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COVER PICTURE CREDITS

Solar PV Panels in Montalto Di Castro, Italy; Courtesy: Bianca Barth.

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1. EXECUTIVE SUMMARY

PV GRID is a European project operating in the framework of the Intelligent Energy Europe Programme. It started in May 2012 and has been running for a period of two and a half years. The project consortium is composed of twenty-one partners covering sixteen European countries, coordinated by the German Solar Industry Association, BSW-Solar.

The overall goal of the PV GRID project is to address the regulatory, normative and administrative barriers hampering the integration of Photovoltaics (PV) into the electricity distribution grids in Europe through two main actions:

- **enhancing PV hosting capacity in distribution grids** by favouring the adoption of available technical solutions;
- **assessing national frameworks for PV development** in the participating countries.

Within the PV GRID assessment of national frameworks, the barriers in these processes are presented from the perspective of PV developers, while within the scope of PV GRID's work of enhancing grid hosting capacity, both perspectives, the distribution system operator's point of view and the PV industry's point of view, are taken into account.

The PV GRID European Advisory Paper[1], the main project's deliverable, aims at providing an overview of the issues and barriers that, at both European and national levels, need to be addressed in order to enhance the distribution grid capacity for PV and other distributed generation. A set of recommendations has been proposed in order to overcome these issues, allowing for the implementation of the identified technical solutions.

The assessment results of national frameworks for PV development are documented in the PV GRID database[2].

Enhancing PV hosting capacity in distribution grids

To integrate higher shares of PV and other distributed energy resources (DER) in saturated distribution grids, voltage and congestion limitations need to be overcome by technical measures.

In the first phase of the PV GRID project, a set of appropriate technical solutions were identified. Then the effectiveness of these technical solutions was analysed by involving the expertise of distribution system operators (DSOs) and other electricity sector experts. Based on these results, in a second phase the PV GRID consortium investigated those normative and regulatory actions that may allow a swifter and economical adoption of the identified solutions.

Identification and Prioritisation of Technical Solutions

When it comes to increasing the PV hosting capacity of distribution grids, voltage limitation is the most common constraint. Another limiting factor when increasing the installed PV capacity is the thermal limitation due to high current flow through electrical devices such as transformers. If these local problems are solved by giving DSOs access to flexibility offered through different technical solutions, higher shares of PV can be integrated.

The technical solutions for enhancing PV hosting capacity in distribution grids illustrated in Table 1.1 have been identified by the PV GRID consortium as the most relevant ones for current and future electrical distribution grids.

Depending on where they can be implemented, the technical measures are categorised in DSO, PROSUMER and INTERACTIVE solutions:

- **DSO** solutions are installed and managed on the grid side and do not require any interaction with the consumers or the PV plants;
- **PROSUMER** solutions are installed beyond the point of common coupling and react on loads or generation units, without any communication need with the DSO;
- **INTERACTIVE** solutions require a communication infrastructure linking the hardware located in different grid locations.

1 The PV GRID European Advisory paper is available at http://www.pvgrid.eu/results-and-publications.html

2 The PV GRID database is accessible online at http://www.pvgrid.eu/database/.

Category	Technical solution
DSO	Network Reinforcement
	On Load Tap Changer for MV/LV transformer
	Advanced voltage control for HV/MV transformer
	Static VAr Control
	DSO storage
	Booster Transformer
	Network Reconfiguration
	Advanced Closed-Loop Operation
PROSUMER	Prosumer storage
	Self-consumption by tariff incentives
	Curtailment of power feed-in at PCC
	Active power control by PV inverter P(U)
	Reactive power control by PV inverter Q(U) Q(P)
INTERACTIVE	Demand response by local price signals
	Demand response by market price signals
	SCADA + direct load control
	SCADA + PV inverter control (Q and P)
	Wide area voltage control

Table 1.1 - Summary of technical solutions for congestion management and voltage quality issues

As part of the overall evaluation, cost and benefits of the different solutions were compared by applying an interactive method based on a multi-criteria analysis, complemented by several stakeholder workshops. In a second step, two multi-criteria indicators have been defined for assessing both the cost-benefit and the regulatory priority for each solution. The cost-benefit indicator is based on the three criteria *cost*, *impact on voltage* and *impact on congestion*. The regulatory priority indicator is based on the two criteria *availability of technology and applicability within existing regulations*. Finally, the results for the different countries have been combined for defining a list with three effectiveness levels (high, medium, and low) of technical solutions at European level for the low and medium voltage levels (LV and MV), by involving the expertise of distribution grid operators (DSOs), PV associations and other stakeholders. In general and despite the different levels of effectiveness, the list of solutions has to be seen as toolbox that contains solutions addressing different technical problems. The selection of the best solutions may differ in each planning process, depending on network regional specifics and/or local feeder constraints.

Normative and Regulatory Recommendations

The PV GRID European Advisory Paper aims at providing an overview of the issues and barriers that, at both European and national levels, need to be addressed in order to enhance the distribution grid capacity for PV and other distributed generation. In light of the identified technical solutions, a systematic framework for barrier analysis relating to their application has been created. Furthermore, a set of recommendations aiming at overcoming these issues and allowing for the implementation of the identified solutions has been proposed.

At European level, the following issues are covered:

- Recovery of DSO investments and costs;
- Moving towards "Smart Grids";
- The Eco-design regulation for transformers;
- The necessity to open a debate on curtailment;
- The impact of Network Codes on PV integration in distribution grids;
- The key role of technical standards;

Many of these issues are cross-cutting topics that affect most of the technical solutions.

While addressing the implementation of technical solutions at national level, the following specific challenges have been identified and addressed:

- Rules forbidding RES energy curtailment except for security issues;
- Insufficient self-consumption frameworks;
- Insufficient DSO access to advanced PV inverter capabilities;
- Insufficient framework for prosumer storage solutions;
- Insufficient framework for DSO storage solutions;
- Insufficient framework for Demand Response;
- Incoherent metering frameworks;
- Regulatory frameworks discouraging "Smart Grid" development.

Application at National level: PV GRID Roadmap

Aiming at providing guidance and advice to member states that either anticipate a significant increase in PV penetration or are planning for such an increase, a roadmap for "Increasing PV Hosting Capacity" in a given national context has been developed. Together with the technical solutions the roadmap can be used to identify gaps in the national regulatory and normative frameworks. To this end, it will support member states in their PV and overall renewable energy sources (RES) strategy as it gives an indication whether the technical solutions to increase the hosting capacity of existing grids should be exploited.

Assessment of national frameworks for PV development

The assessment and comparison of national frameworks for first developing and then operating PV systems in sixteen European countries has been achieved by means of an extensive research activity involving fifteen national industry associations. The results of this assessment are disseminated through the online PV GRID database[3] and were presented in a series of national forums organised in each of the participating countries during the spring and summer of 2013.

Procedures and Indicators

The PV GRID database offers a description of administrative procedures and other requirements necessary to authorise, build, connect (to the grid) and operate a PV system in each of the participating countries. The information is presented by means of easy-to-understand flowcharts, and is organised in three separate market segments: residential, commercial, and industrial ground-mounted PV systems.

