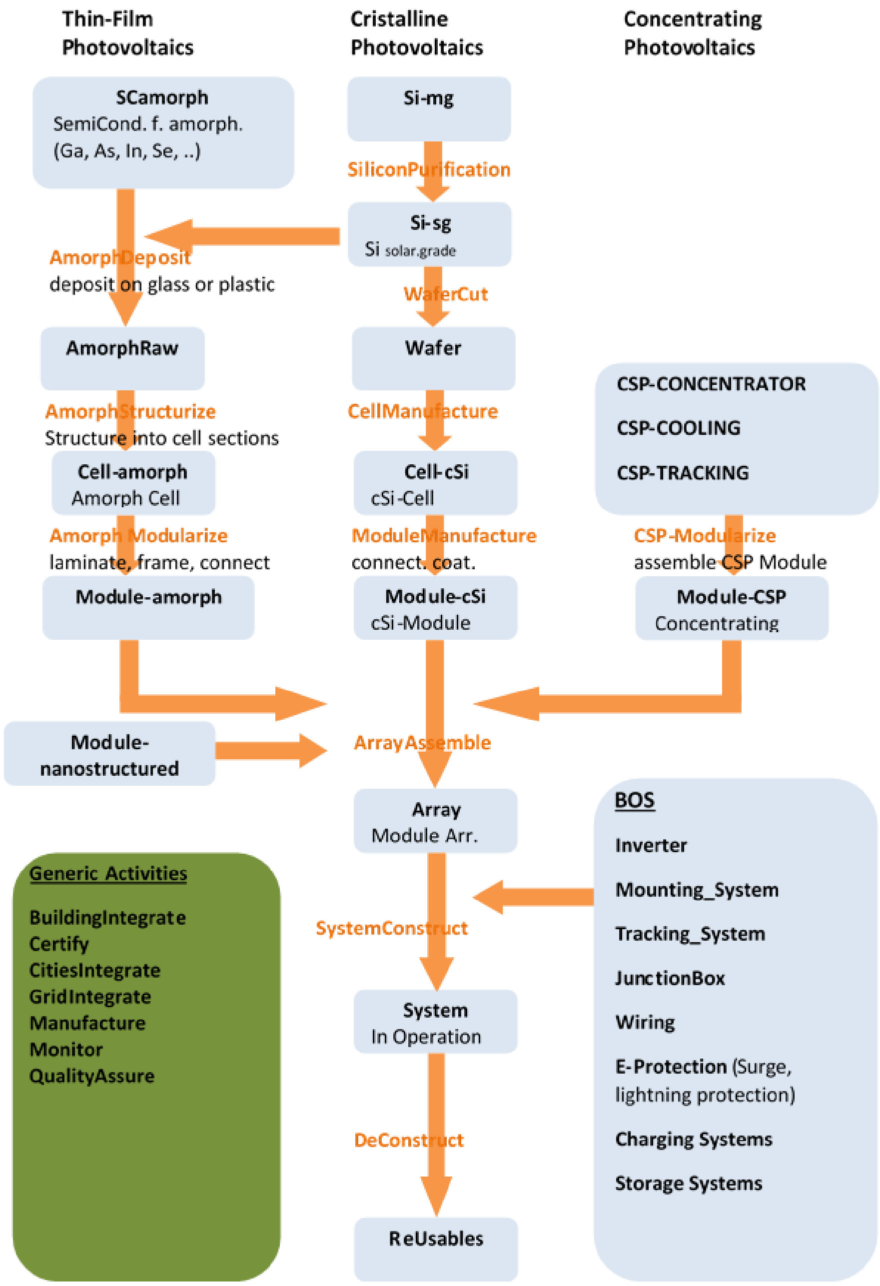
First, the price spread for consumables between mainland China and the rest of the world has contracted significantly in recent quarters, as non-Chinese producers have had to respond to aggressive price cuts by their Chinese competitors. Secondly, unlike most Chinese solar firms, Nexolon and REC have made investments in advanced technology platforms such as quasi-mono ingot growth, diamond wire sawing and backside passivation that, while requiring meaningful upfront capital investment, have yielded significant improvements in their processing costs.

2 THE VALUE CHAIN OF PV INDUSTRY, THE REASONS AND CONSEQUENCES OF INTEGRATION

2.1 Detailed description of PV value chain

The overall PV value chain consists of thin-film PV, crystalline PV and CSP (a more detailed value chain is included in Annex 1).

Figure 10: Photovoltaic value chain



Thin-Film PV supply chain

Manufacturing thin-film modules consists of depositing photovoltaic material on a substrate, structuring it into cells to form an electric circuit and wire and frame it depending on application. According to the material used, the following categories could be identified:

- Silicon-based thin-film
- CIS / CIGS based thin-film
- CdTe based thin-film
- 3rd Generation

Silicon-based thin-film

Silicon-based thin-film supply chain includes the following elements:

- Suppliers of silane precursor and dopant gases for PECVD systems which deposite doped silicon film on the glass (the dopants supplied: trimethyl boron, diborane, phospine and methane);
- Suppliers of Transparent Conductive Oxide (tin oxide) or organometallic precursor (diethyl zinc) for TCO coating and PVD glass coating on the front glass (for the latter the supply of argon for aluminium or silver sputtering is required);
- Suppliers of chemicals (nitrogen trifluoride, sulphur hexafluoride or pure fluorine) for a fluorine-based etch cleaning the equipment chamber.

Optimization of the supply chain by in-sourcing processes:

- To minimize costs and maximize efficiency - and to ensure an environmentally sustainable manufacturing process – on-site generated fluorine is used for chamber cleaning;
- Dopant gas blending on-site;
- Bulk silane storage on-site.

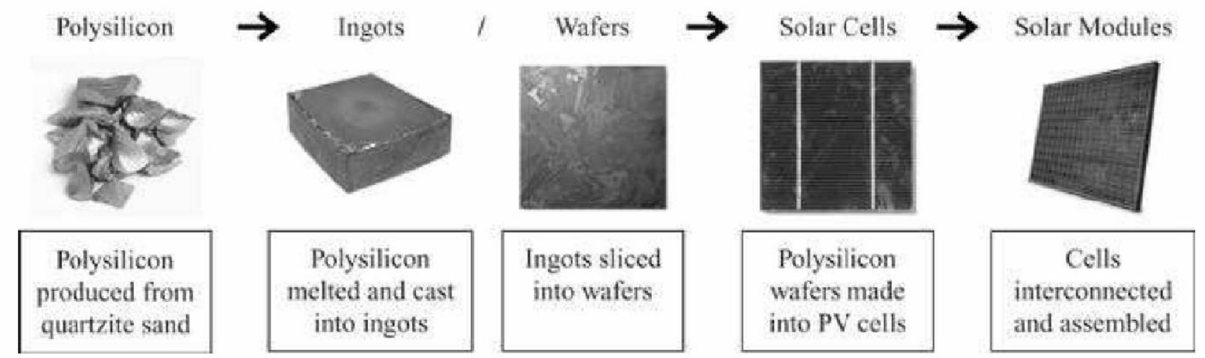
New challenges to supply chain:

- Gas suppliers are evolving from 'traditional suppliers' to integral parts of the manufacturing industry as PV manufacturers seek strong, reliable and knowledgeable partners with expertise in the wide range of specialist materials used in the thin-film silicon production process.
- As the industry grows, other challenges for manufacturers include managing safety and environmental issues, and developing materials technology that will both reduce costs and increase cell efficiency.

Crystalline PV supply chain

The manufacturing process for solar companies differs based on the technology implemented. Traditionally, for crystalline silicon modules, material is the largest cost component. Polysilicon is the material from which solar wafers are made which in turn is used to build solar cells. Shown below is the manufacturing process for c-Si solar systems (Figure 11).

Figure 11: Manufacturing process for c-Si solar systems



Polysilicon manufacturers

In the manufacturing process for both solar based cells and semiconductors, polysilicon is the major raw material component that is used. It is derived after processing raw silicon found as sand. Presently, ~90.0% of solar module production is wafer-based.[11]

Previously, scrap silicon from the semiconductor industry was used to make solar cells. In order to minimize or remove the effects of shortages in supply, wafer manufacturers have started entering into long term contracts for the supply of polysilicon. Sometimes, wafer manufacturers are also required to buy polysilicon at higher spot prices when contracted supplies are not enough to cover the production schedules. Due to the above mentioned factors, some wafer manufacturers have started to invest in polysilicon manufacturing.

Prices of silicon witnessed an upsurge over the last few years wherein the demand had increased significantly, outstripping supply. However, recent market conditions concerning the credit crunch situation have resulted in the prices falling considerably.

The oversupply came into effect in the 2009 with falling prices forecasted, and capacity expansion and production being constrained due to lack of adequate expansion capital resources.

Wacker Chemie and Hemlock Semiconductor are two of the biggest polysilicon suppliers in the industry with capacity of 10,000 metric tons each.[12]

There are three technologies used to produce polysilicon:[13]

- Siemens process (the only commercial route prior to 1980s) – it remains the dominant technology used in the production of prime quality of polysilicon;
- Monosilane process (developed by Union Carbide and further by Komatsu Electronic Metals) – only one company has used this technology to produce polysilicon, namely REC but stopped producing infots in 2012 due to price pressures.

[11] Overview of the Solar Energy Industry and Supply Chain, Stone& Associates, January 2011
[12]Charlie Zhu, As solar panels pile up China takes axe to polysilicon producers, July 2013
[13] Leonid A. Kosyachenko, Solar Cells – Silicon Wafer Based Technologies, November 2011, ISBN 978-953-307-747-5

- Silane-based process in a fluidized bed reactor.

Historically, some wafer suppliers produced also polysilicon to ensure a steady supply. Established suppliers of polysilicon are Hemlock Semiconductor (USA, owned by Dow Corning, Mitsubishi Materials, ShinEtsu), MEMC Electronic Materials (USA), Mitsubishi Materials Polycrystalline Silicon (Japan), Osaka Titanium (Japan), REC (Norway), Tokuyama Corporation (Japan), and Wacker (Germany). New entrants include but are not limited to: OCI Chemical (South Korea), KCC (South Korea), Taiwan Polysilicon (Taiwan), GCL Silicon (China), LDK Solar (China), Daqo Group (China), and Renesola (China).[14]

Upgraded metallurgical grade silicon (UMGS) producer

Another alternative to polysilicon that is currently being used in the production of solar cells is upgraded metallurgical grade silicon which is also referred to as Solar Grade Silicon (SGS). The purity of UMGS is less than that of polysilicon hence cells made using UMGS would generally have lower efficiencies than those fabricated with polysilicon. The efficiency however, can be improved by refining the other manufacturing processes involved in creation of the solar system.

Another major advantage of using UMGS in cell and wafer production is the reduced capital cost incurred in building capacity.

Timminco, a Canadian metal company, claims to have constructed a 3,600 metric tonne solar grade facility at an implied capex cost of $6.0/kg whereas a conventional polysilicon manufacturing process would imply a capex cost of ~$100.0/kg. This would imply a cost that is 17.0x less than that of polysilicon. Another great advantage is that of lower electricity consumption. The Timminco plant used 2kWh/kg compared to around 70-120 kWh/kg in the conventional process.

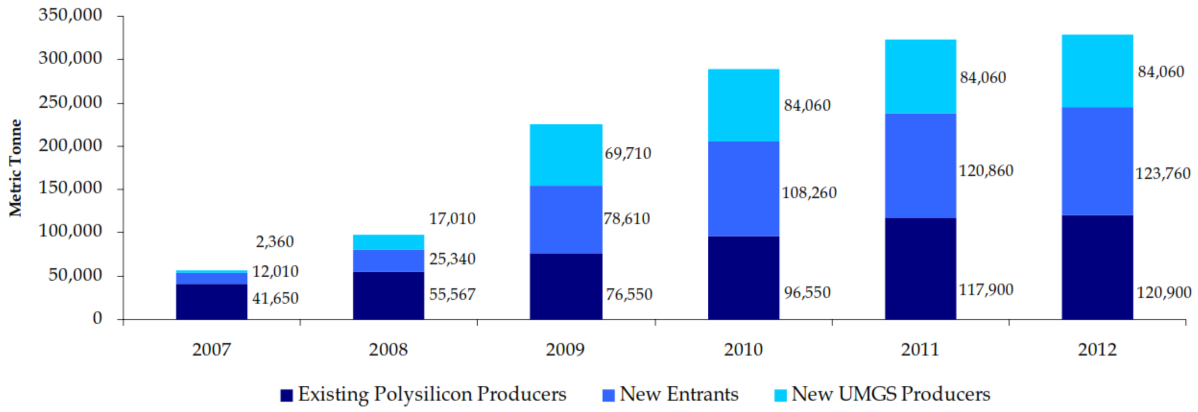
Setting up of UMGS plants take around 2 years compared with a 3-4 year gestation period of polysilicon plants. Overall lower production costs, translating into lower selling prices, provide cost advantages to the solar industry.

Timminco suppliers silicon to Q-Cells, the major wafer producer using UMGS. Other companies which are working on processes to achieve the mass conversion of tonnages of upgrades metallurgical silicon for solar use are 6N Silicon Inc. (Canada), JFE Steel, ARISE Technology Corporation (Canada). LDK is also testing metallurgical silicon.

Combined cumulative silicon capacity, including new UMGS and polysilicon capacity, could reach up to 6.0x its 2007 capacity, in the year 2012. Shown below are the year and capacity forecasts of polysilicon producers.

[14]ArnulfJäger-Waldau, Research, Solar Cell Production and Market Implementation of Photovoltaics, European Commission, DG Joint Research Centre, Institute for Energy and Transport, Renewable Energy Unit, September 2012

Figure 12: Year end capacities of polysilicon producers



Ingots

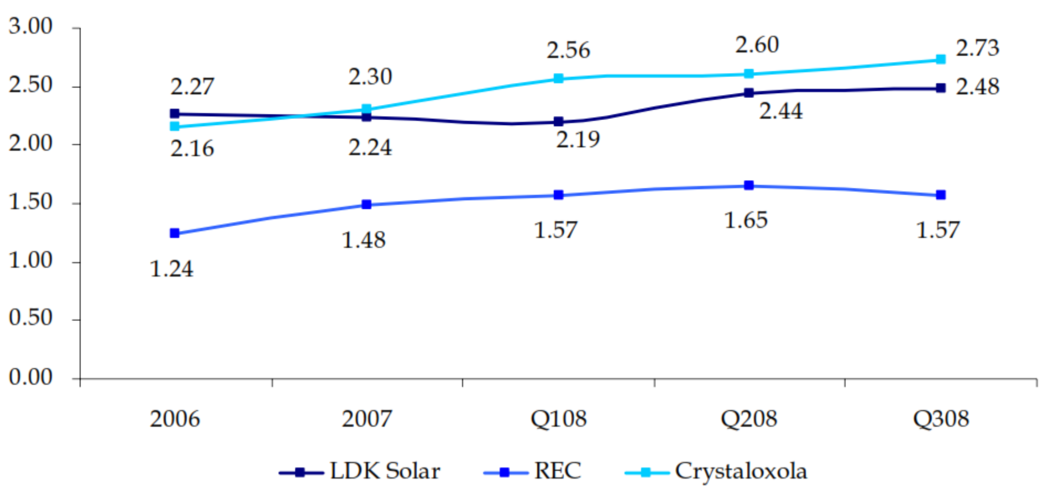
Polysilicon is further processed into ingots, which can either be made from a single crystal (mono-crystalline) or multi-crystalline silicon. Multi-crystalline silicon has a non-uniform crystal structure and hence has lower conversion efficiencies than monocrystalline silicon solar cells. The only drawback is the higher cost of producing mono-crystalline silicon.

Wafers

The ingots are further divided into smaller segments by sawing or slicing them into silicon wafers. This steps results in the wastage of a significant amount of silicon as sawdust, which is also referred to as “kerf loss”. With the recently high prices of silicon, manufactures have come up with a few alternatives to reduce the wastage of silicon and also to utilize lesser silicon per wafer and per solar cell.

The first method is to improve on the wafer sawing techniques and minimizing the kerf loss through the use of wire saws and lasers. Reducing the wafer thickness is another way to reduce significant wastage of silicon. Other alternative manufacturing techniques are also being tested which do no require the manufacturing of ingots and wafers. The average selling prices of select wafer manufacturing companies have been shown below.

Figure 13: Average selling prices of select wafer manufacturers



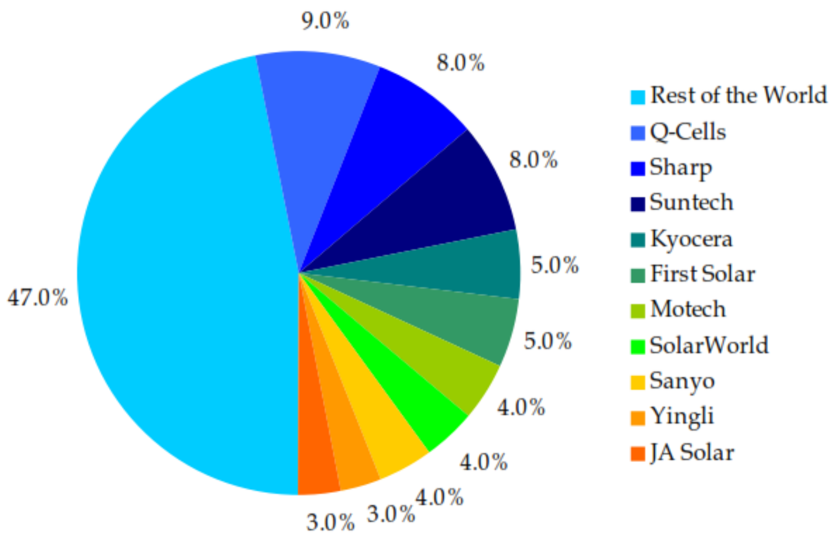
Solar Cells

Crystalline solar wafers are used as substrate to manufacture the solar cell, which is the main part of the solar system that converts the sunlight into electricity. Solar photovoltaic cell production has boomed in the last few years due to the excessive demand for solar systems. The European Union has also given generous subsidies towards solar companies which have resulted in rapid growth. PV cell production has grown at a remarkable rate of ~51.0% in 2007 taking the total PV cell production figure to 3,733.0 MW_p.

Solar cells can be of crystalline silicon or thin-film types. Crystalline silicon currently accounts for a majority of PV cell production.

However, due to silicon shortage negatively impacting the producers in recent periods, thin film based technology has become more popular due to the lowered dependence on silicon as a raw material, also resulting in lowered production costs. The market share of the top 10 solar cell producers is shown in Figure 14.

Figure 14: Market share of the top 10 solar cell producers



Region wise production of solar cells globally reveals that Japan was the largest producer till 2006, with Europe in second place.

Due to a silicon shortage causing Japan's production to remain flat in 2007, Europe took over as the largest producer. Players like Q-cells and SolarWorld led the growth in Europe. China emerged as second largest producer. The USA placed fifth in the 2007 PV cell production list and was overtaken by Japan and Taiwan, who took the third and fourth place respectively.

Though China and Taiwan have both started production only recently, have embarked upon very aggressive capacity expansion plans. The major Chinese players in the market are Yingli Green Energy, China Sunergy, Suntech Power, Solarfun, and JA Solar.

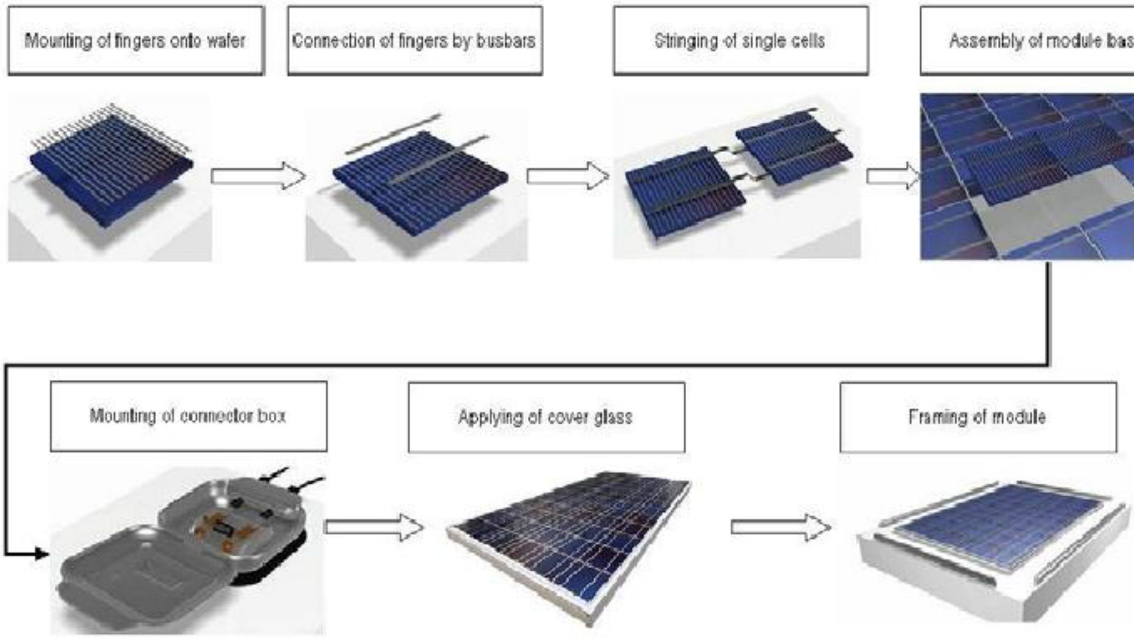
The major Taiwanese players are Motech Industries, Gintech, and E-Ton Solar. Most of these companies have nearly doubled production in 2007 and have set ambitious targets for the coming years as well. Even though reduction of government subsidies in

Germany and Spain have been announced, these two markets have not been discourages and have announced aggressive capacity expansion plans over the next few years.

Solar Modules

To generate sufficient amount of power enabling the operation of residential and commercial systems on solar energy, the power output of the solar cells need to be harnessed by taping and stringing them together to form solar modules which have specified electrical configurations. Most module manufacturers offer power output of ~90.0% and ~80.0% for the first 10 years and 25 years respectively.[15]The diagram of the module manufacturing process is shown in Figure 15.

Figure 15: Diagram of the module manufacturing process



Thin-Film Module Manufacturing Process

The manufacturing of thin film modules is an entirely different process from that of c-Si modules, the most evident dissimilarity being that of the raw materials used. In c-Si modules, it is has been seen that dependence on polysilicon is very high and that raw materials make up the majority of the cost.

In thin-film technology, the time taken to manufacture a module is much less compared to that of a c-Si module. The thin-film manufacturing process, (based on information from First Solar which uses CdTe technology), can produce a solar module from a single sheet of glass in under three hours without any manual labor compared to many more steps required in the value chain for manufacturing c-Si modules.

The major module manufacturers around the world are Solon AG, Aleo Solar, SolarWorld, Suntech Power, Sunpower, Trina Solar, Yingli Green Energy, Sharp Corp,

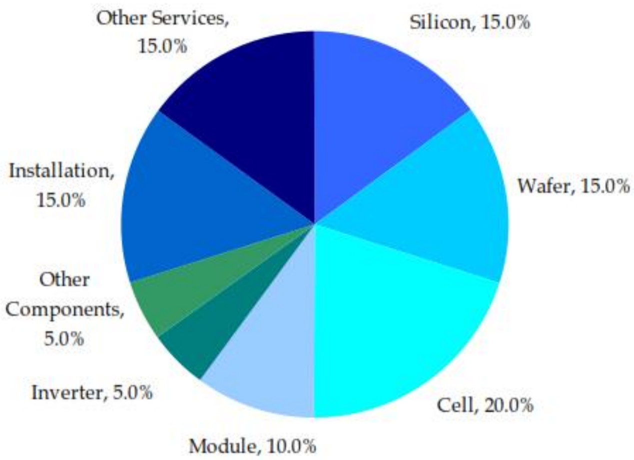
[15] China Sunenergy Co. Ltd, 2012 annual report

Kyocera, and Sanyo Electric. Major thin film module manufacturers are First Solar and United Solar.[16]

Solar Systems

A solar system is an arrangement of solar modules at one specific point or area to capture sunlight to be converted into electricity. Apart from the module arrangement, a solar system's other components (Balance Of System) include an inverter, meters for net metering and feed-in electricity, battery for storing power, if needed, power controls, connectors, and other electrical circuitry and installing materials needed for completing the system. The typical cost structure of a PV system is demarcated in the following illustration.

Figure 16: Average solar system price by its components



The solar systems can be installed on the roofs or walls, of houses and buildings, or can be ground based, for e.g., large solar farm and utility sized solar systems. Solar tracking systems, also called "Heliostats" have become popular and are used to track the sunlight by aligning the modules towards the direction of the sun to capture optimal amount of sunlight. Shown below is the structure of a dual tracking system.

Solar Project Developers

Solar project developers are the next step in the supply chain and are concerned with the designing and construction of solar power projects such as solar power plants. The developers conduct site analysis and select the best possible area for the setting up of a solar power project. After the plant construction is completed and it is operational, it is then sold to investors and customers.

The solar project developers usually also take charge of the maintenance and repairs of the power plant after it is completed. The major solar project developers are Conergy, City Solar, Phoenix Solar, Acciona Solar, Sunpower, and Ecostream.

Power Purchase Agreement (PPA)

A power purchase agreement has become a very widely used means of financing large solar power plant projects and commercial solar systems. Under the PPA agreement, the

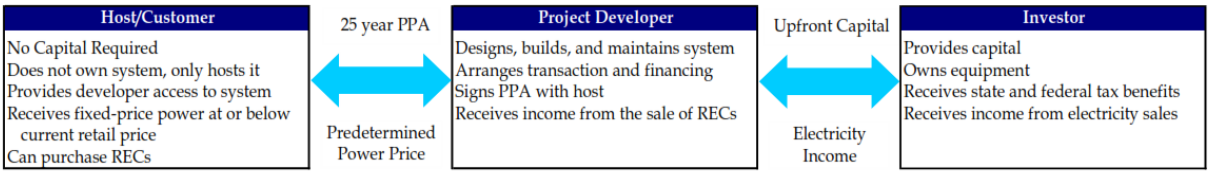
[16]Global Solar Cell and Modules Industry, Global Industry Analysts Inc., February 2011

customer does not buy the solar plant facility directly from the solar project developer; instead they agree to buy the electricity directly from the developers at predetermined prices for a fixed term, usually between 10-25 years.

The solar systems are built, installed, and operated by the solar project developers on behalf of equity investors who provide the capital for building such facilities. The investors receive their return through the electricity sales income, and any other federal or state tax credits. The solar project developer receives his return for building, installing, and operating the system.

In most PPA transactions, there is another player involved, referred to as the Solar Energy Service Providers, who mainly co-ordinate the financing, installing, and operation of solar systems. They approach investors and raise the required capital from them, hire the project developers to construct the system, and co-ordinate the power purchase agreements with the customers. Therefore, all the risks and responsibilities of the PPA rest with the energy service providers. The general structure of a PPA financing model is shown in Figure 17.

Figure 17: General structure of a PPA financing model



At the end of the term, the customer has the option of buying the facility or entering into a new PPA. The advantages of a PPA as opposed to owning a facility outright are:

- There is no significant capital expenditure required
- The customer's only cost is the electricity generated by the system
- The prices are predetermined and hence less susceptible to fluctuation.

The PPA transaction is generally suited to large commercial systems and utility sized power plants. According to Greentech Media Estimates, around 50.0% of commercial solar system installations in 2007 were financed using the PPA model and around 75.0% of installation in 2008 and 2009 will be financed with PPAs.

Solar Equipment Companies

The demand for solar equipment has increased with the explosion of the solar energy space. Many semiconductor companies have started manufacturing equipment for the solar industry as the manufacturing processes and materials required for solar cells very closely resemble those of integrated circuits. Equipment companies have also started providing turnkey solutions for the manufacturing of c-Si cells and modules, as well as thin-film modules.

Subsidies and Support Schemes for the Industry

The solar industry is still economically unfeasible as the electricity produced through solar power is more costly than conventional grid electricity. Hence, to provide impetus to solar power manufacturers, the government must provide certain subventions so that the production of solar powered electricity, apart from benefiting the environment, also results in a benefit for the producers and makes it commercially viable to produce on a large scale. Various countries have adopted different assistance plans and subsidy schemes.

Feed-in Tariffs (FITs)

FITs are the most established and successful policy adopted and used in mostly all of the major European solar markets such as Germany, Spain, Italy, Greece, Ireland, France, Portugal, etc. The feed-in tariff implies that renewable energy plant operators are paid a fixed tariff for every kilowatt hour (kWh) of electricity fed into the grid. The tariff to be paid depends on each country's feed-in tariff plan and varies according to the size of the plant, its location, and the source of the renewable energy.

The feed-in prices to be paid are fixed based on the cost of generating electricity for the renewable energy plant operator. The prices are usually fixed for a certain number of years after which they start declining so as to give the plant operator an incentive to reduce his cost of generating electricity thereby reducing the cost at which it is sold.

In most countries, it is the norm to have the grid operators give priority to the renewable energy plant operators and purchase electricity from them first. The higher price paid by the grid operators is passed on to the utilities who in turn pass on the higher price to the consumers. This implies that consumers would not have to pay a higher price if there was no purchase of electricity from renewable sources.

Germany is a prime example of a success story for feed-in tariffs. It is estimated that in 2008 in Germany, the utilities ended up paying a tariff of between €0.35/kWh and €0.47/kWh, depending on the size and type of PV system from newly installed solar plants.[17] To absorb this extra cost, the utilities passed on this extra cost to electricity consumers resulting in German households paying an additional €1.25 per monthly due to the tariffs for solar electricity. It is also important to reduce the tariffs over time as it gives the plant operator an incentive to reduce his cost for producing solar power. It is because of this reason, that the feed-in tariffs in Germany are reduced each year by 5.0%, with the digression rate in 2009 rate being increased to 8.0% -10.0%.

This policy is only valid for newly installed PV systems. The tariff is to remain constant for a period of 20 years once the PV system is connected to the grid. Hence the 5.0% reduction policy is very important as the market must reduce its costs in proportion to keep the margins from slipping.

Feed-in tariffs offer investment security and provide momentum to the industry to reduce costs while simultaneously benefiting the environment. It can also be customized to suit different types of technologies, such as higher tariffs for costlier and less developed technologies and vice-versa. Also, the cost escalation to be absorbed by the

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[17] China's Solar Future. A Preliminary Report on a Recommended China PV Policy Roadmap, PV Group, May 2009

customer is minimal hence it does not place too much of a burden of households as well. One major disadvantage is of having the tariff rates too high, if cost reductions due to technology improvements and other reasons are not factored in. On the other hand, if the tariffs do not provide enough benefit due to higher production costs, the policy might fail to encourage manufacturers of solar energy.

Renewable Portfolio Standards (RPS Policies)

RPSs are also known as quota obligations and are mostly prevalent in North America, China, Japan, Australia, Italy, and Canada.

By the end of 2007, 44 countries had enacted RPS policies.[18] An RPS policy states that the final retailers of electric energy must have a certain portion of their electricity sales from renewable sources. Countries have also set their own targets for the amount of electricity that should be provided by renewable sources of energy. Since utilities are mostly the final retailers of electricity, it is up to them to meet the targets set which are usually in the range of 5.0%-20.0% to be achieved by 2012.

They can reach the targets by self generation of electricity or by purchasing alternative sources of energy from other power plant operators. There is also another clause known as the Alternative Compliance Payment (ACP) which is the penalty that the utilities and other electricity retailerswould have to pay in case they do not end up meeting the targets set in the RPS policies. The following two policies are usuallyused in conjunction with the RPS policies.

Tendering

Under the tendering scheme, power plant operators are allowed to bid for the projects to provide renewable energy and the lowest price quote wins the project. Therefore, the utilities purchase electricity from power producers at prices quoted by them.

Renewable Energy Certificates (RECs)

Also called green certificates, they help countries meet their obligations under the RPS policies. These green certificates are awarded to renewable energy producers for every unit of electricity produced as a type of proof of renewable electricity generated.

These certificates are traded in the market to help electricity retailers meet their obligations under RPS schemes. The electricity retailers can decide to either self produce the electricity or purchase the RECs from other power producers. The price of the REC is the biggest factor in this decision to make or buy. For example, if the demand for renewable energy is higher than its supply, i.e., its mandated amount under the RPS scheme, the price of the RECs would definitely go up and vice-versa. The ACP is one of the factors on which the price of the REC depends. The ACP needs to be sufficiently higher than the REC to motivate compliance under the RPS scheme.

RPS policies, unlike feed-in tariffs, do not have any investment security, as the fluctuating prices of the RECs are the dictating factor for meeting quota compliance. The

[18] Renewables 2013, Global status report, Renewable Energy Policy Network for the 21st Century, 2013

prices of RECs are also not technology specific, i.e., the price of an REC issued for generating solar powered electricity sells at a price equal to an REC issued for generating power from other sources of energy such as wind energy. Setting a quota for the amount of renewable energy to be generated in essence puts a cap on the amount of energy to be created and does not provide for any additional incentive for energy creation.

Subsidies, rebates, tax incentives, exemptions

Subsidies, rebates, tax incentives/exemptions & tax credits are designed to make investments in renewable energy at lower costs. This can happen either upfront at the time of purchase through subsidies and rebates or it can take place after purchase through tax benefits or tax credits on production of renewable energy.

The direct investment subsidy is offered in a minimum of 35 countries across the world and at least 40 countries offer different types of tax credits and incentives.

Many countries have set aside special public funds for boosting the growth and development of renewable energy by channeling these funds towards directly financing investments, providing cheaper loans, and providing funds for RTD and education.

Net metering

This scheme is a very important incentive for solar installations in private households and especially for the rooftop solar PV installations. Under net metering, the customer is required to pay only for the net electricity consumed, and as and when the amount of electricity generated exceeds its consumption, the excess power can be sold back to the electricity retailers or the grid.

This scheme, in effect allows customers to receive payment of retail prices for the excess electricity that they generate.

2.1.1 Downstream channel structure and volumes

Along the PV value added chain, the term ‘downstream’ refers on the one hand to project developers, general contractors (suppliers of complete solutions) and systems providers, and on the other to financing, in other words lending for photovoltaic projects.

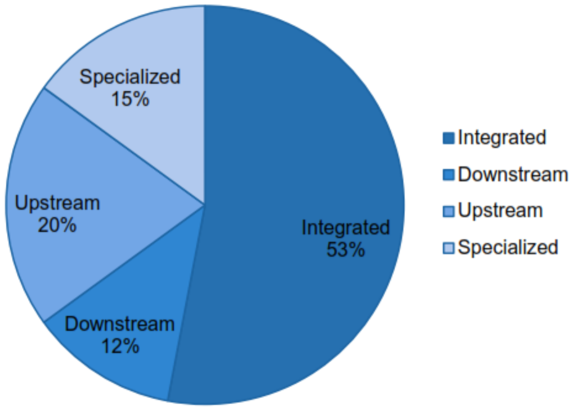
2.1.2 Upstream channel structure and volumes

The term ‘PV upstream’ is taken from the PV value added chain and refers the module and inverter manufacturing phase. This stage of the value chain is responsible for roughly 70% of the total costs of a PV system, and is therefore the area with the greatest savings potential. Since the inception of the PV manufacturing industry, the production of components has undergone dramatic developments.

2.2 Description of the reasons for integration in PV value chain and existing and foreseen consequences

According to the analysis of IHS Solar Research (December, 2012)[19] in 2013 fewer than 150 companies will remain in the photovoltaic upstream value chain, down from more than 750 companies in 2010. To say that consolidation will be occurring next year is to speak optimistically, as most operations are not expected to be absorbed by others, but rather will be written off completely. Most of these companies have already stopped producing in some form or another, and in the majority of cases, will not start up again. Particular key groups of companies are at higher risk than others as this transition occurs.

Figure 18: Top 60 company business models. Source: IHS Solar Research, 2012

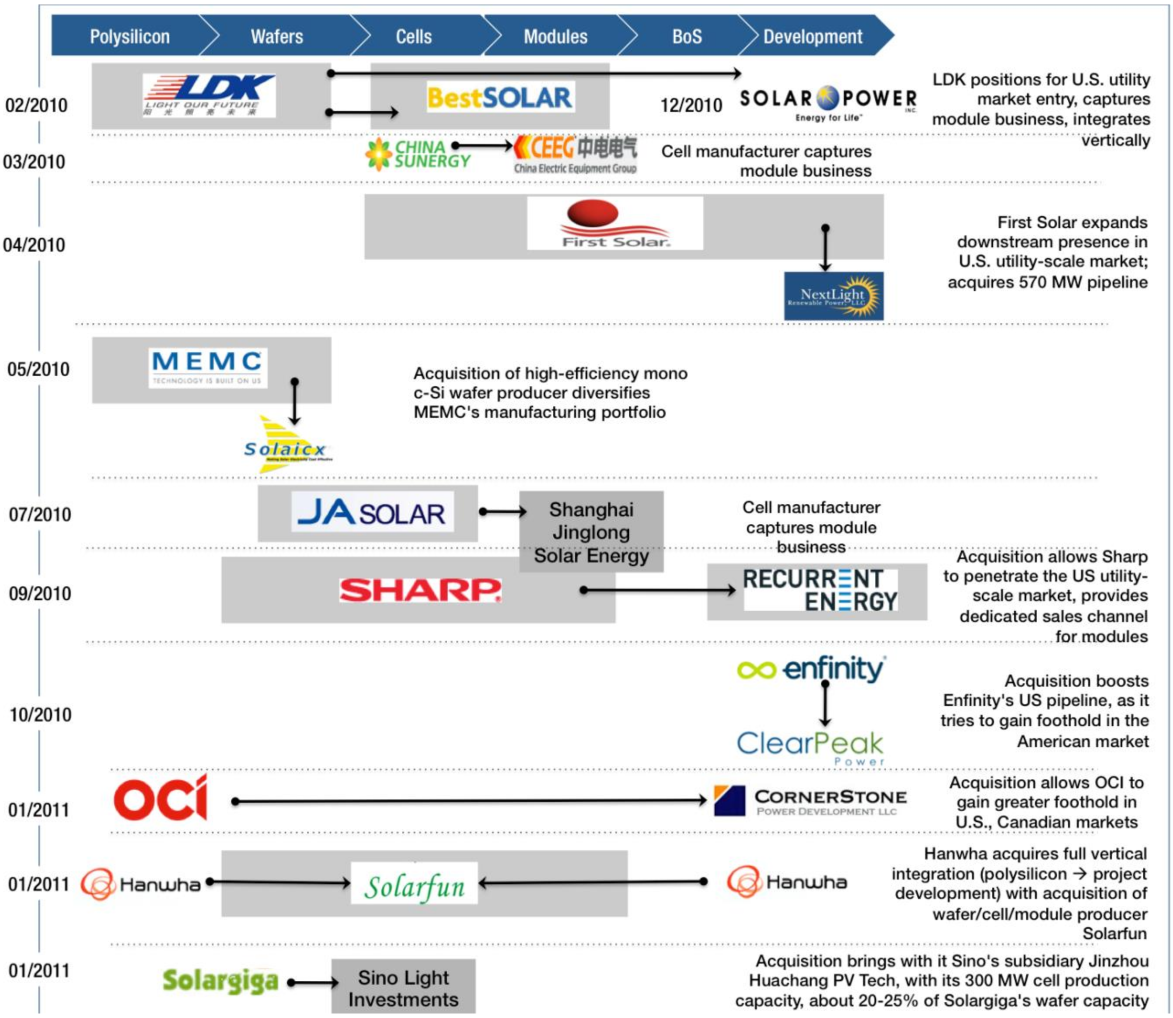


2.2.1 Models of vertical integration

Vertical integration has been a favoured strategy for company survival in the aftermath of the financial crisis. Examples of vertical integration across the PV Value Chain in the period 2010-2011 are provided in Figure 19.

[19]Top-10 Solar Market Predictions for 2013, IHS Solar Research, December 2012

Figure 19: Examples of vertical integration across the PV Value Chain in the period 2010-2011. Source: GMT research



An illustrative example of a completely vertically integrated solar company is Hanwha Chemical. Already involved in the production of polysilicon and project development, the company's acquisition of wafer, cell, and module producer Solarfun enables the recently renamed Hanwha-SolarOne to lower costs across the entirety of the production and installation processes. Another example of nearly complete vertical integration from the top down is MEMC, a polysilicon producer that has so far sold PV wafers largely through tolling arrangements with contract manufacturers. Starting with its acquisition of developer SunEdison in 2008, it has since purchased Solaicx, a high-efficiency wafer producer, and has entered into a joint venture with Flextronics to manufacture MEMC-branded modules for exclusive use by SunEdison. Missing from the value chain is a cell production line, which would subsequently lead to the manufacturing of modules in-house. MEMC's acquisition of Solaicx follows a trend where many manufacturers have adopted an integrated wafer-polysilicon model. Other firms include REC, M.Setek, LDK, Renesola and Yingli, though these companies have moved upstream as opposed to MEMC's downstream acquisitions.

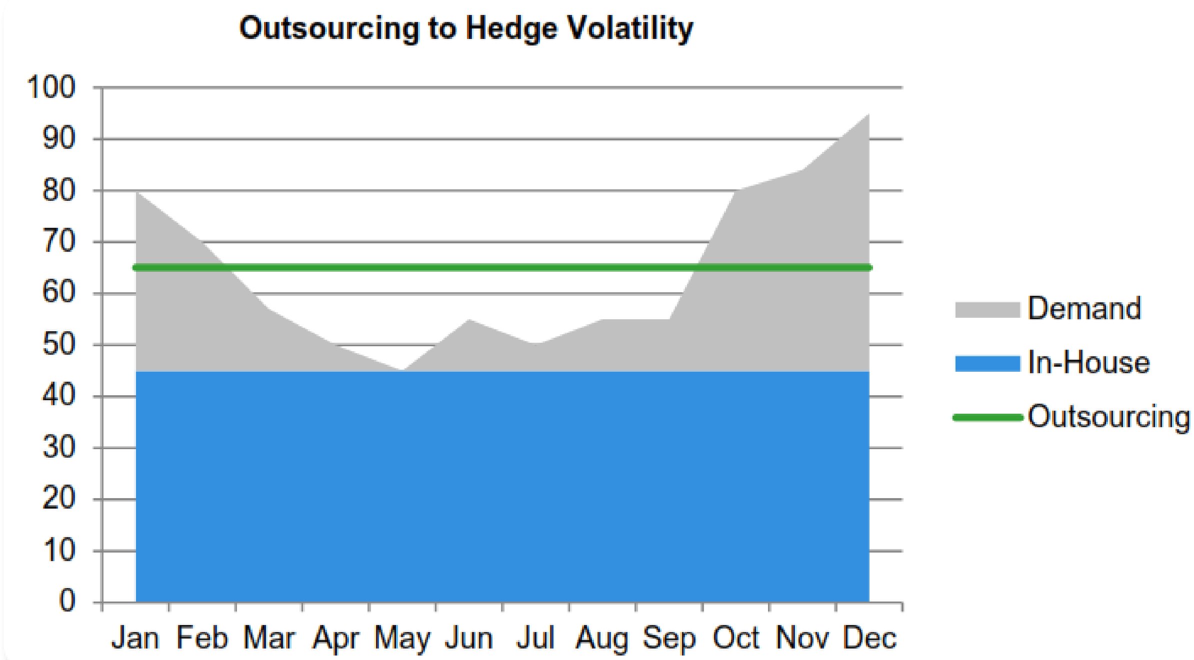
2.2.2 The consequences of the integration of PV value chain

However, latest forecast (December 2012) shows that integrated business model will surface a further decline. Many integrated players will fold up shop in 2013 as the large expense of building integrated facilities—and then underutilizing them for the better part of a year—will be more than many can handle financially. Many of these players are based in China—a significant factor in any PV forecast. Subsidizing such operations in this case is certainly an option, but, according to IHS Solar Research that while some may be propped up during this time, the majority will be left to dissolve.