The description of procedures and requirements is complemented by quantitative indicators, obtained by measuring the hands-on experience of PV developers in the respective countries. An overview of the most significant indicators in each of the participating countries is offered in the following figures.

3 See: http://www.pvgrid.eu/database.html

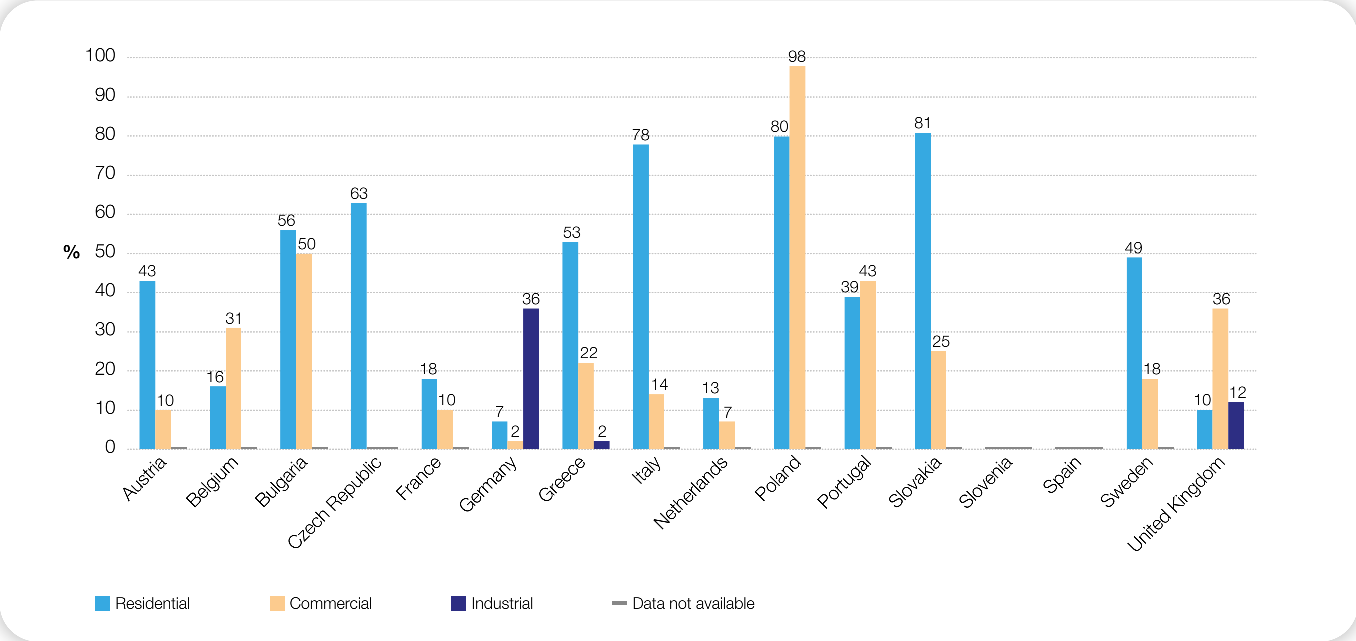

Figure 1.1 - PV project development : Legal-administrative Cost Share

The share of legal-administrative costs over total project development costs (excluding PV equipment and other materials, as show in Figure 1.1) can provide an idea of the economic risks that project developers have to bear in order to secure the authorisations needed to build and connect a PV system. This risk is normally reflected in national PV system prices.

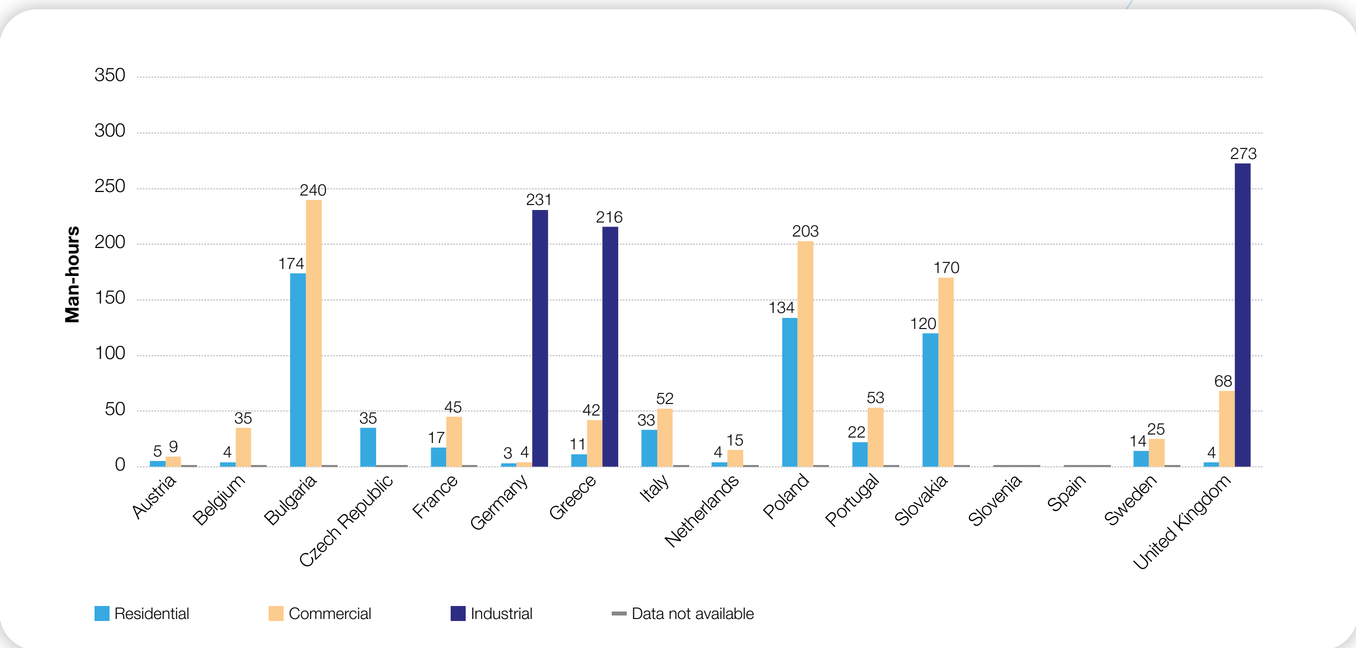

Figure 1.2 - PV project development : Legal-administrative Labour Requirements

The total labour required for accomplishing the permitting and grid connection procedures (as illustrated in Figure 1.2) can serve as a measure of the complexity and to some degree the lack of transparency inherent to these administrative procedures.

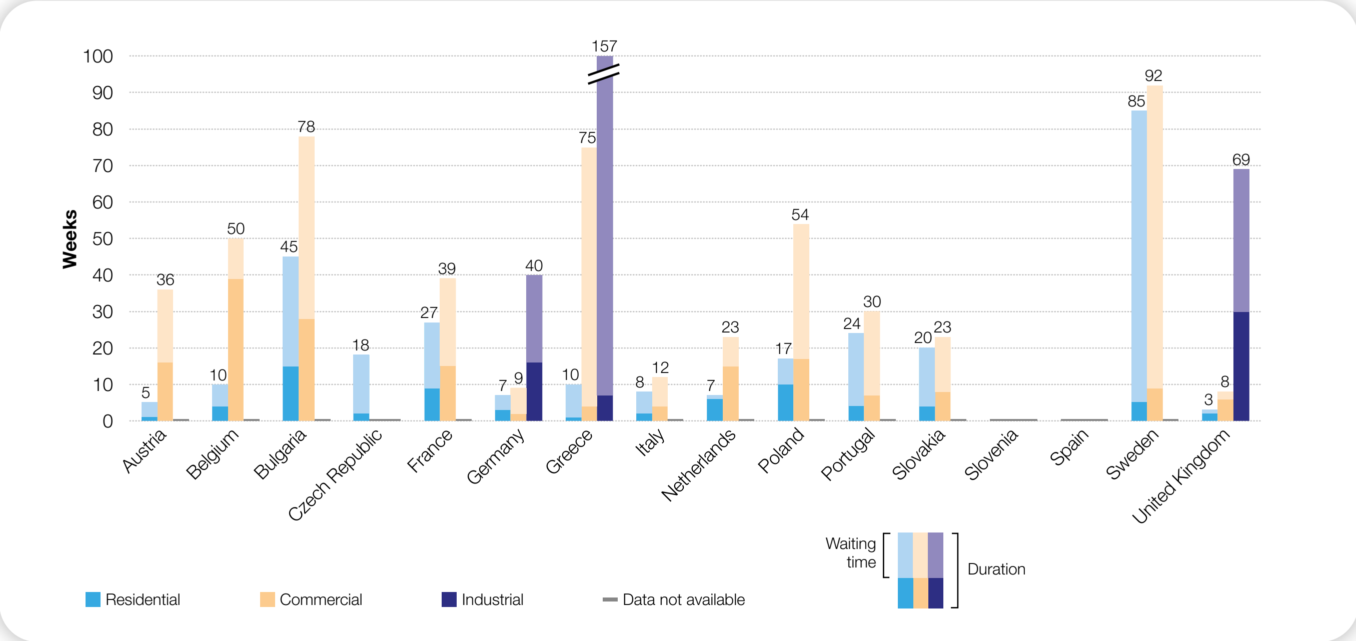

Figure 1.3 - PV project development: Duration and Waiting time

The total duration of the development process for a PV project (as illustrated in Figure 1.3) is another measure of the economic risk faced by investors: the more time it takes to build and connect a PV system, the longer investors are financially exposed without earning revenues.

Barriers

A relevant part of the research carried out in PV GRID deals with the assessment of barriers encountered in the development and operation of PV systems. These barriers have been identified and verified by means of qualitative research and direct communication with PV system developers active in national markets.

The collected barriers have undergone a review process to identify possible similarities and group them in larger categories. As a result, four main categories have been identified:

- **Permitting Procedures**, including barriers involved in those administrative processes necessary to authorise the construction of a PV system: e.g., building permits, environmental impact assessments, electricity production licenses;
- **Grid-related**, including barriers linked to the accomplishment of the grid connection procedures and those dealing with technical grid requirements, grid access or grid capacity issues;
- **Support-related**, including barriers related to regulatory instability and the (arguable) shortage of support schemes;
- **Operation & Maintenance**, including those barriers arising from the instability of support schemes and from administrative or technical requirements for the operation of PV systems.

Conclusions and Outlook

With hindsight and compared to other EU projects, PV GRID had a rather wide scope. This has led to the development of an **overall framework for different categories of technical solutions**, depending on the area of responsibility for implementing them (DSO, Prosumer or both). Furthermore, a **systematic framework for barrier analysis** relating to the application of technical solutions has been created.

Broad recommendations were formulated with respect to overcoming those barriers hampering the application of available technical solutions and adjusting the European and national frameworks in order to support the transition towards integrating higher shares of electricity from PV and other distributed generation facilities.

The barrier analysis framework in combination with the recommendations has also led to the development of an **overall assessment structure pertaining to increasing PV hosting capacity** in a given national context. The so-called **"PV GRID Roadmap"** aims at providing policy makers and other stakeholders with a first and easy indication on where their country is positioned with regards to PV hosting capacity and what needs to be done to actually help increasing penetration levels of PV. The roadmap offers general ideas and advice on how to structure the analysis and then find a course of action, if the national strategy does indeed call for a strong increase in the penetration of PV or of other RES in the distribution networks.

One important lesson learnt from PV GRID is that the process of analysing the current situation will need to be carried out together by all stakeholders, including DSOs, PV industry representatives, policy makers, regulators and other important stakeholders. Applying this inclusive approach will allow for reaching a common ground, developing mutual understanding and helping people to share ways of finding answers to the tough questions regarding the integration of solar into the larger energy delivery system.

A number of other research projects funded by the European Commission are looking into similar issues as those examined and discussed within PV GRID, but with a different focus or perspective. Overall, linking the results of the different projects will be important in the endeavour to develop the electricity networks of the future in Europe enabling high penetrations of a mix of distributed and variables sources, storage and responsive users.

In addition, the transformation of today's electric grid to the future electric grid will require conducting more focused research, data development, and demonstration projects. Last but not least, in an increasingly complex and dynamic environment, the transition will also require improved coordination efforts between all stakeholders participating in the electricity industry and markets.

2. INTRODUCTION

Foreword

In recent years, PV has emerged as a mainstream technology for generating clean and secure electricity in a decentralised fashion, ideally allowing for electricity to be produced on the same premises where it is consumed, albeit often at different times. However, the support schemes that fuelled the growth of PV markets in Europe have in most cases failed to provide the right incentives stimulating the above mentioned match between supply and demand. In this way, large quantities of PV production capacity have often emerged in remote and less densely populated areas, far away from electricity demand, or have been concentrated in other areas in which the development of a PV system was particularly attractive from the economical point of view, due to factors such as abundant solar irradiation, land or roof surface availability.

This unbalanced distribution of PV has, in many countries, generated a series of issues on electricity distribution grids that, as their name reveals, were designed in order to distribute centrally produced electricity to the consumers connected to the grid infrastructure. The resulting power flow direction was clearly defined from generation facilities to consumers and it was for this "one-way" flow that the grids and the grid protection systems were designed. Nowadays instead, with the emergence of PV and other distributed generation facilities, distribution grids often need to work in the opposite direction, transferring decentrally generated electricity to other locations where it can be timely used. This is frequently causing the power to flow back from the prosumer towards the grid infrastructure. As a consequence, since a few years already the hosting capacity of distribution grids has, in certain areas, reached high saturation levels. Such a lack of hosting capacity can either lead to high costs and long waiting times for connecting new PV systems, or in extreme cases to undesirable moratoria completely blocking the development of new PV systems.

The PV GRID project

PV GRID is a transnational collaborative effort in which sixteen national and European solar industry associations, two distribution system operators (DSOs), a policy consultancy, a technical consultancy and a regulatory research institute have collaborated under the umbrella of the Intelligent Energy Europe Programme. The project has been coordinated by the German Solar Industry Association, BSW-Solar.

The overall goal of the PV GRID project was to address the **regulatory, normative and administrative barriers** hampering the integration of PV into the electricity distribution grids in Europe through two main actions:

- the prioritisation of technical solutions available for **enhancing PV hosting capacity in distribution grids** and the formulation of **regulatory and normative recommendations** for their adoption.
- the **assessment and comparison of national frameworks for PV development** in the sixteen participating countries.