Consequences for upstream businesses

With price declines still occurring across the board in 2013, low-cost players will get the lion's share of the global market. Upstream second- and third-tier players (polysilicon/ingot/wafer/cell) will struggle to survive the year in markets without local content requirements, and many will not be able to float operations for such a long period of time. For second-tier module manufacturers, the key to surviving in 2013 will be relationships with downstream players in the emerging markets. Second-tier manufacturers have to move faster than those in the top tier in order to grab mindshare early. Flexible business models, with consistent outsourcing, will be needed to make the approach work. As contract manufacturers require certain levels of business to remain profitable, securing stable relationships with the companies is also critical. Efficiency will lie in the number of firms using this model, given that the more a contract manufacturer is able to hedge against demand volatility, the better the terms will be with channel partners.

Figure 20: Outsourcing strategy. Source: IHS Solar Research, 2012



The need for flexibility calls for capitalizing on the volatility in high-growth markets consisting mostly of small and midsized EPC/developers. These players initially have less allegiance to established top-tier manufacturers; as experience grows, price becomes a primary factor, favoring low-cost producers. This is already true in markets like India, and is becoming a factor in Latin American countries such as Chile.

Consequences for thin film manufacturers

Thin film manufacturers will have to behave similarly like second-tier c-Si module manufacturers if pricing by the former cannot match the extent of decrease in crystalline during the year. The main difference is that investment in these second-tier c-Si module manufacturers will need to be higher to justify any technology concerns, which remain a factor with most thin film technologies. Many of the smaller thin film players will not be able to buy in at this price point, relegating them to select niche markets marked by little demand.

2.3 Detailed description of possibilities and analysis of barriers for market entrance

2.3.1 Possibilities and main barriers

The main barrier is a drastic decline in prices along the silicon supply chain that has taken since March 2011 and was driven by the production overcapacity (mainly in China and Taiwan) and the diminishing governmental support for PV installations (in Europe).

It is expected that prices will stabilize by mid-2013 s changes in market dynamics help restore the global supply-demand balance in particular. The anticipated stabilization of prices—from polysilicon to c-Si modules—will be due to a moderate cut in production among Tier 1 polysilicon suppliers and because some excess capacity in China—from ingot to cells—is also expected to leave the industry by mid-2013, serving to further stem the price decline in wafers and cells the first six months of 2013. It is forecasted that global photovoltaic installations reach almost 15 gigawatts—a record high for a first-half period.

Perhaps more important than next year's changing rankings of the biggest markets is the geographic fragmentation that we predict will accelerate in 2013. While nearly three-quarters of total solar demand in 2012 came from the Top 5 end markets, the total portion will drop to 65% in 2013 as the market fragments. This is because of the increasing importance of "midsized" markets installing a few hundred megawatts per year.

More stability will result for this boom-bust industry, because a single government's incentive policy will have less impact on the overall global market. But along with this stability will come intense challenges for solar companies as they are forced to globalize business by setting up new sales and service networks, complying with local requirements and grid codes, and navigating past the "quick-hit" markets that are here one year and gone the next.

2.3.2 Differences in importance of barriers for SMEs and large companies

Six trade wars (see below) taking place in solar industry globally will make it difficult for SMEs to operate across the supply lines involving parties from opposite side sin the trade wars.

US against China

The main issue of the trade war between the US and China is Anti-dumping tariffs and countervailing duty on Chinese modules using Chinese c-Si cells. At the request of the Coalition for American Solar manufacturing the US Department of Commerce and International Trade Commission had initiated an investigation (started on 19 Oct. 2011) which concluded (Nov 7, 2012) with antidumping tariffs being imposed. On Nov. 7, 2012, the International Trade Commission announced the final tariffs, which range from 34% to 41% to 46.5%—levied on Chinese companies that participated in the U.S. investigation. However, for Chinese companies that were not invited to participate or did not disclose financial records when requested, the tariffs will be a much heftier 265%.

China against US and South Korea

In response to the measures taken by the US Chinese polysicon industry and Chinae's Ministry of Commerce initiated (on 20 July, 2012) an investigation into anti-dumping and countervailing of polysilicon which is still ongoing.

Europe against China

EU ProSun initiative led by SolarWorld has campaigned for similar antidumping tariffs and on 6 Sept, 2012 the EU Commission has started an investigation into anti-dumping of crystalline modules and solar products.

China against Europe

In response to the initiative of the EU Commission China's Ministry of Commerce has initiated an investigation into anti-dumping and countervailing of polysilicon.

India against China

In January 2012 Directorate General of Anti-dumping and Allied Duties (DGAD) at the Ministry of Commerce has started an investigation into anti-dumping in relation to China.

What happens next year will depend very much on the European investigation into China, opened in September 2012. If the European Commission imposes tariffs on Chinese PV products, it is likely that China will retaliate via its own tariffs on European-made solar materials and equipment entering China. It is even possible that the battle will extend to other industries outside photovoltaics.

According to the EU anti-dumping regulation, "a company is dumping if it is exporting a product to the EU at prices lower than the normal value of the product (the domestic prices of the product or the cost of production) on its own domestic market.

In addition to the US anti-dumping investigation procedure the EU Commission when considering anti-dumping takes into the account the EU community interest which in the case of PV does not rest on modules alone. In fact, the larger part and value is generated by installations and by the Balance of Systems (BoS) industry.

Nonetheless, duties on Chinese modules would artificially increase the system price. Increasing the system price, in turn, would result in reduced demand, impacting both the installer and the BoS industry. Given that the value of the installation, BoS and non-module parts is higher than 50% of the total system price, the duty on module prices would have a larger leverage on European industries not concerned with the dumping. A tariff on Chinese modules, then, would have to be well-balanced so as not to further harm the solar industry.

The EU investigation will take 15 months, at a maximum. Meanwhile, IHS is seeing that European wholesalers are already starting to diversify their portfolio and buy non-Chinese modules, aware that retroactive duties on Chinese modules could still be imposed.

The pending trade case makes planning ahead difficult. It is possible that Chinese duties might be paid retroactively once preliminary tariffs are announced (if any); preliminary announcements could be made by Q1 2013. And as long as the EU trade case investigation is continuing, IHS expects that Chinese modules will be sold at a discount—given the uncertainty of the trade case on the one hand, and unwillingness on the part of investors to risk retroactive payments on the other.

The phenomenon of very-fast-growing PV companies will not happen again, even in China, because margins for PV production are not attractive. And with margins not improving in the short term, the solar industry will prove unappealing to Chinese industry tycoons and prevent more entities from entering an already crowded field. From 2009 to 2011, for instance, nameless investors from the Chinese automotive, telecom, and real estate sectors expanded into PV, expecting large profits that instead led to massive overcapacities.

HIS Solar Research expects that the “Anti-dumping Game of Retaliation” to lose importance in 2013. If tariffs appear in the EU like those imposed by the United States, Chinese companies will find solutions to bypass the tariffs—simply outsourcing solar products, for instance, to Taiwan and South Korea; or fielding them to local joint ventures.

Technological barriers

The IHS Solar Manufacturing & Capital Spending Tool estimates that 23.3 GW of module manufacturing equipment will go offline from 2012 through 2015. Estimates for cell and wafer manufacturing equipment are at 24.8 GW and 24.7 GW, respectively, for the same period. This is equipment that has to be replaced regardless, and should already be budgeted for. It presents the all-important opening to implement the latest equipment and tools.

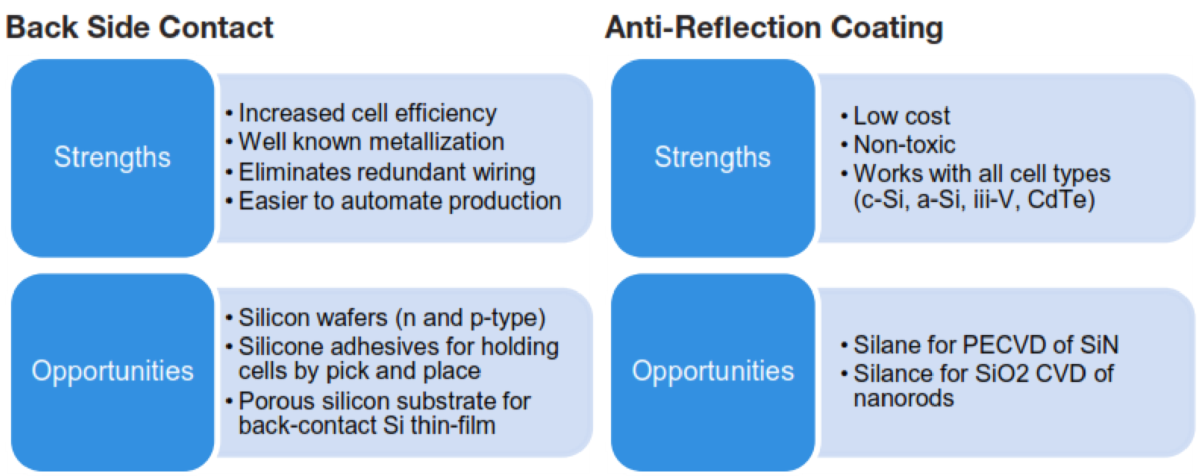
IHS predicts that technology will be the key to our industry's revival—improved technologies that will help PV manufacturers cut costs, increase margins, and ultimately distinguish themselves from the competition. Such a focus creates an opportunity for both manufacturers and equipment suppliers to obtain larger revenue streams.

Key efficiency-improvement opportunities include direct solidification and epitaxial silicon, both of which eliminate the cost and waste left behind by current wafer-sawing techniques. Quasi-mono silicon ingot growth is an alternative that significantly reduces wafer production costs. In thin-film modules, copper indium gallium selenide (CIGS) continues to improve its scalability.

But the real movers to watch out for are cell technologies relating to variants of back-side contact, as well as anti-reflective coatings (ARC) – both poised to grow in market share and help manufacturers maintain more cost-effective operations. IHS predicts these technologies will account for more than 50% of the capital equipment installed through 2016.

The comparison of the aforementioned high-efficiency technologies, listing the strength and opportunities provided by each is presented in Figure 21.

Figure 21: Comparison of prospective technologies



Technology areas for innovation in c-Si

The following technology areas have witnessed major innovative efforts undertaken by c-Si manufacturers in the recent few years:

- Quasi-Mono Wafers
- Diamond Wire Sawing
- Kerfless Wafers
- Selective Emitters
- Reduced-silver Metallization
- Dielectric-Passivated Backside Cell Architecturers

- Conductive Adhesives
- Encapsulant Alternatives to EVA
- Frameless and Plastic-Framed Module Designs.

2.3.3 Success factors for upstream

Key success factors for upstream manufacturers

Scale will be crucial for solar manufacturers. A few years ago, manufacturers needed to have 50 to 100 MW of solar capacity to compete in the PV market; today they need 2 to 3 GW of capacity to compete.[20] To achieve scale, they will also need strong balance sheets. McKinsey experts have identified three steps that manufacturers can take to get there.

Develop or own differentiated and scalable technologies

Companies can capture significant cost advantages by developing proprietary technologies. This is particularly important in manufacturing, where cost curves that were historically quite steep have already flattened significantly and will continue to do so. For example, MEMC and REC have commercialized the fluidized-bed-reactor (FBR) process to reduce the energy intensity of manufacturing polysilicon relative to today's mainstay polysilicon manufacturing process. As a result, the cost of polysilicon is expected to drop significantly by 2015, with the leading players that use the FBR process achieving cash costs of $14 to $16 per kilogram, compared with $16 to $18 per kilogram for leading players that do not use it. Others have developed cell technologies using copper indium gallium selenide that require much less photovoltaic material to harvest the solar energy than crystalline silicon technologies; these new technologies could therefore be less expensive.

Drive operational excellence in manufacturing

Manufacturers should examine every operational step to identify opportunities to reduce costs. They should consider adopting lean production approaches, implementing category-based procurement processes, developing strategic relationships with suppliers, and streamlining their supply chains. To drive operational excellence, leading players often recruit experienced managers from highly competitive industries such as automotives, electronics, or semiconductors. Manufacturers can increase productivity by 30 to 40 percent by pursuing these types of initiatives. They can also develop advantages by adopting practices from other industries to increase their productivity. For example, Taiwanese and Korean companies are applying low-cost approaches for manufacturing solar technologies that were originally developed for manufacturing semiconductors and liquid crystal displays.

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[20]KristerAanesen, Stefan Heck, Dickon Pinner, Solar power: Darkest before dawn, McKinsey on Sustainability & Resource Productivity, May 2012

Address balance-of-system costs

Solar components excluding PV panels—such as wires, switches, inverters, and labour for installing solar modules—represent more than half the cost of a solar system. These components are collectively referred to as the "balance of system" (BOS), and BOS manufacturers could significantly reduce their costs (and thus lower costs for the whole industry) by implementing techniques—such as modularization, preassembly, standardization, and automation—that are common in mature industries. BOS manufacturers could also reduce industry costs by increasing the durability of the components—for example, by developing technologies that significantly extend the lifetime of inverters relative to the 7 to 10 years typical today.

Large manufacturing companies may have the scale to excel at reducing costs and improving product performance, but they sometimes lack the capabilities needed to understand and fulfil customer needs. Incumbent manufacturers could seek to strengthen their positions by acquiring or partnering with companies that are closer to customers and that can support the development of tailored solutions.

2.3.4 Key success factors for downstream

Develop targeted customer offerings

Large commercial customers are likely to prefer suppliers that can install and operate solar systems across a global network of sites. Providers will also increasingly be asked to develop specialist solar applications—for example, direct-current water pumps and mobile-charging units, or applications that combine solar with LED lighting. IBM uses solar applications to power its high-voltage, direct current data centre in Bangalore. Off-grid applications in emerging markets need robust equipment that is easy to install without sophisticated engineering and construction equipment. Companies could partner with local project developers to gain access to reliable distribution channels and secure access to finance for projects that carry risks specific to emerging markets. They could also partner with companies that already deliver products and services. For example, Eight19, a solar-PV start-up, partnered with SolarAid, a nonprofit, to provide Kenyans with bundled products and services that include solar-powered LED lighting and phone-charging options. Customers pay for the services as they use them via scratchcards validated through a text-message service. These products are inexpensive to manufacture, and the innovative pay-as-you-go approach enables partners to address some of the financing challenges that might otherwise stymie their efforts to serve poor communities.

Minimize customer-acquisition and installation costs

In the residential segment, acquisition costs for pure-play solar installers in places such as California vary from about $2,000 to more than $4,000 per customer. Acquisition costs are significantly lower in Germany, but best practices that have enabled German companies to reduce costs are not always transferrable given the regulatory environment and the lack of feed-in tariffs in the United States. For players in the United

States to sufficiently reduce acquisition cost per customer, companies should minimize door-to-door sales efforts and prescreen potential customers for creditworthiness. Digital channels provide opportunities to meet marketing goals at a lower cost than traditional approaches allow.

Companies may also be able to reduce acquisition costs by striking partnerships with companies in other sectors: for example, home builders, security companies, broadband providers, or retail power providers. They can reduce installation costs by optimizing logistics, predesigning systems, training employees to improve their capabilities, and clearly defining standards

Secure low-cost financing

Many companies are partnering with other organizations to gain access to low-cost financing. MEMC's SunEdison joined with First Reserve, a financial provider, to secure a large pool of project equity. SolarCity secured funding from Google to finance residential solar projects, enabling Google to receive tax benefits in exchange for owning electricity-producing solar assets. Other potential innovative approaches include solar real-estate investment trusts, which allow retail investors to provide funding for solar projects or offer options that let distributed-generation customers pay for their solar investments via their monthly utility bill. The cost of capital is often the most crucial factor determining returns on solar projects. To succeed in downstream markets, companies need strong.

2.3.5 Non-financial drivers

The debate on Renewable Energies (RE) continues to attract a significant amount of attention within the academic, managerial and policy making communities. While some scholars and industry experts remain skeptical about the technical and economic viability of these technologies,[21] a different view, championed by the IPCC and especially popular in some European countries, considers RE as one of the most effective solutions to curb greenhouse gas emissions.[22] RE have been also indicated as a powerful instrument to tackle unemployment and stimulate economic growth.[23] The advocates of this view argue that – if the objective of halving CO_2 emissions by 2050 is to be achieved through the diffusion of RE – the contribution of these technologies to primary energy supply must exceed 50%.[24]Yet, notwithstanding the public support received in various countries under the form of incentive schemes, taxation or other governmental expenditures, RE technologies only account for a small fraction of the world's primary energy supply. One reason for this limited diffusion is that, while the transition towards a low-carbon economy requires important investments,[25] private finance has so far

[21] G. Heal. Reflections: the economics of renewable energy in the United States. Rev. Environ. Econ. Policy, 4 (1) (2010), pp. 139–154
[22] EREC Re-thinking 2050 — A 100% Renewable Energy Vision for the European Union. European Renewable Energy Council, Brussels (2010)
[23] H.J. Pulizzi. Renewable energy returns to spotlight. Wall St. J., 27 (October 2009)
[24]IEA.World Energy Outlook. OECD/IEA, Paris (2009)
[25]OECD.OECD Environmental Outlook to 2030. (2008) Vol. 2008, Paris

played a relatively marginal role in this industry.[26] Mobilizing private capital to support RE projects is challenging, particularly in the current economic context, as investors are reluctant to allocate resources to new technologies that guarantee uncertain returns in the short term. The majority of high-tech VCs prefer to invest in technologies with low-risk low-return profiles and "seem to be steering clear of risky green investments, suggesting that clean-tech companies for a variety of reasons don't work".[27] Furthermore, most of the resources so far attracted by the RE industry have been channelled towards mature RE technologies that are closer to grid parity, such as on-shore wind or hydro, on the ground that "accelerated deployment of existing technologies will get you down the cost curve much more rapidly than a breakthrough".[27] Compared to these technologies, radically innovative systems that may display higher long-term potentials have somehow failed to attract the amount of capital necessary to pay for the greater upfront investments they usually require. In the long run, this strategy of privileging relatively mature technologies could stifle the development of technological breakthroughs and, ultimately, cause the premature extinction of technological alternatives with potentially superior performance.[28] Investment strategies that focus on a few mature technologies may be myopic in the short term too, because they reduce valuable opportunities for diversifying energy portfolios and hedging against price fluctuations.

Some scholars have argued that investments in RE technologies can be stimulated only through dedicated policies.[29] Indeed, with the exception of stand-alone systems for remote off-grid applications where RE is sometimes the only available option,[30] most RE markets are heavily reliant on direct subsidies, energy taxes, or feed-in tariffs. Yet, most of the mechanisms so far implemented to stimulate RE investments have produced mixed results,[31] partly because the proposed instruments have been unable to leverage all the drivers of the investment decision process and to fit the broader socio-economic context in which they are deployed.[32] The limited effectiveness of these policies, and the variety of stances that investors take on renewables, suggest that our understanding of the process by which these agents allocate capital to RE technology ventures remains limited.

[26] J.A. Mathews, S. Kidney, K. Mallon, M. Hughes. Mobilizing private finance to drive an energy industrial revolution. Energy Policy, 38 (2010), pp. 3263–3265
[27]Betting on green. The Economist – Technology Quarterly (March 10, 2011)
[28] P. Menanteau. Learning from variety and competition between technological options for generating photovoltaic electricity. Technol. Forecast. Soc. Chang., 63 (1) (2000), pp. 63–80
[29] V. Norberg-Bohm. Creating incentives for environmentally enhancing technological change: lessons from 30 years of U.S. energy technology policy. Technol. Forecast. Soc. Chang., 65 (2) (2000), pp. 125–148
[30] J.K. Kaldellis, D. Zafirakis, K. Kavadias. Minimum cost solution of wind–photovoltaic based stand-alone power systems for remote consumers. Energy Policy, 42 (2012), pp. 105–117
[31] H. Yin, N. Powers. Do state renewable portfolio standards promote in-state renewable generation? Energy Policy, 38 (2) (2010), pp. 1140–1149
[32] M.N. Delmas, M.J. Montes-Sancho. U.S. state policies for renewable energy: context and effectiveness. Energy Policy, 39 (2011), pp. 2273–2288

With a few exceptions,[33] and despite some recent calls to further investigate the role that private finance can play to accelerate RE market deployment, the renewable energy policy literature has seldom incorporated the investors' perspective. Moreover, it has generally focused on the economics of energy systems, adopting market efficiency and full rationality as underlying assumptions to study the behaviors of agents. Yet, there is increasing evidence that a purely rational economic evaluation of the investment alternatives does not suffice to explain how investors deploy capital or how agents choose among competing energy technologies. An emerging stream of literature suggests that broader social and psychological considerations must be included in the analysis of energy systems.[34] Behavioral finance and the bounded rationality perspective have long challenged the validity of the rational-actor models of classical economics in many decision making contexts. Recently, these perspectives have started to draw the attention of energy economists too, mostly for policy evaluation purposes.[35]

2.3.5.1 Renewable energy investments

Investments in renewable energy technologies were still negligible until the early 2000s, with non-governmental expenditures representing a minor share. Since then, they have recorded a substantial growth, reaching almost 150 USD billion in 2007 with a 30% CAGR between 2002 and 2009. After the global financial crisis of 2008–2009, investments in clean energy rebounded, attaining USD 145 billion at the end of 2009. This growth continued in 2010, when the 5 most active players (China, Germany, US, Italy and Brazil) totalled almost 150 USD billion of RE investments (Table 4).[36]

Table 4: Renewable energy investments 2010 and suggested CO_2 emissions reduction targets by country

	Financial new investment and small distributed capacity in renewable energy by country, 2010, and growth on 2009 ($bn)				CO_2 emissions reduction from the Kyoto protocol
	New financial investments	Small distributed capacity	Total	Growth 09–10 (%)	Emission reduction target (% emissions over base year emissions)
China[a]	49.00	0.80	49.80	28%	n.a.
Germany	6.70	34.30	41.00	100%	92%
US[b]	25.00	4.60	29.60	58%	93%
Italy	7.00	6.80	13.80	136%	92%
Brazil	7.50	– 0.60	6.90	– 5%	n.a.
Canada[c]	5.00	0.20	5.20	52%	94%
Spain	4.70	0.20	4.90	– 53%	92%
France	1.20	2.80	4.00	26%	92%
India	3.80	0.20	4.00	29%	n.a.

[33] M.J. Bürer, R. Wüstenhagen. Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. Energy Policy, 37 (12) (2009), pp. 4997–5006
[34] K. Safarzynska, J.C.J.M. van den Bergh. Industry evolution, rational agents and the transition to sustainable energy production. Energy Policy, 39 (2011), pp. 6440–6452
[35] V. Nannen, J.C.J.M. van den Bergh. Policy instruments for evolution of bounded rationality: application to climate-energy problems. Technol. Forecast. Soc. Chang., 77 (1) (2010), pp. 76–93
[36]NEF. Global trends in renewable energy investment 2011, 978-92-807-3183-5 (2011)

	Financial new investment and small distributed capacity in renewable energy by country, 2010, and growth on 2009 ($bn)				CO_2 emissions reduction from the Kyoto protocol
	New financial investments	Small distributed capacity	Total	Growth 09–10 (%)	Emission reduction target (% emissions over base year emissions)
Czech Republic	1.10	2.50	3.60	102%	92%

a Did not ratify the Kyoto protocol.
b Signed but did not ratify the Kyoto protocol.
c Withdrew.

Despite this activity, RE proponents claim that RE investments remain below the level that would be required to attain the CO_2 abatement targets set by the Kyoto Protocol. The contribution of RE technologies to global energy supply is still limited: in 2007 non-hydro renewable energy sources contributed to 3% of global electricity generation. Between 1990 and 2007, the share of non-hydro renewables increased, but only marginally (around 2% in OECD countries, and around 1% in non-OECD countries). It has been estimated that, to attain the CO_2 emission reduction targets set by the Kyoto Protocol, investments will need to increase up to 500 USD billion by 2030[37] and that "the amount of investment required to replace all the petrol consumed in America with renewable fuels will run into the hundreds of billions of dollars".[27]The same RE proponents, particularly in Europe, suggest that achieving the emission reduction targets set by the Kyoto Protocol by means of an accelerated deployment of RE technologies will require a radical departure from existing practices. It will also require dedicated policies that can stimulate RE investments in a much more effective way, by removing barriers and leveraging all the investment decision drivers. Unfortunately, the extant available literature does not seem to have shed full light on all the factors that affect investment decisions in the renewable energy sector. Two gaps could be identified. First, as studies have been mostly framed under the general umbrella of mainstream finance theories, there is a general lack of understanding of how non-financial factors affect investment decisions in the specific domain of renewable energies. Second, the majority of studies that have looked at the RE investment drivers have done so only at an aggregated level. That is, they have not paid sufficient attention to how these factors affect technology-specific investments and to how they impact portfolio diversification. This is a gap which is worth addressing too. Given the importance of diversifying energy portfolios, incentive mechanisms that channel investments towards one specific technology (no matter how good) may ultimately become counterproductive.

2.3.5.2 The role of non-financial factors in RE investment decisions

A significant amount of attention to study the factors that affect the success or failure of RE systems and to examine RE investments and adoption barriers are focused on technical and economic attributes of energy systems and typically adopted full

[37]WEF. Green Investing 2010 – Policy Mechanisms to Bridge the Financing Gap, World Economic Forum, Geneva and New York (2010)

rationality as the paradigmatic approach to explain how agents choose among uncertain options. Various economic constraints to renewable energy development have been suggested, including high capital and maintenance costs; limited experience with new energy technology; as well as under-valuing the long-term benefits of environmental investments.[38] However, recently it was noted that a mere rational techno-economic analysis of energy alternatives is not sufficient to explain RE diffusion and RE adoption barriers. It was suggested that a broader perspective, incorporating behavioral and social aspects, is needed.[39] This perspective advocates the use of social and psychological theory to examine why people form particular views on environmental problems and technologies, and suggests that the actual development of an emerging technology is influenced not only by the technology's performance, but also by its perceived potential influence. Along the same lines, bounded rationality has been suggested as the appropriate framework to study energy technology choices, the reaction of local stakeholders to renewable energy projects as well as the design of environmental policies.[40]

2.3.5.3 The impact of non-financial factors on the RE investment decision process

The conceptual model presented in Figure 22 was proposed to analyse the non-financial factors affecting the willingness to invest in renewable energy technologies, including: a priori beliefs, institutional pressure, propensity for radical technological innovations and the investors' knowledge of the RE operational context.[41]

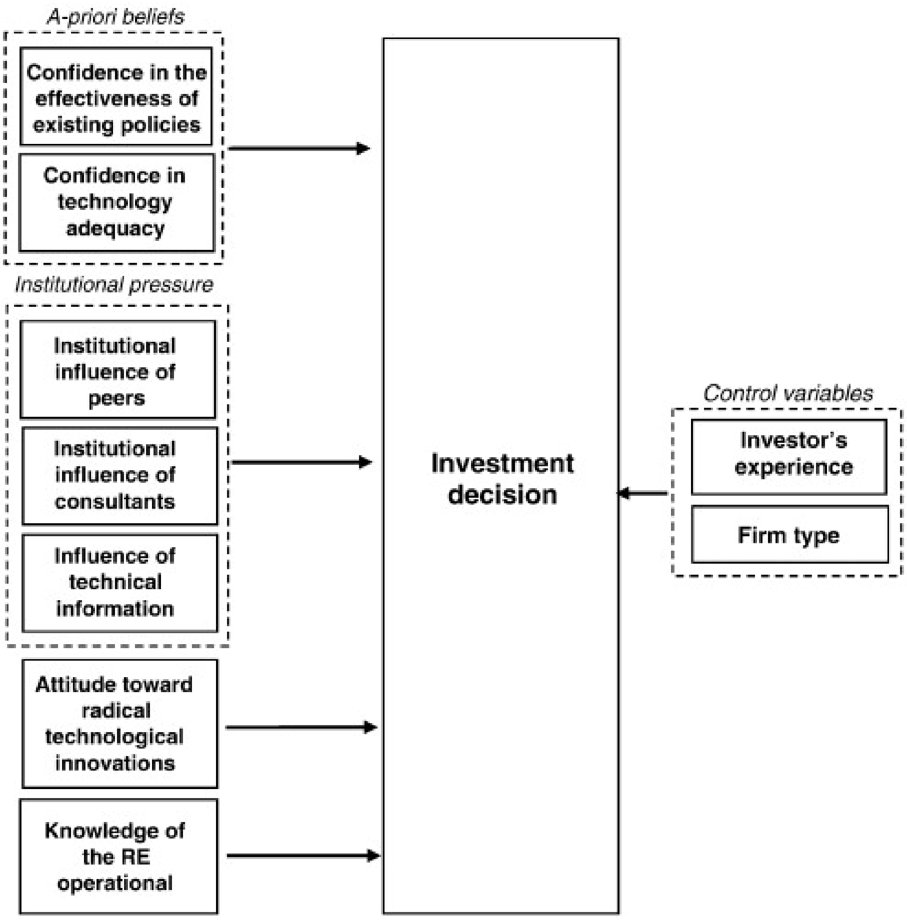
[38] P. Devine-Wright. Reconsidering public acceptance of renewable energy technologies: a critical review. M. Grubb, T. Jamasb, M. Pollitt (Eds.), Delivering a Low Carbon Electricity System: Technologies, Economics and Policy, Cambridge University Press, Cambridge, UK (2007), pp. 443–461

[39] J. West, I. Bailey, M. Winter. Renewable energy policy and public perceptions of renewable energy: a cultural theory approach. Energy Policy, 38 (2010), pp. 5739–5748

[40] C. Reise, O. Musshoff, K. Granoszewski, A. Spiller. Which factors influence the expansion of bioenergy? An empirical study of the investment behaviours of German farmers. Ecol. Econ., 73 (2012), pp. 133–141

[41] A. Masini, E. Menichetti. Investment decisions in the renewable energy sector: An analysis of non-financial drivers. Technological Forecasting and Social Change. Volume 80, Issue 3, March 2013, Pages 510–524

Figure 22: Conceptual model[42]



2.3.5.3.1 A priori beliefs

Two distinct types of beliefs should be considered. First, as the technological feasibility (or lack thereof) of a project has been identified as one of the most relevant barriers to RE adoption[43] and one of the main reasons for conducting demonstration projects,[44] the potential appeal of a RE project for an investor to depend on a priori beliefs about the technical adequacy of the RE technology underlying the investment opportunity. Second, as the economic viability of most RE projects is often dependent on incentive mechanisms, the investors are influenced by their level of confidence in the effectiveness of RE policy measures. The uncertainty of public policies, in particular, has been identified as a powerful deterrent in securing private-sector investment,[45] as demonstrated by the investment downturns caused by changing regulation. Incentive mechanisms and public policies are particularly important to support radical

[42]Technological Forecasting and Social Change, 2013
[43] M. Loock. Going beyond best technology and lowest price: on renewable energy investors' preference for service-driven business models. Energy Policy, 40 (2012), pp. 1–10
[44] C. Hendry, P. Harborne, J. Brown. So what do innovating companies really get from publicly funded demonstration projects and trials? Innovation lessons from solar photovoltaics and wind. Energy Policy, 38 (2010), pp. 4507–4519
[45] M.J. Barradale. Impact of public policy uncertainty on renewable energy investment: wind power and the production tax credit. Energy Policy, 38 (2010), pp. 7698–7709

technological innovations at an early stage of their life cycle (i.e. when they are far from full market competitiveness). Therefore their impact is relevant not only for the aggregated RE share, but also for portfolio diversification. That is, why the investors with a high degree of confidence in the effectiveness of RE policies are more willing than their counterparts to include radical RE innovations in their portfolios. Two a priori beliefs, having a positive impact on aggregated percentage of RE in the portfolio and the degree of technological diversification of the portfolio, could be stated as follows:

- Greater confidence in the effectiveness of existing policies is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.
- Greater confidence in technology adequacy is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

2.3.5.3.2 Institutional pressure

A second set of factors influencing the investment process is related to institutional isomorphism, i.e. the tendency of decision makers to conform to the rules and the norms prevailing in their institutional environment. The institutional isomorphism affects the behaviors of investors too, because agents facing similar institutional pressures will eventually adopt similar investment strategies. Institutional pressure can be of coercive nature (e.g. deriving from regulation), of normative nature (e.g. as a result of explicit or implicit industry standards), or mimetic (i.e. deriving from the influence of successful examples). Accordingly, for an investor to invest in a RE project, there must be either legal obligations (coercive isomorphism), some sort of pressure exerted from senior managers or the community of reference (normative isomorphism), or there must be proven evidence of successful RE investments undertaken by other investors (mimetic isomorphism). The institutional pressure is primarily exerted through mimetic and normative isomorphism. In turn, this is determined by the information sources investors use to make decisions. The effect of institutional isomorphism is even more significant in contexts of incomplete information, because when decision makers lack the necessary knowledge to make objective assessments of complex technological options, they refer to experts and recognized authorities to draw conclusions. Interviews with RE investors indicated that these agents use three primary sources of information to make their investment decisions: first, they observe the behavior of their peers (i.e. well known investors in the same industry); second, they consider the opinion of external consultants who specialize in the RE industry, and third, they also use factual information originating either from technical reports or from due diligences conducted in house. Therefore, the degree of RE share in the investment portfolio, as well as the rate of adoption of each individual technology is influenced by the extent to which investors are sensitive to these information sources. However, while it is legitimate to argue for a significant impact of institutional pressure on RE adoption, it is more difficult to anticipate the direction of this impact. As both the business and the academic communities seem to be evenly split between RE enthusiasts and die-hard sceptics, it is impossible to hypothesize whether an investor receive positive or negative institutional pressure without knowing which community (pro or against RE) she/he referred to before making decisions. The statements could be the following:

- Institutional pressure from peers exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.
- Institutional pressure from external consultants exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.
- Institutional pressure from published technical information exerts a significant impact (either positive or negative) on both the share of RE in the investment portfolio and the diversification of the investment portfolio.

2.3.5.3.3 Attitude towards radical technological innovations

One more factor influencing the investment process pertains to the attitude toward radical technological innovations and the uncertainty which is inherently associated with them. Uncertainty plays an important role in technology adoption and investment decisions. In the energy sector, different forms of uncertainty, including regulatory, technical and market uncertainty have been found to have an effect (typically negative) on RE adoption and RE investments.[46,47] Technological uncertainty is also inherently related to the investors' attitude towards risk, which has been a central theme in behavioral finance. Not surprisingly, some scholars have also noted an agent's *attitude* towards technological uncertainty and risk has a strong influence on technology adoption decisions and, also, on portfolio diversification strategies.[48]

As renewable energy technologies are often perceived as unproven technologies with greater technological uncertainty but, also, with the potential to generate higher future returns, we argue that an agent's attitude vis-à-vis technological uncertainty has also a strong influence on investment decisions. The investors with a favorable attitude towards radical (and hence more uncertain) technological innovations are more likely to invest in RE compared to more conservative actors. In other words, the investors who manifest a preference for radical technological innovations over more mature systems will be inherently less risk-averse, and, therefore, more inclined to select technologies with a greater upside potential, even if they display a higher expected cost. This statement could be formalized as follows:

[46] M.J. Barradale. Impact of public policy uncertainty on renewable energy investment: wind power and the production tax credit. Energy Policy, 38 (2010), pp. 7698–7709

[47] I. Milstein, A. Tishler. Intermittently renewable energy, optimal capacity mix and prices in a deregulated electricity market. Energy Policy, 39 (7) (2011), pp. 3922–3927

[48] S. Fuss, J. Szolgayova, N. Khabarov, M. Obersteiner. Renewables and climate change mitigation: irreversible energy investment under uncertainty and portfolio effects. Energy Policy, 40 (2012), pp. 59–68

- Greater propensity for radical technological innovations is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

2.3.5.3.4 Knowledge of the operational context

The investment decisions are also influenced by the level of knowledge that investors have of the broad operational context in which RE projects are deployed. It was noted that incomplete or imperfect information on RE technologies may increase adoption barriers and slow down RE diffusion. The impact of knowledge gaps is further reinforced by the presence of a priori biases because if incorrect or incomplete knowledge about a particular technology fits with the decision maker's personal biases, it is taken as a fact and perpetuated.[49]

In line with these findings, it is expected that agent's knowledge of the operational context in which RE are implemented (i.e. her knowledge of the whole RE ecosystem) to affect RE investment decisions. Industry knowledge influence the investment decisions primarily through its effect on uncertainty. Imperfect knowledge of the RE operational context increases the perceived level of uncertainty of the investment opportunity. As greater uncertainty is usually associated with greater barriers to RE adoption, risk-neutral investors with more limited industry knowledge will be less likely to invest in RE projects. Also, even risk-seeking investors that may value the higher upside potential of projects with greater technological uncertainty may feel unable to hedge against this technological uncertainty if they have limited understanding of the overall context in which they operate. These arguments are summarized as follows:

- Greater knowledge of the RE operational context is associated with both a higher share of RE in the investment portfolio and a higher diversification of the investment portfolio.

The profound analysis of non-financial drivers (as the impact of the factors on three distinct variables: i) the overall degree of RE share in the investment portfolio; ii) the degree of technological diversification of the portfolio and iii) the share of each specific technology in the investment portfolio) was performed by A. Masini and E. Menichetti (Technological Forecasting and Social Change, 2013) the results of which are presented in Table 5(analysis of RE share in the investment portfolio), Table 6 (analysis of the degree of portfolio diversification) and

Table 7 (analysis of individual technology choices).

[49] T. Teel, R. Bright, M. Manfredo, J. Brooks. Evidence of biased processing of natural resource-related information: a study of attitudes toward drilling for oil in the Arctic National Wildlife Refuge. Soc. Nat. Resour., 19 (2006), pp. 447–463

Table 5: Impact of non-financial factors on RE share: results of the regression models (source: Technological Forecasting and Social Change, 2013)

	Dependent variable: RE share in the investment portfolio			
	OLS		Logistic regression	
	Parameter estimate	Heteroskedasticity consistent std. error	Parameter estimate	St. error
Confidence in the effectiveness of existing policies	0.16	0.17	0.09	0.23
Confidence in technological adequacy	0.49***	0.16	0.53**	0.23
Attitude toward radical technological innovations	− 0.33***	0.08	− 0.53	0.38
Investor's experience	0.42**	0.18	0.48**	0.23
Knowledge of the RE operational context	0.63***	0.20	0.80***	0.27
Institutional influence of peers	− 0.15	0.18	− 0.20	0.23
Institutional influence of outside consultants	− 0.23*	0.14	− 0.28*	0.23
Influence of technical information	− 0.05	0.17	− 0.10	0.22
Dummy funds	− 0.86	0.69	− 0.95	0.86
Dummy VC	0.41	0.42	0.39	0.54
R^2	0.38			
F	4.58			
p	< 0.01			
− Log likelihood			37.69	
$p\ (> \chi^2)$			< 0.001	

** Significant at the 0.1 level.*
*** Significant at the 0.05 level.*
**** Significant at the 0.01 level.*

Table 6: Impact of non-financial factors on portfolio diversification: results of the regression models (source: Technological Forecasting and Social Change, 2013)

	Degree of diversification of the investment portfolio		Adjusted degree of diversification of the invest portfolio	
	Parameter estimate	Heteroskedasticity consistent std. error	Parameter estimate	Heteroskedasticity consistent std. error
Confidence in the effectiveness of existing policies	0.06	0.11	− 0.01	0.11
Confidence in technological adequacy	0.14*	0.09	0.21***	0.08
Attitude toward radical technological innovations	− 0.07	0.05	− 0.09*	0.05
Investor's experience	0.23**	0.10	0.24**	0.11
Knowledge of the RE operational context	0.23**	0.10	0.30***	0.11
Institutional influence of peers	− 0.16**	0.08	− 0.17**	0.07
Institutional influence of outside consultants	− 0.22**	0.09	− 0.25***	0.08
Influence of technical information	− 0.04	0.08	− 0.03	0.08

	Degree of diversification of the investment portfolio		Adjusted degree of diversification of the invest portfolio	
	Parameter estimate	Heteroskedasticity consistent std. error	Parameter estimate	Heteroskedasticity consistent std. error
Dummy funds	0.00	0.38	− 0.01	0.32
Dummy VC	0.24	0.22	0.24	0.21
R^2	0.28		0.40	
F	2.92		5.03	
p	< 0.01		< 0.01	

** Significant at the 0.1 level.*
*** Significant at the 0.05 level.*
**** Significant at the 0.01 level.*

Table 7: Impact of non-financial factors on specific technology choices: results of the logistic regressions (source: Technological Forecasting and Social Change, 2013)

	Hydro		PV		Solar thermal		Wind		Other	
	Par est	St. error	Par est	St. error	Par est	St. error	Par est	St. error	Par est	St. error
Confidence in the effectiveness of existing policies	0.58*	0.36	0.57*	0.35	−0.07	0.31	0.32	0.28	−0.63*	0.37
Confidence in technological effectiveness	−0.49	0.38	0.90***	0.34	0.19	0.31	0.43	0.27	0.34	0.35
Attitude toward radical technological innovations	−1.53	1.29	−0.90	0.80	−0.20	0.51	−0.61	0.66	0.19	0.28
Investor's experience	0.85*	0.46	0.25	0.31	0.29	0.29	0.09	0.27	0.42	0.32
Knowledge of the RE operational context	−0.51	0.45	−0.28	0.32	0.31	0.30	−0.14	0.28	0.22	0.33
Institutional influence of peers	−0.80*	0.49	−0.22	0.32	−0.44	0.36	−0.69**	0.32	−0.57	0.40
Institutional influence of outside consultants	−0.75	0.53	−0.58*	0.34	−0.07*	0.31	−0.13	0.27	−0.02	0.30
Influence of technical information	0.09	0.42	0.22	0.30	−0.50	0.30	0.14	0.28	−0.29	0.35
Dummy funds	−2.10	1.95	−0.55	1.10	1.09	1.10	−0.12	1.04	2.03*	1.20
Dummy VC	0.33	0.92	2.06	0.77	1.06*	0.66	−0.44	0.63	0.93	0.73
− Log likelihood	56.502		86.240		82.319		101.462		69.265	
p (> χ^2)	0.01		0.00		0.00		0.11		0.18	

** Significant at the 0.1 level.*
*** Significant at the 0.05 level.*
**** Significant at the 0.01 level.*

RE proponents, especially in Europe, suggest that renewable energy sources have the potential to play a crucial role in reducing carbon emissions and fossil fuel consumption in all sectors of the economy. Yet, the difficulties encountered by many countries in meeting their Kyoto emission reduction targets, as well as the resistance to setting new legally binding targets at the Copenhagen Summit, prove that exploiting this potential is far from obvious. Indeed, while the advocates of the RE option suggested that huge additional investments are needed to realize the RE potential and achieve the proposed carbon emission reduction targets, no agreement could be reached on this point.[50]Needless to say, this is particularly challenging in a context of global economic uncertainty. Although investors can play a key role in mobilizing capital to support renewable energy technologies, evidence suggests that they are often reluctant to do so. Clearly, dedicated policies can be, and have been, implemented to stimulate renewable energy investments. However, many of the efforts conducted so far have been only moderately effective because, by failing to understand the behavioural context in which investors make decisions, they have been unable to leverage some key drivers of the investment process. In a market economy, the effectiveness of a policy is dependent upon its impact on investors' behaviours. Thus, to maximize the impact of future policies, policy makers need to get a better understanding of how investors behave and take their decisions, particularly in relation to the psychological factors that may influence their behaviours and actions.

The analysis has revealed that a priori beliefs on the technical adequacy of the investment opportunities play a much more important role in driving investments than the perceived effectiveness of existing policies. Implicitly, this suggests that agents consider the proven reliability of a technology as a necessary condition for investing in it, while they believe that market inefficiencies can be corrected through the adoption of appropriate policy instruments. The results have also revealed a group of investors with extremely short investment horizons, who are extremely sensitive to the institutional pressure of peers and external consultants in their investment decisions. A priori beliefs and limited knowledge of the broader RE context create additional barriers that restrain the likelihood of raising capital for clean energy investments. The analysis of these elements as opposed to more rational factors can help investors get a more balanced view of risks and opportunities in this industry. The implications for policy makers are also clear. Investors seem to have very little faith in dedicated policy measures that directly support RE technologies (for instance through short lived subsidies). Conversely, they seem much more sensitive to the technical feasibility or the proven performance record of a technology as well as to institutional pressure. As a consequence, RE budgets should be redirected to leverage these factors, for instance by supporting R&D programs in the public and private sectors, by promoting demonstration projects, and by further disseminating information on RE systems within the relevant business circles and key stakeholders.