Enhancing PV Hosting Capacity in Distribution Grids

The objective of enhancing PV hosting capacity in distribution grids was pursued by an initial **prioritisation of available technical solutions**, analysed by involving DSOs and other electricity sector experts in the four focus countries of the project: Czech Republic, Germany, Italy and Spain. This task mainly built on the experience of two DSOs: ENEL Distribuzione (Italy) and RWE Deutschland (Germany) and was coordinated by DERLab, an association of laboratories and research institutes in the field of distributed energy resources based in Kassel, Germany.

Starting from the most effective solutions identified and the analysis of the barriers to their implementation in national markets, the project consortium has formulated a set of **European-wide regulatory and normative recommendations**. The initial set of recommendations was discussed at national and European level during a series of high level workshops involving DSOs, transmission system operators (TSOs), electricity regulators, national authorities and the PV sector. Based on the workshops outcomes, the barrier analysis and recommendations have been fine-tuned and presented in the PV GRID European Advisory Paper, published in July 2014. The Institute for Research in Technology of the Madrid-based Comillas Pontifical University coordinated the development of this publication. The Advisory Paper also features, in its annexes, eight national case studies further detailing the barrier analysis and recommendation in the four focus countries and other four promising PV markets: France, Greece, the Netherlands and the United Kingdom.

The main achievements of this process are documented in detail in section 3 of this report.

Assessment of National Frameworks for PV Development

The assessment and comparison of national frameworks for developing and then operating PV systems in sixteen European countries was achieved by means of an extensive research activity involving fifteen national industry associations and coordinated by the policy consultancy Eclareon GmbH, based in Berlin, Germany. The results of this assessment, initially presented within a series of national forums that took place during the spring and summer of 2013, are available through the online PV GRID database, which has been regularly updated over the duration of the project.

The outcome of this assessment is documented in section 4 and 6 of this report.

National and European Level Communication

The national and European level communication activities for the dissemination of the project's results are coordinated by EPIA, the European PV Industry Association based in Brussels, Belgium.

3. ENHANCING PV HOSTING CAPACITY IN DISTRIBUTION GRIDS

As discussed in the introduction, PV GRID's main focus was on the challenges linked to the integration of high shares of PV electricity into the distribution grid infrastructure. The main goal was to prepare the grounds for large-scale integration of PV systems into the distribution grids across Europe.

Throughout the duration of the project, PV GRID project partners and external experts have collaborated in researching, analysing and discussing solutions on a trans-national level. The main tasks have been to:

- Review and evaluate the **most appropriate technical solutions for integrating PV systems** into the distribution grid infrastructure;
- **Recommend normative and regulatory changes** that allow for swifter and economic implementation of these solutions.

The **regulatory and normative recommendations** address barriers and other obstacles that either DSOs or PV operators have to face when adopting technical solutions that would instead allow for higher grid hosting capacity. For instance, a certain national regulatory framework may not allow a DSO to recover the costs of necessary grid-enhancing investments. Also, a PV system operator may not be correctly incentivised (by means of network fees for instance) to make an efficient use of the distribution grid.

3.1. Prioritising Technical Solutions for PV Integration

Technical Problems and Barriers to PV Integration

In order to identify technical solutions for increasing the hosting capacity of distribution grids towards the integration of high shares of PV, initially the project consortium needed to frame the problems a power system has to cope with in such a context. These problems can be grouped in four categories: **frequency stability, voltage quality, fault conditions** and **congestion management**.

However, dealing with frequency stability and fault conditions aspects would require a full system picture also including the transmission grid level, which is out of the PV GRID project's scope, whose main focus is instead on the distribution grids.

Therefore, only those technical solutions having an impact on **voltage quality** and local **congestion management** have been considered in the framework of PV GRID.

Technical Solutions for PV Integration

For the purpose of assessing the state of the art of technical solutions addressing the aforementioned issues, the project consortium collected several documents mainly originating from national, European and international R&D projects, grid codes and technical standards. In order to complement the project consortium's expertise, several external experts were selected amongst stakeholders of the European electricity sector: representatives of TSO, DSOs, inverter and storage manufacturers. Technical solutions variants and combinations were discussed in depth through a series of project workshops, in order to reach a large consensus between stakeholders.

The results of this process are listed in Table 3.1. The table presents the list of technical solutions that potentially can increase the hosting capacity in distribution grids. As already mentioned, only those technical solutions having an impact on voltage quality and local congestion management were considered.

Category	#	Technical solution
DSO	1	Network Reinforcement
	2	On Load Tap Changer for MV/LV transformer
	3	Advanced voltage control for HV/MV transformer
	4	Static VAr Control
	5	DSO storage
	6	Booster Transformer
	7	Network Reconfiguration
	8	Advanced Closed-Loop Operation
PROSUMER	9	Prosumer storage
	10	Self-consumption by tariff incentives
	11	Curtailment of power feed-in at PCC
	12	Active power control by PV inverter P(U)
	13	Reactive power control by PV inverter Q(U) Q(P)
INTERACTIVE	14	Demand response by local price signals
	15	Demand response by market price signals
	16	SCADA + direct load control
	17	SCADA + PV inverter control (Q and P)
	18	Wide area voltage control

Table 3.1 – Summary of technical solutions for congestion management and voltage quality issues

As some of these technical solutions may be applied for both voltage quality and congestion management problems, they have been classified in the following three categories:

- **DSO** solutions that are implemented within the grid operator infrastructure and require no communication with the consumer (or prosumer);
- **PROSUMER** solutions which are implemented within the consumer (or prosumer) infrastructure and require no communication with the grid operator;
- **INTERACTIVE** solutions that are implemented within both the grid operator and the prosumer infrastructures and where the different components react based on signals exchanged via a communication infrastructure.

DSO solutions

- **Network reinforcement** - Further grid hosting capacity is provided by additional cable and transformer capacity installations.
- **On Load Tap Changer (MV/LV transformer)** - The OLTC device is able to adjust the lower voltage value of an energized transformer.
- **Advanced voltage control (HV/MV transformer)** - This solution includes new control methods for existing HV/MV transformers with already installed OLTC.
- **Static VAR Control** - Utilizing Static VAR Compensators (SVC) enables to provide instantaneously reactive power under various network conditions.
- **DSO storage** - Storing electricity with a central storage situated in a suitable position of the feeder enables to mitigate voltage and congestion problems.
- **Booster Transformers** - Boosters are MV-MV or LV-LV transformers used to stabilize the voltage along a long feeder.
- **Network Reconfiguration** - Revising network operational conditions by reconfigurations, in particular the boundaries between feeders in MV networks, is a method to enhance the voltage profiles in distribution networks.
- **Advanced Closed-Loop Operation** - Two feeders are jointly operated in a meshed grid topology controlled by a Smart Grid architecture to decrease the circuit impedance while increasing the short circuit power.

Prosumer solutions

- **Prosumer Storage** - Storing electricity at prosumer level enables to mitigate voltage and congestion problems if a reduction of the feed-in peaks can be ensured.
- **Self-consumption by tariff incentives** - With a fixed tariff structure (e.g. feed-in price lower than consumption price), the prosumer is motivated to shift its electricity consumption in order to reduce its injected PV energy. A maximum feed-in power based tariff (e.g. kWh price set to zero or to negative values above some feed-in power limits) could further help in reducing injected PV peak power.
- **Curtailment of power feed-in at PCC** - The meter at the customer's site controls that the feed-in power is never above the contracted maximum power or above a fixed value (e.g. 70% of the installed PV capacity as implemented in the German Renewable Energy Act). This solution requires the meter to be able to control down the PV production or to activate a dump load.
- **Active power control by PV inverter P(U)** - Voltage and congestion problems can be solved by curtailing the PV feed-in power. Contrary to the fixed power curtailment as described in previous solution the LV grid voltage is used as an indicator for the grid situation and for the curtailment level.
- **Reactive power control by PV inverter Q(U), Q(P)** - Providing reactive power as a function of the local voltage value [Q=Q(U)] or as a function of the active power production [Q=Q(P)], limits the voltage rise caused by distributed generators.

Interactive solutions

- **Demand response by local price signals** - Demand response is triggered by local price signals available only to consumers located in feeders that experience voltage and/or congestion problems.
- **Demand response by market price signals** - Demand response is triggered by electricity market price signals, which are identical for consumers wherever they are located.
- **SCADA + direct load control** - In critical grid situations, DSOs or energy aggregators are allowed to remotely activate (or curtail) dedicated consumer loads, based on agreed contract.
- **SCADA + PV inverter control (Q and P)** - The level of reactive power provision and the active power reduction of dedicated PV inverters are remotely controlled by a feeder supervisory control system.
- **Wide area voltage control** - All controllable equipment (like transformers with OLTC, static VAR compensators, dedicated loads and PV inverters) are coordinated to optimize voltage and power factor in the whole DSO area. Smart grid technologies are applied to measure the voltage and power factor at several points, controlling the equipment, coordinating and optimizing the generation and load.

Prioritisation of Technical Solutions

Once different possible technical solutions for increasing the grid hosting capacity were identified, the following objective was to define a list of most effective technical solutions at European level, by involving the expertise of DSOs, PV associations and other stakeholders. It was decided to apply an iterative method based on a multi-criteria analysis, discussed and agreed during a series of project workshops.

In a second step, utilising the evaluation results obtained in the first step, two multi-criteria performance indicators were defined for assessing both the techno-economic and the regulatory priority for each solution:

- **techno-economic indicator**, based on the three criteria: *investment cost*, *impact on voltage* and *impact on congestion*, opportunely weighted in order to represent the current priorities for DSOs;
- **regulatory priority indicator**, which indicates if the implementation of a technical solution is facing a regulatory barrier and how urgent it is to remove this regulatory barrier. This indicator is defined as in Table 3.2.

Regulatory Priority Index	Technology available?	Regulation needed?	Meaning
1	YES	YES	Adoption of solution requires regulatory development
2	NO	YES	Adoption of solution requires regulatory and technology development
3	NO	NO	Technology is not mature
4	YES	NO	Solution can be applied where problems occur

Table 3.2 - Regulatory priority indicator

Finally, the results of the techno-economic indicator for the different countries were combined in order to define a ranked list of technical solutions at European level for two grid types (LV and MV). An additional consultation with the PV industry and other stakeholders involved in the electricity sector was organized during a final consultation workshop. These stakeholders were represented by PV industry associations participating to the project and invited external experts selected from research institutes, DSOs, TSO, inverter and storage manufacturers. Based on the outcome of this last consultation round, the ranking of technical solutions was finally adjusted. The results for the techno-economic indicators were aggregated in two preference lists (one for each voltage level) with three effectiveness levels (high, normal and low) in order to better reflect the position of all stakeholders. These preference lists are illustrated in Table 3.3 and Table 3.4.

Prioritisation results for LV grids

Table 3.3[4] presents the final evaluation results based on the stakeholder consultation. The list of high effectiveness solutions includes two DSO solutions (the classical network reinforcement and the new product OLTC for MV/LV transformers) and four PROSUMER solutions (storage, reactive power provision by PV inverters and the two curtailment variants of PV power). No regulatory barriers have been identified for the DSO solutions (green colour in table). However, regulatory barriers are present for PROSUMER solutions. In the low effectiveness category, solutions gathered are based on electricity price signals, also including the sophisticated closed loop operation and solutions less relevant to this voltage level.

Effectiveness of solutions	Technical solution	CZ	DE	ES	IT
HIGH EFFECTIVNESS	Curtailment of power feed-in at PCC	Red	Red/Green (striped)	Red	Red
	Network Reinforcement	Green	Green	Green	Green
	Reactive power control by PV inverter Q(U) Q(P)	Red	Green	Red	Green
	Active power control by PV inverter P(U)	Red	Red	Red	Red
	Prosumer storage	Red	Green	Red	Green
	On Load Tap Changer for MV/LV transformer	Green	Green	Green	Green
NORMAL EFFECTIVENESS	SCADA + direct load control	Red	Red	Red	Red
	Network Reconfiguration	Green	Green	Green	Green
	Self-consumption by tariff incentives	Green	Green	Red	Red
	Wide area voltage control	Yellow	Yellow	Green	Yellow
	Static VAr Control	Green	Green	Green	Green
	Booster Transformer	Green	Green	Green	Green
	SCADA + PV inverter control (Q and P)	Yellow	Red	Yellow	Yellow
	DSO storage	Red	Red	Red	Red
LOW EFFECTIVENESS	Demand response by local price signals	Red	Red	Red	Red
	Advanced voltage control for HV/MV transformer	Green	Green	Green	Green
	Demand response by market price signals	Yellow	Yellow	Yellow	Red
	Advanced Closed-Loop Operations	Grey	Green	Yellow	Grey

- Red: Adoption of solution requires regulatory development
- Yellow: Adoption of solution requires regulatory and technology development
- Green: Solution can be applied where problems occur
- Grey: Technology for the solution is not mature

Table 3.3 - Priority list of technical solutions for LV grids

4 As curtailment is legally possible in Germany under the Renewable Energy Sources Act (EEG), but is considered to be an exemption from the DSO's general duty to provide capacity and to enhance the grid infrastructure, German members of the PV Grid consortium opted for a "green/red" indication, i.e. curtailment can be applied if problems occur, however, a more general adaption of the solution requires regulatory development. Cf. the extensive discussion of the curtailment issue within the German context in Annex I of the European Advisory Paper.

Prioritisation results for MV grids

Table 3.4[5] presents the final evaluation results based on the stakeholder consultation. The list of most effective solutions includes three DSO solutions (the classical network reinforcement, OLTC for HV/MV transformer and network reconfiguration), three PROSUMER solutions reactive power provision by PV inverters and curtailment variants of PV power) and one INTERACTIVE solution (supervised control of PV active and reactive power). No regulatory barriers have been identified for the DSO solutions (green colour in table). However, regulatory barriers are present for PROSUMER solutions (red colour in table, with exception of autonomous reactive power control in Germany). In the low effectiveness category, solutions gathered are based on electricity price signals, including also the sophisticated closed loop operation.