[50] J.G.J. Olivier et al. Long-term trend in global CO2 emissions: 2011 report. PBL Netherlands Environmental Assessment Agency; Institute for Environment and Sustainability (IES) of the European Commission's Joint Research Centre (JRC), 978-90-78645-68-9The Hague, Netherlands (2011)

3 ANALYSIS AND PROGNOSIS OF SITUATION, WHEN THE PV INCENTIVES ARE OVER

3.1 Overview of PV incentive programmes, trends in development and foreseen deadlines

3.1.1 The latest status on PV funding policy and programs

IHS has modelled typical photovoltaic investment cases in 2013 for the three leading European markets of today—Germany, Italy, and the United Kingdom. With the subsidy schemes that are currently in place, all countries continue to offer attractive conditions for both private and institutional investors. Meanwhile, an evaluation of no-incentive scenarios shows that the most mature market segments are on the cusp of grid parity.

Estimated returns of European PV projects

Until today, European countries for the most part have been driving global PV installations. But with China, India, and Japan gaining momentum in 2012, the focus of global installations is increasingly shifting to Asia. Nevertheless, IHS forecasts Europe to account for half of the world market this year.

The three leading European regions in 2012 are Germany with a predicted installation volume of 7.9 gigawatts, Italy with 3.5 GW, and the U.K. with 0.9 GW.[51] In each of these countries, PV incentive schemes were revised in the course of this year, and subsidies were slashed. Comparing German feed-in tariffs in Q1 2013 to those of Q1 2012, IHS estimates the incremental cuts to amount to 32% for residential rooftop installations, and to 36% for both commercial rooftop and ground installations—very much higher than the approximate annual reduction of 10% envisioned in the first version of the German Renewable Energy Act.

Many PV stakeholders are expecting these subsidy cuts to harm project economics substantially— and maybe even lead to a collapse of individual markets. To evaluate the conditions that potential PV investors will find in Q1 2013, IHS has developed scenarios for the three leading European countries and modelled representative investment cases:

1) 5 kilowatt rooftop installation without self-consumption/with approximately 20% self-consumption;
2) 250 kilowatt rooftop installation without self-consumption/ with approximately 20% self-consumption;
3) 1 megawatt ground installation without self-consumption.

Relevant parameters were chosen such that they reflect a conservative rather than an aggressive scenario. For instance, electricity price inflation was assumed at 3%, and the electricity exchange price—the price at which the PV-generated electricity can be sold in

[51]HIS Electronics & Media Whitepaper, Ten Predictions for the Electronics Industry for 2013

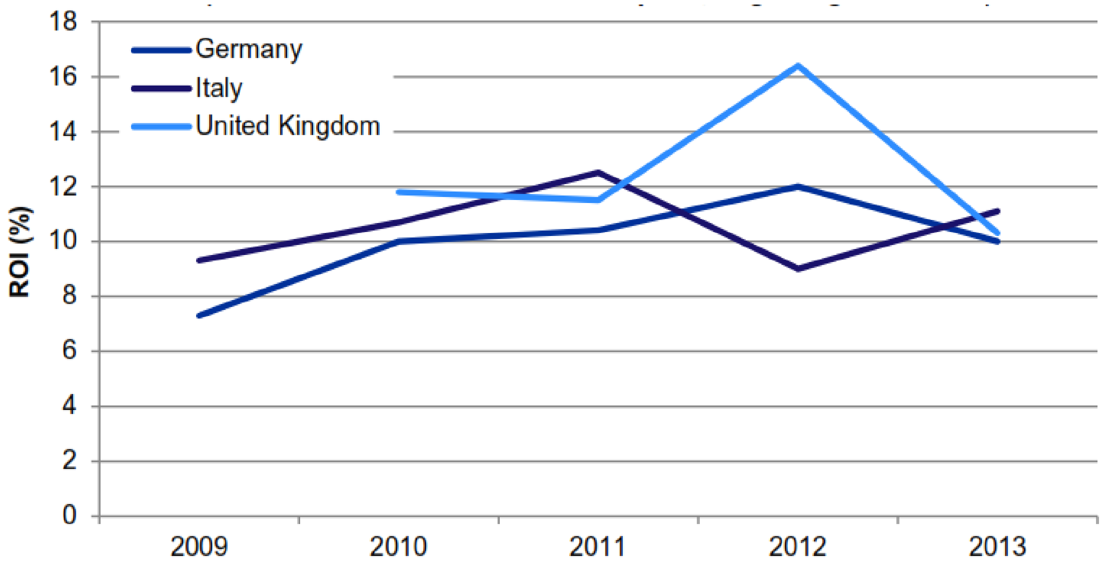
the free market was assumed at €0.04 per kilowatt-hour. The resulting return on investment on projects can be seen in the table below.

Table 8: PV Project ROI, Q1 2013 (source: IHS Solar Research, December 2012)

Country	5kW rooftop, No Self-Consumption	5kW rooftop, ~20% Self-Consumption	250kW rooftop, No Self-Consumption	250kW rooftop, ~20% Self-Consumption	1 MW Ground
Germany	5.8%	10.0%	6.6%	7.9%	6.6%
Italy	6.3%	11.1%	7.6%	10.1%	9.1%
United Kingdom	8.5%	10.3%	9.3%	10.1%	8.4%

In the current financial environment featuring record-low interest rates, the ROIs on these PV projects will make extremely attractive investments at the beginning of 2013—possible in each market segment and in each of the three countries. Previous years have shown that investors request ROI in the range of 6% to 8% in Germany, and from 9% to 11% in Italy. These conditions that were sufficient to propel extraordinary market growth since 2008 are still being met. Using the example of the 5-kW rooftop installation with self-consumption, the following graph illustrates that despite subsidy cuts, ROIs in Q1 2013 will be comparable to those of the past four years.

Figure 23: PV Project ROI in Germany, Italy and UK, 2009-2013 (5kW Installation with Self-Consumption, Beginning of the Year) (source: IHS Solar Research, December 2012)



It is important to note that in Germany and Italy, in particular, which are the most mature markets globally, the actual incentive schemes clearly guide the markets toward maximum self-consumption.

Both the residential rooftop sector as well as the segment for large commercial rooftops can enjoy remarkably improved financial benefits. IHS predicts that the portion of commercial PV projects relying on the on-site consumption of a percentage of PV-generated electricity will grow strongly in 2013; first projects, such as installations on supermarket roofs, had been initiated in 2012. By stimulating these business models, current policies are already paving the way for the post-subsidy era of solar power generation.

The fundamental growth drivers, including an attractive investment framework, will still be in place in the leading European markets by early next year. Nonetheless, subsidized installation volumes are likely to be limited. In Italy the total remaining budget is capped and may be exploited in the course of 2013. In Germany the seemingly endless series of policy adjustments will continue, and a revision of the current Renewable Energy Act is likely. With further incentive cuts to be expected and a phase-out of governmental support appearing on the horizon, the question of grid parity will arise earlier than most stakeholders expect.

Addressing the barriers

Despite the significant declines in installed PV system pricing over the past 12-18 months, most European markets are actually seeing declining investment returns due to the reductions in PV incentives now available.

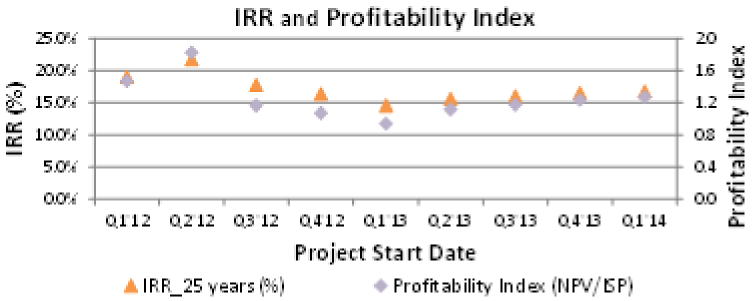
However, consumer savings associated with avoiding retail electricity purchase (related to onsite consumption of PV production) can help economic returns on the initial investments, particularly within the residential segment.

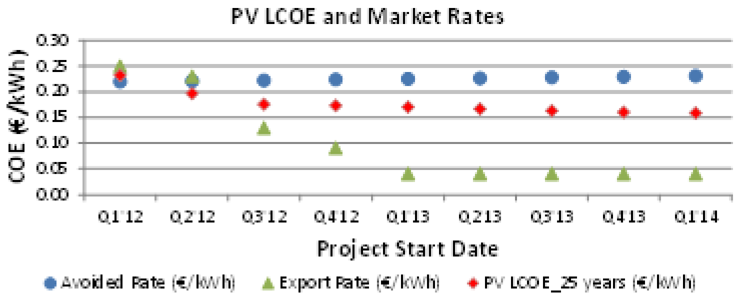
Purchase avoidance benefits are typically regulated regionally, as part of net-metering allowances. For example, residential PV operators in the Flanders region of Belgium have recently incurred a retroactive (and negative economic) impact on their net-metering allowance, due to emerging barriers arising from utility companies being successful in lobbying to impose grid-access fees.

Addressing this type of barrier - and turning it into an opportunity that may drive PV adoption going forward - requires that PV operators accept ‘reasonable and fair’ grid-access fees. In addition, the European PV lobby may now need to act with an increasingly unified voice, in order to achieve fair treatment from a variety of parties each with vested interests.

The figures shown here highlight a Flanders-based residential 6 kW c-Si installation benefitting from remuneration on 100% of PV production at the Green Certificate rate minus the new grid-access fee (composite Export Rate). Additional benefits are provided by avoiding purchase at €0.22/kWh (Avoided Rate) on 100% of annual PV electricity production. The 25 year Project IRR excludes taxes, finance charges, and salvage value (Annual O&M is included).

Figure 24: Source: Adapted from NPD Solarbuzz European PV Markets Quarterly report, January 2013





The PV LCOE analysis (shown in the figure) is most sensitive to the discount rate applied. In the analysis here, this is set at 6%. Sensitivity to the precise installed system price (ISP) is significant. However, in the more mature European markets, the regional variability of the ISPs has become less significant, as countries converge to more standard pricing levels across Europe.

Coincidentally, the southern Europe markets with higher solar resource also exhibit slightly higher ISP's, lower retail electricity rates, and lower conversion efficiency. Therefore, the resulting PV LCOE advantage that comes from the higher solar resource diminishes when compared with regional retail electricity rates.

The net impact of the new grid-access fee structure in Flanders provides (on average) a 15% reduction in PV-production-related benefits: a level that appears excessive, considering the actual impact of PV production injected on the grid. Moreover, the imposed average flat-rate of €53/kW-year (on inverter rating) impacts (in a disproportionate manner) on users that installed over-sized inverters to help mitigate local grid characteristics and on installations with performance losses due to less-than-optimal array orientation/shading.

Another new barrier still to be addressed relates to 'saturated' local grids. The saturation condition can result especially during midday as power moves 'upstream' to (and through) voltage transformer stations. This can incur wire and voltage transformer losses and must share other grid operation costs. Successive transformation incurs incremental losses and is only feasible if the transformers are prepared for bi-directional operation. An undesirable scenario is provided by at least two transformation stages: first staged-up into medium voltage, and later staged-down for low voltage consumption.

A further grid-access related barrier is provided by limited international transport facilities. This can be seen in the case of Spain, where only 1 GW of international transport is available. This can result in over-supply intervals that may cause the disconnection of renewable electricity sources.

The pan-European commercial electricity market environment exhibits a range of demands that arise from a highly competitive sector comprising powerful parties coupled with historic levels of subsidy for traditional energy sources. Additional challenges arise also from regional politics, in particular at a time of fiscal deficit reduction across Europe.

3.2 Prognosis for PV competitiveness

The Grid Parity Concept

The grid parity concept denotes the price level at which the generation of electricity from renewable energy sources becomes equal to or cheaper than the cost of producing conventional grid electricity. Since the module cost is the main cost component of the PV system, the reduction in module costs will dictate the ability of solar power companies to reach grid parity. Therefore, to achieve grid parity without any government subsidies is the ultimate goal of the solar PV industry.

The factors that will help companies reach grid parity quicker are technology differentiation and scale production. It has been proven that the cost per watt of manufacturing solar modules decreases with the increase in capacity. This would result in only companies with larger production scale being able to weather any pricing storm that might take place, with technology playing an important role in reducing manufacturing costs. Emerging thin film technologies are revolutionizing the module manufacturing process by reducing process times and costs associated with materials.

The price of solar electricity differs from country to country depending upon the sunlight conditions, financing costs in the country, tax incentives and other subsidies provided. The PV module typically makes up around 60.0% of the cost for a residential or commercial system.[52]

For a PV system to near grid parity and to be able to compete with utility scale installations, prices would have to be reduced considerably. As a reference, conventional sources of electricity such as coal, nuclear, and hydroelectric plants generate electricity at a cost of ~€0.02 - €0.06 per kWh. A list of residential grid prices in different regions at price per kWh is given in Table 9.

Table 9: Residential grid prices in different regions

Europe (in €)	Per kWh
France	0.16
Spain	0.16
United Kingdom	0.17
Germany	0.25
Italy	0.30

[52]Equity Report, January 2009, Ticker - FSLR

USA (in US$)	Per kWh
Illinois	0.10
Florida	0.11
Texas	0.12
California	0.14
New York	0.17

The conventional thinking is that the cost of modules needs to be reduced to $1.00 per watt to reach grid parity and to be competitive. Since current module costs range from around $2.50 - $4.00 per watt, to reach a $1.00 per watt target may take some time.

The truth of the situation is that the grid parity is not an exclusive number which applies to every country and every power producer. Grid parity levels depend on how cheaply grid electricity is available and which grid is being compared based on whom the electricity is provided to. For e.g., for residential or commercial scale distributed solar electricity, as opposed to utility scale power which is centralized, the grid that should be weighed against are the retail electricity rates. This needs to then be compared to the LOCE, which is the levelized cost of energy. The LOCE for solar power is essentially the present value of all the cost flows generated over the life of the PV system, divided by the total energy generated by the system.

Hence, depending on which grid we are comparing with for parity the target cost could vary anywhere between 5.0¢/kWh for countries like and China and India, to a massive 25.0¢/kwh for a country like Italy. In the USA, retail rates for electricity can vary by a factor of up to 5.0x. Accordingly, for countries with high demand and consumption of electricity such as Italy, Spain, Holland, Great Britain, and California, the $1.00 per watt target would be around twice as low as we would have to go to achieve grid parity.

Another major factor influencing the grid parity levels will be the cost of fossil fuels. The lower the price of fossil fuels, the lower will be the cost of producing electricity from the fossil fuels. Hence as the cost of producing conventional energy reduces, the cost of producing solar energy will have to be reduced even further to be able to reach grid parity. The general observance is that when prices of conventional sources of producing electricity go down, solar energy becomes less attractive.

As defined from the investors' point of view, grid parity is achieved when the investment into a PV project yields a sufficient return in the absence of any subsidies.

IHS Solar Research has evaluated such no-incentive scenarios for the leading European markets. Even with conservative boundary conditions, grid parity will become a reality in several mature market segments by next year.

Clearly, a key parameter impacting the investment case is the portion of self-consumed electricity. A rate of 30% in self-consumption is sufficient for the residential rooftop segment in Germany, as well as for both the residential and commercial rooftop segments in Italy, in order for grid parity to be achieved in the course of 2013.

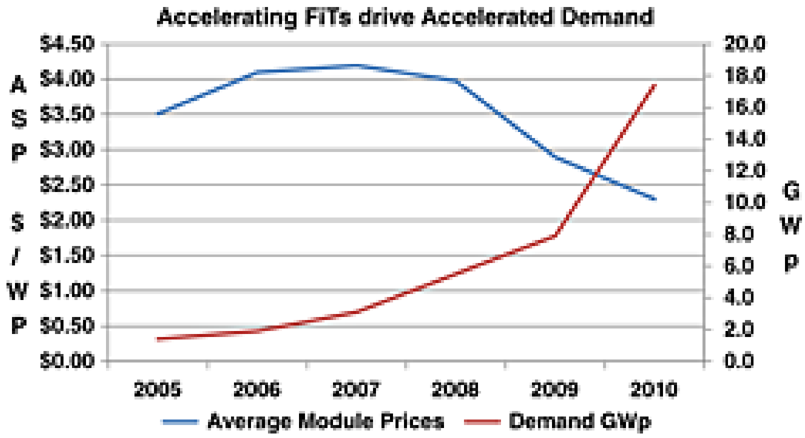
Although grid-parity-driven projects cannot immediately replace the installation volumes enabled through subsidies, these two countries are already beginning to transition into a self-sustaining market.

3.3 Prognosis of the situation after closure of PV incentives

3.3.1.1 Before 2013: European feed-in tariffs expand globally and markets overheat

The incentive climate began to accelerate in the late 1990s, driven by energy insecurity (fossil fuels will run out) and the beginnings of climate change awareness. During this period, demand growth accelerated with the decade seeing growth at a compound annual rate of 35% with average module prices decreasing by a compound annual rate of 3.5%. The subsidy in Japan drove strong “captive” growth in its domestic market, enabling manufacturers in that country to hold global leadership. During the late 1990s, Germany's 100 000 rooftop program along with zero interest financing drove accelerated demand. In February 2000, Germany implemented a 99-pfennig power production buyback for grid-connected PV systems with a 20-year duration of payments. Beginning in January 2002, the initial rate began to decrease by 5% per year until the end of the program. In 2004, the revision of the EEG created an even more attractive market for solar, and other countries in Europe began taking notice of this market's success. In the USA, the renewable portfolio standards (RPS), requiring the use of renewable technologies by utilities began expanding, although with the deadline for RPS fulfilment not imminent and penalties for noncompliance often weak, these platform programs did little to drive demand. This period could be viewed as the calm before the incentive storm. During this decade, Germany made bold choices to design a creative program that would stimulate its domestic market for photovoltaic systems. The German government made these choices for environmental, energy security, and economic reasons. Economically, the goal was to create a strong domestic industry. Figure 25 presents module average selling prices (ASPs) and demand (MWP) from 1995 to 2005.

Figure 25: Module average selling prices (ASPs) and demand 2005 to 2010. Accelerating feed-in tariffs (FiTs) drive accelerated demand. Source: 26th EU PVSEC, Hamburg, Germany 2011



During this period, FiTs proliferated across Europe and other countries such as South Korea, Japan, and (to some degree) the USA. Along with actual FiT programs, announcements of programs that did not come to pass emerged, creating anticipation and anxiety on the demand side of the industry. Poorly designed FiTs along with the sometimes abrupt changes resulting from poor design, such as those in South Korea (where a government budget was rapidly overwhelmed), Spain, where speculation helped balloon an overly generous tariff turning it into a market crash, but also Italy, France, and recently the UK, inserted instability into already unstable market for photovoltaic systems. Ninety per cent of industry activity in terms of megawatts installed took place in the 2005–2010 period. To be clear, this means that 90% of total industry cumulative volume took place in 5 years. At the beginning of this period, average module prices for all technologies and system prices increased in some cases to >$4.00/Wp. In 2009, with aggressive pricing for share by manufacturers in China and Taiwan as the primary driver, ASPs fell by 40–50%. Unfortunately, individual FiT-driven market successes created out-of-control markets that needed to be controlled. The governments in Spain and the Czech Republic instituted retroactive changes that were, essentially, changes to the tariffs in these countries, whereas Italy, France, and recently the UK instituted rapid and often unexpected changes to their FiT programs. Germany began degressingitsFiT more rapidly. At this point, however, capacity levels were at a multi-gigawatt level, and prices began to be pressured down. These early FiTs are also responsible for the proliferation of utility scale (multi-megawatt) systems. Investors, encouraged by the stability of 20-year tariff payments, rushed into this new segment of the market. Many of these investors (although not all) did so with little understanding of the technology or the industry. This surge of investment and activity into a market with little controls created a balloon of activity. Unfortunately, this activity coincided with a global recession that in 2009 affected many industries, including solar. It also coincided with the industry's first significant, although, by no means the first, polysilicon shortage. In the USA, with RPS requirements coming due, utilities began to announce large projects, many of which were interrupted because of externalities such as the availability of capital, permitting roadblocks, and the interference of other stakeholders. Nevertheless, utilities in the USA were forced by RPS to accelerate their use of solar and other renewables. Project developers and others in the USA must juggle tax incentives, grants, and other incentives, none as transparent as most FiTs, nor as generous, in order to successfully deploy systems in the various application segments. The utility scale application sells PV electricity as a commodity, forcing prices down. Decelerating incentives also provide price pressure. Bankability (of the supplier) force prices down for second and third tier suppliers of technology. Aggressive pricing by China and Taiwan pressured margins and prices and led to domination of the supply side of the industry by manufacturers in China and Taiwan. In sum, by the end of 2010, margins were pressured along with prices leading to module prices, in some cases, <$1.40/Wp. With significant price pressure and the commoditization of solar electricity into the utility scale application, vertical integration became a survival technique (First Solar, SunPower for example). During this 5-year period, average module prices fell by a compound annual 8%, with demand growing by a compound annual rate of 65%, into gigawatt level. Figure 25 presents average module prices and demand from 2005 to 2010.

3.3.1.2 2013 and beyond: overheated markets lead to changes in FiT structures, credit trading, and government minimum requirements for production by renewables

The market stability promised by the FiT incentive model succeeded in stimulated multi-gigawatt levels of demand, unfortunately, at a micro (market by market level), the result was an over-stimulation, or overheating, of some regional markets. As market stimulation tool, the FiT is still relatively new and it was implemented on an immature industry, in some cases unfortunately. The implementation of the FiT led directly, although on a market-to-market basis, to multi-megawatt solar farms. Throughout its history, the PV industry has been held hostage by:

- the need for incentives to stimulate demand;
- a lack of awareness by the energy buying public that all energy receives incentives of some sort; and
- the perception that PV (and solar) is excessively expensive without subsidies, whereas other energy technology are much cheaper. This last point, although redundant, is worth reiterating. On a level playing field with other energy choices, such as nuclear, PV has many advantages, even in terms of cost.

By its very overwhelming success, the feed-in tariff incentive model proved that solar is a popular choice for energy consumers. Given the stop–start history of the PV industry and its incentives, it is no wonder that when an attractive and easy to understand incentive is offered, consumers and investors would answer its siren call. Unfortunately, designers of FiT programs failed to take into account that market behaviour is not orderly, but instead operates more like a stampede. For example, when a cap, a degression, or any change that would alter the market is announced or expected, demand increases. Using Germany as a solid example, when the time for a new degression approaches, demand increases even if the current tariff has led to compressed margins. This market behaviour will continue until tariffs are at zero. It may well be that given the immaturity of the industry, a system simply cannot be constructed that would control this activity.Given this observable market behaviour and to avoid the traditional start/stop incentive landscape that threatens to remerge, several options, or combinations of options, have promise for the future:

- Portfolio standards (similar to the USA) that require utilities to install renewables, specifically PV or other solar, either owning the asset themselves, or leasing it to customers, or, buying from investor-owned systems.
    - Does not necessarily encourage ownership, unless there is a lease-to-own model
    - Downward pressure on prices and margins
- Setting FiT rates by auction and capping the number of megawatts that will receive the FiT annually.

    - Downward pressure on prices and margins until industry learns to appropriately set bid rates
- Annual FiTs with strict annual caps.
    - Continues popular FiT model but lowers annual demand
    - Downward price pressure
    - May encourage innovation so that business can continue after cap is reached
- Renewable Energy Credits, RECs or Solar RECs, essentially allow for the trading credits somewhat similar to the stock market or other securities.
    - Does not defray up front capital costs but may provide FiT-like rewards
    - May encourage a large investor market and discourage, or, eliminate small buyer market
- Leasing, renting, and so on, the investor installs the system and rents the electricity to the end user, similar to buying utility electricity. The investor has the initial outlay and eliminates electricity rate volatility for the consumer. Both seller and buyer are assuming performance and substitute risk.
    - Lease terms may not favor end users
    - When electricity prices are high, consumer wins, when low, end consumer loses
- Government and utility demonstration projects.
    - Stop/start market mechanism does not lead to market stability
- Price elastic customers who need a reliable supply (mines) in areas with no incentives.
    - Unknown market with significant expenses to discover and serve
    - Once discovered, this market is ideal for benefits of solar.

For the future, a method of encouraging system ownership by different stakeholders (governments, utilities, end users) that neither overwhelms nor underwhelms the market is imperative for the future of the solar industry. A combination of methods is the fairest and most likely outcome, but hard choices will have to be made. Given the current accelerated growth, no matter how low the FiT levels threaten to go, government forbearance cannot be counted on indefinitely and nor can an orderly march to the FiT finish line be assumed. Instead, as governments step back and reassess, the solar industry should step in to suggest models that combine caps, REC trading, portfolio standards with a reliable payout similar to the FiT model and likely set by auction, so that incentives continue for the near term. The expectation in this regard is that business models, such as leasing, along with trading schemes and portfolio standards will become the norm over time.

3.3.1.3 The promotion of photovoltaic energy self-consumption

The promotion of PV electricity self-consumption is important because it equates the PV generation costs and the household electricity prices. Although it is too early to analyse the effects of the promotion of PV energy self-consumption, its study should be an important part of future research, given that recent studies suggest that in the residential sector, grid parity will happen in the next decade. Self-consumption is of vital importance for several reasons:

- Because it saves costs for the public;
- Because it is an important marketing factor;
- Because it provides a market trial for the case of high penetration PV on the network, as in the case where grid parity might be reached.

Table 10presents the most important regulations regarding PV energy self-consumption.

Table 10: Photovoltaic energy self-consumption in different countries

Country/region	Regulation applied
Germany	In the framework of the EEG, self-consumed energy in 2010 is remunerated with about EUR-ct 8 more than injected energy for plants >30 kW. The detailed remuneration guaranteed for 20 years from July 2010 include the following:
	Plants up to 30 kW EUR-ct 20.88/kWh
	Plants up to 100 kW EUR-ct 19.27/kWh
	Plants up to 800 kW EUR-ct 17.59/kWh
Italy	Plants <20 kW receive 5% higher feed-in tariffs if more than 70% of the energy produced is self-consumed. Moreover, self-consumed energy in plants <200 kW makes the plants eligible for net metering conditions. Self-consumed energy is rewarded with bonuses for the following year. Nevertheless, self-consumed energy also receives the effective feed-in tariff.
California	Net metering is applied. Because of the existence of non-time-differentiated (i.e. 'flat') rates and a time-of-use rates for household electricity the effect of net metering strongly depends on the chosen electricity rates.

The following are the major conclusions and recommendations made for post-incentive period in PV sector:[53]

- If financial incentive programmes are implemented over a reasonable time frame, they work with respect to both significant price decreases and increases in quantities;
- There are remarkable differences regarding the economic efficiency of promotion programmes for PV. In fact, we consider that Japan in the late 1990s and early 2000s has been the only market without oversubsiding. Excessive investment subsidies or FiT distort the market and reduce the acceptance of PV because of high public costs and low effectiveness of PV diffusion;

[53] A. Polo, R. Haas. An international overview of promotion policies for grid-connected photovoltaic systems.Progress in Photovoltaics: Research and ApplicationsDOI: 10.1002/pip (2012)

- FiT schemes and also investment subsidies and combined concepts are able to increase the market penetration and the diffusion of PV systems. Investment subsidies are especially relevant in the context of optimising the own use of PV electricity generated;
- In the markets for PV systems, some price volatility could be observed over time because of adaptation of supply and demand. More precisely, because of temporarily overheated demand due to rather high financial support, for example, in Germany in 2005, prices for PV even increased for some time. Yet, in the long term, there has been clear evidence that competition and market forces work. For example, the emergence of Chinese manufacturers has led to an important stimulation of the worldwide market;
- A major problem was that obviously, policy makers were often ignorant with respect to perceptions from scientific analyses. So often, higher financial support was provided than necessary, and overall, too much money has been and is spent for the promotion of PV. Such high tariffs has, for example, in Spain and the Czech Republic, led to skyrocketing demand followed by a full standstill in the years following;
- Promotion systems must on the one hand consider customers' WTP and on the other hand include a well-defined dynamic component, which considers the effects of Technological Learning. In this context, capacity corridors, as were introduced in Germany, are essential. This tool allows predictable legislations and the correction of incentive payments without generating boom-bust cycles as in Spain in 2009;
- So, more important than the achievement of cost effectiveness is the convergence of system costs and consumers' WTP. Although the profitability was the main driver in countries whose main promotion policy was a FiT (e.g. Germany and Spain), in Japan, with a predominant investment subsidy, the main driver was a higher WTP;
- So, it should by no means be an objective of a financial incentive programme to address large investors with attractive return-on-investments;
- With respect to the future, the most important perception is, with looming grid parity, a major challenge will be to link incentives for the effective own use of PV with market-based prices for feeding PV electricity into the grid. This investigation is left for future research work.

3.4 Risk Factors

- Given the policy-driven nature of the industry, any unexpected change in governmental policies around the world, particularly in North America and Europe and concerning renewable energy, could have an unexpected impact on revenue and earnings estimates.

- Thin-film technology has a short history, and thin-film technology and solar modules may perform below expectations. Problems with product quality or performance may cause thin-film manufacturers to incur warranty expenses, damage its market reputation, and prevent it from maintaining or increasing market share.
- Cadmium telluride is a toxic material, and any product leak could have a significant adverse impact on the ability to sell its products, while the warranty measures taken on the balance sheet could prove to be inadequate.
- Chinese competitors could sacrifice some margins for the purpose of taking market share.
- If the company's estimates regarding the future cost of collecting and recycling its solar modules are incorrect, manufacturers could accrue additional expenses and face a significant unplanned cash drain.
- Project development or construction activities may not be successful, projects under development may not receive required permits, or construction may not commence as scheduled, which could increase the company's costs and impair its ability to recover its investments.
- The company could face unforeseen challenges, such as its ability to acquire or lease land and/or obtain the approvals, licenses and permits necessary to build and operate PV power plants in a timely and cost-effective manner, and regulatory agencies, local communities or labor unions may delay, prevent or increase the cost of construction and operation of the PV plants the company plans to build.
- Inadequate financing for third parties interested in acquiring developed PPAs from companies or paying for EPC contracts.
- Any unexpected change in interest rates could adversely impact project IRRs and delay the funding/construction of such projects.

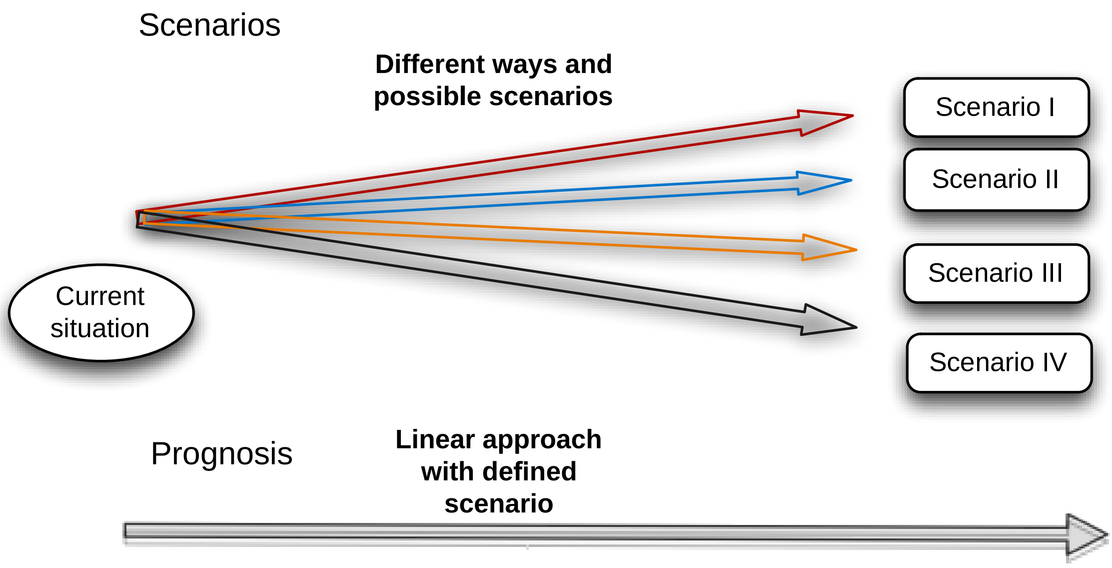
4 SCENARIOS FOR DEVELOPMENT OF LITHUANIAN PV INDUSTRY

4.1 Methodology

4.1.1 Scenarios versus prognosis

The main objective of the PV sector foresight – to propose strategic recommendations for development of Lithuanian PV sector competitiveness viable across different future environmental scenarios. Methodology for development of the future scenarios of PV sector in Lithuania towards 2025 is mainly based on explorative, qualitative approach. Scenarios are not prognosis or forecasts or prediction of the future trends or events, but rather stories (or statements) about possible future explorative contexts that will possibly surround PV sector in Lithuania (Figure 26).

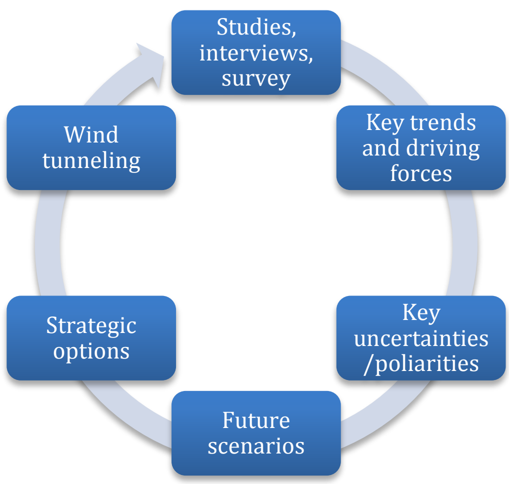
Figure 26: Scenarios versus prognosis



4.1.2 PV foresight cycle

Figure 27 illustrates the steps for the whole process of the PV foresight.

Figure 27: PV Foresight cycle



4.1.2.1 Key trends and driving forces, key uncertainties and polarities

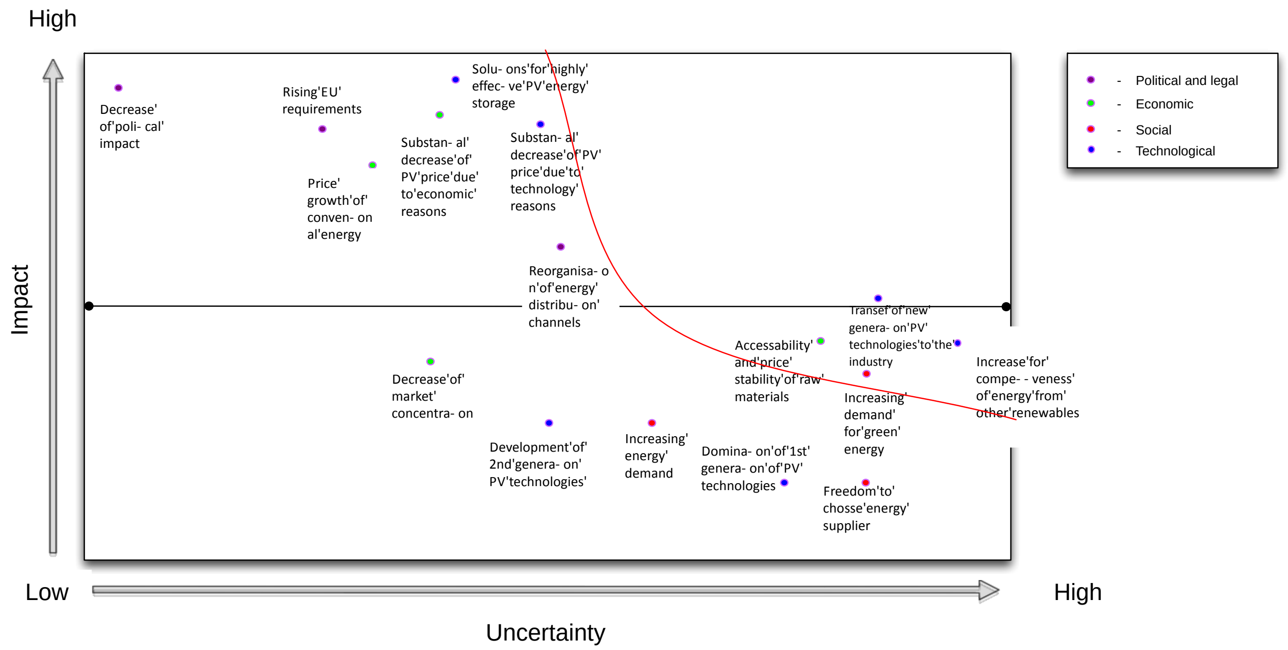
The following studies were undertaken at analysis stage:

- Study on mid-term and long-term trends of global photovoltaic industry development
- Study on state of the art and next generation photovoltaic
- Study on present and prospective PV applications and challenges for PV industry.
- Study on dynamics of photovoltaics business: integration and competitiveness in energy sector.

Main objective of the PC experts - identification and evaluation of trends and key drivers for PV industry in terms of their certainty and possible impact for PV sector in Lithuania as well as possible strategic options. Main objective of PV expert interviews - to gain understanding about current situation of PV sector in Lithuania in terms of challenges, opportunities, existing and currently developed capabilities as well as possible strategic options for PV sector as a whole.

As result of PV expert survey, trend impact and uncertainty matrix was developed. The matrix served for selection of key uncertainties for setting future scenario axis. Participants of the Expert Panel were introduced to the results of the 70 expert internet survey, including the trend impact and uncertainty matrix (Figure 28).

Figure 28: Trend Impact / Uncertainty Matrix



4.1.2.2 Future Scenarios

Expert Panel for scenario development was divided in the following steps (Figure 29).

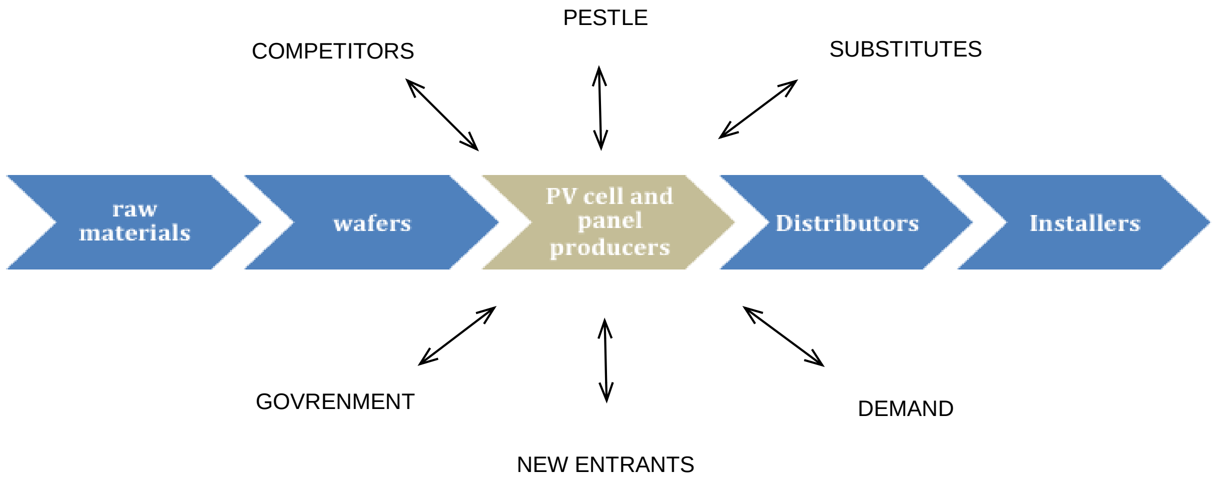
Figure 29: Process of scenario development

Trends PV value chain Current situation of PV sector	Highest impact Level of uncertainty	Macro-environment PV value chain Key PV technologies Competetive landscape, KSF Threats and opportunities	Business choices Required capabilities/competences Required resources

As a result of Expert Panel developed 4 mutually exclusive scenarios based on selected scenario matrix. Scenario development embraced the PESTLE for PV sector in 2025, value chain, competitive environment, as well as implications for PV sector in Lithuania in terms of threats and opportunities and proposal of KSF for PV sector in Lithuania in different scenarios.

Value chain was discussed around the framework provided below (Figure 30).

Figure 30: Value chain



Scenarios further are dedicated to test robustness and strategic fit of different strategic options (business choices or capabilities) for PV sector in Lithuania.

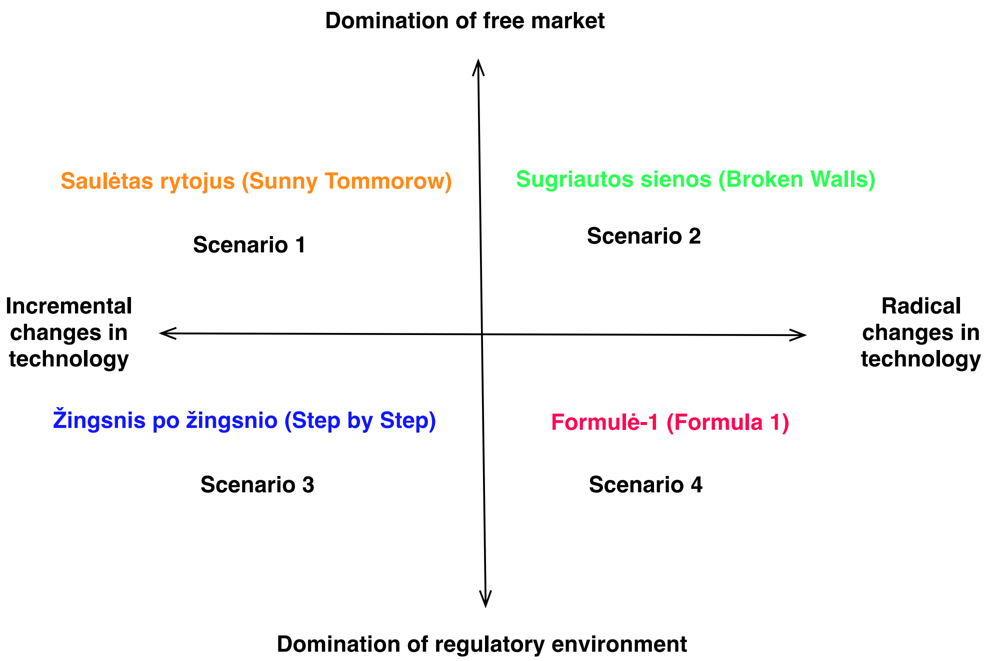
4.2 Main statements form the expert panel

A public meeting "Expert Panel Meeting on the future scenarios of PV sector in Lithuania towards 2025" of an independent Expert Panel was convened on September 6, 2013, at *The Northtown Technology Park (NTP)*, Galvydzio str. 5, Vilnius. Lithuania. The meeting minutes of the panel is provided as an attachment to this Study (Annex II).

The main statements form the expert panel are as follow:

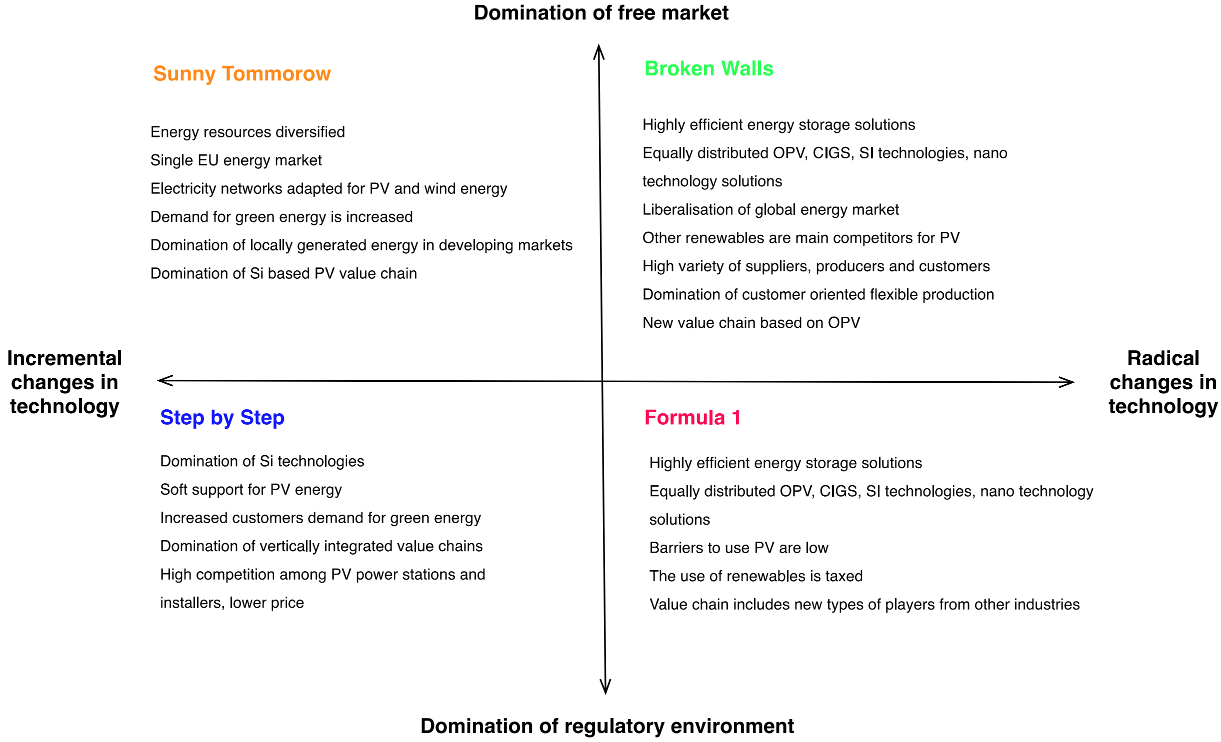
1. On the basis of trend impact and uncertainty matrix the following axis for future scenario development were selected. (Figure 31).

Figure 31: Scenario axis



2. Main assumptions defined as common for all scenarios:
    - PV is competitive all over EU and the world, however, to different degrees depending on different scenarios
    - SMART-GRID becomes a global reality;
    - PV part in energy balance will highly increase;
    - No raw material providers will have dominating position, except for CIGS in Bolivia;
    - Demand for energy will constantly grow;
    - Increased price for conventional energy;
    - Increased demand for energy independence;
    - Higher number of green energy admirers;
    - Substitutes do not pose significant threat to PV industry;
    - PV value chain closer to end-user.
3. The summary of four scenarios proposed by experts is depicted in Figure 32. The scope of the future scenario and its implications were developed during discussion in the experts groups on the following questions:
    - PESTLE for PV sector in 2025
    - Value chain, competitive environment, KSF
    - Implications for PV sector in Lithuania in terms of threats and opportunities
    - KSF for PV sector in Lithuania

Figure 32: Future scenarios



4.3 Presentation of Scenarios

The four scenarios, which were developed, center around two uncertainties identified as the critical ones:

- The further development of the regulatory environment (polarity of domination of free market or domination of regulatory environment).
- The development of technologies (polarity radical changes in technology or incremental changes in technology).

The first uncertainty incorporates the possible futures in the case of Policy-Driven or Moderate scenario ("business-as-usual") scenarios. However, it was indicated that the development of technology should be also emphasised. Hence, the explorative approach was chosen. Based on these uncertainties as well as horizontal trends the four scenarios emerge on how the Lithuanian photovoltaic technology cluster and photovoltaic sector might evolve between now and the year 2025, addressing the main aspects – global environment and value chain.

4.3.1 Scenario "Sunny Tomorrow"

Environment

Power supply sources are diversified. Single EU energy market effectively adapts electricity networks for the consumption of PV and wind energy. PV technology is the EU's smart specialization area. PV provides competitive price compared to the price of conventional energy sources. Green energy consumption in the world accounts for a significant part of the energy balance. Unlike developed countries, developing country markets locally generated electricity constitutes a significant part of the energy supply.

Value chain

Silicon remains the main raw material and is widely available. PV value chain remains substantially unchanged.

4.3.2 Scenario "Broken Walls"

Environment

Political / legal incentives for PV or other renewable energy resources are not available anymore. Nevertheless, political priorities focus on environmental regulation in relation to climate change through introduction of clean energy promotion measures. The energy market is dominated by economic factors. Key competitors for PV are thermonuclear energy, biomass and significantly more efficient fossil fuels.

Radical changes in energy storage solutions as well as PV technologies (Si, CIGS, OPV, nano-technology solutions) providing high efficiency PV cells and modules. There is a rapid development of global PV markets.

Value chain

A large variety of manufacturers, suppliers and customers. The production and supply chain is flexible providing customized solutions adapted to customers ' needs and wants. Value chain is shorter, closer to the end user. The main conditions for competitiveness: price and flexible production.

4.3.3 Scenario "Step by Step"

Environment

There is still on-going moderate promotion of the production, allowing the PV sector to participate in the overall energy supply. The Governments systematically implement measures to combat climate change, enabling countries to increase energy independence. The market is witnessing a moderate increase in energy consumption. The price of energy is increased as fossil fuel resources are in decline. PV is competitive EU-wide. Consumers show better awareness and intention to use renewable energy.

Value chain

Raw materials (Si) prices remain stable and there is no shortage of raw materials. The costs of installers are significantly reduced due to increased competition. Si-based photovoltaic modules, PV power plant efficiency increased to 18-20 percent (after at least 1 percent. every 5 years). PV value chain includes other types of industries (PV integrated in buildings, vehicles, etc.).

4.3.4 Scenario "Formula 1"

Environment

The majority of today's technological market barriers that impede the use of FE and development are removed. Energy storage technologies are significantly improved. The market is dominated by silicon (Si) solar and other new high-efficiency solar cells and modules. The main technologies used are organic (OPV), CIGS (copper - indium - gallium - selenide) solar cells and nanotechnology (quantum confinement) solutions. PV part of the energy package is highly increased. Renewable energy substitutes for PV energy are not distributed globally and are not yet competitive. Renewable resources are taxed in order to preserve other types of conventional energy Smart- grid electricity network is fully developed and functioning.

Value chain

Value chain includes new participants from other industries. Co-operation between members of the value chain is significantly enhanced. The current solar cell manufacturers adjust their production to adapt to new technologies, modules manufacturers commit minor production changes and installers improve their competences in order to install other modifications and installation options in new application domains. Raw material suppliers do not have a dominant position in relation to OPV and Si -based PV manufacturers. Bolivia dominant position in the area of raw material (largest indium reserves (minerals)) for CIGS based producers.

4.4 Key results of Lithuanian PV industry development scenarios

4.4.1 Key success factors for PV sector in Lithuania in different scenarios

PV industry displays all the hallmarks of a relatively young industry. This includes a notoriously fickle supply chain for the all-important polysilicon, a large number of different technologies and the distinct absence of companies that cover the whole value chain. As the industry becomes more mature, it will no doubt see significant consolidation and fewer technologies.Though different segments of the value chain have different logistics (which are explored in the following pages), there are common drivers that are key to the success of individual businesses proposed by Green Rihno Energy:[54]

- Product Parameters:
    - Technology Differentiation: to avoid having to compete just on price, firms must offer a product that is technologically differentiated. Whilst there are many distinguishing features, the one number to beat is "efficiency" as measured in "$/kWp" followed closely by the module efficiency measured in "kWp/m^2 ". This is so important because a 1% point efficiency increase in the cell, results in an additional energy yield of 6%. In addition, it brings down requirements for area and electrical components.
    - Technology Strategy: the technologies that are installed today, may not be the technologies of tomorrow. For instance, with the sharp drop in polysilicon prices, some of the thin-film technologies no longer look as appealing as they did a year ago. As a mitigation strategy, we would expect alternative technologies to be present in any company's product portfolio.
    - Product Quality and Certification: the presence of module certification from independent bodies such as TÜV is no longer a distinguishing feature; it is in fact a quasi- license to operate.
- Production Capability: it is essential that production can be scaled up to significant levels. For a new technologies (e.g. a new thin-film photovoltaic material), the capability of ramping up production very quickly is crucial; otherwise, the new product will not make a difference.
- Cost Structure: how well a company can control costs is one of the most important factors, especially in an industry that sees an ever-growing number of new entrants. Silicon manufacturers with access to cheap energy, for instance, have a distinct competitve advantage, as 85% of the energy needed to build a module, is used in producing silicon. Other cost advantages come from economies of scale and supply contracts at low pricing level.
- Vertical Integration: in order to be able to capture more value and to mitigate the inherent risks of the supply chain, it is crucial to either integrate vertically or build strong partnerships with others in the value chain.
- Financial Strength: whilst this is a fairly obvious, a strong balance sheet is required not only to weather a downturn, but also to finance growth.
- Branding: finally, success is determined by how well a company can communicate the value it creates for customers, its brand strength and access to distribution channels.

[54]Green Rhino Energy Ltd:http://www.greenrhinoenergy.com/solar/industry/ind_ksfs.php. Accessed Sep. 2013

The specific key success factors for PV sector in Lithuania for different scenarios are indicated in Table 11.

Table 11: Key success factors for PV sector in Lithuania in different scenarios

Scenario	Key success factors
Sunny Tomorrow	• PV value chain closer to the end-user • Cost effectiveness due to technical innovation in the production process • Strong international marketing and sales skills • Cooperation with other EU countries in R & D, manufacturing, marketing, and other areas • PV part of smart specialisation of Lithuania in EU • High level of professional training of specialists, whose knowledge applicable in PV sector
Broken walls	• PV value chain closer to the end-user • Manufacturers are able to adapt to new technologies • Accumulation of technical and financial resources • Close relationship with international research institutions (development of new PV technologies) • Able to introduce new technologies to the market • Able to offer an attractive product to global markets • Production efficiency depends on the development of other sectors
Step by step	• Competitiveness due to enlarged vertical integration • Si-based photovoltaic cells and modules, PV power plant efficiency significantly increased (at least 1 per cent. every 5 years) • PV sector is oriented and fills niche markets, to satisfy specific needs of users (eg PV integrated in buildings, vehicles, etc.).
Formula - 1	• Value chain includes new types of participants from other industries (for instance, automotive) • Cooperation between members of the value chain is significantly enhanced • Cell and module manufacturers adjust their production to new technologies • Close relationship with international research institutions (development of new PV technologies)

The four developed scenarios and the indicated key success factors for PV sector in Lithuania scenarios are employed for further visualisation of prognosis for potential markets up to 2030 which are presented in the further sections dedicated for each scenario. The prognosis for manufacturing capacity and energy output are made. The level of investment required, the number of jobs that could be created and the effect that increased input from solar electricity will have on greenhouse gas emissions are also assessed.

4.4.2 Methodology

4.4.2.1 Aim and objectives of Forecasting

The purpose of the forecasting is to discover the possible future trends of Lithuanian PV market development through the application of scientific modelling. Such forecasts enables PV businesses answer questions and plan steps forward. Forecasting period takes from 2013 to 2030. Other specific forecasting objectives are:

- To prepare a forecasting model which allows to visualise the trends of four different scenarios of Lithuanian PV sector (including manufacturing of PV cells and modules separately and the market as the whole);
- To estimate growth rates of the Lithuanian PV manufacturers' manufacturing capabilities and actual production (in MW; PV cells and modules separately and the market as the whole);
- To identify what part of global PV market Lithuania would take in four different future scenarios;
- To project the income of Lithuanian PV manufacturers (PV cells and modules separately and the market as the whole);
- To estimate the numbers of high-tech jobs created due to Lithuanian PV ant its collaboration with relevant industries;
- To forecast the investments in Lithuanian PV sector needed for sustaining of competitive advantage;
- To forecast the electricity generation in Lithuania from installed Lithuanian PV modules (kWh);
- To forecast the CO_2 savings in Lithuanian from installed Lithuanian PV modules (kg).

4.5 Data collection and forecasting model preparation

The statistical data about the PV market was collected in order to obtain the concrete outlook of the situation and key figures in European and Global PV market. First of all, the EPIA (European Photovoltaic Industry Association) publications have been used to obtain the data on the global cumulative PV market. The latest EPIA publication provides the data on two forecasts for the period of 2013-2017.[55] Two scenarios have been provided of global cumulative PV market (with grey colour indicating the forecast):

Table 12: The statistical data provided by EPIA

Year	Global PV cumulative (EPIA historical data and EPIA Policy-Driven Forecast) (MW)	Global PV cumulative (EPIA historical data and EPIA Business-as-usual Forecast) (MW)
2003	2,820	2,820
2004	3,952	3,952
2005	5,364	5,364
2006	6,946	6,946
2007	9,521	9,521
2008	16,229	16,229
2009	23,605	23,605
2010	40,670	40,670
2011	71,061	71,061

[55] EPIA, 2013.Global market outlook for photovoltaics 2013-2017. Available from: <http://www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=/uploads/tx_epiapublications/GMO_2013_-_Final_PDF_01.pdf&t=1385907329&hash=e2533b1ccb2e6cbae6a3b8c9f19eee22cc7b3a76> [Reviewed 09-09-2013]

Year	Global PV cumulative (EPIA historical data and EPIA Policy-Driven Forecast) (MW)	Global PV cumulative (EPIA historical data and EPIA Business-as-usual Forecast) (MW)
2012	102,156	102,156
2013	149,120	129,960
2014	201,750	160,770
2015	264,390	197,600
2016	338,650	239,920
2017	422,890	288,220

However, to provide model with data for current PV model till the year 2030 the longer forecast must have been generated. Using the same statistical data, the polynomial forecasting trend was used for both scenarios (with R correlation coefficient reaching 0.99) (Figure 33 and Figure 34).

Figure 33: Global PV cumulative (adjusted policy-driven forecast)

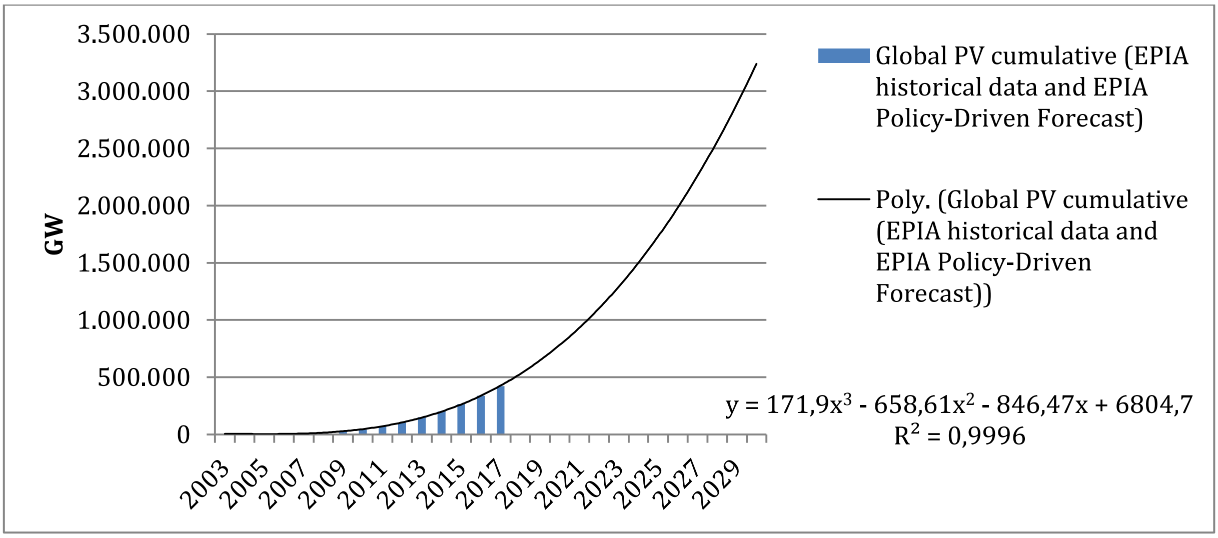
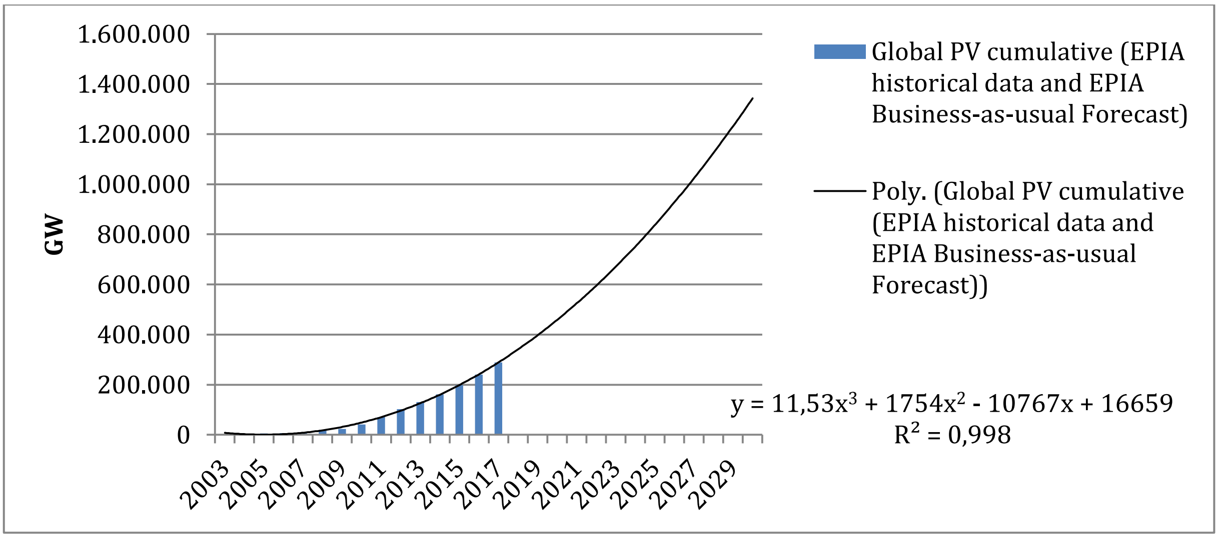


Figure 34: Global PV cumulative (adjusted business-as-usual forecast)



Next, the data for the module[56] and cell[57] prices was obtained. Similarly to previously described situation, the statistical data provided needed the further scientific data processing in order to obtain the forecasts till the year 2030. Below, two figures are provided with the details about price forecasting for the period 2013-2030 (Figure 35 and Figure 36). Both trends also show a significant correlation reaching nearly 0.9.

Figure 35: Forecast of prices of PV modules, € (2013-2030)

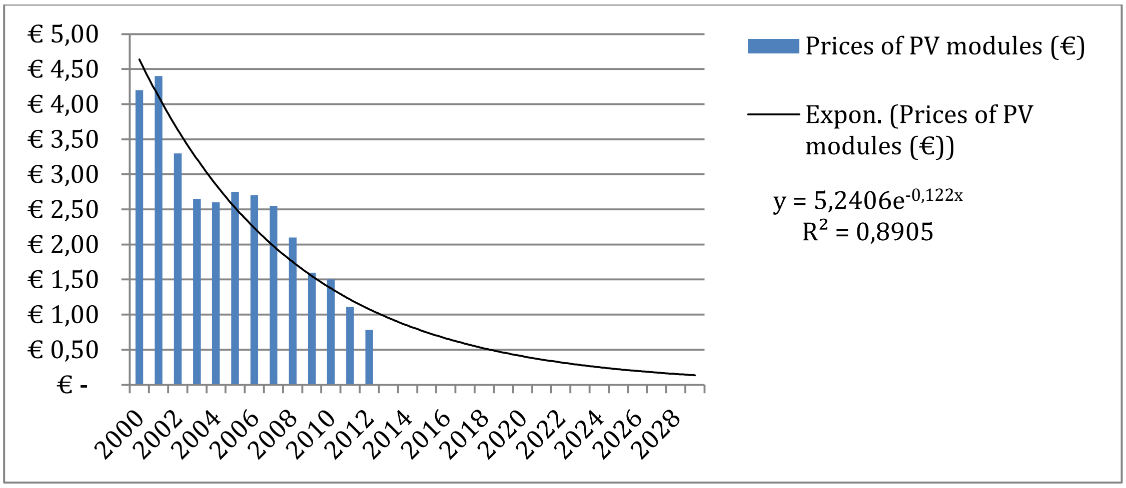
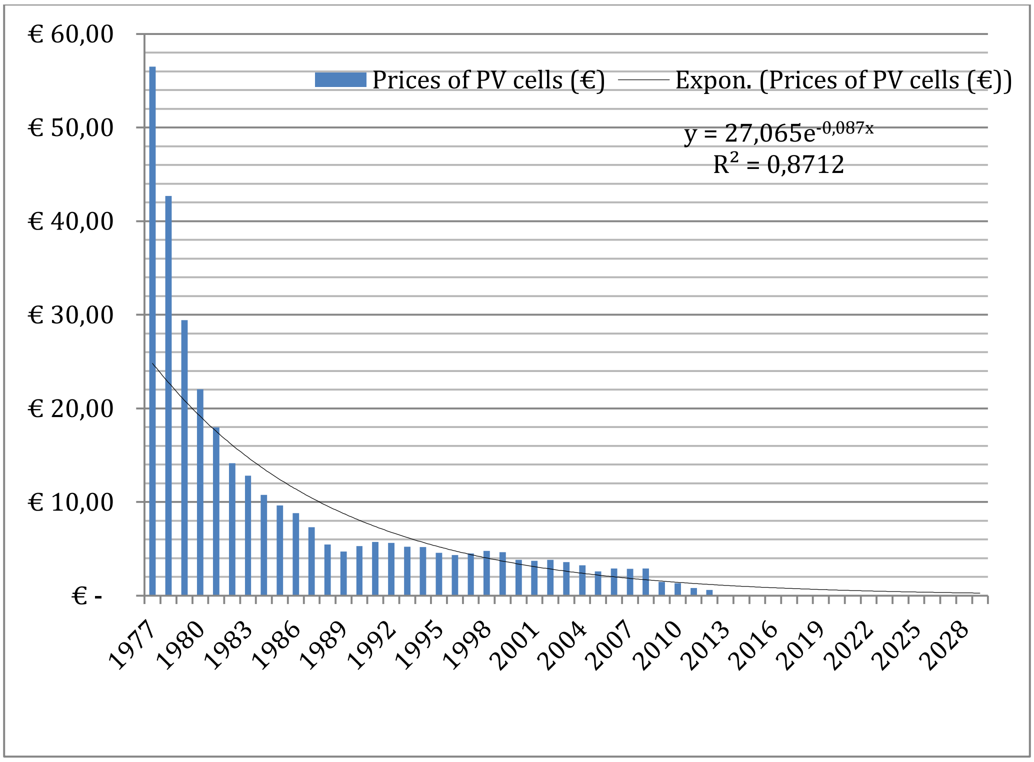


Figure 36: Forecast of prices of PV cells (2013-2030)



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56 PV Magazine, 2013. Module price index. Available from: <http://www.pv-magazine.com/investors/module-price-index/#axzz2hhBCij7f> [Reviewed 09-09-2013].

57 Economia Historia, 2013. The arrival of photovoltaics electrical *Autoconsumo* (esp: La llegadadel Autoconsumo Eléctrico Fotovoltaico). Available from: <http://dfc-economiahistoria.blogspot.com/2013/01/la-llegada-del-autoconsumo-electrico.html> [Reveiwed 09-09-2013]

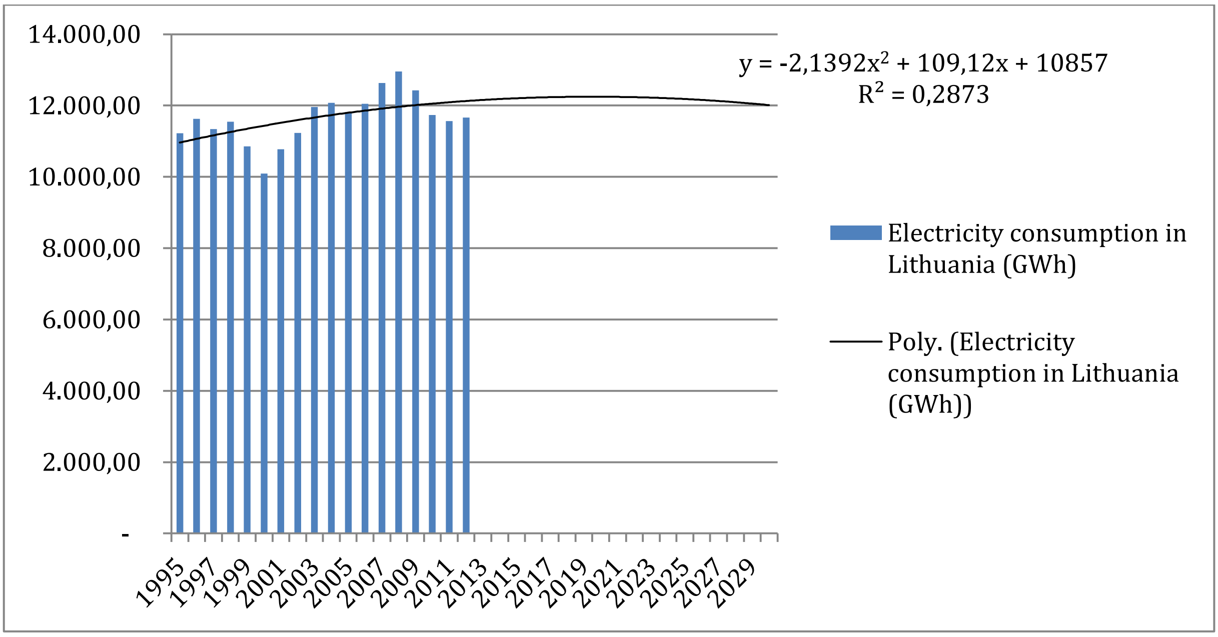
The forecasting outcome then was adjusted to comply with realistic price trends – in the future the prices are not expected to be higher than current prices. Therefore, the gradually decreasing residual was then deducted from each next year of the forecast.

Also, the data for the electricity consumption in Lithuania[58] was collected and is presented within the Table 13. The polynomial forecast was performed to identify the expected market size for the year 2013-2030 (Figure 37). Even though correlation coefficient does not identify a significant match of trend line, it was the best matching trend and represents a reasonable growth of Lithuanian electricity market.

Table 13: Electricity consumption in Lithuania

Year	Electricity consumption in Lithuania (GWh)
1995	11,220
1996	11,630
1997	11,336
1998	11,549
1999	10,853
2000	10,088
2001	10,773
2002	11,234
2003	11,958
2004	12,079
2005	11,818
2006	12,054
2007	12,636
2008	12,954
2009	12,426
2010	11,738
2011	11,560
2012	11,661

Figure 37: The forecast of electricity consumption in Lithuania for the year (GWh), 2013-2030



[58]Official Statistics Portal in Lithuania, 2013.Gross energy consumption (GWh). Available from: <http://osp.stat.gov.lt/en/statistiniu-rodikliu-analize?id=1110&status=A> [Last seen: 2013-11-18].

Finally, several important constant for forecasting model have been identified:

- Solar module instalment price comparing to the module price is considered to be constant and kept to the 85.65 % (Following the calculations based on module prices and estimations made by V. Maciulis[59]);
- According to EPIA estimation, for each MW of solar power installed 30 full time equivalent jobs are created; and in Lithuania 10 full time equivalent jobs are created in case of manufacturing without installation (5 jobs for manufacturing 1MW of solar cells and 5 jobs for manufacturing 1MW of solar modules). These estimations were used as constant for Lithuanian market;
- According to EPIA estimations, global average CO_2 savings per 1kWh electricity generated with PV modules is 0.6 kg[60];
- According to online PV performance calculator, the average electricity generation per 1 kW solar module in Lithuania is equal to 1,000 kWh[61];
- Lastly, in some cases the currency change of 3.4528 LTL = 1 EUR has been used to harmonise measures from different sources.[62]

Within the next sections of this Study the four visualisations of the trends for development of Lithuanian PV sector in different future scenarios are presented.

4.5.1 Scenario "Sunny Tomorrow"

The critical variables which were formulated on the taking into account the key success factors (Table 11) and are essential for gaining the competitive advantage of Lithuanian PV sector in future highly competitive situation of this scenario are the following:(i) actual manufacturing capacity of moderate level due to high global competitiveness based on price; (ii) the adequate investments to RTD activities, dedicated to sustain the existing technological progress and (iii) orientation to export markets. The key results for scenario "Sunny Tomorrow" until 2030 on manufacturing capacity (Figure 38) and actual manufacturing (Figure 39), market share in the global PV market (Figure 40), export indicators, including generated income (Figure 41, Figure 42, Figure 43 and Table 15 and Table 16), investments (Figure 44 and Table 17), generated employment (Figure 45 and Table 18), electricity production (Figure 46, Figure 47, Figure 48, and Table 19) and environmental issues (Figure 49, Figure 50 and Table 19) are presented in the indicated tables and figures below.

[59]Vitas Mačiulis, 2013-09-19. Presentation: The future of Lithuanian solar energy: ways and possibilities of development (Lith.: Saulės energetikos ateitis Lietuvoje: plėtros variantai ir galimybės). Lithuanian Association of Solar Energy.
[60]EPIA , 2011. Solar generation 8: Solar photovoltaic electricity empowering the world. Available from: <http://www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=/uploads/tx_epiapublications/Solar_Generation_6__2011_Full_report_Final.pdf&t=1385550576&hash=f33119cfba2af810417f40e1c02bdfc1b0870b6d>[Reviewed 09-09-2013]
[61]Joint Research Centre, 2013.PV potential estimation utility. Available from: <http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php> [Reviewed: 09-09-2013]
[62]Lithuanian Bank, 2013. Currency rates. Available from: <http://www.lb.lt/exchange/default.asp> [Reviewed: 09-09-2013].

Figure 38: Sunny Tomorrow: Growth of Lithuanian PV manufacturing capabilities in 2011-2030 time-frame

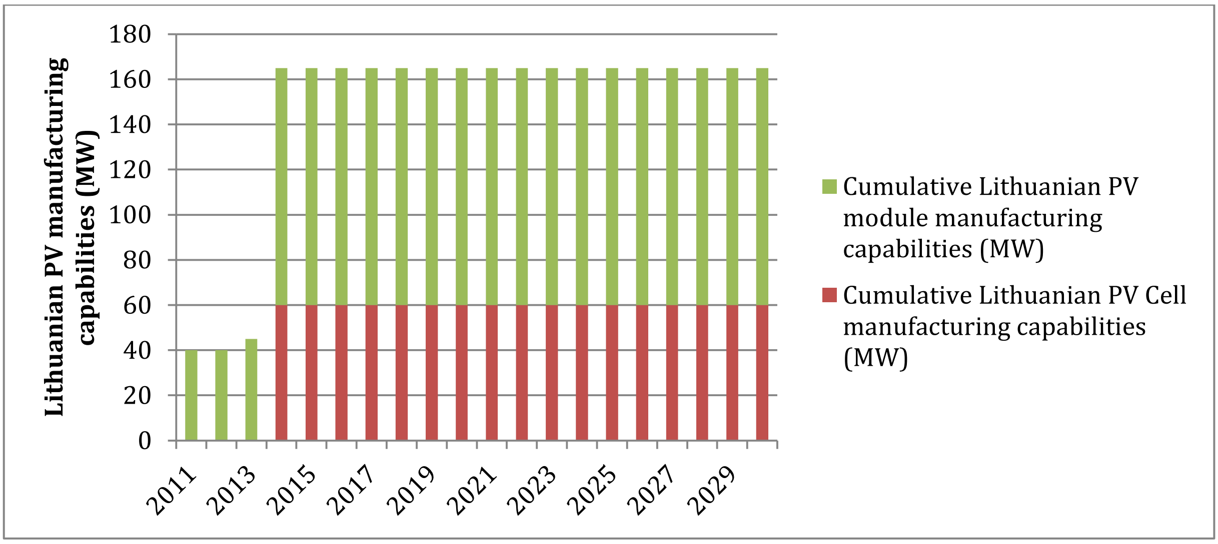


Figure 39: Sunny Tomorrow: Lithuanian PV actual manufacturing in 2011-2030 time-frame

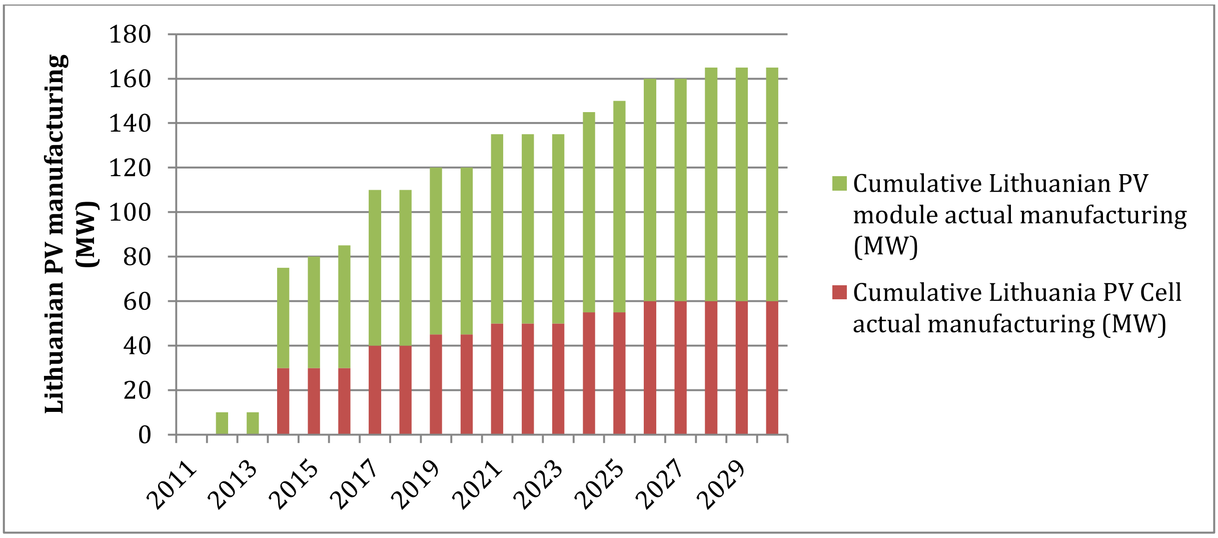


Figure 40: Sunny Tomorrow: Prognosis of Lithuanian market share in the global outlook

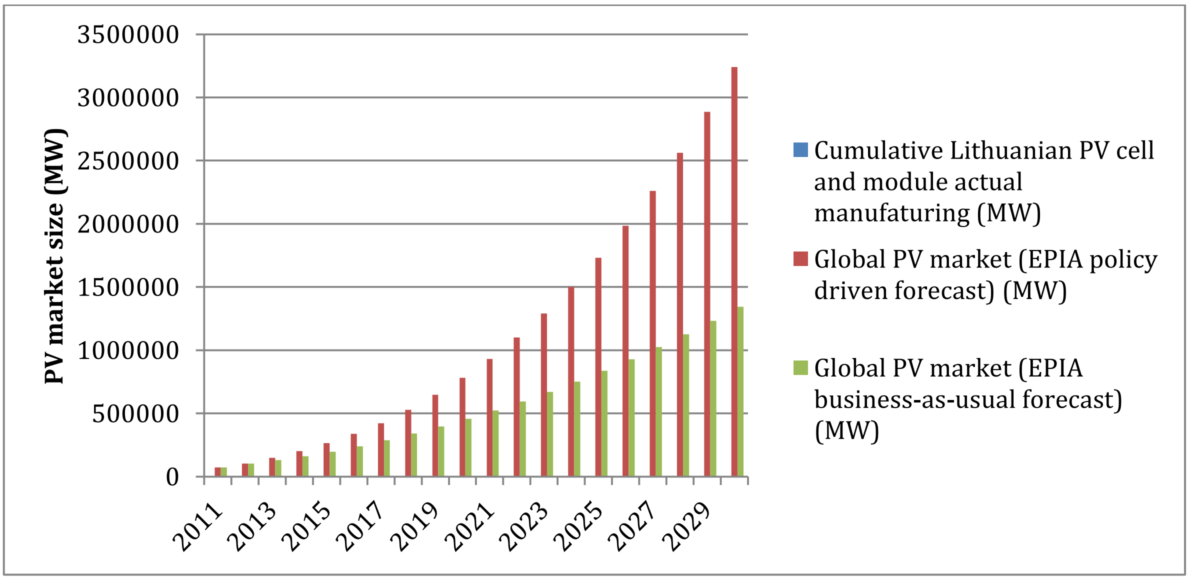


Table 14: Sunny Tomorrow: Prognosis of Lithuanian market size by MW, global market share in 2011-2030 time-frame

Year	Cumulative Lithuanian PV Cell manufacturing capabilities (MW)	Cumulative Lithuania PV Cell actual manufacturing (MW)	Cumulative Lithuanian PV module manufacturing capabilities (MW)	Cumulative Lithuanian PV module actual manufacturing (MW)	Cumulative Lithuanian PV cell and module manufacturing capabilities (MW)	Cumulative Lithuanian PV cell and module actual manufaturing (MW)	Lithuanian share in global market (according to the policy driven forecast) (%)	Lithuanian share in global market (according to the business-as-usual forecast) (%)	Global PV market (EPIA policy driven forecast) (MW)	Global PV market (EPIA business-as-usual forecast) (MW)
2011	0	0	40	-	40	-	-	-	71.061	71.061
2012	0	0	40	10	40	10	0,010%	0,010%	102.156	102.156
2013	0	0	45	10	45	10	0,007%	0,008%	149.120	129.960
2014	60	30	105	45	165	75	0,037%	0,047%	201.750	160.770
2015	60	30	105	50	165	80	0,030%	0,040%	264.390	197.600
2016	60	30	105	55	165	85	0,025%	0,035%	338.650	239.920
2017	60	40	105	70	165	110	0,026%	0,038%	422.890	288.220
2018	60	40	105	70	165	110	0,021%	0,032%	528.762	340.638
2019	60	45	105	75	165	120	0,019%	0,030%	646.624	397.173
2020	60	45	105	75	165	120	0,015%	0,026%	780.702	458.392
2021	60	50	105	85	165	135	0,014%	0,026%	932.029	524.364
2022	60	50	105	85	165	135	0,012%	0,023%	1.101.634	595.159
2023	60	50	105	85	165	135	0,010%	0,020%	1.290.551	670.845
2024	60	55	105	90	165	145	0,010%	0,019%	1.499.809	751.492
2025	60	55	105	95	165	150	0,009%	0,018%	1.730.442	837.170
2026	60	60	105	100	165	160	0,008%	0,017%	1.983.479	927.946
2027	60	60	105	100	165	160	0,007%	0,016%	2.259.952	1.023.890
2028	60	60	105	105	165	165	0,006%	0,015%	2.560.894	1.125.072
2029	60	60	105	105	165	165	0,006%	0,013%	2.887.334	1.231.561
2030	60	60	105	105	165	165	0,005%	0,012%	3.240.305	1.343.426

Figure 41: Sunny Tomorrow: Lithuanian income from PV cellsin 2011-2030 time-frame

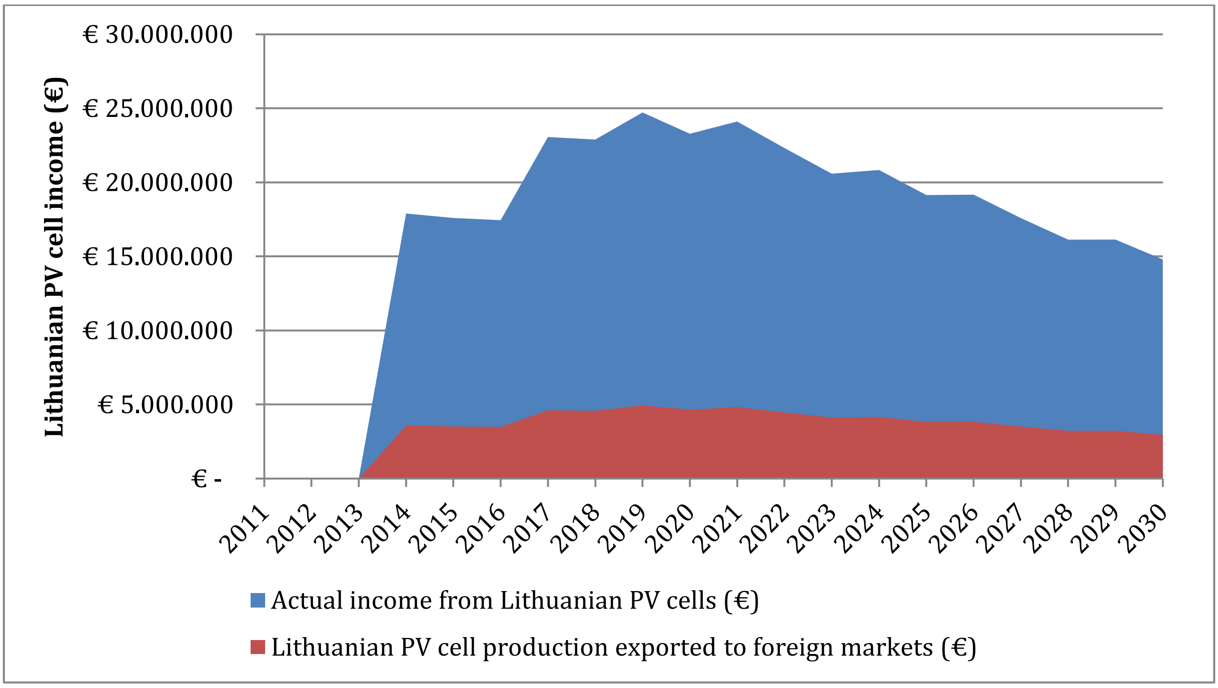


Figure 42: Sunny Tomorrow: Lithuanian income from PV modules in 2011-2030 time-frame

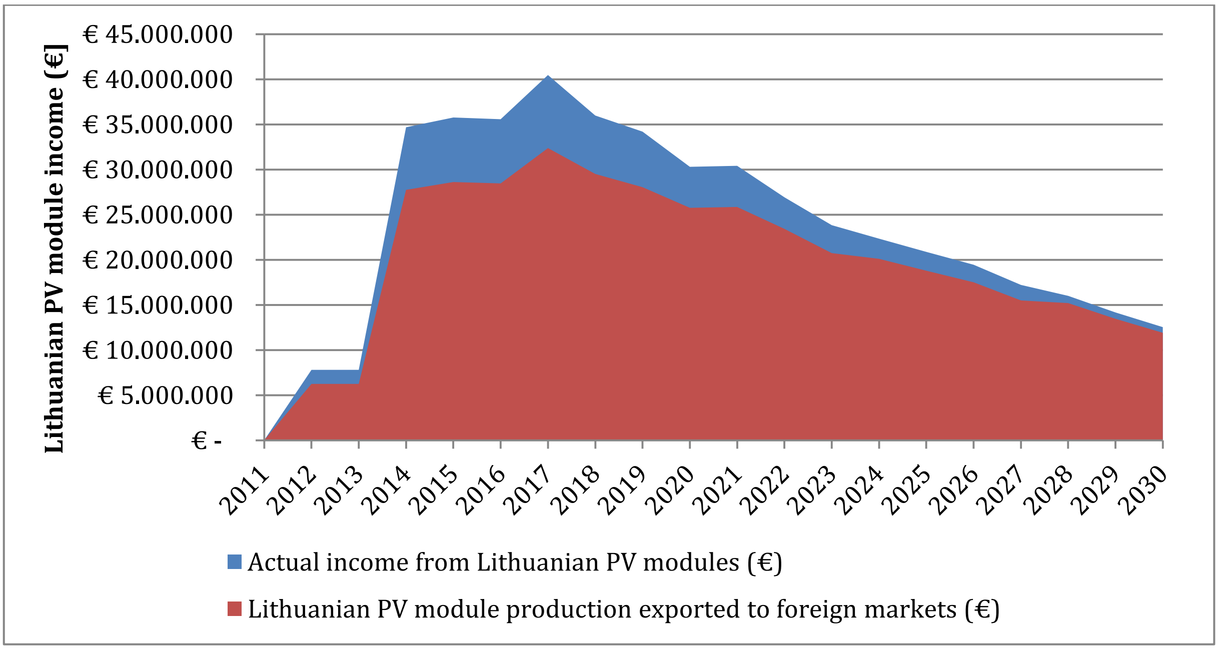


Figure 43: Sunny Tomorrow: Lithuanian cumulative income from PV in 2011-2030 time-frame