Effectiveness of solutions	Technical solution	CZ	DE	ES	IT
HIGH EFFECTIVNESS	Network Reinforcement	Green	Green	Green	Green
	Reactive power control by PV inverter Q(U) Q(P)	Red	Green	Red	Green
	Curtailment of power feed-in at PCC	Red	Green/Red (hatched)	Red	Red
	Active power control by PV inverter P(U)	Red	Red	Red	Red
	Network Reconfiguration	Green	Green	Green	Green
	SCADA + PV inverter control (Q and P)	Red	Red	Red	Red
	Advanced voltage control for HV/MV transformer	Green	Green	Green	Green
NORMAL EFFECTIVENESS	Static VAr Control	Green	Green	Green	Green
	SCADA + direct load control	Yellow	Yellow	Red	Red
	Self-consumption by tariff incentives	Green	Green	Yellow	Red
	Wide area voltage control	Yellow	Yellow	Green	Yellow
	DSO storage	Red	Red	Red	Red
	Prosumer storage	Red	Green	Red	Green
LOW EFFECTIVENESS	On Load Tap Changer for MV/LV transformer	Green	Green	Green	Green
	Booster Transformer	Green	Green	Green	Green
	Demand response by local price signals	Red	Red	Red	Red
	Demand response by market price signals	Yellow	Yellow	Yellow	Red
	Advanced Closed-Loop Operations	Grey	Green	Yellow	Grey

- Red: Adoption of solution requires regulatory development
- Yellow: Adoption of solution requires regulatory and technology development
- Green: Solution can be applied where problems occur
- Grey: Technology for the solution is not mature

Table 3.4 - Priority list of technical solutions for MV grids

5 As curtailment is legally possible in Germany under the Renewable Energy Sources Act (EEG), but is considered to be an exemption from the DSO's general duty to provide capacity and to enhance the grid infrastructure, German members of the PV Grid consortium opted for a "green/red" indication, i.e. curtailment can be applied if problems occur, however, a more general adaption of the solution requires regulatory development. Cf. the extensive discussion of the curtailment issue within the German context in Annex I of the European Advisory Paper.

3.2. Normative and Regulatory Recommendations: The PV GRID European Advisory Paper

The PV GRID European Advisory Paper[6], the main project's deliverable, aims at providing an overview of the issues and barriers that, at both European and national levels, need to be addressed in order to enhance the distribution grid capacity for PV and other distributed generation. A set of recommendations is proposed in order to overcome these issues, allowing for the implementation of the identified technical solutions. The document deals first with issues and recommendations at European level, covering the following topics:

- Recovery of DSO investments and costs;
- The moving towards an "Smart Grid";
- The Eco-design regulation for transformers;
- The necessity to open a debate on curtailment;
- The impact of Network Codes on PV integration in distribution grids;
- The key role of technical standards;

Many of these issues are cross-cutting topics that affect most of the technical solutions.

Successively, the implementation of technical solutions at national level is addressed, identifying challenges and recommendations. The specific challenges identified have been:

- Rules forbidding RES energy curtailment except for security issues;
- Insufficient self-consumption frameworks;
- Insufficient DSO access to advanced PV inverter capabilities;
- Insufficient framework for prosumer storage solutions;
- Insufficient framework for DSO storage solutions;
- Insufficient framework for Demand Response;
- Incoherent metering frameworks;
- Regulatory frameworks discouraging "Smart Grid" development.

Finally, the European Advisory Paper features eight national case studies on focus countries and other key European markets, summarising the PV market and grid integration statuses in those countries, as well as the main barriers and the recommendations to overcome them.

Barrier Assessment

In order to establish which of the barriers identified in the European advisory paper occur in participating European countries, the PV GRID consortium has also undertaken a basic research of existing studies at European level, and conducted a short barrier assessment survey. The barrier assessment has been carried out in 15 European countries that were represented by a national partner (typically a PV industry association) within the PV GRID project. These countries are namely Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Greece, Italy, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden and United Kingdom.

This barrier assessment was initiated with an on-line survey that was prepared in July 2013. The survey was completed by national PV associations (based on their knowledge of national frameworks), and often (but not always) with support from regulators, DSOs, TSOs and consultancies in the concerned countries. This initial version had simple yes or no answers, and didn't allow the partners to specify all the details of each country. Therefore, at the project meeting in London in October 2013 all partners agreed to collect another version with the possibility to include more detailed answers. This revised version was provided to all partners in November 2013, and the first results were collected in November and December 2013.

6 The PV GRID European Advisory paper is available at http://www.pvgrid.eu/results-and-publications.html

The process continued with several revisions and comments from Comillas, Eclareon, BSW-Solar and EPIA which were addressed by the national associations. Furthermore, each survey was vetted with participants of national consultation workshops (or bilateral meetings) and was adjusted according to the feedback received. In June 2014 the final versions of the barrier assessment were collected, and finally the results are presented as an annex of the European Advisory Paper.

The barrier assessment addresses the current barriers with respect to the following topics:

- **DSO investment recovery.** Significant delay between the moment of investment and the moment they are remunerated for such investment; DSOs not efficiently remunerated for their incurred investments.
- **Grid connection charges and network tariffs.** Type of connection charges; agent responsible for calculating the connection charges; not simple or transparent rules; connection charge unknown before requesting the connection.
- **RES priority access and PV Curtailment.** PV curtailment accepted only for emergency situation; DSOs not operating PV curtailment for violation of technical constraints (congestions and voltage control).
- **Self-consumption framework.** Self-consumption of PV energy not allowed, no direct or indirect incentives; no net-metering.
- **DSO access to advanced inverter capabilities.** DSOs without the rights to use or impose functions to PV inverters; no direct control over the inverter.
- **Prosumer storage framework.** Not allowed and/or not incentivised.
- **DSO storage framework.** Not allowed.
- **Demand response framework.** DSO not contracting demand response services with customers; no load activation services; retailers not offering the option of contracting demand response services; communication system not defined.
- **Metering framework.** Countries with no 80% target on smart meters for 2020; smart meters not installed on PV systems.
- **"Smart Grid" Incentivising framework.** No incentives to smart grids; networks not periodically monitored.

Cross-cutting challenges

The current European directives limit the possibility of **RES curtailment** to system security or security of supply reasons, and force grid operators to take grid measures to minimize the curtailment of electricity produced from renewable energy sources. However, one of the results of the discussions in this project is that curtailment is a technical solution which can make sense from a global economic point of view if the compensation to the PV agent for curtailment is lower than the cost of the reinforcements required for preventing it. Otherwise the network should be expanded or reinforced.

For this solution to be applied, it is necessary to open a fair debate on the use of curtailment of PV electricity. This debate should cover the determination of 1) a national cost-benefit analysis methodology, 2) boundary conditions and 3) adequate compensation rules for the PV agent. DSO driven curtailment should only be considered when congestion or voltage problems arise in the local network and when all other available measures have been evaluated and utilized if possible. In any case curtailment should be kept as low as possible. An example of a quantitative indicative measure is that for instance it should not exceed 5% of the annual production of each single installation. Although identified as a technical solution, it is possible that curtailment can put RES market growth at risk, bringing investment insecurity. To prevent this, it should only apply to new installations.