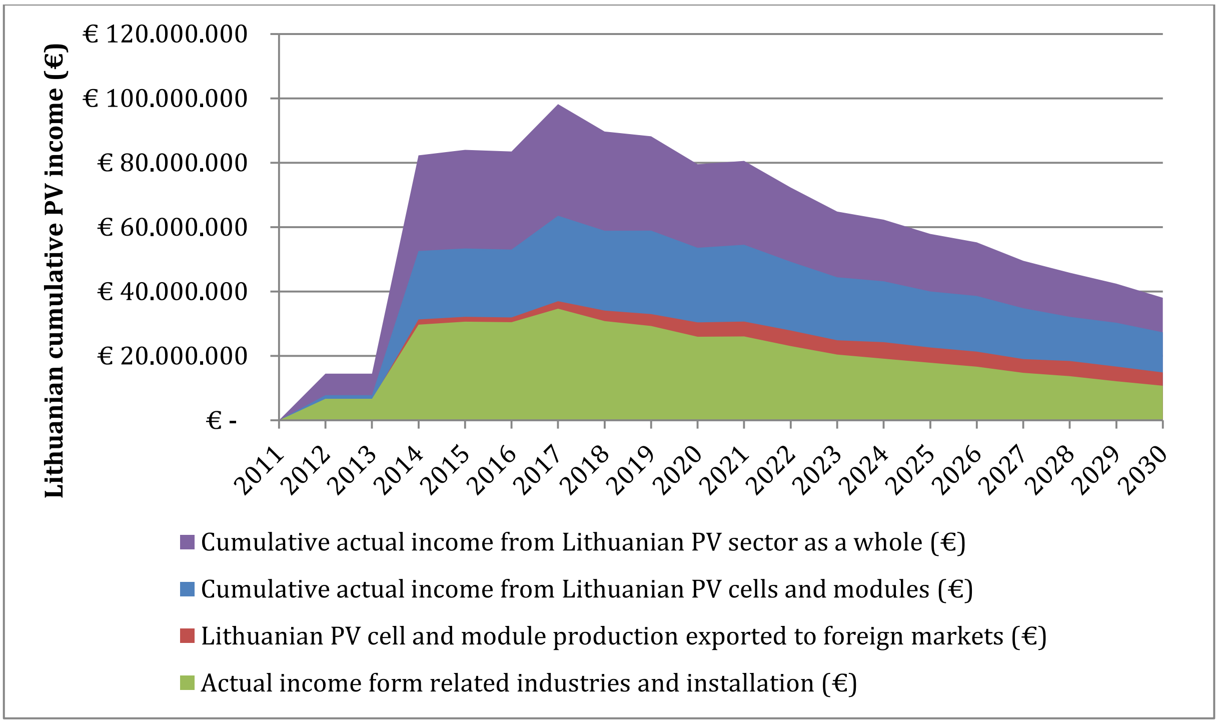


Table 15: Sunny Tomorrow: Prognosis of Lithuanian potential and actual income from PV cells and modules (€) in 2011-2030 time-frame

Year	Potential income from Lithuanian PV cells (€)	Actual income from Lithuanian PV cells (€)	Potential income from Lithuanian PV modules (€)	Actual income from Lithuanian PV modules (€)	Cumulative potential income from Lithuanian PV cells and modules (€)	Cumulative actual income from Lithuanian PV cells and modules (€)	Actual income form related industries and installation (€)	Cumulative actual income from Lithuanian PV sector as a whole (€)
2011	€ -	€ -	€ 44.400.000	-	€ 44.400.000	-	0	€ -
2012	€ -	€ -	€ 31.200.000	€ 7.800.000	€ 31.200.000	€ 7.800.000	€ 6.680.700	€ 14.480.700
2013	€ -	€ -	€ 35.101.929	€ 7.800.429	€ 35.101.929	€ 7.800.429	€ 6.681.067	€ 14.481.496
2014	€ 35.793.985	€ 17.896.992	€ 80.919.651	€ 34.679.850	€ 116.713.636	€ 52.576.843	€ 29.703.292	€ 82.280.135
2015	€ 35.193.985	€ 17.596.992	€ 75.099.917	€ 35.761.865	€ 110.293.902	€ 53.358.858	€ 30.630.037	€ 83.988.895
2016	€ 34.893.985	€ 17.446.992	€ 67.907.576	€ 35.570.635	€ 102.801.561	€ 53.017.628	€ 30.466.249	€ 83.483.877
2017	€ 34.593.985	€ 23.062.657	€ 60.699.385	€ 40.466.257	€ 95.293.370	€ 63.528.914	€ 34.659.349	€ 98.188.263
2018	€ 34.335.733	€ 22.890.489	€ 53.971.788	€ 35.981.192	€ 88.307.522	€ 58.871.681	€ 30.817.891	€ 89.689.572
2019	€ 32.955.295	€ 24.716.471	€ 47.873.617	€ 34.195.441	€ 80.828.912	€ 58.911.912	€ 29.288.395	€ 88.200.307
2020	€ 31.044.632	€ 23.283.474	€ 42.416.741	€ 30.297.672	€ 73.461.373	€ 53.581.146	€ 25.949.956	€ 79.531.102
2021	€ 28.929.138	€ 24.107.615	€ 37.562.222	€ 30.407.513	€ 66.491.361	€ 54.515.129	€ 26.044.035	€ 80.559.164
2022	€ 26.784.537	€ 22.320.448	€ 33.255.199	€ 26.920.875	€ 60.039.736	€ 49.241.323	€ 23.057.730	€ 72.299.053
2023	€ 24.702.762	€ 20.585.635	€ 29.438.697	€ 23.831.326	€ 54.141.459	€ 44.416.961	€ 20.411.531	€ 64.828.492
2024	€ 22.729.077	€ 20.834.987	€ 26.058.816	€ 22.336.128	€ 48.787.893	€ 43.171.115	€ 19.130.893	€ 62.302.008
2025	€ 20.882.965	€ 19.142.718	€ 23.066.414	€ 20.869.612	€ 43.949.379	€ 40.012.330	€ 17.874.823	€ 57.887.153
2026	€ 19.169.870	€ 19.169.870	€ 20.417.403	€ 19.445.145	€ 39.587.273	€ 38.615.015	€ 16.654.767	€ 55.269.782
2027	€ 17.587.776	€ 17.587.776	€ 18.072.515	€ 17.211.919	€ 35.660.291	€ 34.799.695	€ 14.742.009	€ 49.541.704
2028	€ 16.130.884	€ 16.130.884	€ 15.996.892	€ 15.996.892	€ 32.127.776	€ 32.127.776	€ 13.701.338	€ 45.829.114
2029	€ 16.136.864	€ 16.136.864	€ 14.159.637	€ 14.159.637	€ 30.296.501	€ 30.296.501	€ 12.127.729	€ 42.424.231
2030	€ 14.795.023	€ 14.795.023	€ 12.533.386	€ 12.533.386	€ 27.328.408	€ 27.328.408	€ 10.734.845	€ 38.063.253

Table 16: Sunny Tomorrow: Prognosis of Lithuanian export (€) until 2030

Year	Lithuanian PV cell production exported to foreign markets (€)	Lithuanian PV module production exported to foreign markets (€)	Lithuanian PV cell and module production exported to foreign markets (€)
2011	-	-	€ -
2012	-	€ 6.240.000	€ 6.240.000
2013	-	€ 6.240.343	€ 6.240.343
2014	€ 3.579.398	€ 27.743.880	€ 31.323.279
2015	€ 3.519.398	€ 28.609.492	€ 32.128.891
2016	€ 3.489.398	€ 28.456.508	€ 31.945.907
2017	€ 4.612.531	€ 32.373.006	€ 36.985.537
2018	€ 4.578.098	€ 29.504.578	€ 34.082.675
2019	€ 4.943.294	€ 28.040.261	€ 32.983.556
2020	€ 4.656.695	€ 25.753.021	€ 30.409.716
2021	€ 4.821.523	€ 25.846.386	€ 30.667.909
2022	€ 4.464.090	€ 23.421.162	€ 27.885.251
2023	€ 4.117.127	€ 20.733.254	€ 24.850.381
2024	€ 4.166.997	€ 20.102.515	€ 24.269.512
2025	€ 3.828.544	€ 18.782.651	€ 22.611.195
2026	€ 3.833.974	€ 17.500.631	€ 21.334.605
2027	€ 3.517.555	€ 15.490.727	€ 19.008.282
2028	€ 3.226.177	€ 15.197.047	€ 18.423.224
2029	€ 3.227.373	€ 13.451.655	€ 16.679.028
2030	€ 2.959.005	€ 11.906.716	€ 14.865.721

Figure 44: Sunny Tomorrow: Investments in Lithuanian PV sector by investment type in short-, mid- and long-term

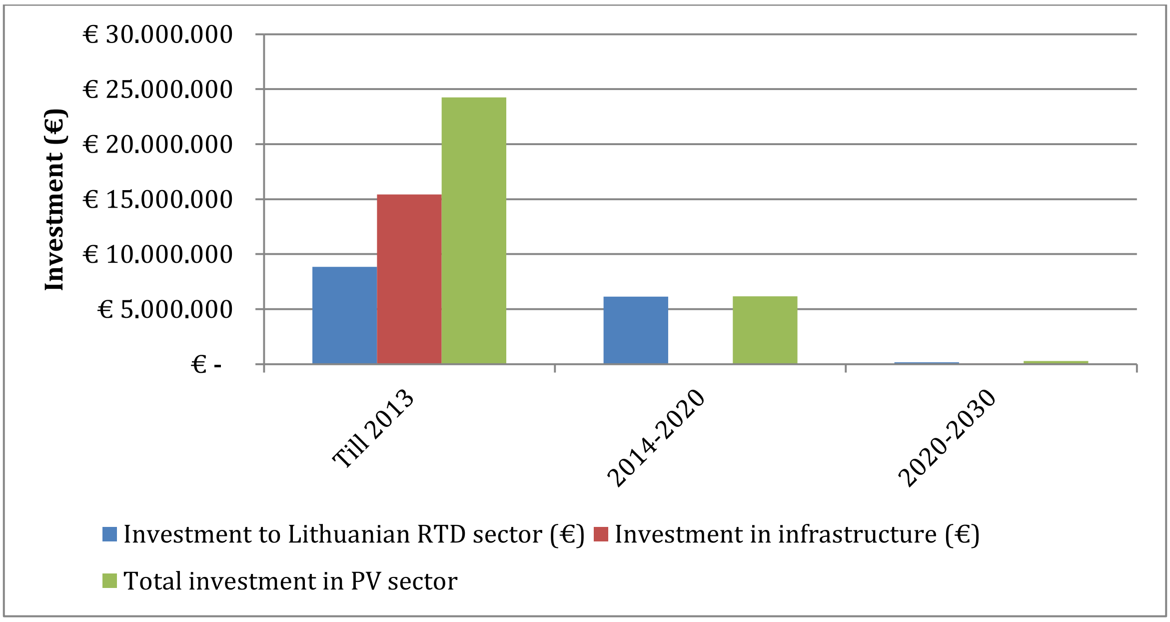


Table 17: Sunny Tomorrow: Investments in Lithuanian PV sector (€) until 2030

Year	Investment to Lithuanian RTD sector (€)	Investment in infrastructure (€)	Total investment in PV sector
Till 2013	€ 8.833.312	€ 15.418.054	€ 24.251.366
2014-2020	€ 6.146.756	€ 26.415	€ 6.173.171
2020-2030	€ 181.784	€ 90.892	€ 272.676

Figure 45: Sunny Tomorrow: Jobs created in Lithuanian PV sector in 2011-2030 time-frame

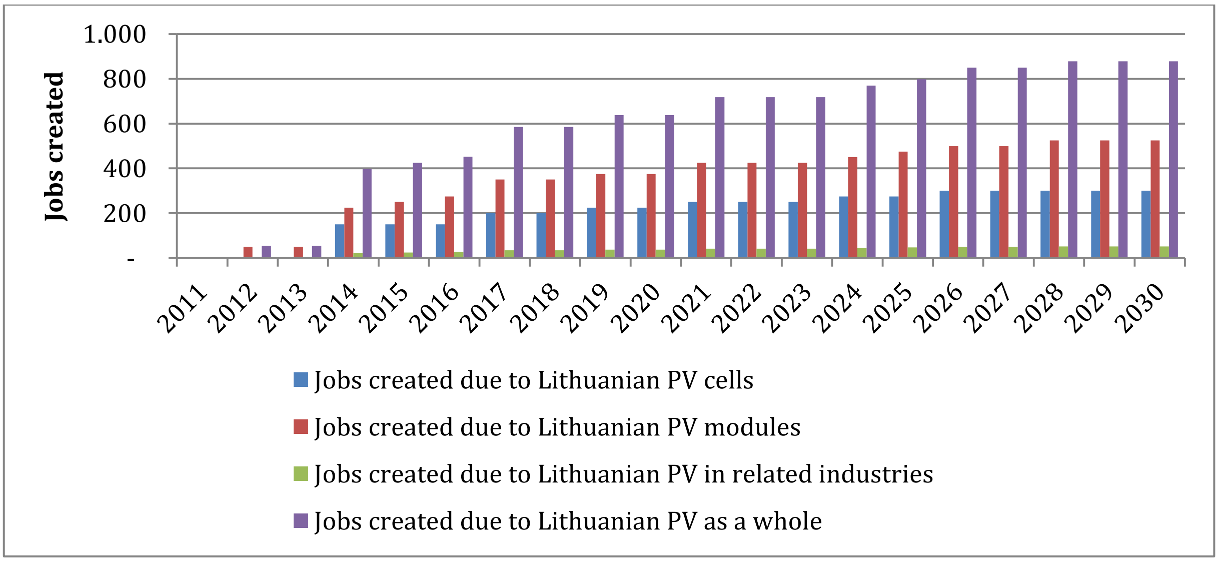


Table 18: Sunny Tomorrow: Employment in Lithuanian PV sector in 2011-2030 time-frame

Year	Jobs created due to Lithuanian PV cells	Jobs created due to Lithuanian PV modules	Jobs created due to Lithuanian PV in related industries	Jobs created due to Lithuanian PV as a whole
2011	-	-	-	-
2012	-	50	5	55
2013	-	50	5	55
2014	150	225	23	398
2015	150	250	25	425
2016	150	275	28	453
2017	200	350	35	585
2018	200	350	35	585
2019	225	375	38	638
2020	225	375	38	638
2021	250	425	43	718
2022	250	425	43	718
2023	250	425	43	718
2024	275	450	45	770
2025	275	475	48	798
2026	300	500	50	850
2027	300	500	50	850
2028	300	525	53	878
2029	300	525	53	878
2030	300	525	53	878

Figure 46: Sunny Tomorrow: Prognosis of annual electricity generation from newly installed Lithuanian PV modules (kWh)

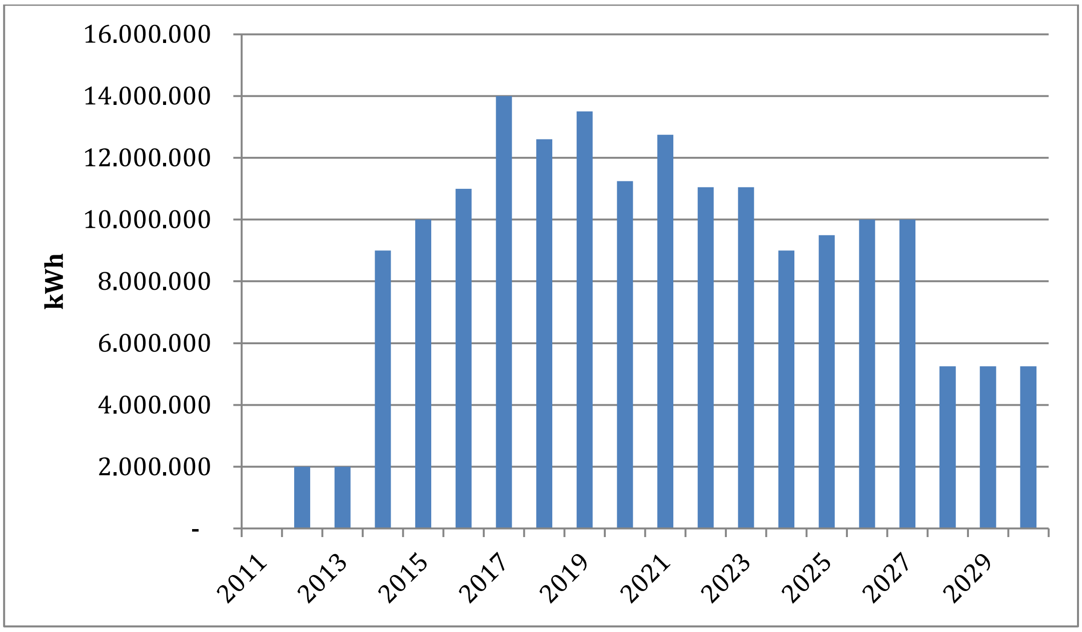


Figure 47: Sunny Tomorrow: Cumulative electricity generation from installed Lithuanian PV modules (kWh)

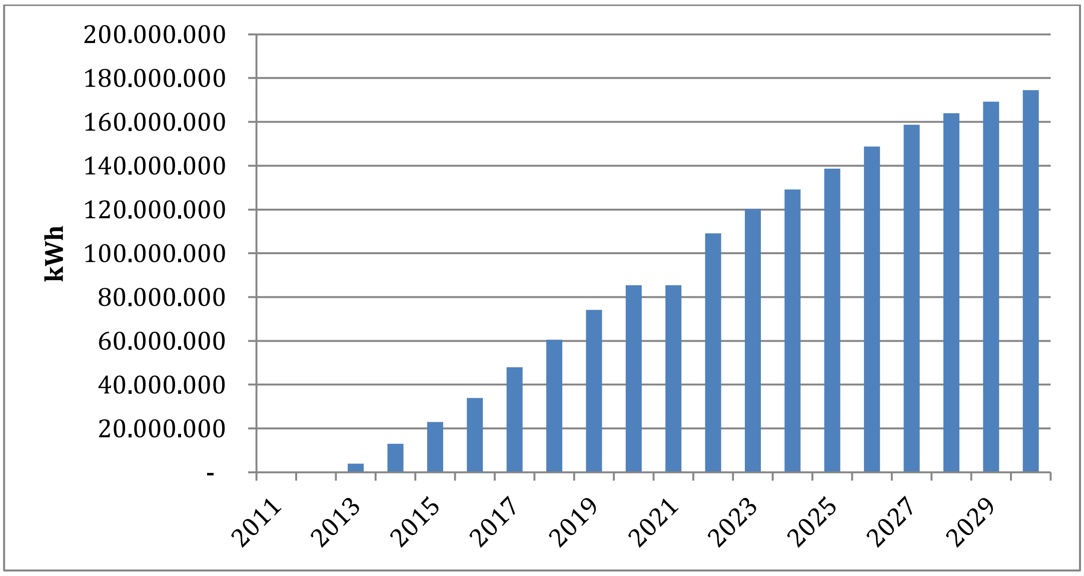


Figure 48: Sunny Tomorrow: Share of PV in Lithuanian electricity market in 2011-2030 time-frame

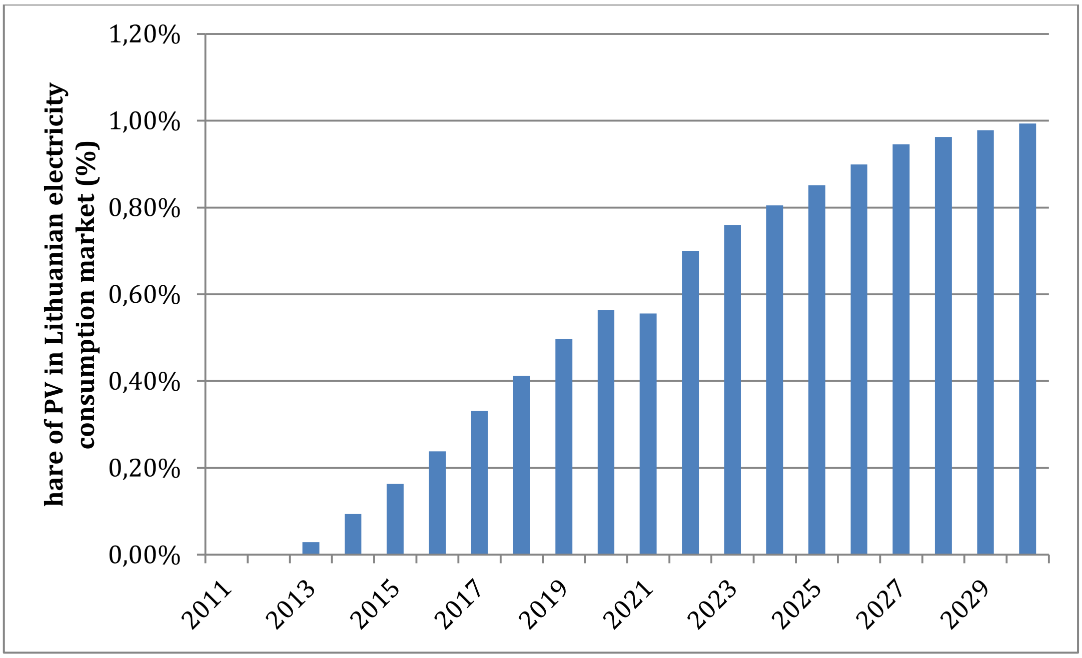


Figure 49: Sunny Tomorrow: Annual CO_2 savings from newly installed Lithuania PV modules (kg)

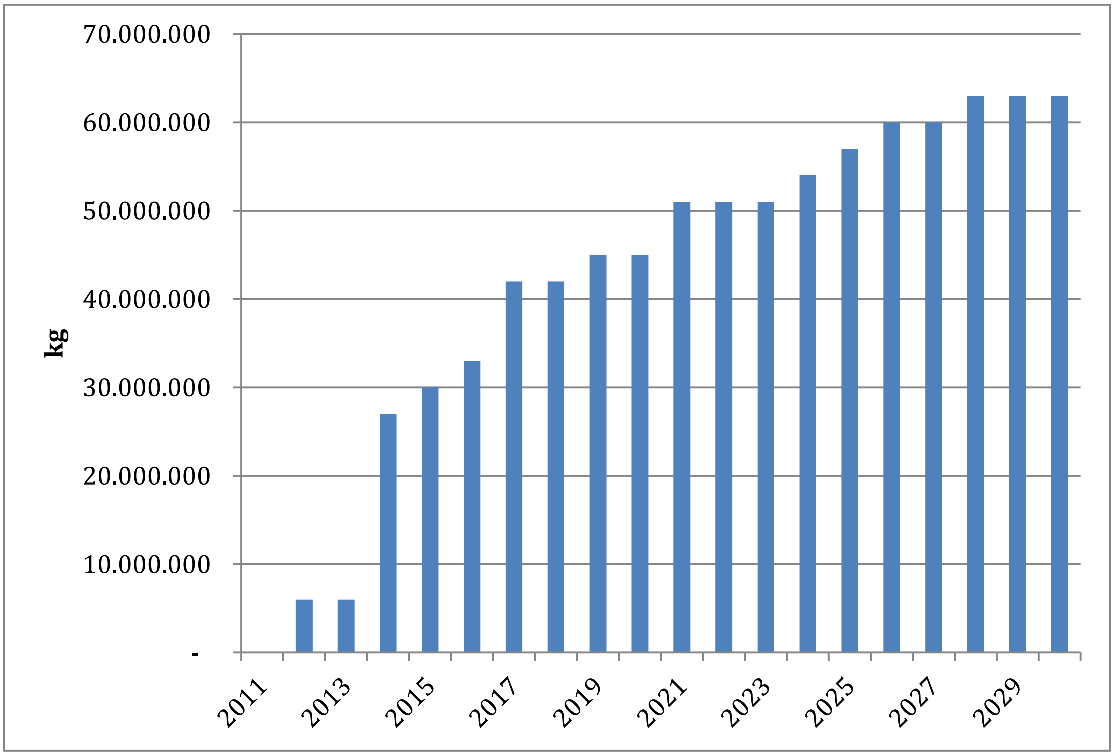


Figure 50: Sunny Tomorrow: Cumulative CO_2 savings from installed Lithuanian PV modules (kg)

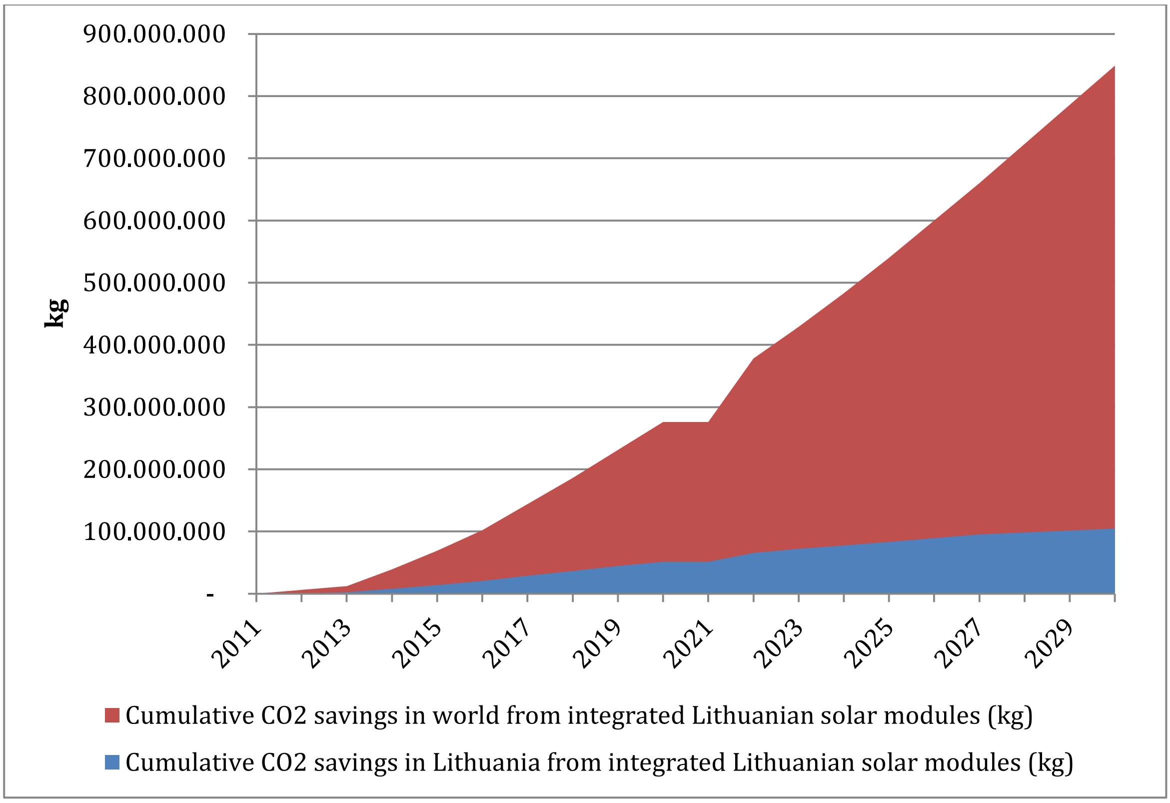


Table 19: Sunny Tomorrow: Electricity generation and CO_2 savings

Year	Installed PV modules in Lithuania (MW)	Electricity generation from newly installed Lithuanian PV modules (kWh)	Cumulative electricity generation from installed Lithuanian PV modules (kWh)	CO2 savings in Lithuania from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in Lithuania from integrated Lithuanian solar modules (kg)	Share of PV in Lithuanian electricity consumption market (%)	Electricity generation from newly installed Lithuanian PV modules (kWh), worldwide	Cumulative electricity generation from installed Lithuanian PV modules (kWh), worldwide	CO2 savings in world from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in world from integrated Lithuanian solar modules (kg)
2011	0	-	-	-	-	0,00%	-	-	-	-
2012	2	2.000.000	-	1.200.000	-	0,00%	10.000.000	10.000.000	6.000.000	6.000.000
2013	2	2.000.000	4.000.000	1.200.000	2.400.000	0,03%	10.000.000	20.000.000	6.000.000	12.000.000
2014	9	9.000.000	13.000.000	5.400.000	7.800.000	0,09%	45.000.000	65.000.000	27.000.000	39.000.000
2015	10	10.000.000	23.000.000	6.000.000	13.800.000	0,16%	50.000.000	115.000.000	30.000.000	69.000.000
2016	11	11.000.000	34.000.000	6.600.000	20.400.000	0,24%	55.000.000	170.000.000	33.000.000	102.000.000
2017	14	14.000.000	48.000.000	8.400.000	28.800.000	0,33%	70.000.000	240.000.000	42.000.000	144.000.000
2018	12,6	12.600.000	60.600.000	7.560.000	36.360.000	0,41%	70.000.000	310.000.000	42.000.000	186.000.000
2019	13,5	13.500.000	74.100.000	8.100.000	44.460.000	0,50%	75.000.000	385.000.000	45.000.000	231.000.000
2020	11,25	11.250.000	85.350.000	6.750.000	51.210.000	0,56%	75.000.000	460.000.000	45.000.000	276.000.000
2021	12,75	12.750.000	85.350.000	7.650.000	51.210.000	0,56%	85.000.000	460.000.000	51.000.000	276.000.000
2022	11,05	11.050.000	109.150.000	6.630.000	65.490.000	0,70%	85.000.000	630.000.000	51.000.000	378.000.000
2023	11,05	11.050.000	120.200.000	6.630.000	72.120.000	0,76%	85.000.000	715.000.000	51.000.000	429.000.000
2024	9	9.000.000	129.200.000	5.400.000	77.520.000	0,80%	90.000.000	805.000.000	54.000.000	483.000.000
2025	9,5	9.500.000	138.700.000	5.700.000	83.220.000	0,85%	95.000.000	900.000.000	57.000.000	540.000.000
2026	10	10.000.000	148.700.000	6.000.000	89.220.000	0,90%	100.000.000	1.000.000.000	60.000.000	600.000.000
2027	10	10.000.000	158.700.000	6.000.000	95.220.000	0,95%	100.000.000	1.100.000.000	60.000.000	660.000.000
2028	5,25	5.250.000	163.950.000	3.150.000	98.370.000	0,96%	105.000.000	1.205.000.000	63.000.000	723.000.000
2029	5,25	5.250.000	169.200.000	3.150.000	101.520.000	0,98%	105.000.000	1.310.000.000	63.000.000	786.000.000
2030	5,25	5.250.000	174.450.000	3.150.000	104.670.000	0,99%	105.000.000	1.415.000.000	63.000.000	849.000.000

4.5.2 Scenario "Broken Walls"

The critical variables which were formulated on the taking into account the key success factors (Table 11) and are essential for gaining the competitive advantage of Lithuanian PV sector in future environmental situation of this scenario are the following: (i) growing manufacturing capacity due to new instalments of manufacturing infrastructure dedicated to next generation technologies; (ii) high competitiveness with other renewables (iii) production flexible, accustomed to the changing needs of end-users. The key results for scenario "Broken Walls" until 2030 on manufacturing capacity (Figure 51) and actual manufacturing (Figure 52), market share in the global PV market (Figure 53), export indicators, including generated income (Figure 54, Figure 55, Figure 56, Table 21Table 22), investments (Figure 57andTable 23), generated employment (Figure 58andTable 24), electricity production (Figure 59, Figure 60 and Figure 61) and environmental issues (Figure 62, Figure 63andTable 25) are presented in the indicated tables and figures below.

Figure 51: Broken Walls: Growth of Lithuanian PV manufacturing capabilities in 2011-2030 time-frame

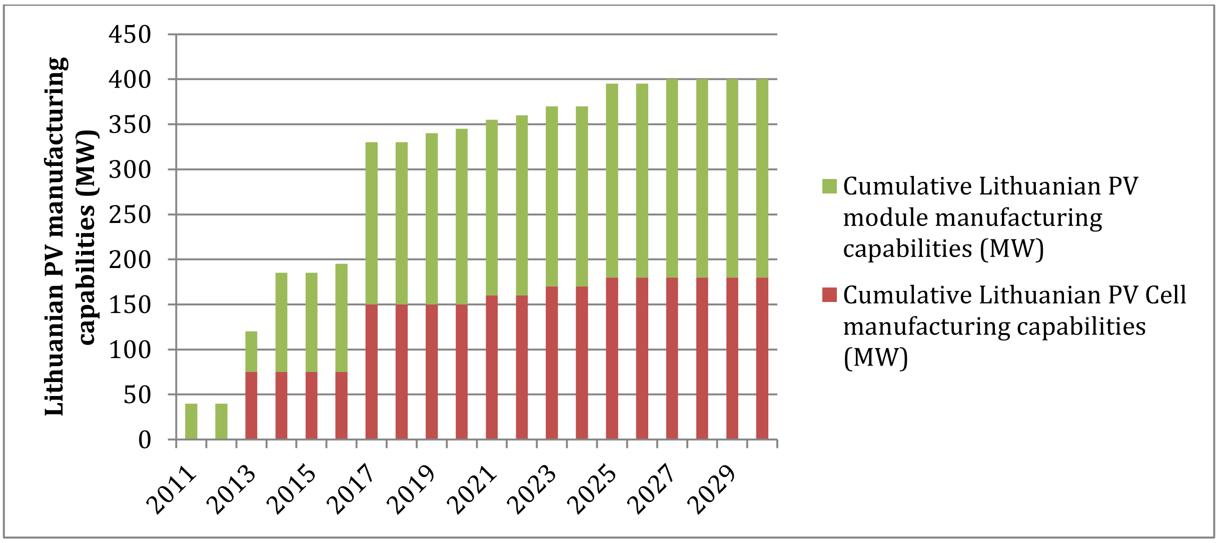


Figure 52: Broken Walls: Lithuanian PV actual manufacturing in 2011-2030 time-frame

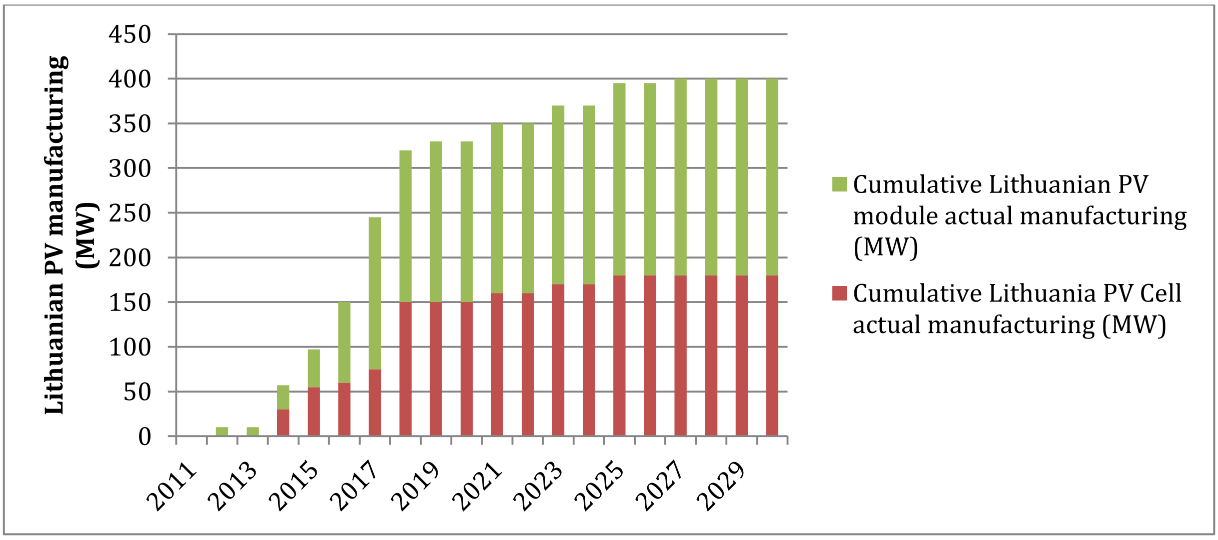


Figure 53: Broken Walls: Prognosis of Lithuanian market share in the global outlook

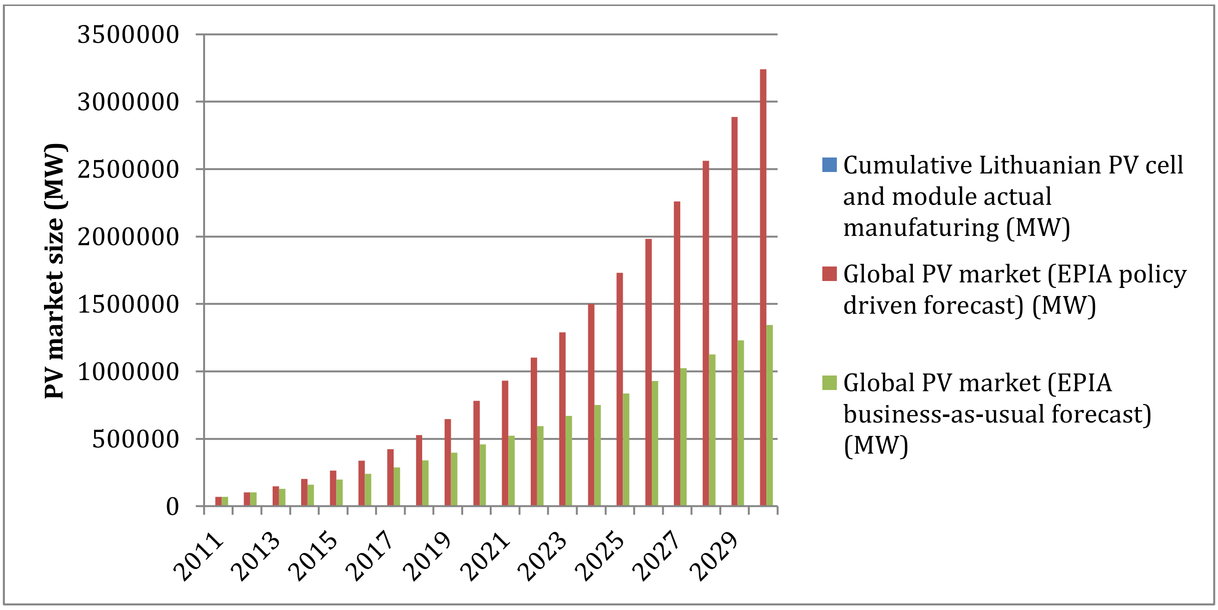


Table 20: Broken Walls: Prognosis of Lithuanian market size by MW, global market share in 2011-2030 time-frame

Year	Cumulative Lithuanian PV Cell manufacturing capabilities (MW)	Cumulative Lithuania PV Cell actual manufacturing (MW)	Cumulative Lithuanian PV module manufacturing capabilities (MW)	Cumulative Lithuanian PV module actual manufacturing (MW)	Cumulative Lithuanian PV cell and module manufacturing capabilities (MW)	Cumulative Lithuanian PV cell and module actual manufaturing (MW)	Lithuanian share in global market (according to the policy driven forecast) (%)	Lithuanian share in global market (according to the business-as-usual forecast) (%)	Global PV market (EPIA policy driven forecast) (MW)	Global PV market (EPIA business-as-usual forecast) (MW)
2011	0	0	40	-	40	-	-	-	71.061	71.061
2012	0	0	40	10	40	10	0,010%	0,010%	102.156	102.156
2013	75	0	45	10	120	10	0,007%	0,008%	149.120	129.960
2014	75	30	110	27	185	57	0,028%	0,035%	201.750	160.770
2015	75	55	110	42	185	97	0,037%	0,049%	264.390	197.600
2016	75	60	120	90	195	150	0,044%	0,063%	338.650	239.920
2017	150	75	180	170	330	245	0,058%	0,085%	422.890	288.220
2018	150	150	180	170	330	320	0,061%	0,094%	528.762	340.638
2019	150	150	190	180	340	330	0,051%	0,083%	646.624	397.173
2020	150	150	195	180	345	330	0,042%	0,072%	780.702	458.392
2021	160	160	195	190	355	350	0,038%	0,067%	932.029	524.364
2022	160	160	200	190	360	350	0,032%	0,059%	1.101.634	595.159
2023	170	170	200	200	370	370	0,029%	0,055%	1.290.551	670.845
2024	170	170	200	200	370	370	0,025%	0,049%	1.499.809	751.492
2025	180	180	215	215	395	395	0,023%	0,047%	1.730.442	837.170
2026	180	180	215	215	395	395	0,020%	0,043%	1.983.479	927.946
2027	180	180	220	220	400	400	0,018%	0,039%	2.259.952	1.023.890
2028	180	180	220	220	400	400	0,016%	0,036%	2.560.894	1.125.072
2029	180	180	220	220	400	400	0,014%	0,032%	2.887.334	1.231.561
2030	180	180	220	220	400	400	0,012%	0,030%	3.240.305	1.343.426

Figure 54: Broken Walls: Lithuanian income from PV cells in 2011-2030 time-frame

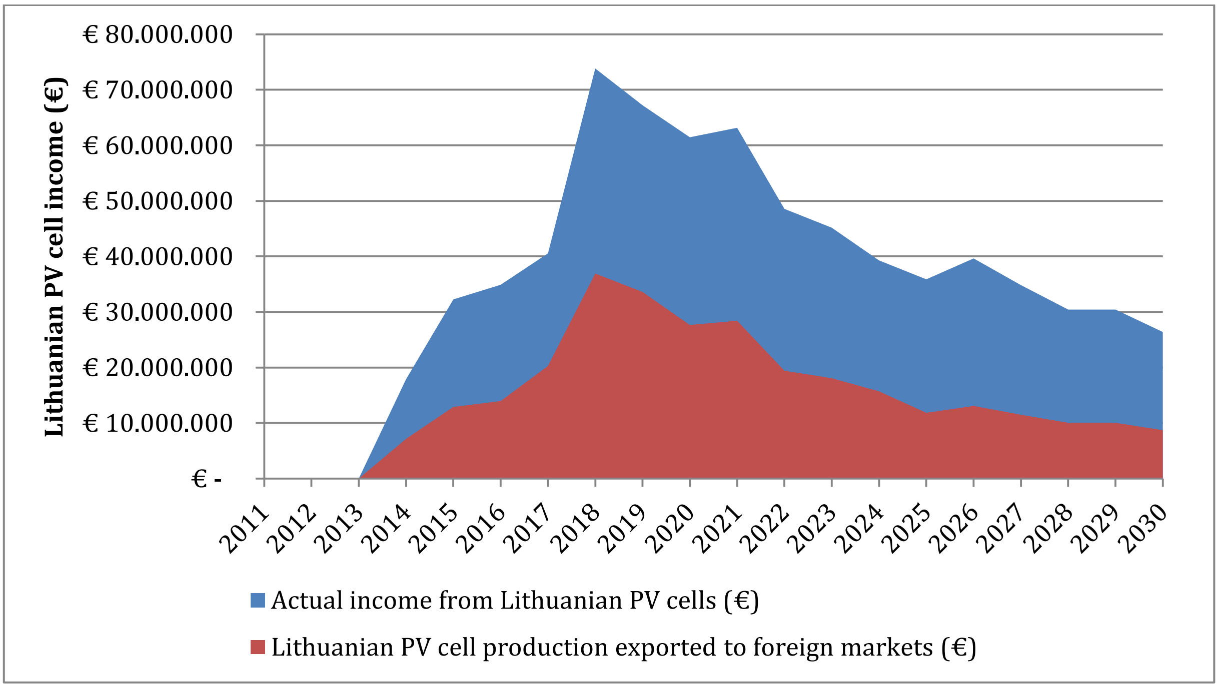


Figure 55: Broken Walls: Lithuanian income from PV modules in 2011-2030 time-frame

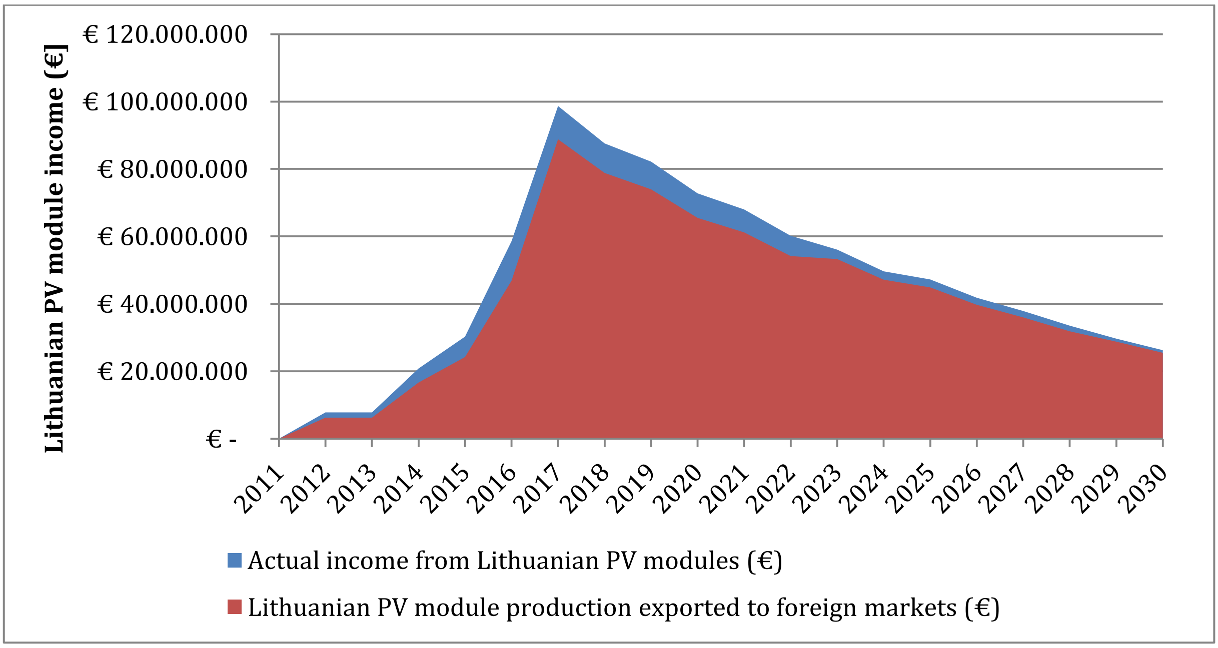


Figure 56: Broken Walls: Lithuanian cumulative income from PV in 2011-2030 time-frame

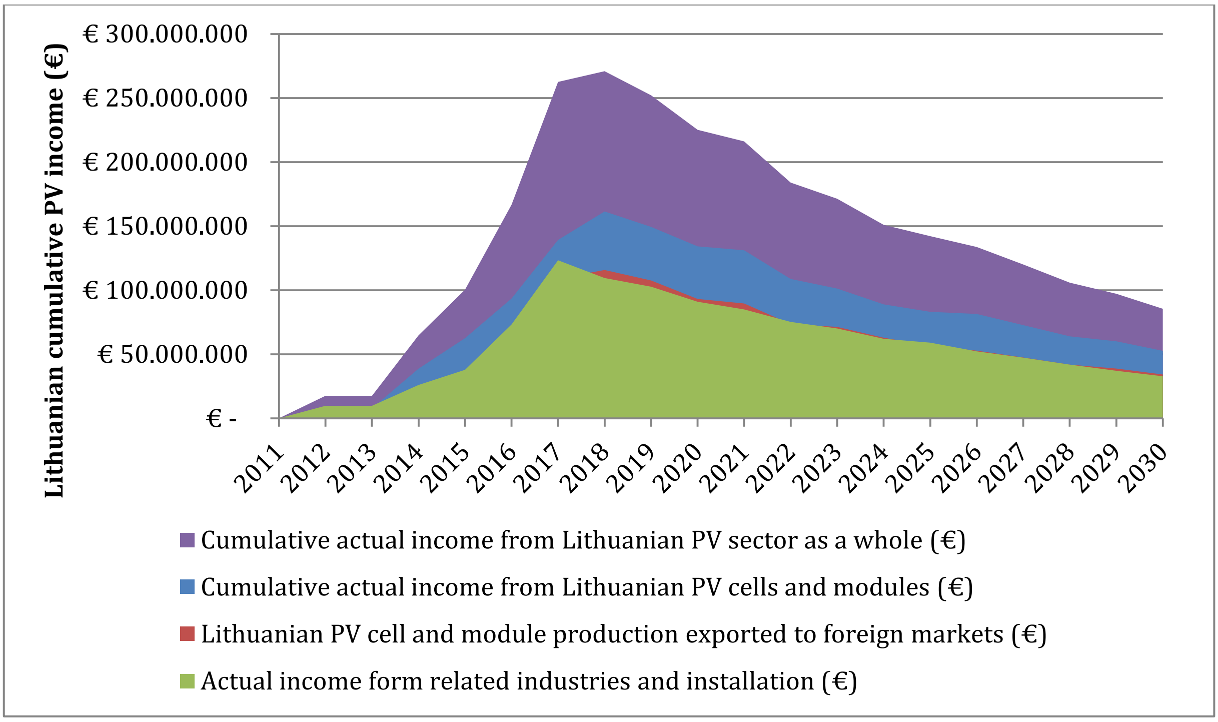


Table 21: Broken Walls: Prognosis of Lithuanian potential and actual income from PV cells and modules (€) in 2011-2030 time-frame

Year	Potential income from Lithuanian PV cells (€)	Actual income from Lithuanian PV cells (€)	Potential income from Lithuanian PV modules (€)	Actual income from Lithuanian PV modules (€)	Cumulative potential income from Lithuanian PV cells and modules (€)	Cumulative actual income from Lithuanian PV cells and modules (€)	Actual income form related industries and installation (€)	Cumulative actual income from Lithuanian PV sector as a whole (€)
2011	€ -	€ -	€ 44.400.000	-	€ 44.400.000	-	0	€ -
2012	€ -	€ -	€ 31.200.000	€ 7.800.000	€ 31.200.000	€ 7.800.000	€ 9.750.000	€ 17.550.000
2013	€ 46.992.481	€ -	€ 35.101.929	€ 7.800.429	€ 82.094.410	€ 7.800.429	€ 9.750.536	€ 17.550.964
2014	€ 44.742.481	€ 17.896.992	€ 84.772.968	€ 20.807.910	€ 129.515.449	€ 38.704.903	€ 26.009.888	€ 64.714.791
2015	€ 43.992.481	€ 32.261.153	€ 79.285.630	€ 30.272.695	€ 123.278.111	€ 62.533.848	€ 37.840.869	€ 100.374.717
2016	€ 43.617.481	€ 34.893.985	€ 78.104.587	€ 58.578.440	€ 121.722.068	€ 93.472.425	€ 73.223.050	€ 166.695.475
2017	€ 81.096.258	€ 40.548.129	€ 104.473.762	€ 98.669.664	€ 185.570.021	€ 139.217.794	€ 123.337.081	€ 262.554.874
2018	€ 73.839.333	€ 73.839.333	€ 92.732.294	€ 87.580.500	€ 166.571.627	€ 161.419.833	€ 109.475.625	€ 270.895.458
2019	€ 67.218.310	€ 67.218.310	€ 86.732.548	€ 82.167.677	€ 153.950.857	€ 149.385.986	€ 102.709.596	€ 252.095.582
2020	€ 61.453.642	€ 61.453.642	€ 78.822.464	€ 72.759.198	€ 140.276.106	€ 134.212.840	€ 90.948.997	€ 225.161.837
2021	€ 63.155.573	€ 63.155.573	€ 69.779.908	€ 67.990.679	€ 132.935.481	€ 131.146.253	€ 84.988.349	€ 216.134.602
2022	€ 48.560.101	€ 48.560.101	€ 63.352.837	€ 60.185.195	€ 111.912.937	€ 108.745.296	€ 75.231.493	€ 183.976.789
2023	€ 45.171.319	€ 45.171.319	€ 56.077.837	€ 56.077.837	€ 101.249.156	€ 101.249.156	€ 70.097.297	€ 171.346.453
2024	€ 39.282.779	€ 39.282.779	€ 49.637.599	€ 49.637.599	€ 88.920.378	€ 88.920.378	€ 62.046.998	€ 150.967.377
2025	€ 35.878.119	€ 35.878.119	€ 47.232.028	€ 47.232.028	€ 83.110.147	€ 83.110.147	€ 59.040.035	€ 142.150.182
2026	€ 39.638.931	€ 39.638.931	€ 41.807.400	€ 41.807.400	€ 81.446.331	€ 81.446.331	€ 52.259.249	€ 133.705.580
2027	€ 34.836.288	€ 34.836.288	€ 37.866.366	€ 37.866.366	€ 72.702.655	€ 72.702.655	€ 47.332.958	€ 120.035.613
2028	€ 30.433.815	€ 30.433.815	€ 33.517.358	€ 33.517.358	€ 63.951.173	€ 63.951.173	€ 41.896.697	€ 105.847.870
2029	€ 30.433.815	€ 30.433.815	€ 29.667.836	€ 29.667.836	€ 60.101.652	€ 60.101.652	€ 37.084.795	€ 97.186.447
2030	€ 26.398.169	€ 26.398.169	€ 26.260.437	€ 26.260.437	€ 52.658.607	€ 52.658.607	€ 32.825.547	€ 85.484.153

Table 22: Broken Walls: Prognosis of Lithuanian export (€) until 2030

Year	Lithuanian PV cell production exported to foreign markets (€)	Lithuanian PV module production exported to foreign markets (€)	Lithuanian PV cell and module production exported to foreign markets (€)
2011	-	-	€ -
2012	-	€ 6.240.000	€ 6.240.000
2013	-	€ 6.240.343	€ 6.240.343
2014	€ 7.158.797	€ 16.646.328	€ 23.805.125
2015	€ 12.904.461	€ 24.218.156	€ 37.122.617
2016	€ 13.957.594	€ 46.862.752	€ 60.820.346
2017	€ 20.274.065	€ 88.802.698	€ 109.076.763
2018	€ 36.919.666	€ 78.822.450	€ 115.742.116
2019	€ 33.609.155	€ 73.950.909	€ 107.560.064
2020	€ 27.654.139	€ 65.483.278	€ 93.137.417
2021	€ 28.420.008	€ 61.191.611	€ 89.611.619
2022	€ 19.424.040	€ 54.166.675	€ 73.590.716
2023	€ 18.068.528	€ 53.273.946	€ 71.342.473
2024	€ 15.713.112	€ 47.155.719	€ 62.868.831
2025	€ 11.839.779	€ 44.870.427	€ 56.710.206
2026	€ 13.080.847	€ 39.717.030	€ 52.797.877
2027	€ 11.495.975	€ 35.973.048	€ 47.469.023
2028	€ 10.043.159	€ 31.841.490	€ 41.884.649
2029	€ 10.043.159	€ 28.777.801	€ 38.820.960
2030	€ 8.711.396	€ 25.472.624	€ 34.184.020

Figure 57: Broken Walls: Investments in Lithuanian PV sector by investment type in short-, mid- and long-term

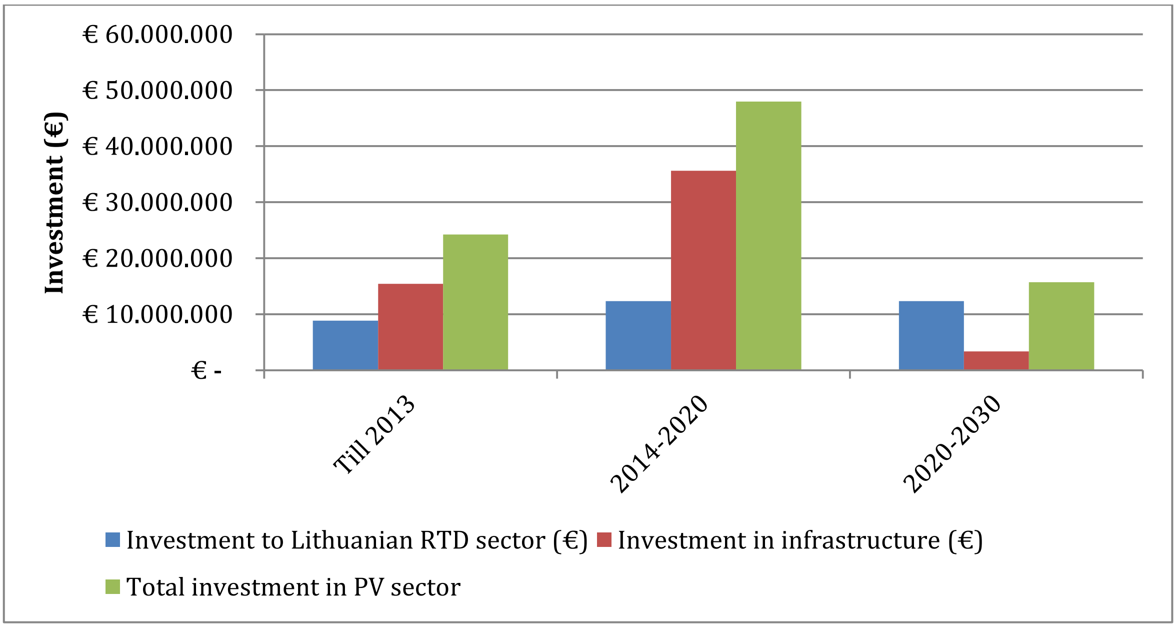


Table 23: Broken Walls: Investments in Lithuanian PV sector (€) until 2030

Year	Investment to Lithuanian RTD sector (€)	Investment in infrastructure (€)	Total investment in PV sector
Till 2013	€ 8.833.312	€ 15.418.054	€ 24.251.366
2014-2020	€ 12.343.987	€ 35.631.737	€ 47.975.723
2020-2030	€ 12.344.213	€ 3.342.077	€ 15.686.290

Figure 58: Broken Walls: Jobs created in Lithuanian PV sector in 2011-2030 time-frame

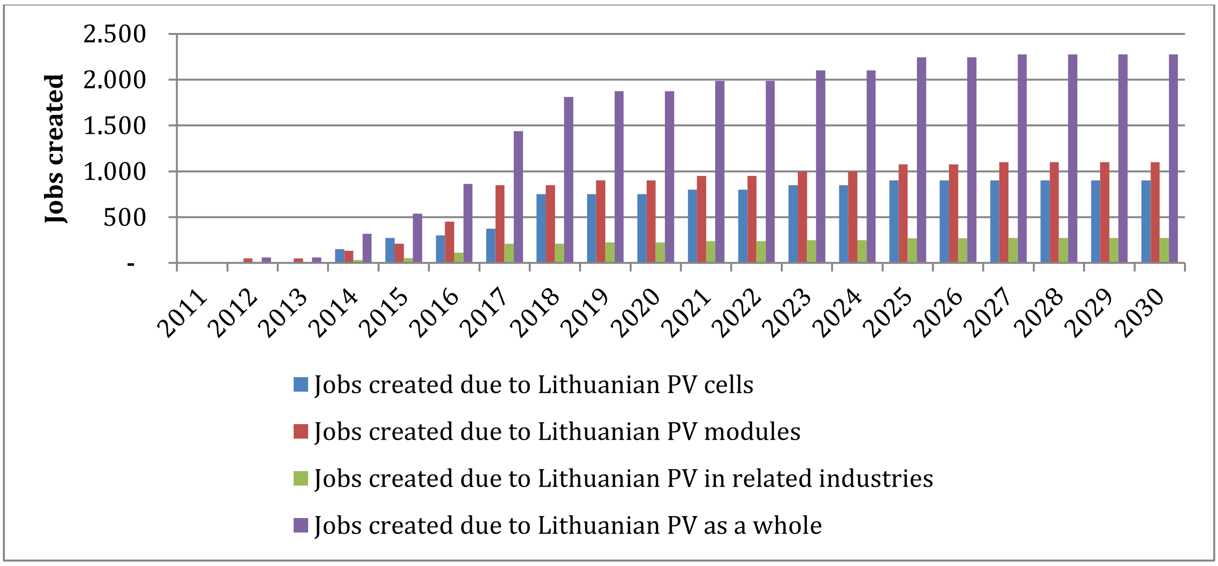


Table 24: Broken Walls: Employment in Lithuanian PV sector in 2011-2030 time-frame

Year	Jobs created due to Lithuanian PV cells	Jobs created due to Lithuanian PV modules	Jobs created due to Lithuanian PV in related industries	Jobs created due to Lithuanian PV as a whole
2011	-	-	-	-
2012	-	50	13	63
2013	-	50	13	63
2014	150	135	34	319
2015	275	210	53	538
2016	300	450	113	863
2017	375	850	213	1.438
2018	750	850	213	1.813
2019	750	900	225	1.875
2020	750	900	225	1.875
2021	800	950	238	1.988
2022	800	950	238	1.988
2023	850	1.000	250	2.100
2024	850	1.000	250	2.100
2025	900	1.075	269	2.244
2026	900	1.075	269	2.244
2027	900	1.100	275	2.275
2028	900	1.100	275	2.275
2029	900	1.100	275	2.275
2030	900	1.100	275	2.275

Figure 59: Broken Walls: Prognosis of annual electricity generation from newly installed Lithuanian PV modules (kWh)

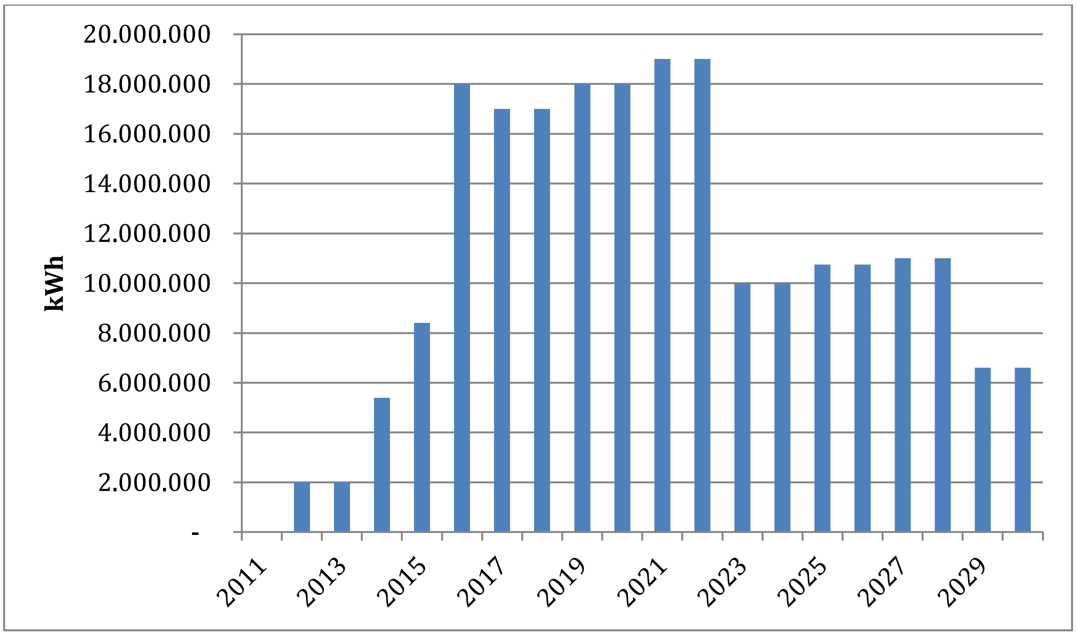


Figure 60: Broken Walls: Cumulative electricity generation from installed Lithuanian PV modules (kWh)

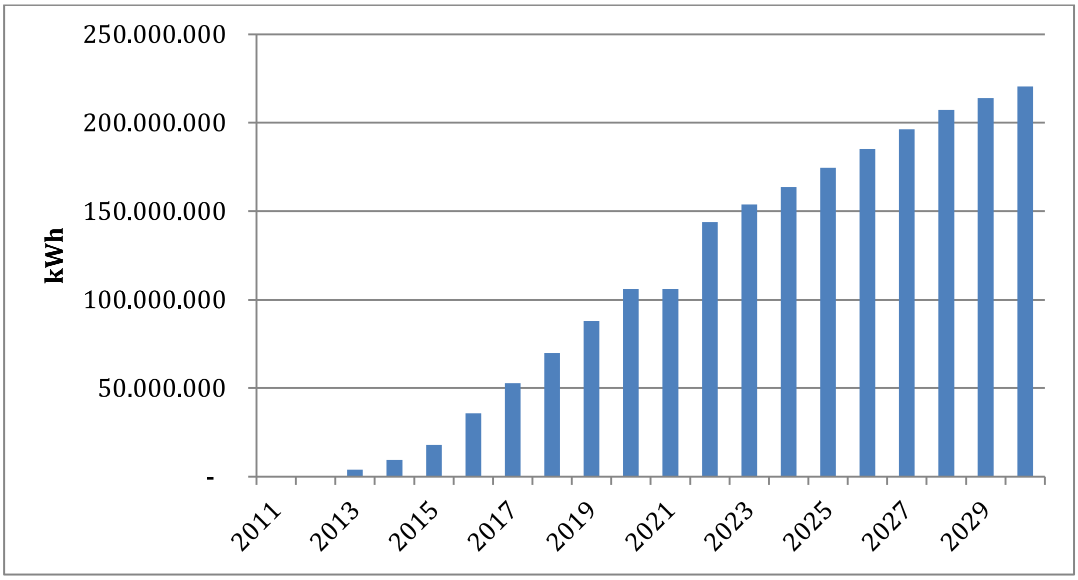


Figure 61: Broken Walls: Share of PV in Lithuanian electricity market in 2011-2030 time-frame

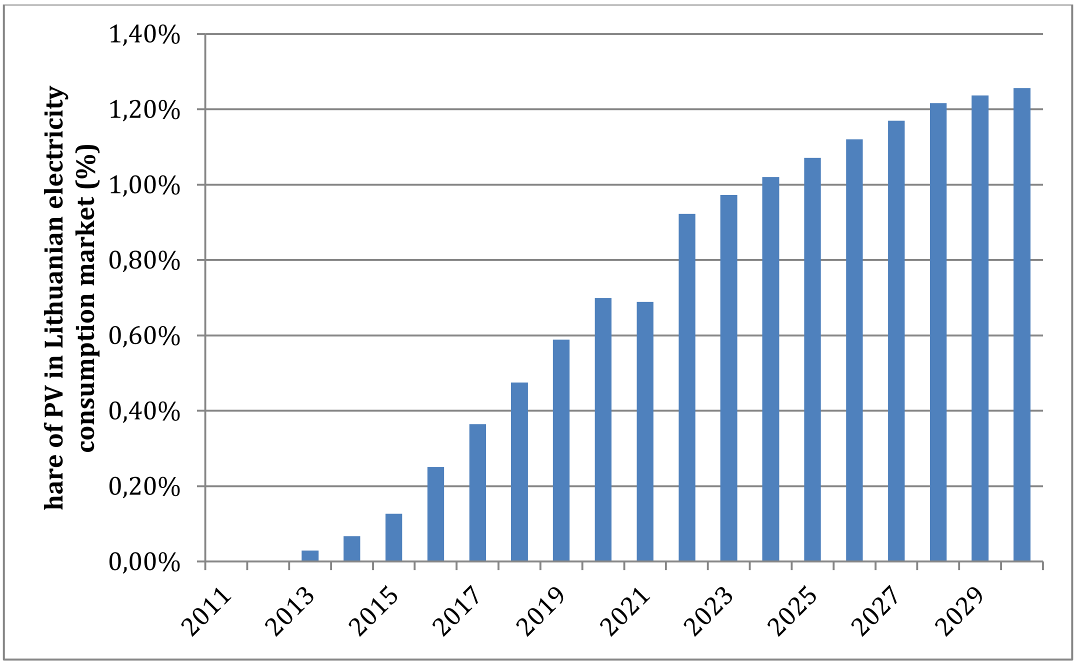


Figure 62: Broken Walls: Annual CO_2 savings from newly installed Lithuanian PV modules (kg)

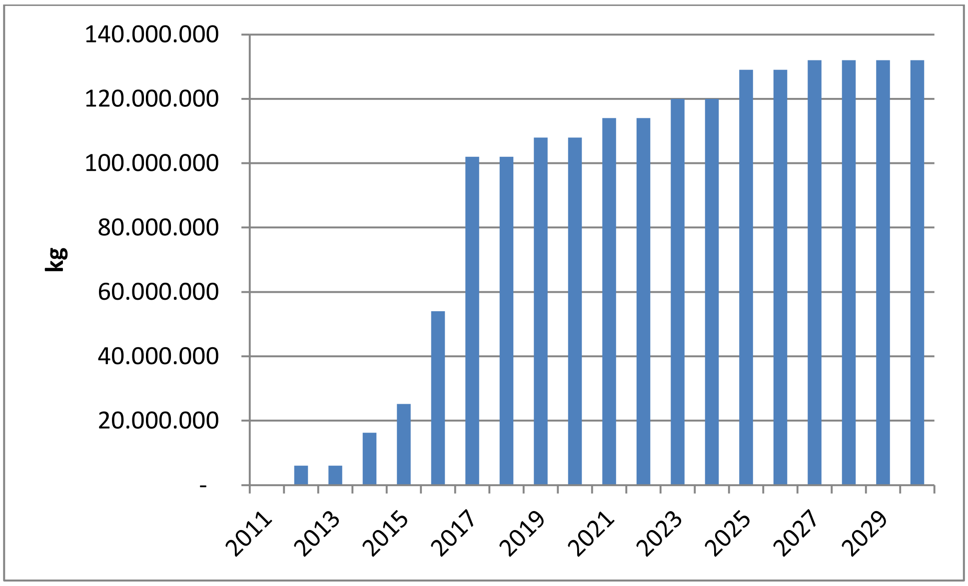


Figure 63: Broken Walls: Cumulative CO_2 savings from installed Lithuanian PV modules (kg)

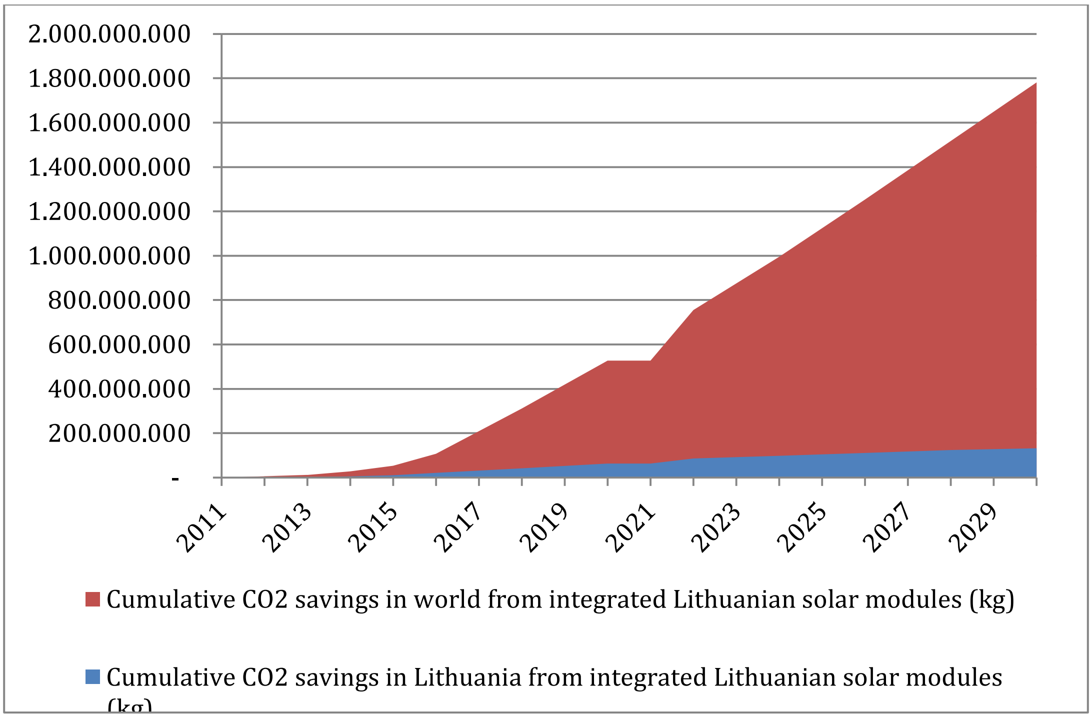


Table 25: Broken Walls: Electricity generation and CO_2 savings

Year	Installed PV modules in Lithuania (MW)	Electricity generation from newly installed Lithuanian PV modules (kWh)	Cumulative electricity generation from installed Lithuanian PV modules (kWh)	CO2 savings in Lithuania from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in Lithuania from integrated Lithuanian solar modules (kg)	Share of PV in Lithuanian electricity consumption market (%)	Electricity generation from newly installed Lithuanian PV modules (kWh), worldwide	Cumulative electricity generation from installed Lithuanian PV modules (kWh), worldwide	CO2 savings in world from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in world from integrated Lithuanian solar modules (kg)
2011	0	-	-	-	-	0,00%	-	-	-	-
2012	2	2.000.000	-	1.200.000	-	0,00%	10.000.000	10.000.000	6.000.000	6.000.000
2013	2	2.000.000	4.000.000	1.200.000	2.400.000	0,03%	10.000.000	20.000.000	6.000.000	12.000.000
2014	5,4	5.400.000	9.400.000	3.240.000	5.640.000	0,07%	27.000.000	47.000.000	16.200.000	28.200.000
2015	8,4	8.400.000	17.800.000	5.040.000	10.680.000	0,13%	42.000.000	89.000.000	25.200.000	53.400.000
2016	18	18.000.000	35.800.000	10.800.000	21.480.000	0,25%	90.000.000	179.000.000	54.000.000	107.400.000
2017	17	17.000.000	52.800.000	10.200.000	31.680.000	0,36%	170.000.000	349.000.000	102.000.000	209.400.000
2018	17	17.000.000	69.800.000	10.200.000	41.880.000	0,47%	170.000.000	519.000.000	102.000.000	311.400.000
2019	18	18.000.000	87.800.000	10.800.000	52.680.000	0,59%	180.000.000	699.000.000	108.000.000	419.400.000
2020	18	18.000.000	105.800.000	10.800.000	63.480.000	0,70%	180.000.000	879.000.000	108.000.000	527.400.000
2021	19	19.000.000	105.800.000	11.400.000	63.480.000	0,69%	190.000.000	879.000.000	114.000.000	527.400.000
2022	19	19.000.000	143.800.000	11.400.000	86.280.000	0,92%	190.000.000	1.259.000.000	114.000.000	755.400.000
2023	10	10.000.000	153.800.000	6.000.000	92.280.000	0,97%	200.000.000	1.459.000.000	120.000.000	875.400.000
2024	10	10.000.000	163.800.000	6.000.000	98.280.000	1,02%	200.000.000	1.659.000.000	120.000.000	995.400.000
2025	10,75	10.750.000	174.550.000	6.450.000	104.730.000	1,07%	215.000.000	1.874.000.000	129.000.000	1.124.400.000
2026	10,75	10.750.000	185.300.000	6.450.000	111.180.000	1,12%	215.000.000	2.089.000.000	129.000.000	1.253.400.000
2027	11	11.000.000	196.300.000	6.600.000	117.780.000	1,17%	220.000.000	2.309.000.000	132.000.000	1.385.400.000
2028	11	11.000.000	207.300.000	6.600.000	124.380.000	1,22%	220.000.000	2.529.000.000	132.000.000	1.517.400.000
2029	6,6	6.600.000	213.900.000	3.960.000	128.340.000	1,24%	220.000.000	2.749.000.000	132.000.000	1.649.400.000
2030	6,6	6.600.000	220.500.000	3.960.000	132.300.000	1,26%	220.000.000	2.969.000.000	132.000.000	1.781.400.000

4.5.3 Scenario “Step by Step”

The critical variables which were formulated on the taking into account the key success factors (Table 11) and are essential for gaining the competitive advantage of Lithuanian PV sector in future environmental situation of this scenario are the following: (i) growing manufacturing capacity due to new instalments of manufacturing infrastructure dedicated to dominating mature Si technologies; (ii) high level vertical integration and (iii) amount of investments dedicated to RTD activities and new infrastructure. The key results for scenario “Step by Step” until 2030 on manufacturing capacity (Figure 64) and actual manufacturing (Figure 65), market share in the global PV market (Figure 66), export indicators, including generated income (Figure 67, Figure 68, Figure 69 and Table 26, Table 27 and Table 28), investments (Figure 70andTable 29), generated employment (Figure 71and Table 18), electricity production (Figure 72, Figure 73 and Figure 74) and environmental issues (Figure 75, Figure 76andTable 31) are presented in the indicated tables and figures below.

Figure 64: Step by Step: Growth of Lithuanian PV manufacturing capabilities in 2011-2030 time-frame

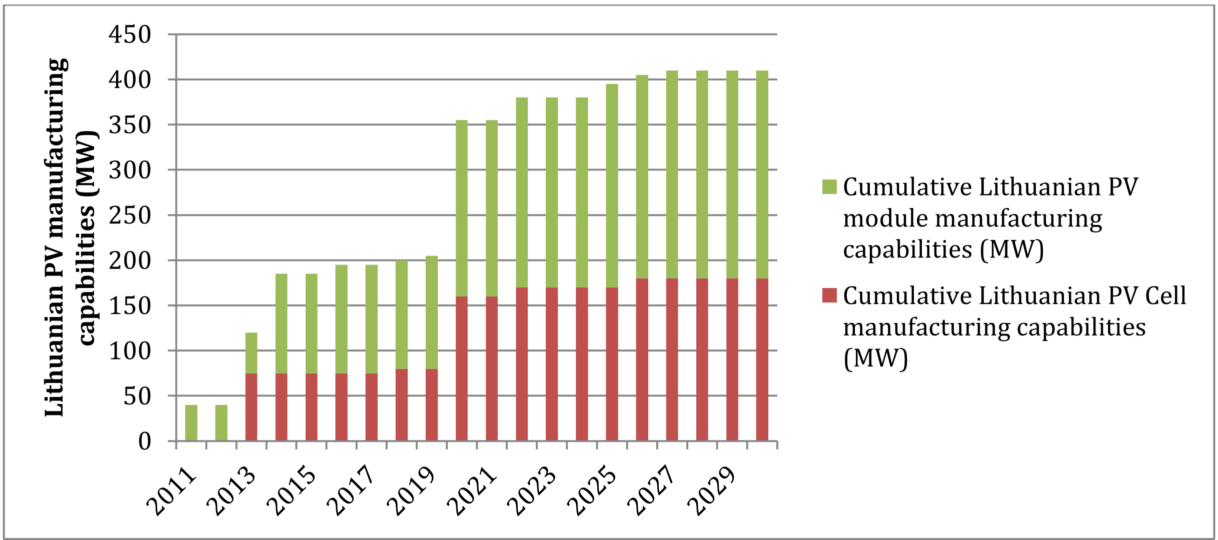


Figure 65: Step by Step: Lithuanian PV actual manufacturing in 2011-2030 time-frame

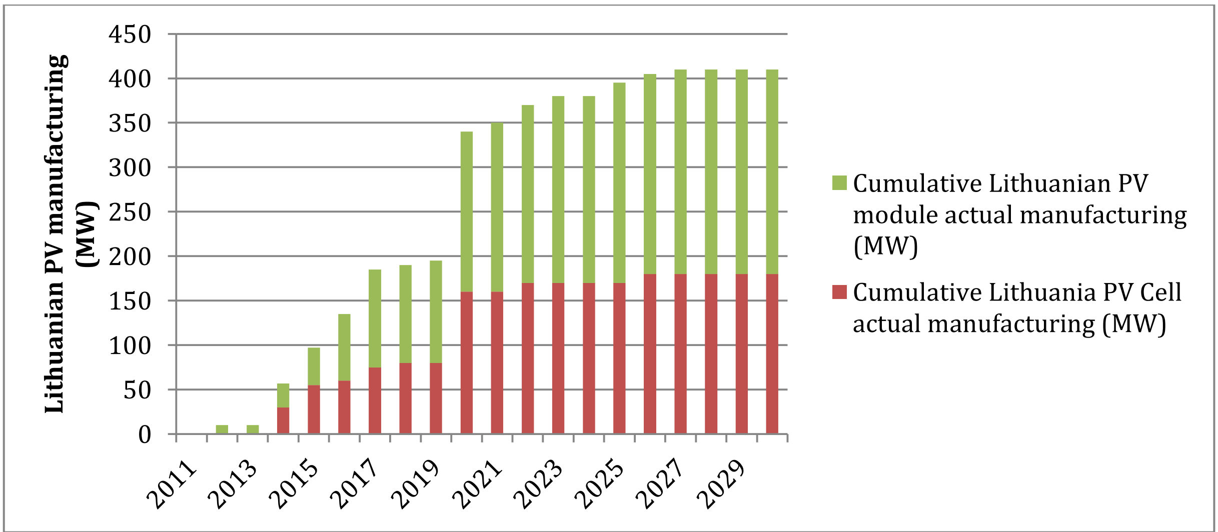


Figure 66: Step by Step: Prognosis of Lithuanian market share in the global outlook

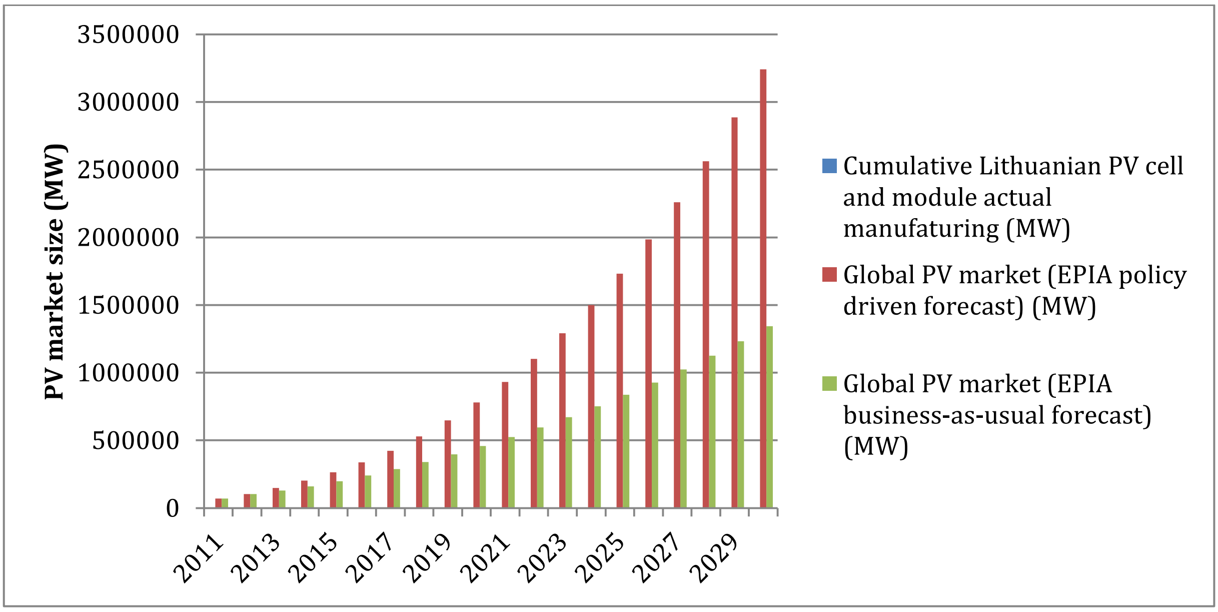


Table 26: Step by Step: Prognosis of Lithuanian market size by MW, global market share in 2011-2030 time-frame

Year	Cumulative Lithuanian PV Cell manufacturing capabilities (MW)	Cumulative Lithuania PV Cell actual manufacturing (MW)	Cumulative Lithuanian PV module manufacturing capabilities (MW)	Cumulative Lithuanian PV module actual manufacturing (MW)	Cumulative Lithuanian PV cell and module manufacturing capabilities (MW)	Cumulative Lithuanian PV cell and module actual manufaturing (MW)	Lithuanian share in global market (according to the policy driven forecast) (%)	Lithuanian share in global market (according to the business-as-usual forecast) (%)	Global PV market (EPIA policy driven forecast) (MW)	Global PV market (EPIA business-as-usual forecast) (MW)
2011	0	0	40	-	40	-	-	-	71.061	71.061
2012	0	0	40	10	40	10	0,010%	0,010%	102.156	102.156
2013	75	0	45	10	120	10	0,007%	0,008%	149.120	129.960
2014	75	30	110	27	185	57	0,028%	0,035%	201.750	160.770
2015	75	55	110	42	185	97	0,037%	0,049%	264.390	197.600
2016	75	60	120	75	195	135	0,040%	0,056%	338.650	239.920
2017	75	75	120	110	195	185	0,044%	0,064%	422.890	288.220
2018	80	80	120	110	200	190	0,036%	0,056%	528.762	340.638
2019	80	80	125	115	205	195	0,030%	0,049%	646.624	397.173
2020	160	160	195	180	355	340	0,044%	0,074%	780.702	458.392
2021	160	160	195	190	355	350	0,038%	0,067%	932.029	524.364
2022	170	170	210	200	380	370	0,034%	0,062%	1.101.634	595.159
2023	170	170	210	210	380	380	0,029%	0,057%	1.290.551	670.845
2024	170	170	210	210	380	380	0,025%	0,051%	1.499.809	751.492
2025	170	170	225	225	395	395	0,023%	0,047%	1.730.442	837.170
2026	180	180	225	225	405	405	0,020%	0,044%	1.983.479	927.946
2027	180	180	230	230	410	410	0,018%	0,040%	2.259.952	1.023.890
2028	180	180	230	230	410	410	0,016%	0,036%	2.560.894	1.125.072
2029	180	180	230	230	410	410	0,014%	0,033%	2.887.334	1.231.561
2030	180	180	230	230	410	410	0,013%	0,031%	3.240.305	1.343.426

Figure 67: Step by Step: Lithuanian income from PV cells in 2011-2030 time-frame

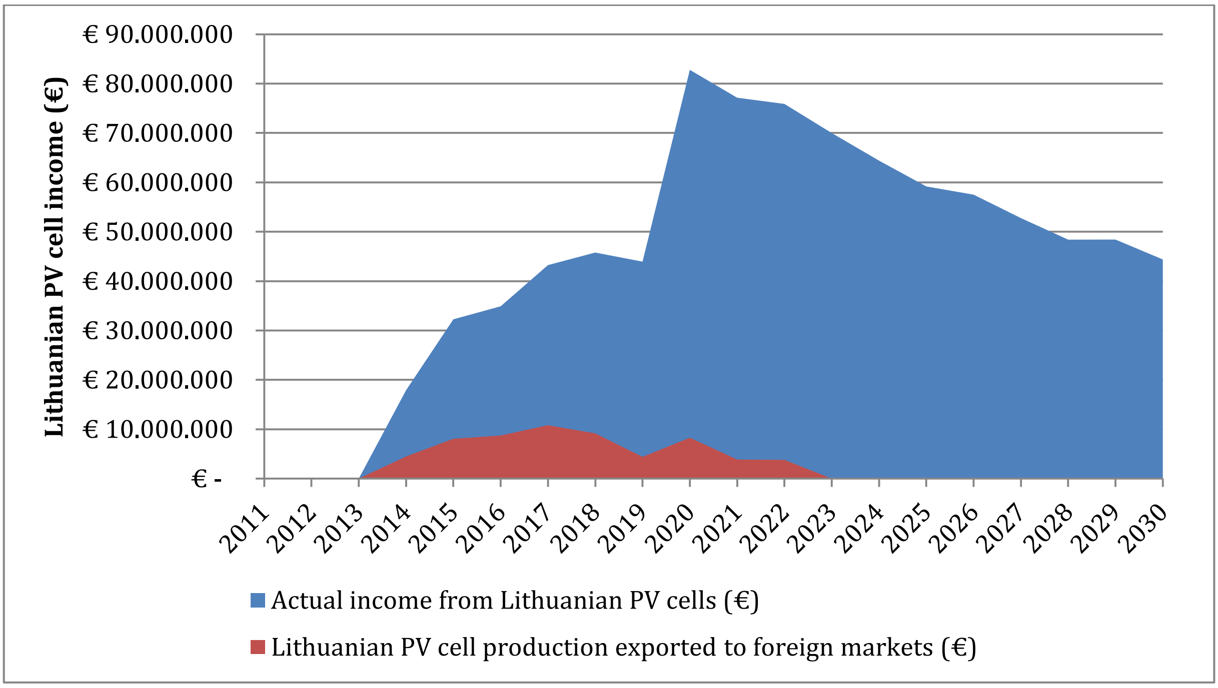


Figure 68: Step by Step: Lithuanian income from PV modules in 2011-2030 time-frame