A review of **EU network codes** (NC) has been carried out to evaluate their consequences on the technical solutions, as they may affect most of them. It has been concluded, that as many prescriptions contained in EU NCs are non-exhaustive, practical implementation details should be agreed upon at national level within a coordinated EU-wide process involving DSOs, PV and other RES/DG associations. Besides, technical capabilities defined in the NC RfG should be further defined in standards developed within CENELEC. Such standards should be applied by all Member States when implementing the NC. Also, the following details have been highlighted:

- The revision of the standard on technical requirements for connection and operation of micro-generators and their protection devices up to and including 16A should be accelerated;
- Technical specifications for connection and operation of micro-generators and their protection devices above 16A should be turned into standards;
- Standards for testing and product certificates should be developed *ex-nihilo* as soon as possible;
- As possible anti-islanding defense actions (triggered by the use of certain PV capabilities prescribed in the NC RfG) may differ according to the operational criteria and protection schemes of MV and LV networks, scrutiny of present prescriptions set by each national regulatory authority at national level might be appropriate.

Another common topic to be addressed for all the technical solutions is that the **DSO** has to be **remunerated** for their **investments** in implementing these technical solutions. In particular, general regulatory principles suggest that DSOs should be efficiently remunerated for their incurred investments. Although this is not easy to determine, it should be the objective we should aim for. National regulators should adjust DSOs' investment and cost recovery schemes so as to encourage the investments needed for the decentralisation of the energy system and the roll-out of technical solutions enhancing grid integration of PV and other smart grid investments. In order to diminish DSOs' risks, the delay between the moment in which an investment in equipment is made and the moment in which the cost incurred for the investment is recovered via allowed revenues should be shortened. In particular, the evolution of the existing grids involving more distributed energy resources is demanding an increasing use of communication infrastructures, reducing the costs that conventional reinforcements would otherwise require. In this case the DSO revenue framework is critical. While preserving national specificities, guidance at European level should foster the transformation of national schemes into more smart grid-oriented frameworks.

Specific barriers

As a result of a literature research, a set of technical solutions have been identified within PV GRID project. Some of the prosumer and interactive solutions require controlling the PV installation, either in terms of active or reactive power. In the case of interactive solutions, the necessity of allowing the **DSO** some kind of **control** over the **PV inverter** appears essential. This control can range from more invasive solutions, such as direct control, to more moderate approaches, such as allowing the DSO to set or impose functions on the PV inverters. In any case, it appears necessary that, if advanced technical solutions are available in the PV inverter[7], the DSO shall have access to them, so that they can be really used for solving congestions or voltage issues in the distribution grids. In this case, the boundary conditions for using these solutions must be clearly defined by the competent national authority. There is a trade-off between the mandatory requested capabilities that can be imposed on the PV inverter (set by grid codes) and the capabilities that can be offered on a voluntary basis in exchange for an economic compensation. For example, as commented in the Spanish case study, it should be avoided that this technical requirements turn out to be a barrier to small PV installations. So it may be the case that small size PV installations (for which the benefits of this control are lower) could be exempt from this obligation and provide it instead on a voluntary basis. On the other hand, the control of the PV inverter could also be useful to TSOs and energy providers, so, when defining this control, it is also essential to avoid conflicts of interest among all these agents.

A **"smart grid"** can bring about many advantages, such as a more sustainable, efficient and secure electricity supply to customers. However, each of these benefits is accompanied by significant costs related to the purchase, the operation and maintenance of the required components, and the management of the information and communication infrastructure associated with them. Careful consideration of both costs and benefits will be required. National regulators should discuss with all relevant stakeholders the adaptation of national regulatory frameworks in order to concretely promote "smart grid" investments. A stable and transparent regulatory framework (avoiding frequent changes), and an ex-ante approach should also be established in order to favor such evolution. If the conclusion of careful analysis suggests the implementation of smart grids to support integration of renewables and where necessary, explicit (pecuniary) incentives should also be established. Incentives can apply to innovative projects in smart grids, approved by the national regulators. These incentives in pilot projects can be useful for making the technology ready for broad adoption, but they are not sufficient for achieving the recovery of this type of investments by the DSO. In case that these incentives are to be generalized, it would be required to clearly define a "smart grid" in terms of what are the services it has to provide, and (in the cases in which such a fixed list of equipment exists) its architecture and components.

In particular, deploying and using **smart meters** can be seen as a first stage towards smart grids. Although smart meters are not considered as a technical solution by themselves, they are at least an enabler to some of the technical solutions identified within PV GRID. Where a cost-benefit analysis on the deployment of smart meters has not been carried out yet, as foreseen by the European Directive 2009/72/EC, it should be rapidly performed at national level. The consortium has also raised the potential benefits of having smart meters installed at PV plants and not only for consumers. In countries where the roll-out of smart meters has so far been focused only on consumption meters, it should be analyzed whether DG installations could also be equipped with these devices. For smart meters deployed on DG, it should be ensured that their potential is used for implementing telemetry and other applications, increasing the hosting capacity of the distribution network. However, mandatory introduction of intelligent metering systems should be assessed carefully. It may be the case that installing the required intelligent infrastructure is only viable with large PV installations.

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7 This is often the case nowadays as inverter series are produced for a continent and the grid functions are disabled based on the requirements at the national level.

Two other technical solutions identified are **demand response** by either local price signals or by market price signals. When demand response is triggered by market price signals, a global price signal for all prosumers will not allow distinguishing between the different local situations in the distribution grid. Therefore demand response by local price signals is more appropriate for grid integration issues. Technical features and market models for Demand Response should be assessed taking into account that they are related to wider objectives than the mere integration of DG. While they may have important side effects on DG hosting capacity, the main focus of Demand Response must be on the benefits on the customers' side. Market model-neutral enabling factors, such as the communication between DSO and final customers, can and should be defined as soon as possible. For instance, the "traffic light concept" as it is currently discussed throughout Europe is a good starting point. When focusing on DG integration, load activation is more useful than load interruption, although less common. DSOs should be allowed to manage load reduction and activation services in order to fully utilize any demand-side management potential. In any case, a compensation scheme for users participating voluntarily in demand response and load reduction services should be discussed and put in place.

An alternative to demand response for reducing the power flows is **self-consumption**. Self-consumption can bring benefits to the whole system, since it reduces the electricity that needs to be distributed or transmitted through the grid. These benefits are at their best if the overall peak power demand is reduced either globally or locally, since distribution and transmission networks have to be sized for the peak scenario. However, it has to be pointed out that self-consumption only allows reducing the local peaks to the extent that generation is encouraged to be located closer to the load points. Once the DG is installed, the physical power flows are the same regardless of the metering scheme (unless prosumer storage is installed or demand response is applied). Countries not having a self-consumption framework in place should consider legislation for allowing it. In addition, economic incentives stimulating PV electricity self-consumption to contribute to network operation (reducing peaks) should be assessed.

From the PV GRID perspective, connection solutions and processes for individual PV agents can be simplified if, and only if, "dependable" self-consumption[8] behaviour is available. In this respect, self-consumption obligations should be introduced with the aim of reducing electricity injection peaks in order to ease the grid connection and overall grid capacity requirements.