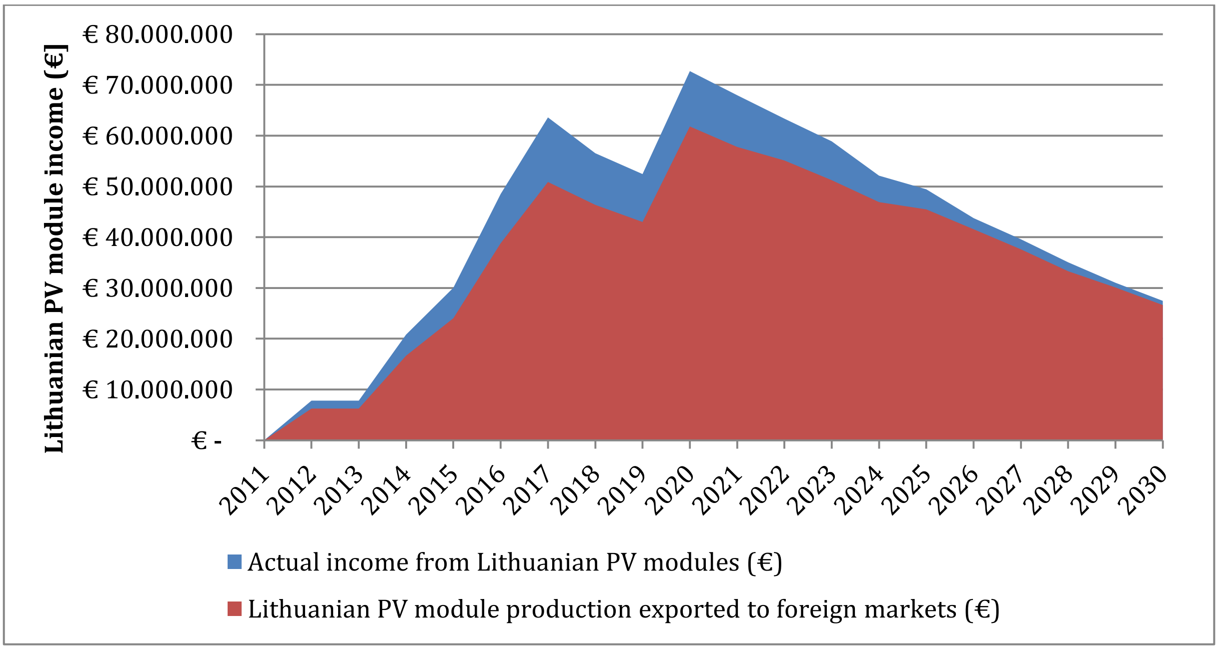


Figure 69: Step by Step: Lithuanian cumulative income from PV in 2011-2030 time-frame

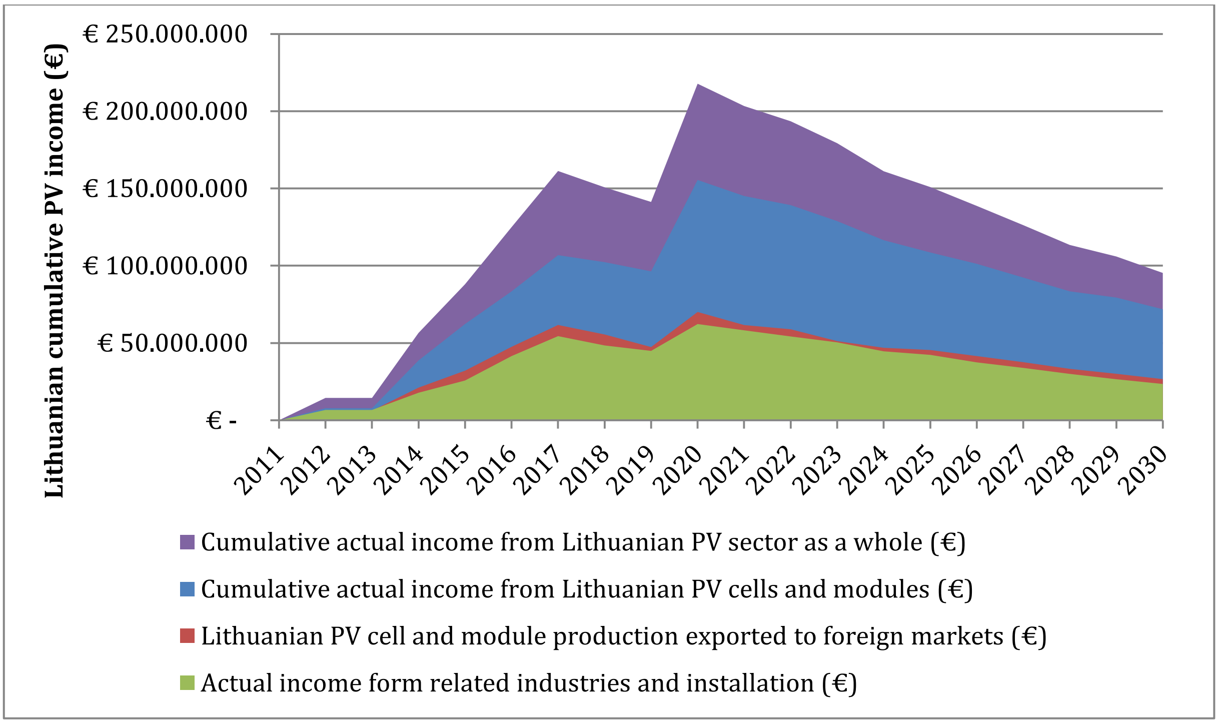


Table 27: Step by Step: Prognosis of Lithuanian potential and actual income from PV cells and modules (€) in 2011-2030 time-frame

Year	Potential income from Lithuanian PV cells (€)	Actual income from Lithuanian PV cells (€)	Potential income from Lithuanian PV modules (€)	Actual income from Lithuanian PV modules (€)	Cumulative potential income from Lithuanian PV cells and modules (€)	Cumulative actual income from Lithuanian PV cells and modules (€)	Actual income form related industries and installation (€)	Cumulative actual income from Lithuanian PV sector as a whole (€)
2011	€ -	€ -	€ 44.400.000	-	€ 44.400.000	-	0	€ -
2012	€ -	€ -	€ 31.200.000	€ 7.800.000	€ 31.200.000	€ 7.800.000	€ 6.680.700	€ 14.480.700
2013	€ 46.992.481	€ -	€ 35.101.929	€ 7.800.429	€ 82.094.410	€ 7.800.429	€ 6.681.067	€ 14.481.496
2014	€ 44.742.481	€ 17.896.992	€ 84.772.968	€ 20.807.910	€ 129.515.449	€ 38.704.903	€ 17.821.975	€ 56.526.878
2015	€ 43.992.481	€ 32.261.153	€ 78.676.103	€ 30.039.967	€ 122.668.584	€ 62.301.120	€ 25.729.231	€ 88.030.351
2016	€ 43.617.481	€ 34.893.985	€ 77.608.659	€ 48.505.412	€ 121.226.140	€ 83.399.397	€ 41.544.885	€ 124.944.282
2017	€ 43.242.481	€ 43.242.481	€ 69.370.726	€ 63.589.832	€ 112.613.207	€ 106.832.314	€ 54.464.691	€ 161.297.005
2018	€ 45.780.977	€ 45.780.977	€ 61.682.044	€ 56.541.874	€ 107.463.021	€ 102.322.851	€ 48.428.115	€ 150.750.966
2019	€ 43.940.394	€ 43.940.394	€ 56.992.401	€ 52.433.009	€ 100.932.795	€ 96.373.403	€ 44.908.872	€ 141.282.275
2020	€ 82.785.684	€ 82.785.684	€ 78.773.948	€ 72.714.414	€ 161.559.632	€ 155.500.098	€ 62.279.895	€ 217.779.993
2021	€ 77.144.369	€ 77.144.369	€ 69.758.413	€ 67.969.736	€ 146.902.782	€ 145.114.105	€ 58.216.079	€ 203.330.184
2022	€ 75.889.523	€ 75.889.523	€ 66.510.398	€ 63.343.236	€ 142.399.920	€ 139.232.759	€ 54.253.482	€ 193.486.240
2023	€ 69.991.160	€ 69.991.160	€ 58.877.394	€ 58.877.394	€ 128.868.554	€ 128.868.554	€ 50.428.488	€ 179.297.042
2024	€ 64.399.052	€ 64.399.052	€ 52.117.631	€ 52.117.631	€ 116.516.683	€ 116.516.683	€ 44.638.751	€ 161.155.434
2025	€ 59.168.401	€ 59.168.401	€ 49.428.029	€ 49.428.029	€ 108.596.430	€ 108.596.430	€ 42.335.107	€ 150.931.537
2026	€ 57.509.610	€ 57.509.610	€ 43.751.577	€ 43.751.577	€ 101.261.187	€ 101.261.187	€ 37.473.226	€ 138.734.413
2027	€ 52.763.328	€ 52.763.328	€ 39.587.414	€ 39.587.414	€ 92.350.742	€ 92.350.742	€ 33.906.620	€ 126.257.362
2028	€ 48.392.653	€ 48.392.653	€ 35.040.811	€ 35.040.811	€ 83.433.464	€ 83.433.464	€ 30.012.455	€ 113.445.919
2029	€ 48.410.593	€ 48.410.593	€ 31.016.348	€ 31.016.348	€ 79.426.941	€ 79.426.941	€ 26.565.502	€ 105.992.443
2030	€ 44.385.068	€ 44.385.068	€ 27.454.083	€ 27.454.083	€ 71.839.150	€ 71.839.150	€ 23.514.422	€ 95.353.572

Table 28: Step by Step: Prognosis of Lithuanian export (€) until 2030

Year	Lithuanian PV cell production exported to foreign markets (€)	Lithuanian PV module production exported to foreign markets (€)	Lithuanian PV cell and module production exported to foreign markets (€)
2011	-	-	€ -
2012	-	€ 6.240.000	€ 6.240.000
2013	-	€ 6.240.343	€ 6.240.343
2014	€ 4.474.248	€ 16.646.328	€ 21.120.576
2015	€ 8.065.288	€ 24.031.973	€ 32.097.262
2016	€ 8.723.496	€ 38.804.329	€ 47.527.826
2017	€ 10.810.620	€ 50.871.866	€ 61.682.486
2018	€ 9.156.195	€ 46.364.336	€ 55.520.532
2019	€ 4.394.039	€ 42.995.068	€ 47.389.107
2020	€ 8.278.568	€ 61.807.251	€ 70.085.820
2021	€ 3.857.218	€ 57.774.275	€ 61.631.494
2022	€ 3.794.476	€ 55.108.615	€ 58.903.092
2023	€ -	€ 51.223.333	€ 51.223.333
2024	€ -	€ 46.905.868	€ 46.905.868
2025	€ -	€ 45.473.787	€ 45.473.787
2026	€ -	€ 41.563.998	€ 41.563.998
2027	€ -	€ 37.608.043	€ 37.608.043
2028	€ -	€ 33.288.770	€ 33.288.770
2029	€ -	€ 30.085.858	€ 30.085.858
2030	€ -	€ 26.630.460	€ 26.630.460

Figure 70: Step by Step: Investments in Lithuanian PV sector by investment type in short-, mid- and long-term

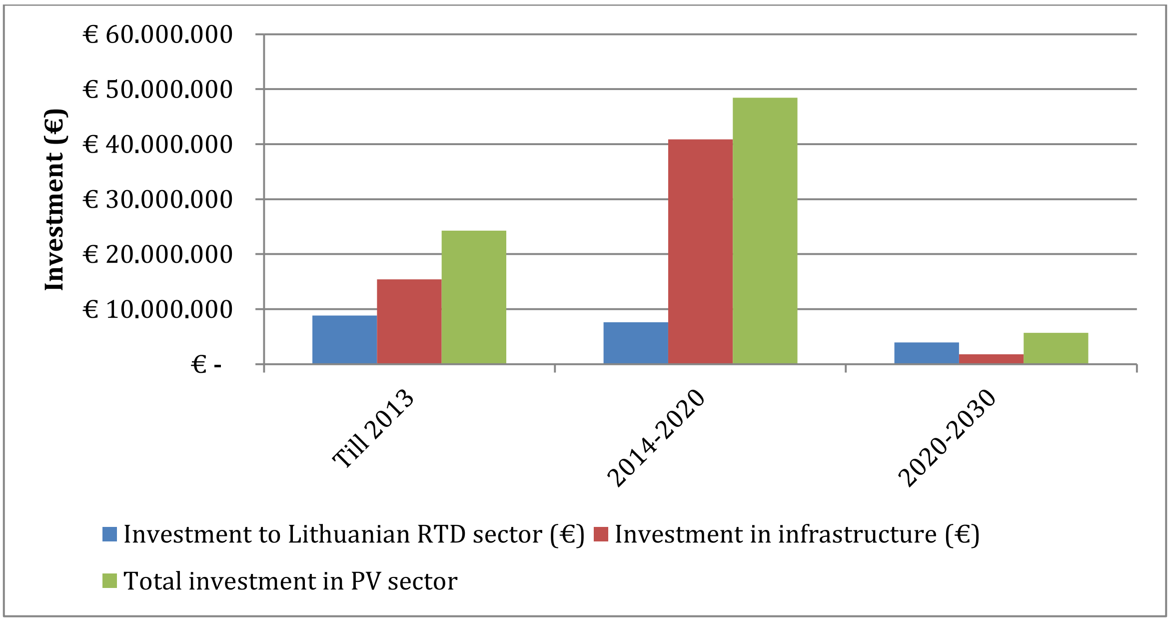


Table 29: Step by Step: Investments in Lithuanian PV sector (€) until 2030

Year	Investment to Lithuanian RTD sector (€)	Investment in infrastructure (€)	Total investment in PV sector
Till 2013	€ 8.833.312	€ 15.418.054	€ 24.251.366
2014-2020	€ 7.595.665	€ 40.851.668	€ 48.447.333
2020-2030	€ 3.933.410	€ 1.787.705	€ 5.721.115

Figure 71: Step by Step: Jobs created in Lithuanian PV sector in 2011-2030 time-frame

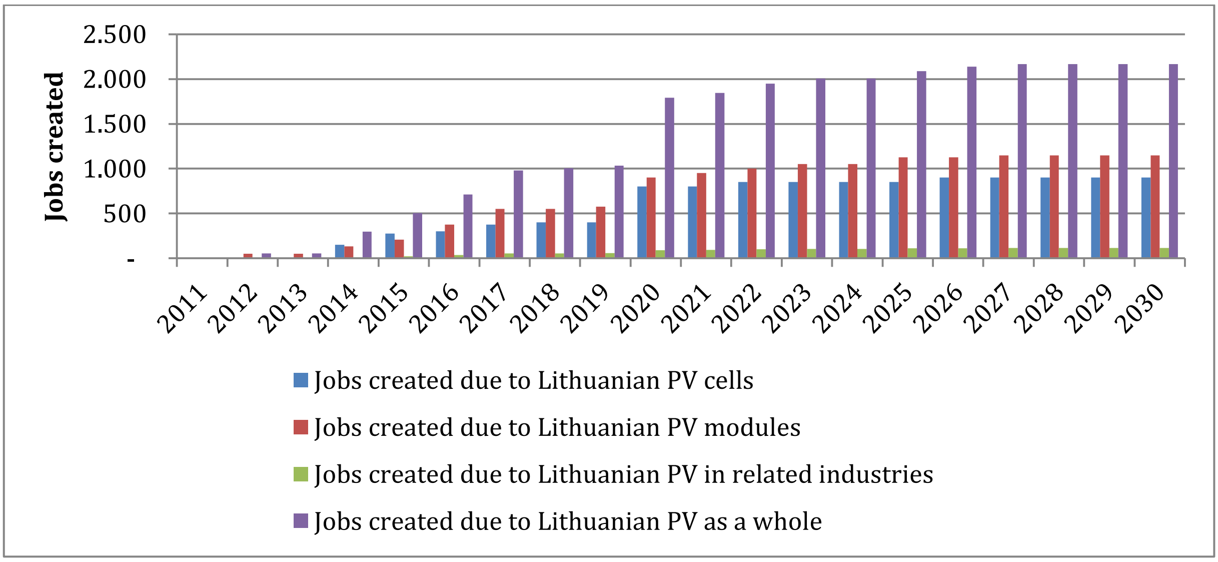


Table 30: Step by Step: Employment in Lithuanian PV sector in 2011-2030 time-frame

Year	Jobs created due to Lithuanian PV cells	Jobs created due to Lithuanian PV modules	Jobs created due to Lithuanian PV in related industries	Jobs created due to Lithuanian PV as a whole
2011	-	-	-	-
2012	-	50	5	55
2013	-	50	5	55
2014	150	135	14	299
2015	275	210	21	506
2016	300	375	38	713
2017	375	550	55	980
2018	400	550	55	1.005
2019	400	575	58	1.033
2020	800	900	90	1.790
2021	800	950	95	1.845
2022	850	1.000	100	1.950
2023	850	1.050	105	2.005
2024	850	1.050	105	2.005
2025	850	1.125	113	2.088
2026	900	1.125	113	2.138
2027	900	1.150	115	2.165
2028	900	1.150	115	2.165
2029	900	1.150	115	2.165
2030	900	1.150	115	2.165

Figure 72: Step by Step: Prognosis of annual electricity generation from newly installed Lithuanian PV modules (kWh)

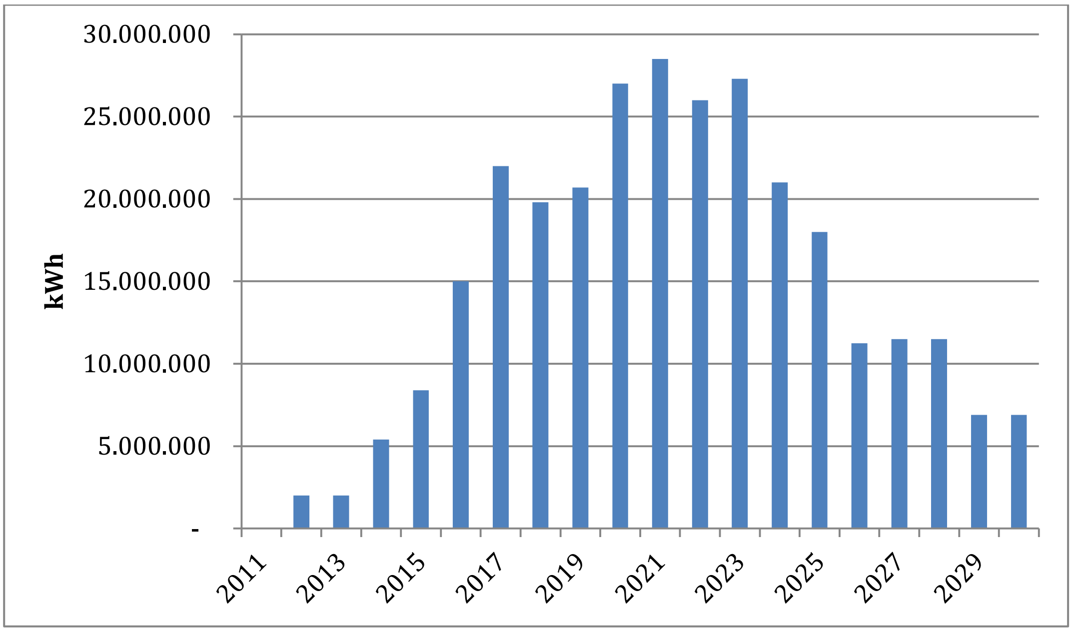


Figure 73: Step by Step: Cumulative electricity generation from installed Lithuanian PV modules (kWh)

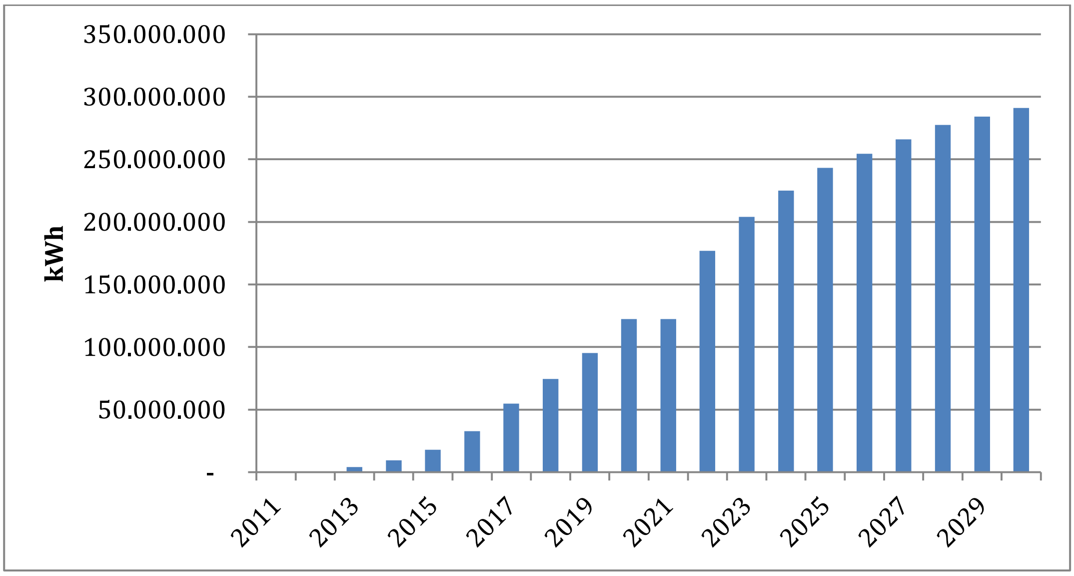


Figure 74: Step by Step: Share of PV in Lithuanian electricity market in 2011-2030 time-frame

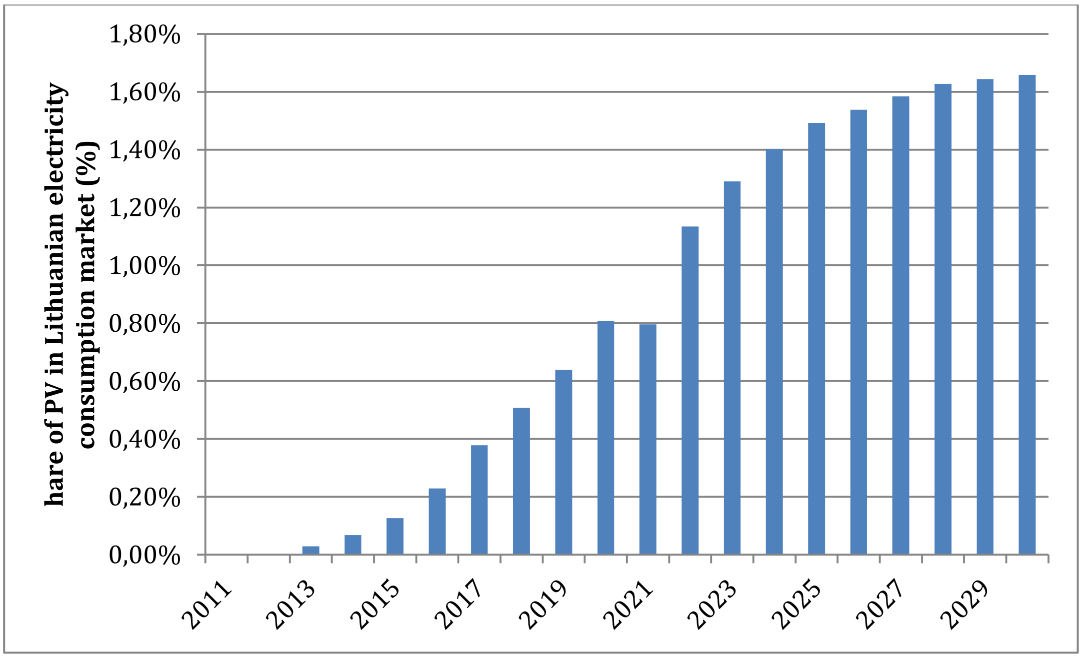


Figure 75: Step by Step: Annual CO_2 savings from newly installed Lithuanian PV modules (kg)

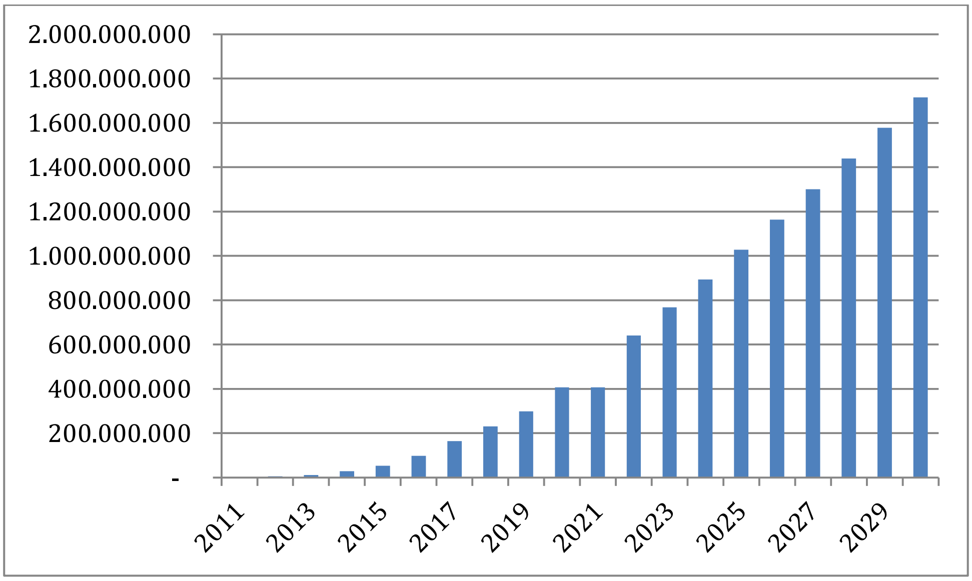


Figure 76: Step by Step: Cumulative CO_2 savings from installed Lithuanian PV modules (kg)

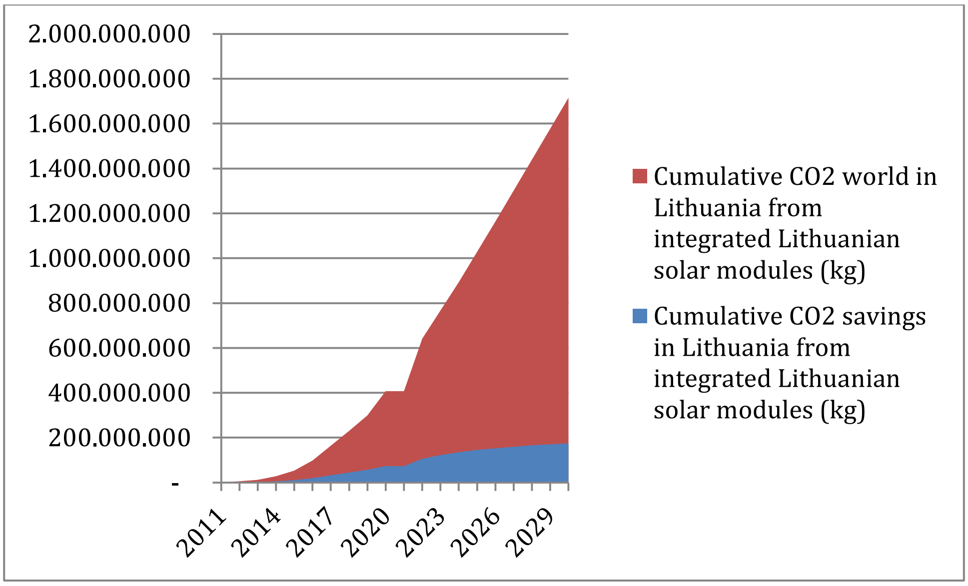


Table 31: Step by Step: Electricity generation and CO_2 savings

Year	Installed PV modules in Lithuania (MW)	Electricity generation from newly installed Lithuanian PV modules (kWh)	Cumulative electricity generation from installed Lithuanian PV modules (kWh)	CO2 savings in Lithuania from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in Lithuania from integrated Lithuanian solar modules (kg)	Share of PV in Lithuanian electricity consumption market (%)	Electricity generation from newly installed Lithuanian PV modules (kWh), worldwide	Cumulative electricity generation from installed Lithuanian PV modules (kWh), worldwide	CO2 savings in world from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 world in Lithuania from integrated Lithuanian solar modules (kg)
2011	0	-	-	-	-	0,00%	-	-	-	-
2012	2	2.000.000	-	1.200.000	-	0,00%	10.000.000	10.000.000	6.000.000	6.000.000
2013	2	2.000.000	4.000.000	1.200.000	2.400.000	0,03%	10.000.000	20.000.000	6.000.000	12.000.000
2014	5,4	5.400.000	9.400.000	3.240.000	5.640.000	0,07%	27.000.000	47.000.000	16.200.000	28.200.000
2015	8,4	8.400.000	17.800.000	5.040.000	10.680.000	0,13%	42.000.000	89.000.000	25.200.000	53.400.000
2016	15	15.000.000	32.800.000	9.000.000	19.680.000	0,23%	75.000.000	164.000.000	45.000.000	98.400.000
2017	22	22.000.000	54.800.000	13.200.000	32.880.000	0,38%	110.000.000	274.000.000	66.000.000	164.400.000
2018	19,8	19.800.000	74.600.000	11.880.000	44.760.000	0,51%	110.000.000	384.000.000	66.000.000	230.400.000
2019	20,7	20.700.000	95.300.000	12.420.000	57.180.000	0,64%	115.000.000	499.000.000	69.000.000	299.400.000
2020	27	27.000.000	122.300.000	16.200.000	73.380.000	0,81%	180.000.000	679.000.000	108.000.000	407.400.000
2021	28,5	28.500.000	122.300.000	17.100.000	73.380.000	0,80%	190.000.000	679.000.000	114.000.000	407.400.000
2022	26	26.000.000	176.800.000	15.600.000	106.080.000	1,13%	200.000.000	1.069.000.000	120.000.000	641.400.000
2023	27,3	27.300.000	204.100.000	16.380.000	122.460.000	1,29%	210.000.000	1.279.000.000	126.000.000	767.400.000
2024	21	21.000.000	225.100.000	12.600.000	135.060.000	1,40%	210.000.000	1.489.000.000	126.000.000	893.400.000
2025	18	18.000.000	243.100.000	10.800.000	145.860.000	1,49%	225.000.000	1.714.000.000	135.000.000	1.028.400.000
2026	11,25	11.250.000	254.350.000	6.750.000	152.610.000	1,54%	225.000.000	1.939.000.000	135.000.000	1.163.400.000
2027	11,5	11.500.000	265.850.000	6.900.000	159.510.000	1,58%	230.000.000	2.169.000.000	138.000.000	1.301.400.000
2028	11,5	11.500.000	277.350.000	6.900.000	166.410.000	1,63%	230.000.000	2.399.000.000	138.000.000	1.439.400.000
2029	6,9	6.900.000	284.250.000	4.140.000	170.550.000	1,64%	230.000.000	2.629.000.000	138.000.000	1.577.400.000
2030	6,9	6.900.000	291.150.000	4.140.000	174.690.000	1,66%	230.000.000	2.859.000.000	138.000.000	1.715.400.000

4.5.4 Scenario "Formula 1"

The critical variables which were formulated on the taking into account the key success factors (Table 11) and are essential for gaining the competitive advantage of Lithuanian PV sector in future environmental situation of this scenario are the following: (i) growing manufacturing capacity due to new instalments of manufacturing infrastructure dedicated to next generation technologies; (ii) barriers to use PV are low and PV is closely related with other industries(iii) 30% faster than current prognosis price reduction of W_p, including additional taxes. The key results for scenario "Formula 1" until 2030 on manufacturing capacity (Figure 77) and actual manufacturing (Figure 78), market share in the global PV market (Figure 79), export indicators, including generated income (Figure 80, Figure 81, Figure 82and Table 32, Table 33 and Table 34), investments (Figure 83 and Table 35), generated employment (Figure 84andTable 36), electricity production (Figure 85, Figure 86, Figure 87) and environmental issues (Figure 88, Figure 89andTable 37) are presented in the indicated tables and figures below.

Figure 77: Formula 1: Growth of Lithuanian PV manufacturing capabilities in 2011-2030 time-frame

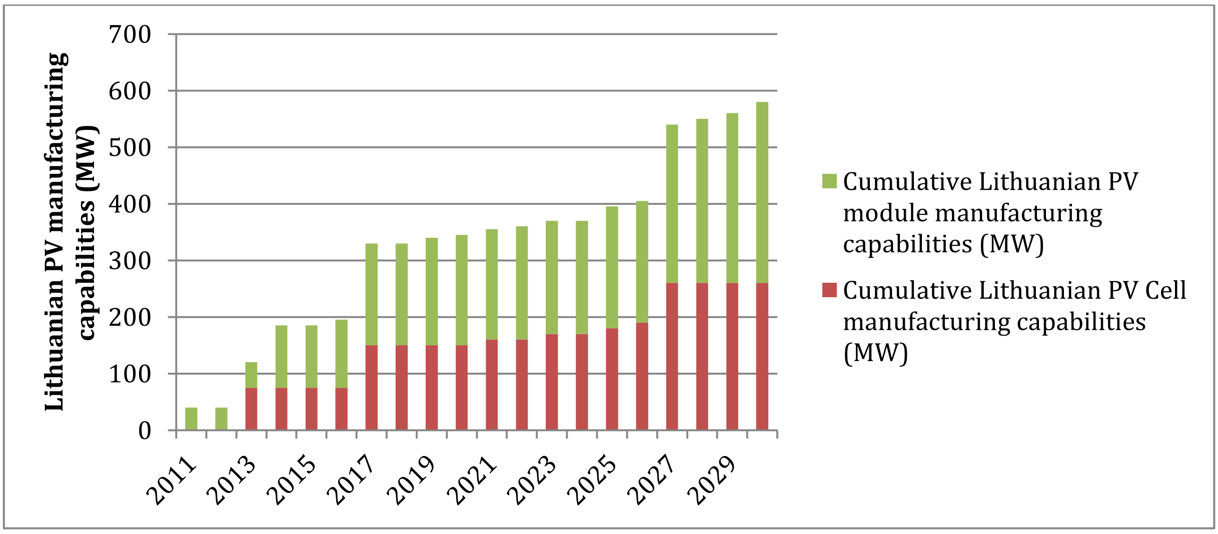


Figure 78: Formula 1: Lithuanian PV actual manufacturing in 2011-2030 time-frame

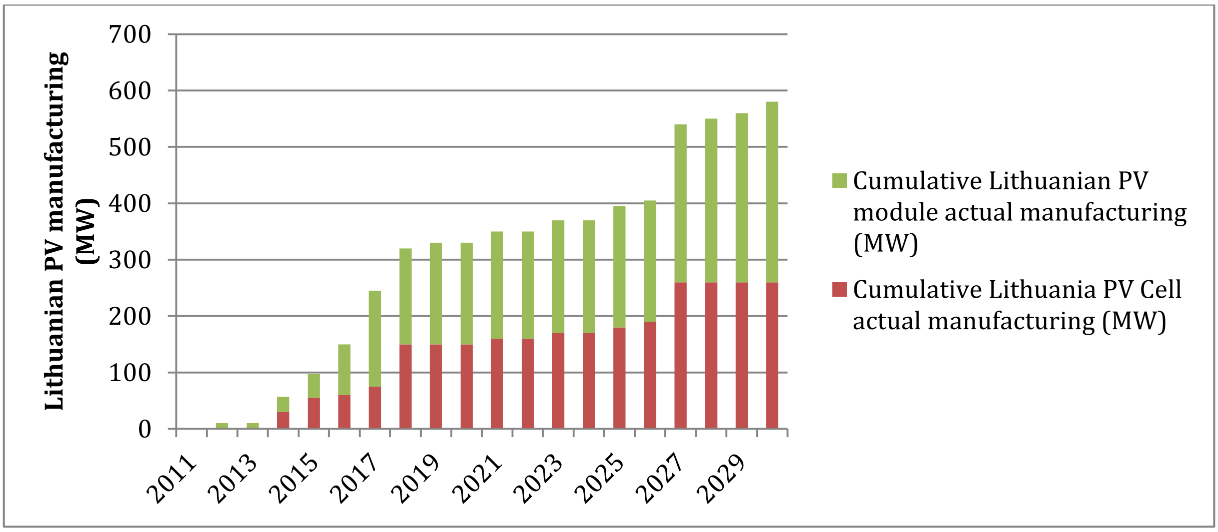


Figure 79: Formula 1: Prognosis of Lithuanian market share in the global outlook

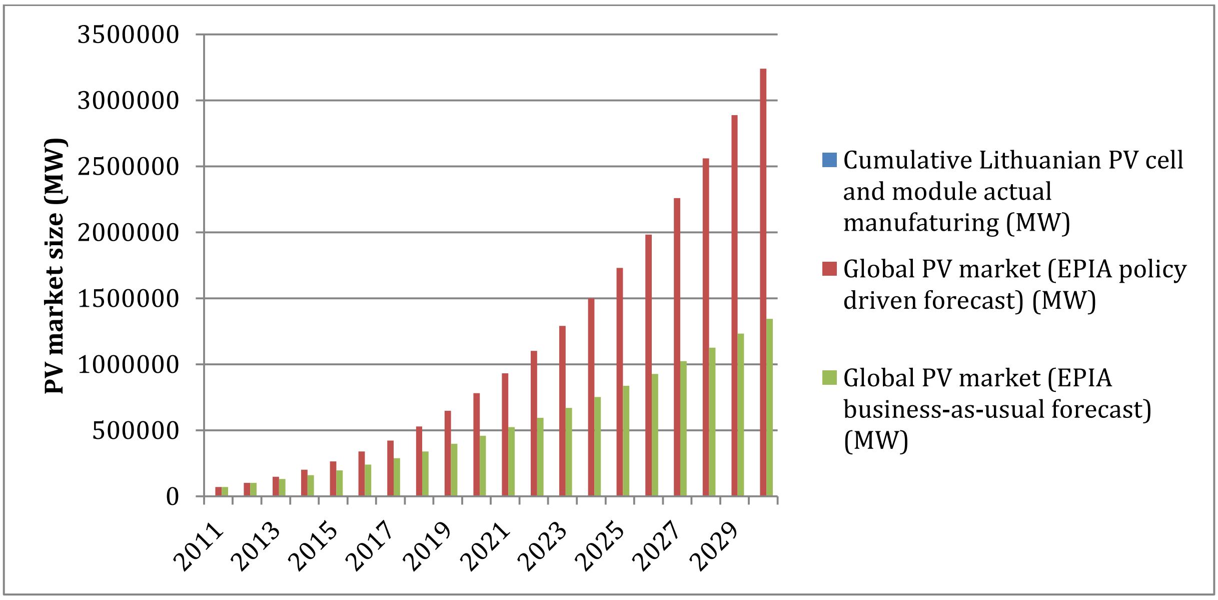


Table 32: Formula 1: Prognosis of Lithuanian market size by MW, global market share in 2011-2030 time-frame

Year	Cumulative Lithuanian PV Cell manufacturing capabilities (MW)	Cumulative Lithuania PV Cell actual manufacturing (MW)	Cumulative Lithuanian PV module manufacturing capabilities (MW)	Cumulative Lithuanian PV module actual manufacturing (MW)	Cumulative Lithuanian PV cell and module manufacturing capabilities (MW)	Cumulative Lithuanian PV cell and module actual manufaturing (MW)	Lithuanian share in global market (according to the policy driven forecast) (%)	Lithuanian share in global market (according to the business-as-usual forecast) (%)	Global PV market (EPIA policy driven forecast) (MW)	Global PV market (EPIA business-as-usual forecast) (MW)
2011	0	0	40	-	40	-	-	-	71.061	71.061
2012	0	0	40	10	40	10	0,010%	0,010%	102.156	102.156
2013	75	0	45	10	120	10	0,007%	0,008%	149.120	129.960
2014	75	30	110	27	185	57	0,028%	0,035%	201.750	160.770
2015	75	55	110	42	185	97	0,037%	0,049%	264.390	197.600
2016	75	60	120	90	195	150	0,044%	0,063%	338.650	239.920
2017	150	75	180	170	330	245	0,058%	0,085%	422.890	288.220
2018	150	150	180	170	330	320	0,061%	0,094%	528.762	340.638
2019	150	150	190	180	340	330	0,051%	0,083%	646.624	397.173
2020	150	150	195	180	345	330	0,042%	0,072%	780.702	458.392
2021	160	160	195	190	355	350	0,038%	0,067%	932.029	524.364
2022	160	160	200	190	360	350	0,032%	0,059%	1.101.634	595.159
2023	170	170	200	200	370	370	0,029%	0,055%	1.290.551	670.845
2024	170	170	200	200	370	370	0,025%	0,049%	1.499.809	751.492
2025	180	180	215	215	395	395	0,023%	0,047%	1.730.442	837.170
2026	190	190	215	215	405	405	0,020%	0,044%	1.983.479	927.946
2027	260	260	280	280	540	540	0,024%	0,053%	2.259.952	1.023.890
2028	260	260	290	290	550	550	0,021%	0,049%	2.560.894	1.125.072
2029	260	260	300	300	560	560	0,019%	0,045%	2.887.334	1.231.561
2030	260	260	320	320	580	580	0,018%	0,043%	3.240.305	1.343.426

Figure 80: Formula 1: Lithuanian income from PV cells in 2011-2030 time-frame

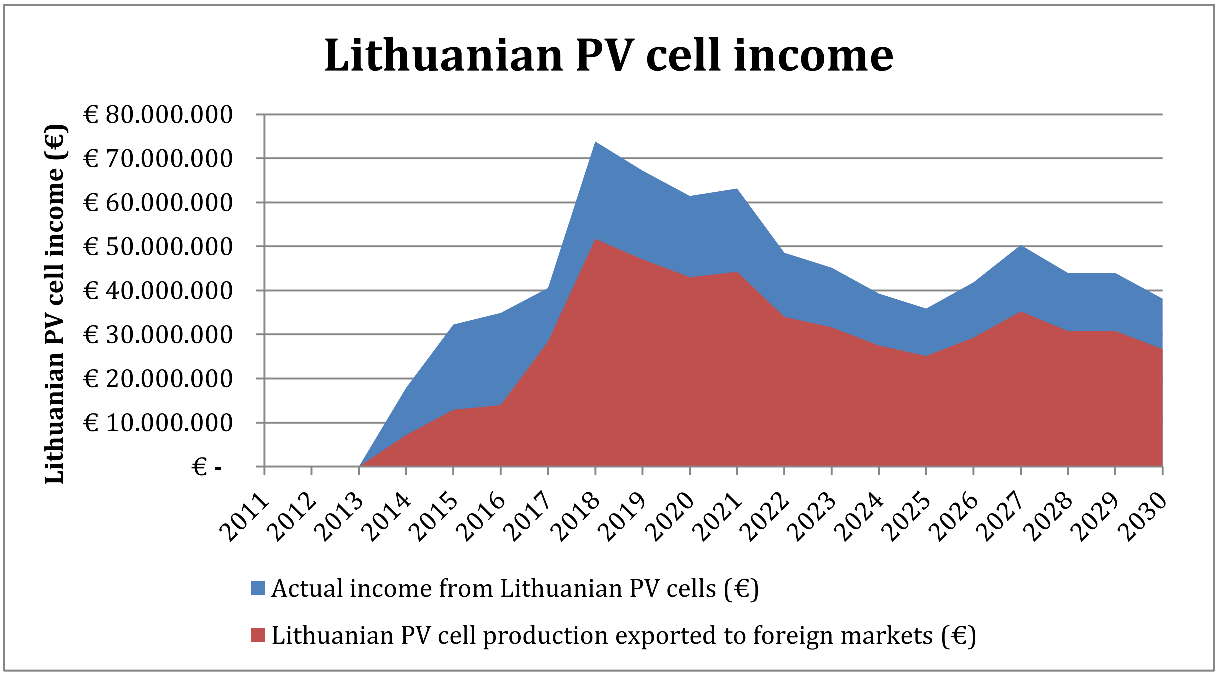


Figure 81: Formula 1: Lithuanian income from PV modules in 2011-2030 time-frame

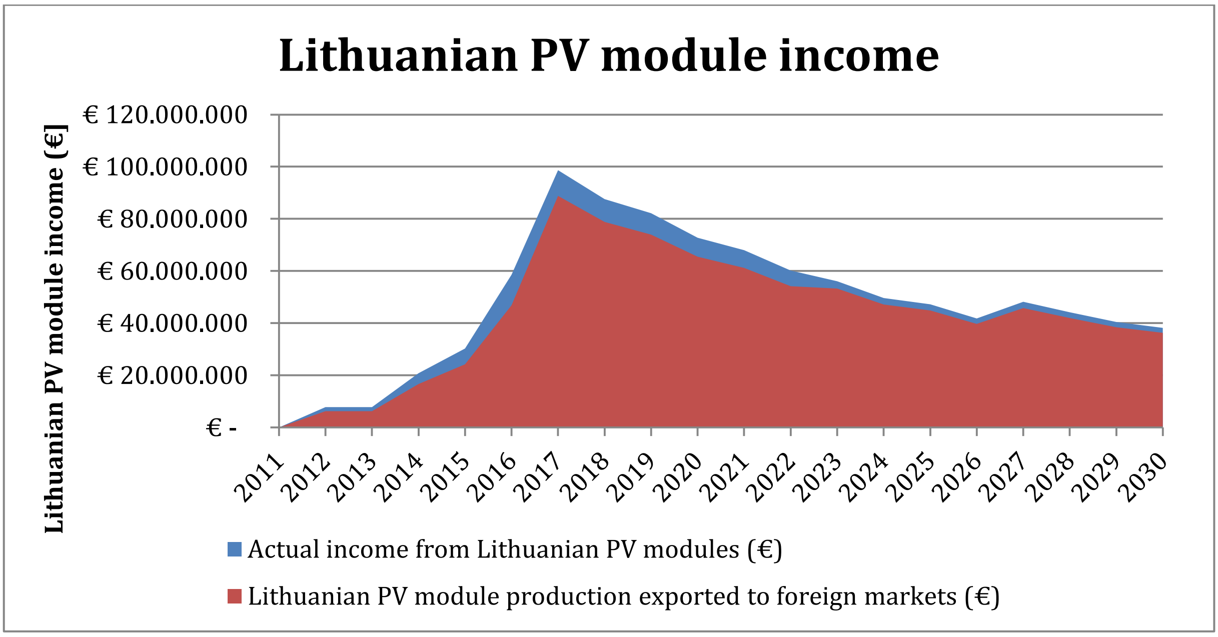


Figure 82: Formula 1: Lithuanian cumulative income from PV in 2011-2030 time-frame

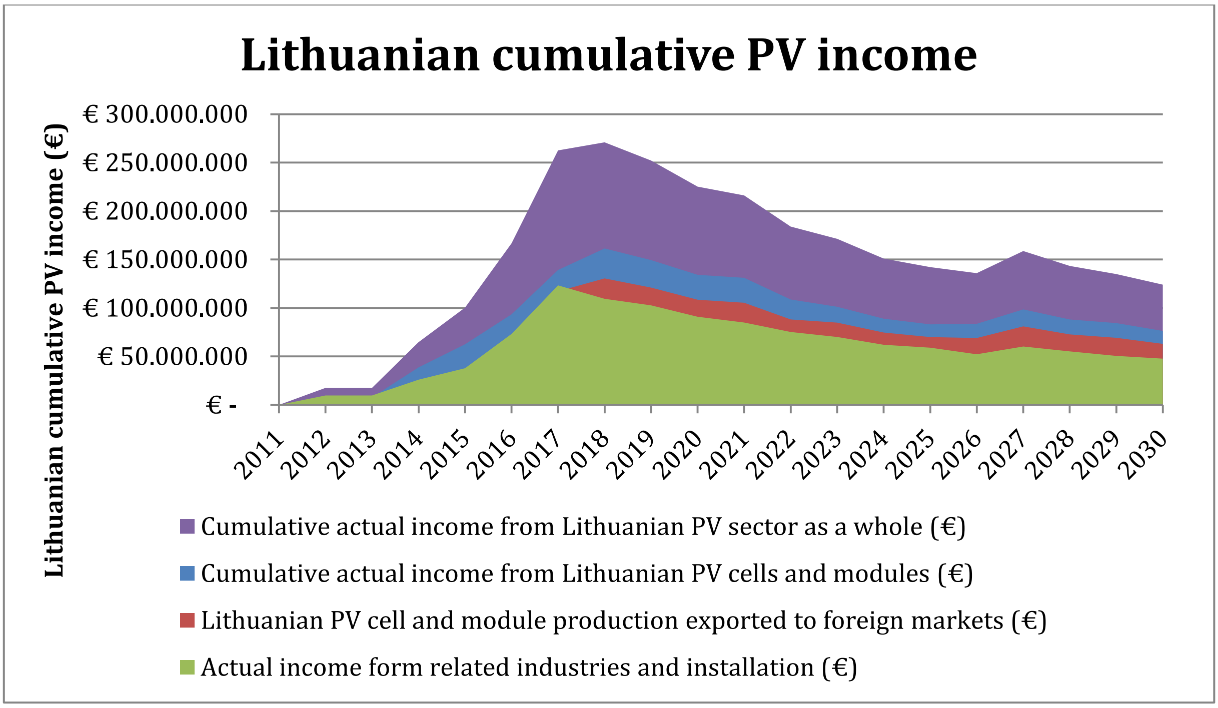


Table 33: Formula 1: Prognosis of Lithuanian potential and actual income from PV cells and modules (€) in 2011-2030 time-frame

Year	Potential income from Lithuanian PV cells (€)	Actual income from Lithuanian PV cells (€)	Potential income from Lithuanian PV modules (€)	Actual income from Lithuanian PV modules (€)	Cumulative potential income from Lithuanian PV cells and modules (€)	Cumulative actual income from Lithuanian PV cells and modules (€)	Actual income form related industries and installation (€)	Cumulative actual income from Lithuanian PV sector as a whole (€)
2011	€ -	€ -	€ 44.400.000	-	€ 44.400.000	-	0	€ -
2012	€ -	€ -	€ 31.200.000	€ 7.800.000	€ 31.200.000	€ 7.800.000	€ 9.750.000	€ 17.550.000
2013	€ 46.992.481	€ -	€ 35.101.929	€ 7.800.429	€ 82.094.410	€ 7.800.429	€ 9.750.536	€ 17.550.964
2014	€ 44.742.481	€ 17.896.992	€ 84.772.968	€ 20.807.910	€ 129.515.449	€ 38.704.903	€ 26.009.888	€ 64.714.791
2015	€ 43.992.481	€ 32.261.153	€ 79.285.630	€ 30.272.695	€ 123.278.111	€ 62.533.848	€ 37.840.869	€ 100.374.717
2016	€ 43.617.481	€ 34.893.985	€ 78.104.587	€ 58.578.440	€ 121.722.068	€ 93.472.425	€ 73.223.050	€ 166.695.475
2017	€ 81.096.258	€ 40.548.129	€ 104.473.762	€ 98.669.664	€ 185.570.021	€ 139.217.794	€ 123.337.081	€ 262.554.874
2018	€ 73.839.333	€ 73.839.333	€ 92.732.294	€ 87.580.500	€ 166.571.627	€ 161.419.833	€ 109.475.625	€ 270.895.458
2019	€ 67.218.310	€ 67.218.310	€ 86.732.548	€ 82.167.677	€ 153.950.857	€ 149.385.986	€ 102.709.596	€ 252.095.582
2020	€ 61.453.642	€ 61.453.642	€ 78.822.464	€ 72.759.198	€ 140.276.106	€ 134.212.840	€ 90.948.997	€ 225.161.837
2021	€ 63.155.573	€ 63.155.573	€ 69.779.908	€ 67.990.679	€ 132.935.481	€ 131.146.253	€ 84.988.349	€ 216.134.602
2022	€ 48.560.101	€ 48.560.101	€ 63.352.837	€ 60.185.195	€ 111.912.937	€ 108.745.296	€ 75.231.493	€ 183.976.789
2023	€ 45.171.319	€ 45.171.319	€ 56.077.837	€ 56.077.837	€ 101.249.156	€ 101.249.156	€ 70.097.297	€ 171.346.453
2024	€ 39.282.779	€ 39.282.779	€ 49.637.599	€ 49.637.599	€ 88.920.378	€ 88.920.378	€ 62.046.998	€ 150.967.377
2025	€ 35.878.119	€ 35.878.119	€ 47.232.028	€ 47.232.028	€ 83.110.147	€ 83.110.147	€ 59.040.035	€ 142.150.182
2026	€ 41.841.094	€ 41.841.094	€ 41.807.400	€ 41.807.400	€ 83.648.494	€ 83.648.494	€ 52.259.249	€ 135.907.743
2027	€ 50.319.083	€ 50.319.083	€ 48.193.557	€ 48.193.557	€ 98.512.640	€ 98.512.640	€ 60.241.947	€ 158.754.587
2028	€ 43.959.955	€ 43.959.955	€ 44.181.972	€ 44.181.972	€ 88.141.927	€ 88.141.927	€ 55.227.464	€ 143.369.391
2029	€ 43.959.955	€ 43.959.955	€ 40.456.140	€ 40.456.140	€ 84.416.096	€ 84.416.096	€ 50.570.176	€ 134.986.271
2030	€ 38.130.689	€ 38.130.689	€ 38.197.000	€ 38.197.000	€ 76.327.689	€ 76.327.689	€ 47.746.250	€ 124.073.939

Table 34: Formula 1: Prognosis of Lithuanian export (€) until 2030

Year	Lithuanian PV cell production exported to foreign markets (€)	Lithuanian PV module production exported to foreign markets (€)	Lithuanian PV cell and module production exported to foreign markets (€)
2011	-	-	€ -
2012	-	€ 6.240.000	€ 6.240.000
2013	-	€ 6.240.343	€ 6.240.343
2014	€ 7.158.797	€ 16.646.328	€ 23.805.125
2015	€ 12.904.461	€ 24.218.156	€ 37.122.617
2016	€ 13.957.594	€ 46.862.752	€ 60.820.346
2017	€ 28.383.690	€ 88.802.698	€ 117.186.388
2018	€ 51.687.533	€ 78.822.450	€ 130.509.983
2019	€ 47.052.817	€ 73.950.909	€ 121.003.726
2020	€ 43.017.550	€ 65.483.278	€ 108.500.828
2021	€ 44.208.901	€ 61.191.611	€ 105.400.513
2022	€ 33.992.071	€ 54.166.675	€ 88.158.746
2023	€ 31.619.923	€ 53.273.946	€ 84.893.869
2024	€ 27.497.946	€ 47.155.719	€ 74.653.664
2025	€ 25.114.683	€ 44.870.427	€ 69.985.110
2026	€ 29.288.766	€ 39.717.030	€ 69.005.796
2027	€ 35.223.358	€ 45.783.879	€ 81.007.237
2028	€ 30.771.969	€ 41.972.873	€ 72.744.842
2029	€ 30.771.969	€ 38.433.333	€ 69.205.302
2030	€ 26.691.482	€ 36.287.150	€ 62.978.632

Figure 83: Formula 1: Investments in Lithuanian PV sector by investment type in short-, mid- and long-term

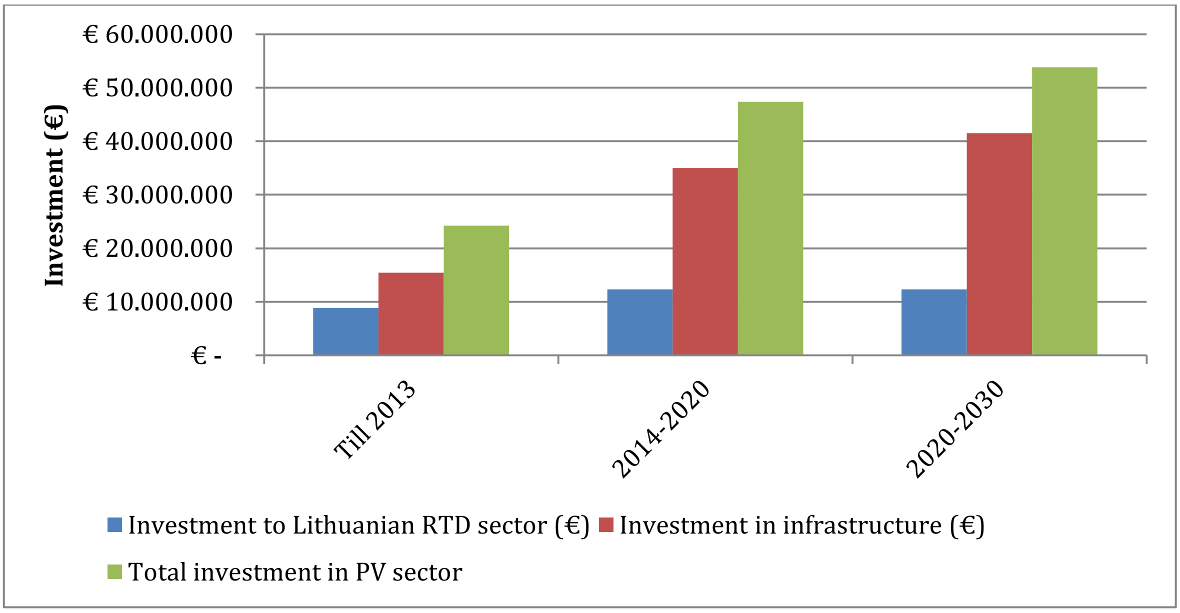


Table 35: Formula 1: Investments in Lithuanian PV sector (€) until 2030

Year	Investment to Lithuanian RTD sector (€)	Investment in infrastructure (€)	Total investment in PV sector
Till 2013	€ 8.833.312	€ 15.418.054	€ 24.251.366
2014-2020	€ 12.343.987	€ 35.000.000	€ 47.343.987
2020-2030	€ 12.344.213	€ 41.488.498	€ 53.832.711

Figure 84: Formula 1: Jobs created in Lithuanian PV sector in 2011-2030 time-frame

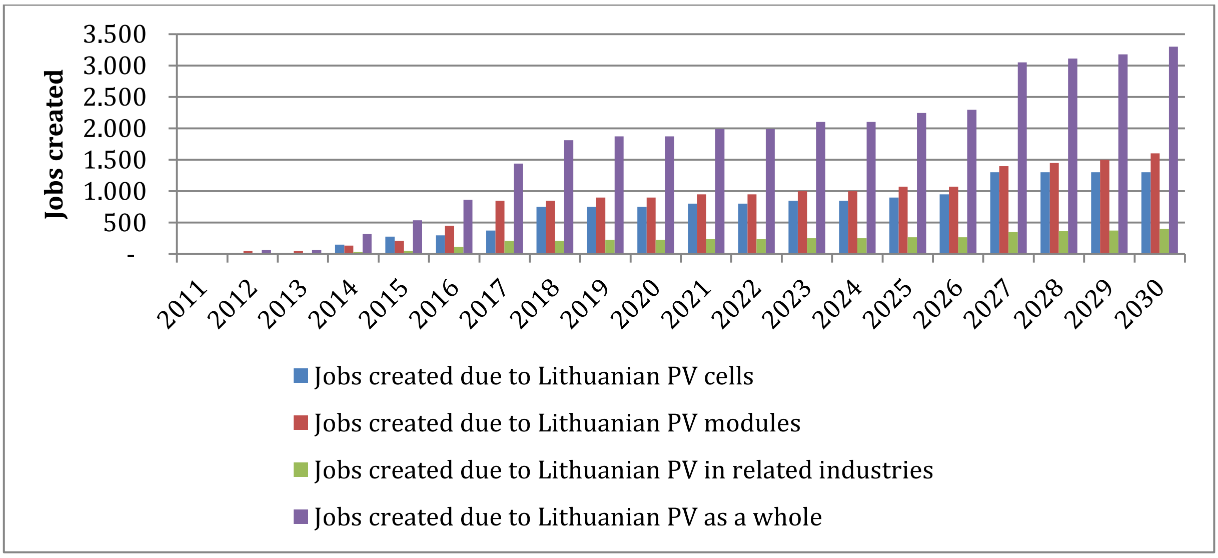


Table 36: Formula 1: Employment in Lithuanian PV sector in 2011-2030 time-frame

Year	Jobs created due to Lithuanian PV cells	Jobs created due to Lithuanian PV modules	Jobs created due to Lithuanian PV in related industries	Jobs created due to Lithuanian PV as a whole
2011	-	-	-	-
2012	-	50	13	63
2013	-	50	13	63
2014	150	135	34	319
2015	275	210	53	538
2016	300	450	113	863
2017	375	850	213	1.438
2018	750	850	213	1.813
2019	750	900	225	1.875
2020	750	900	225	1.875
2021	800	950	238	1.988
2022	800	950	238	1.988
2023	850	1.000	250	2.100
2024	850	1.000	250	2.100
2025	900	1.075	269	2.244
2026	950	1.075	269	2.294
2027	1.300	1.400	350	3.050
2028	1.300	1.450	363	3.113
2029	1.300	1.500	375	3.175
2030	1.300	1.600	400	3.300

Figure 85: Formula 1: Prognosis of annual electricity generation from newly installed Lithuanian PV modules (kWh)

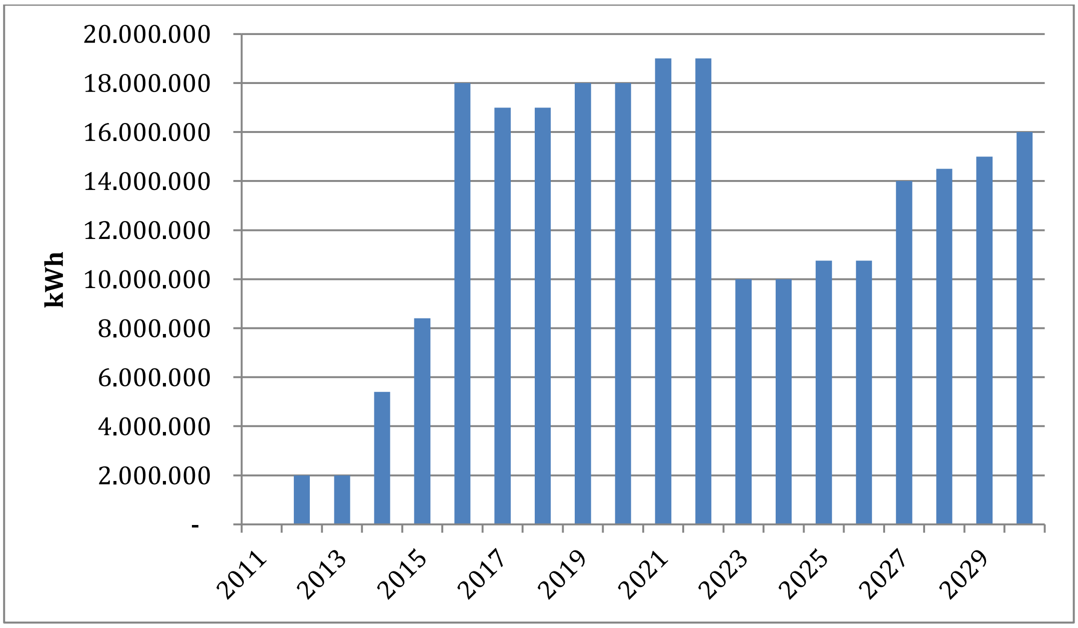


Figure 86: Formula 1: Cumulative electricity generation from installed Lithuanian PV modules (kWh)

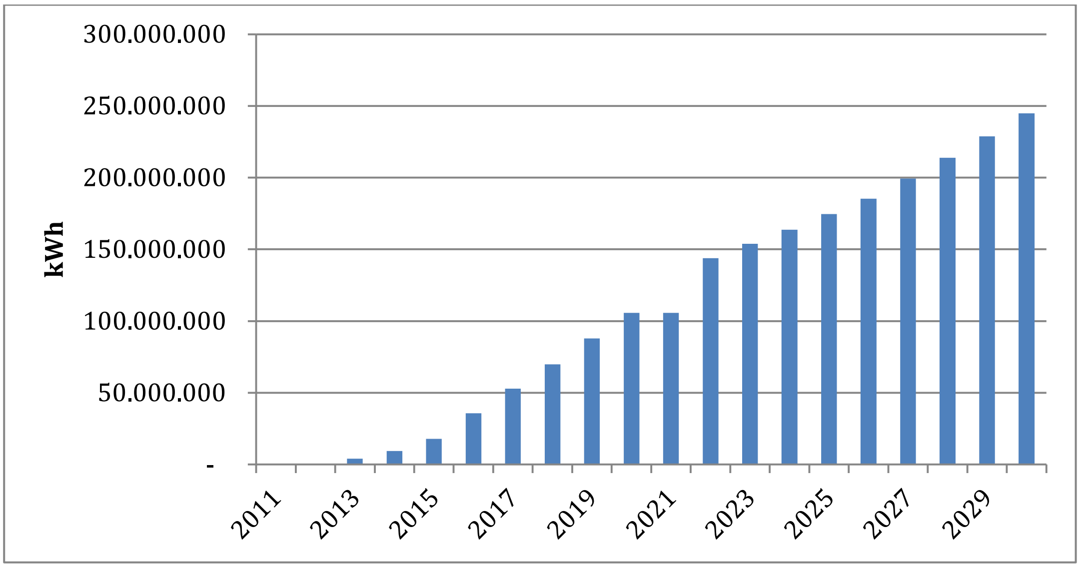


Figure 87: Formula 1: Share of PV in Lithuanian electricity market in 2011-2030 time-frame

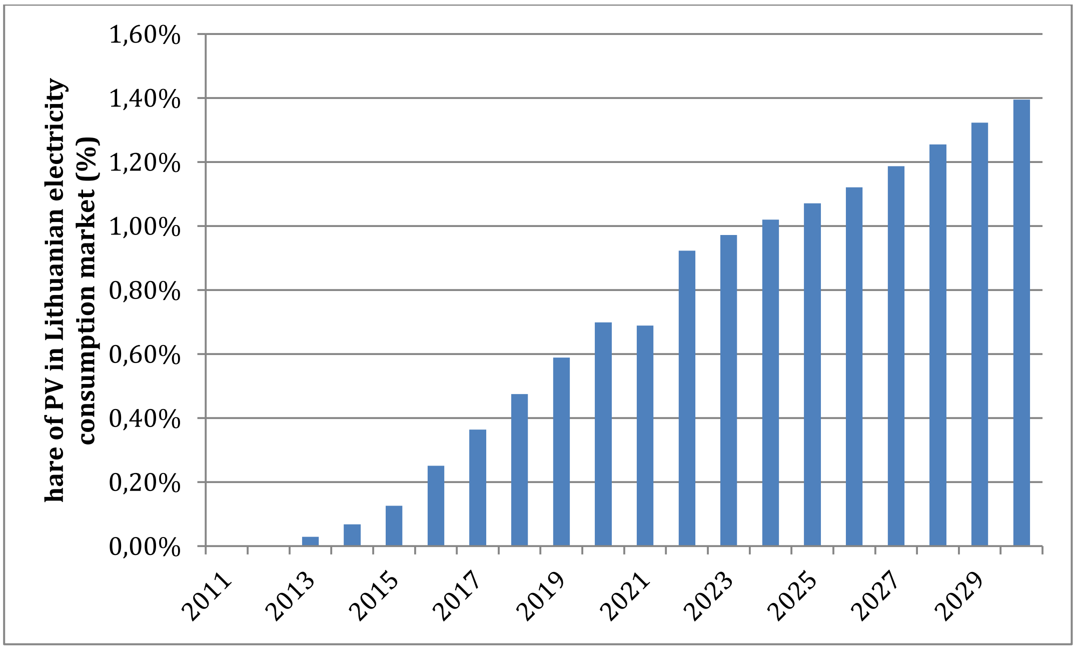


Figure 88: Formula 1: Annual CO_2 savings from newly installed Lithuanian PV modules (kg)

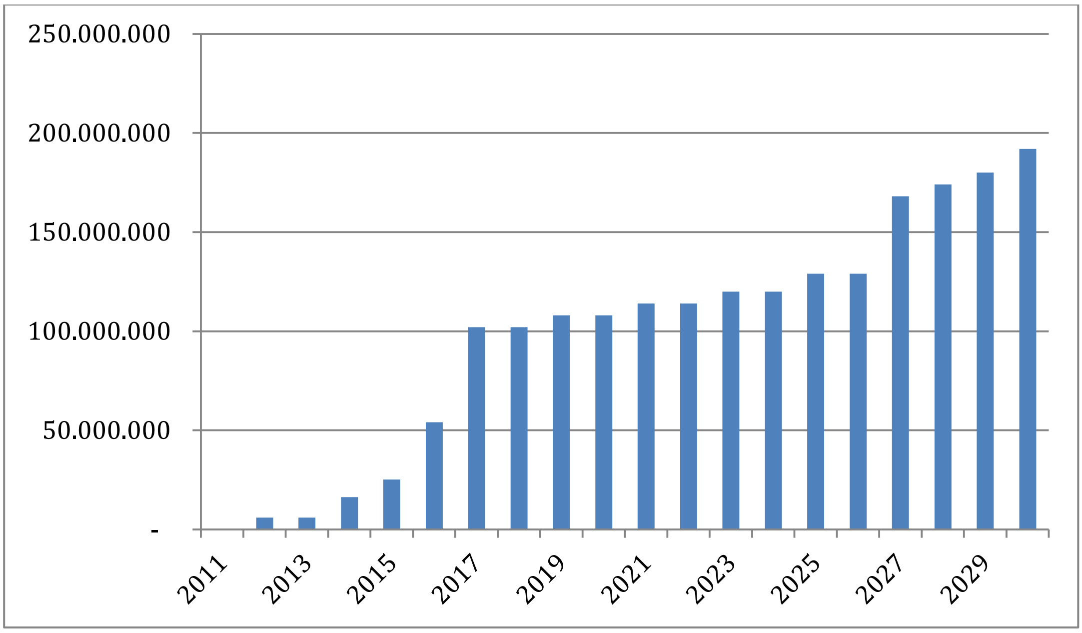


Figure 89: Formula 1: Cumulative CO_2 savings from installed Lithuanian PV modules (kg)

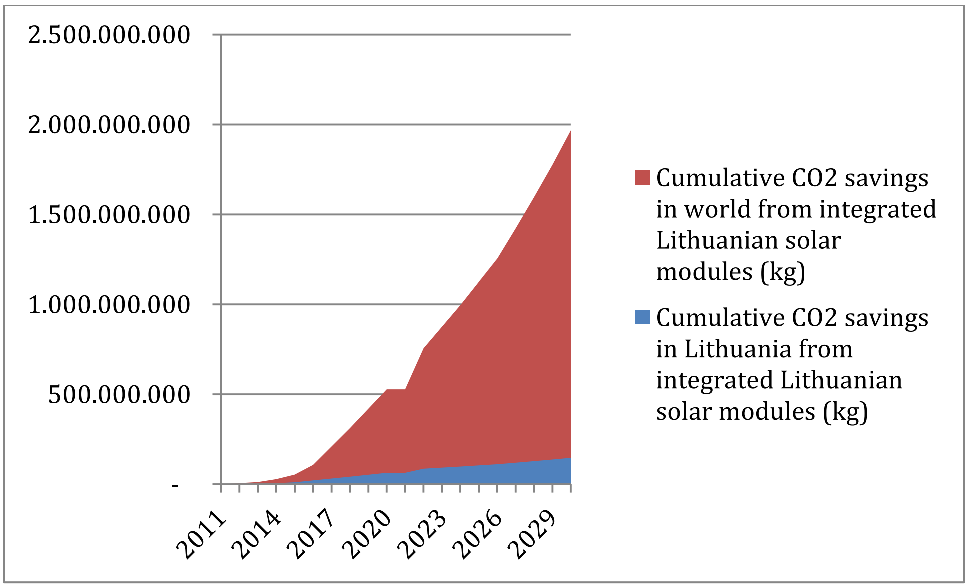


Table 37: Formula 1: Electricity generation and CO_2 savings

Year	Installed PV modules in Lithuania (MW)	Electricity generation from newly installed Lithuanian PV modules (kWh)	Cumulative electricity generation from installed Lithuanian PV modules (kWh)	CO2 savings in Lithuania from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in Lithuania from integrated Lithuanian solar modules (kg)	Share of PV in Lithuanian electricity consumption market (%)	Electricity generation from newly installed Lithuanian PV modules (kWh), worldwide	Cumulative electricity generation from installed Lithuanian PV modules (kWh), worldwide	CO2 savings in world from newly integrated Lithuanian solar modules (kg)	Cumulative CO2 savings in world from integrated Lithuanian solar modules (kg)
2011	0	-	-	-	-	0,00%	-	-	-	-
2012	2	2.000.000	-	1.200.000	-	0,00%	10.000.000	10.000.000	6.000.000	6.000.000
2013	2	2.000.000	4.000.000	1.200.000	2.400.000	0,03%	10.000.000	20.000.000	6.000.000	12.000.000
2014	5,4	5.400.000	9.400.000	3.240.000	5.640.000	0,07%	27.000.000	47.000.000	16.200.000	28.200.000
2015	8,4	8.400.000	17.800.000	5.040.000	10.680.000	0,13%	42.000.000	89.000.000	25.200.000	53.400.000
2016	18	18.000.000	35.800.000	10.800.000	21.480.000	0,25%	90.000.000	179.000.000	54.000.000	107.400.000
2017	17	17.000.000	52.800.000	10.200.000	31.680.000	0,36%	170.000.000	349.000.000	102.000.000	209.400.000
2018	17	17.000.000	69.800.000	10.200.000	41.880.000	0,47%	170.000.000	519.000.000	102.000.000	311.400.000
2019	18	18.000.000	87.800.000	10.800.000	52.680.000	0,59%	180.000.000	699.000.000	108.000.000	419.400.000
2020	18	18.000.000	105.800.000	10.800.000	63.480.000	0,70%	180.000.000	879.000.000	108.000.000	527.400.000
2021	19	19.000.000	105.800.000	11.400.000	63.480.000	0,69%	190.000.000	879.000.000	114.000.000	527.400.000
2022	19	19.000.000	143.800.000	11.400.000	86.280.000	0,92%	190.000.000	1.259.000.000	114.000.000	755.400.000
2023	10	10.000.000	153.800.000	6.000.000	92.280.000	0,97%	200.000.000	1.459.000.000	120.000.000	875.400.000
2024	10	10.000.000	163.800.000	6.000.000	98.280.000	1,02%	200.000.000	1.659.000.000	120.000.000	995.400.000
2025	10,75	10.750.000	174.550.000	6.450.000	104.730.000	1,07%	215.000.000	1.874.000.000	129.000.000	1.124.400.000
2026	10,75	10.750.000	185.300.000	6.450.000	111.180.000	1,12%	215.000.000	2.089.000.000	129.000.000	1.253.400.000
2027	14	14.000.000	199.300.000	8.400.000	119.580.000	1,19%	280.000.000	2.369.000.000	168.000.000	1.421.400.000
2028	14,5	14.500.000	213.800.000	8.700.000	128.280.000	1,25%	290.000.000	2.659.000.000	174.000.000	1.595.400.000
2029	15	15.000.000	228.800.000	9.000.000	137.280.000	1,32%	300.000.000	2.959.000.000	180.000.000	1.775.400.000
2030	16	16.000.000	244.800.000	9.600.000	146.880.000	1,39%	320.000.000	3.279.000.000	192.000.000	1.967.400.000

4.5.5 Overview of key results from all scenarios

At the end of 2011 Lithuania had 40 MW of PV manufacturing capacity. By 2025, it could be a cumulative manufacturing capacity of 165 MW for PV in the Sunny Tomorrow scenario and 395 MW in case of other scenarios. After a decade, the initial rate of growth would slow down, taking into account repowering from 2025-2030 onwards. However, even with slower growth by 2030, there could be around 5500 MW produced and 250 MW of clean PV energy installed in Lithuanian under the all scenarios, and respectively:

- 2930 MW in the Sunny Tomorrow scenario;
- 5955 MW in the Broken Walls scenario;
- 5655 MW in the Step by Step scenario;
- 6595 MW in the Formula 1 scenario.

The share of PV in the global and Lithuanian electricity market will depend on what happens to electricity consumption in light of global efforts to reduce greenhouse gas emissions. PV could provide as much as 11.3% to21.2% of global electricity demand by 2050.By 2020, the penetration of PV in the world electricity market could reach a global average of3.9%, in Europe the share could be up to 12%.[63] In the case of Lithuanian the following share of PV in global PV market and national electricity market could be anticipated respectively:

- 0,012% and0,99% in the Sunny Tomorrow scenario;
- 0,030%and 1,26% in the Broken Walls scenario;
- 0,031%and 1,66% in the Step by Step scenario;
- 0,043%and 1,39% in the Formula 1 scenario.

The moderate assumption that, 10 FTE jobs are created for each MW of solar power modules produced and 2-3 FTE jobs when PV are installed. Using this assumption, more than228,000 people are employed in Lithuanian solar energy sector from 2013. In all scenarios Lithuanian solar electricity sector would become a large employer providing high-tech employment to almost 1500 people by 2020 and 2000 by 2030:

- 878 jobs in the Sunny Tomorrow scenario;
- 2275 jobs in the Broken Walls scenario;
- 2165 jobs in the Step by Step scenario;
- 3300 jobs in the Formula 1 scenario.

In terms of investments, the PV industry needs to attract ~1M€ per year for RTD and ~30M€by 2020 in technology breakthrough scenarios and lower investments in the case of incremental changes of technologies.

[63]EPIA & Greenpeace.Solar generation 6. Solar photovoltaic electricity empowering the world (2011)

Under all scenarios, up to 10 K tonnes of CO_2 equivalent would be avoid edevery year by 2030 in Lithuania. The cumulative total from 2011to 2030 would represent up to 150K tonnes ofCO_2 equivalent saved. There is no doubt that PV can be an efficient tool to replace conventional power generation and contribute to mitigation of climate change under each of the scenarios:

- 104K tonnes of CO_2 equivalent saved in Lithuania and 0,8 M tonnes in the Sunny Tomorrow scenario;
- 132K tonnes of CO_2 equivalent saved in Lithuania and 1,7 M tonnes in the Broken Walls scenario;
- 174K tonnes of CO_2 equivalent saved in Lithuania and 1,7 M tonnes in the Step by Step scenario;
- 146K tonnes of CO_2 equivalent saved in Lithuania and 1,9 M tonnes in the Formula 1 scenario.

5 CONCLUSIONS

The main conclusions that can be drawn from this study are detailed below.

Conclusion 1: Photovoltaic market remains large and durable, however volatile due to historical dependence on the incentives and current level of maturity

Conclusion 1 is based on the following:

Sustainability	Decline
(1) Around the world 31.1 GW of PV systems were installed in 2012, up from 30.4 GW in 2011; PV remains, after hydro and wind power, the third most important renewable energy source interims of globally installed capacity. (2) PV in 2012 covered 2.6% of the electricity demand and 5.2% of the peak electricity demand in Europe. (3) Despite Europe's dramatic decline in 2013, the double-digit growth will occur again in global installations. Growth rates of 250%, 50% and 65% are forecast for Middle-East & Africa, Americas, and Asia respectively, supporting global growth, but continuing the industry's geographic fragmentation.	(1) European solar PV demand in 2013 is forecast to decline by 37 percent year-over-year to 10.5 GW, which is a four-year low and almost half of the peak demand achieved by Europe back in 2011. (2) The factors lined up against the continued strong growth of PV in Europe and around the world are formidable: a economic and financial difficulties; industry consolidation; a global market rebalancing; political and regulatory instability as governments reconsider their commitment to renewable energy sources and climate-change mitigation.
(4) Strong demand from Europe was due primarily to premium incentives that remained in place during 2012, along with lower installed system prices Current transition period is dedicated to development a more sustainable approach, based on: - simple, transparent, certain incentive structure / value proposition - regular incentive declines to drive & follow cost reduction - promotion of PV electricity self-consumption, which is important because it equates the PV generation costs and the household electricity prices	(3) Despite the significant declines in installed PV system pricing over the past 12-18 months, most European markets are actually seeing declining investment returns due to the reductions in PV incentives now available.
(5) The expansion of RE is often motivated by its potential to reduce climate change, energy security (6) PV power processing plants connected to the grid are increasing both in the number of installations and also in the rated power of each plant, and will cover a significant percentage of the electric generation mix.	(4) While distributed PV electricity generation can make a compelling economic case in Europe, relative to higher retail electricity rates, emerging grid-access barriers will constrain growth. Utility companies will continue to provide barriers to PV, and are likely to undertake more lobbying related to grid-access fee schemes and smart-meter implementation.

Note: These points are drawn from Chapter 2 and Chapter 3 primarily.

Conclusion 2: Photovoltaic industry is approaching a grid parity in major economies and in particularly in EU

Conclusion 2 is based on the following:

Driving costs down	Driving costs up
(1) Price drop accelerates as installed capacity increases. The price of PV modules decreasing by over 20% every time the cumulative sold volume of PV modules has doubled (learning factor). The average price of a PV module in Europe in 2012 is about 70% lower than 10 years ago. Over the next 10 years, system prices could decline by 36-51%, depending on the segment and technology employed.	(1) Due to substantial reductions in global PV module market, system cost reductions were not realised by customers
(2) System costs are driven down by maturity of the market and economy of scale, including reduced margins, experienced network of installers, developers and retailers, fair competition between players, transparent and efficient administrative rules and grid connection processes (3) Scale will be crucial for solar manufacturers. A few years ago, manufacturers needed to have 50 to 100 MW of solar capacity to compete in the PV market; today they need 2 to 3 GW of capacity to compete.	(2) Rising energy prices increases the manufacturing costs and dampens the level of demand
(4) Higher market concentration in EU than in US and Asia. The observed market prices in several countries contrast with the lowest prices in Germany, where the market is more mature; however that gap is narrowing quickly.	(3) Expected in 2015 recovery of markets and margins after 2011-2013 production overcapacity and oversupply
(5) High competition among manufacturers and installers	(4) Regularly declining FiT

Note: These points are drawn from Chapter 2 primarily.

Conclusion 3: Geographical defragmentation of global PV market increases

Conclusion 3 is based on the following:

Increasing defragmentation	Domination of EU in PV market
(1) Europe is losing a leading market position: China and Taiwan entered the mass production market in 2004 and ramped up a PV industry with strong growth rates. At the end of 2012 their market share was 57 %, or 17 GWp of the 30 GWp 2012 worldwide shipments	(1) Europe contributed 66 % of the total cumulated installations in 2012. In contrast, installations in China and Taiwan accounted for 7 % of the total cumulated installations.
(2) Renewable energy attractiveness is ranked on a country-by-country base: the Energy Payback Time of PV systems is dependent on the geographical location: PV systems in Northern countries need around 2.5 years to balance the inherent energy, while PV systems in the South equal their energy input after 1.5 years and less.	(2) In 2012 Germany accounted for about 32 %, or 32.3 GWp, of the cumulative PV capacity installed worldwide (100 GWp at the end of 2012). By 2012 about 1.3 million PV systems were installed in Germany.
(3) Due to further reductions in European premium incentives, demand in this region will fall to approximately 12 GW, which is of 26% annual decline. In contrast, new policies across leading PV countries in the Asia-Pacific region, led by China, Japan, and India, stimulated regional growth of over 50% and account for more than 11 GW of PV demand in 2013	(3) Diminishing government subsidies mean overall revenues in the European PV solar market will shrink to €6.57 billion by 2015. Several European countries are scaling back the feed-in tariffs, while placing limits on annual capacity additions.

Note: These points are drawn from Chapter 2 and Chapter 3primarily.

Conclusion 4: PV supply chain is a mix of vertically integrated companies and value chain segment specialists, where some companies seek to maintain a competitive advantage in specific technologies or processes and others seek an advantage through risk management or economies of scale and scope

Conclusion 4 is based on the following:

Vertical integration of the Supply Chain	Fragmentation of the Supply Chain
(1) Large-scale global application of PV requires further technology improvements and cost reductions along the value chain (2) Considerable number of PV manufacturers invest heavily in upstream PV power plant construction in order to fully digest their own capacity (3) The number of companies in the first stage of the PV production chain is small, as polysilicon production and processing require intensive technical knowledge and substantial investment. Towards the end of the production chain, the number of manufacturers is larger, due to lower investment requirements and less knowledge-intensiveness required. There are also fully integrated companies combining wafer, cell, and module manufacturing. (4) Most cell manufacturing is integrated with module manufacturing. Integration allows these manufacturers to export at lower cost, compared to other non-integrated module manufacturers; moreover, their market demand is not limited by the capacity of module manufacturers. And since the process technology and equipment are easy to buy, a lot of big cell producers have established their own module production line	(1) Further fragmentation of the supply chain for PV modules and balance-of-systems components is expected across a range of addressable markets due to shifts in geographic access, new and ongoing import trade barriers, and changes in PV application segments. (2) Global trade wars and excessive local manufacturing capacity levels will create micro-environments for PV supply and demand, with each PV supplier serving only a subset of the 31 GW demand total

Note: These points are drawn from Chapter 2 primarily.

Conclusion 5: Lithuanian PV sector is able to sustain competitiveness and viability in different future scenarios, however strategic planning is prerequisite

Conclusion 5 is based on the following:

Scenario	Key success factors
(1) Scenario "Sunny Tomorrow": domination of free market and incremental changes in technology	(1) PV value chain closer to the end-user; Cost effectiveness due to technical innovation in the production process; Strong international marketing and sales skills; Cooperation with other EU countries in R & D, manufacturing, marketing, and other areas; PV part of smart specialisation of Lithuania in EU; High level of professional training of specialists, whose knowledge applicable in PV sector.
(2) Scenario "Broken Walls": domination of free market and radical changes in technology	(2) PV value chain closer to the end-user; Manufacturers are able to adapt to new technologies; Accumulation of technical and financial resources; Close relationship with international research institutions; Able to introduce new technologies to the market; Able to offer an attractive product to global markets; Production efficiency depends on the development of other sectors.
(3) Scenario "Step by Step": domination of regulatory environment and incremental changes in technology	(3) Competitiveness due to enlarged vertical integration; Si-based photovoltaic cells and modules, PV power plant efficiency significantly increased; PV sector is oriented and fills niche markets, to satisfy specific needs of users. Approximate investment needed to sustain competitive advantage:
(4) Scenario "Formula 1":domination of regulatory environment and radical changes in technology	(4) Value chain includes new types of participants from other industries; Cooperation between members of the value chain is significantly enhanced; Cell and module manufacturers adjust their production to new technologies; Close relationship with international research institutions.

Note: These points are drawn from Chapter 4 primarily.

6 ANNEX 1: PHOTOVOLTAIC SUPPLY / VALUE CHAIN AND ACTIVITIES