As commented, the benefits of self-consumption are at their best when the peak power demand is reduced. In order to ensure this, storage could be a rather interesting option, when the costs turn affordable for these uses. Theoretically, there could be at least two alternatives. The storage could be installed on the prosumer side or on the DSO side. Where they are currently forbidden, national regulatory frameworks should allow **prosumer storage** solutions. In order to avoid technical problems, the connection and operation requirements currently under discussion should ensure that prosumer storage does not pose a security problem to the system or interfere with the metering of DG production. Explicit mechanisms should be established for supporting prosumer storage solutions, when these are applied to reduce the peaks of PV installations. For the other alternative, **DSO storage**, there is currently an enormous barrier represented by the unbundling of activities, which prevents the DSO from using storage, as it is usually considered a market interfering activity. Although recognizing the importance of such a restriction, a solution should be found so as to allow DSOs to make use of such a technical solution. Given the network operation benefits potentially brought about by DSO storage, national regulators should reflect on how to activate this potential. Roles, rights and limitations of DSOs (and TSOs) in the use of storage must be clearly defined by the national regulating authorities.

3.3. Application of PV GRID Recommendations at national level

PV GRID Roadmap

Aiming at providing guidance and advice to member states that either anticipate a significant increase in PV penetration or are planning for such an increase, a roadmap (shown in Figure 3.1) for "Increasing PV Hosting Capacity" in a given national context has been developed. Together with the technical solutions and the recommendations developed in the project, the PV GRID roadmap can be used to identify gaps in the national regulatory and normative frameworks. To this end, it will support member states in their PV and overall RES strategy, as it provides a structured approach to determining whether the technical solutions to increase the hosting capacity of existing grids should be exploited.

8 Self-consumption on a voluntary basis cannot lead to a simplification of connection solutions at local level, due to the unpredictability of user consumption behaviours. Therefore, this also means that a widespread self-consumption implementation scenario will not significantly enhance the grid connection process, unless it is opportunely combined with the obligation not to inject within the grid a significant part of the PV production. In particular, boundary conditions for self-consumption obligations should be aimed at reducing the peaks of electricity injection in order to ease the grid connection and overall grid capacity requirements. This way, self-consumption becomes a more reliable technical solution and can potentially be taken into account by DSOs in their planning principles and procedures.

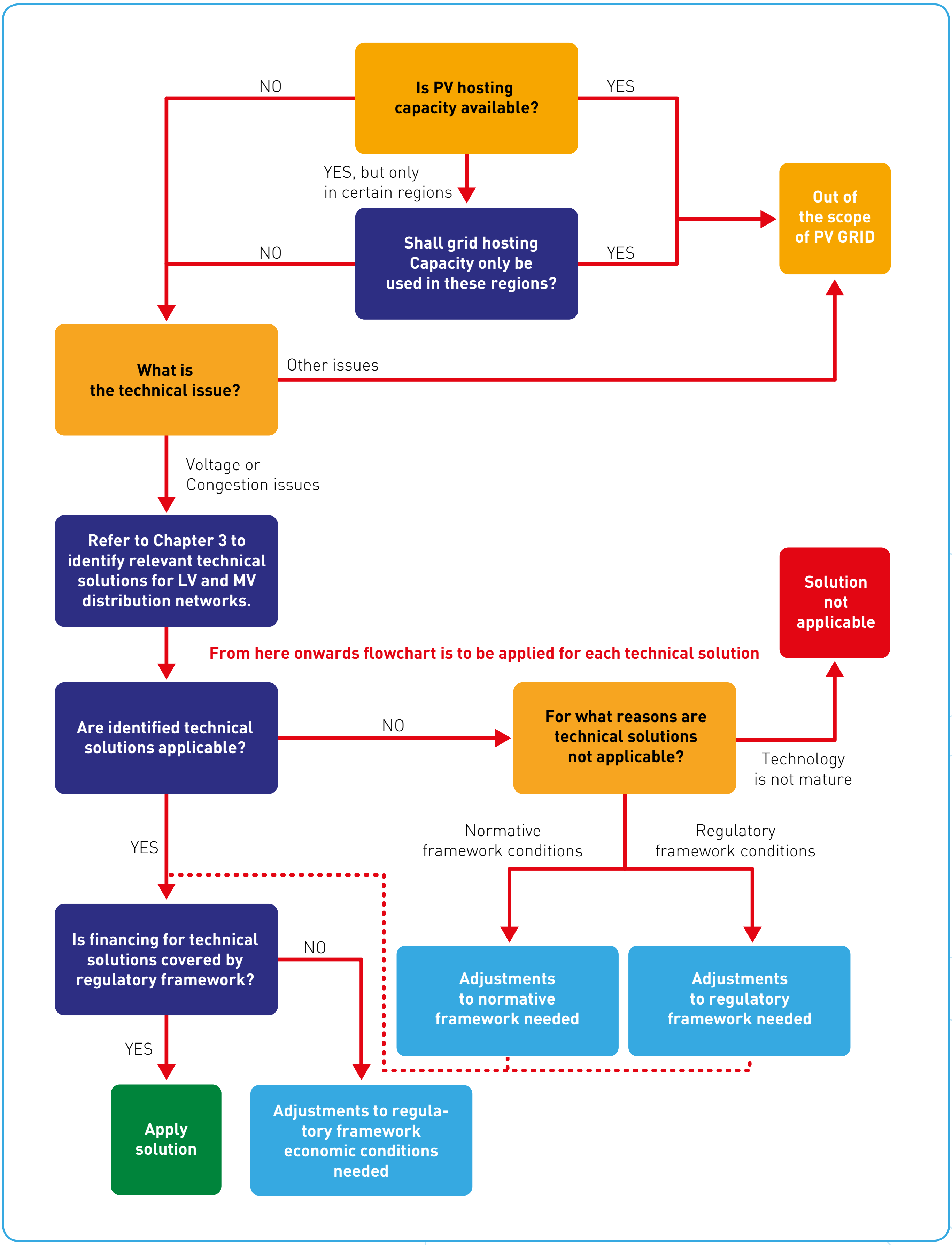

Figure 3.1 - PV GRID roadmap for applying the technical solutions

According to the roadmap, first of all and based on a country's RES goals and policies for increasing PV penetration, it has to be determined if is there a need for action regarding the distribution grid hosting capacity. If so, policymakers need to determine whether PV is supposed to be installed uniformly distributed, or only in certain regions. It is highly recommendable to base this decision upon broad stakeholder input. In case available regional hosting capacities should be used first, it may be necessary to introduce regulatory and normative steering instruments offering incentives for PV systems in those regions with grid hosting capacity available.

If not enough grid hosting capacity is available, stakeholders need to identify why capacity is limited and on which voltage level. PV GRID addresses two main problems: voltage and congestion. Other problems are out of the project's scope and hence, not addressed.

Subsequently, DSOs in collaboration with other stakeholders need to check which of the technical solutions identified by PV GRID best suit the task of handling the particular situation in a certain region or country, thereby identifying the optimal mix of solutions to address the problems. It needs to be checked whether those solutions are actually applicable. This step involves the analysis of the barriers outlined in section 3.2 to determine whether technical solutions are easily applicable or not. If not, necessary changes in the normative and/or regulatory framework conditions need to be identified and all stakeholders should work together towards implementing them.

The final test is whether the most suitable solutions identified above can be financed, either by DSOs or by other stakeholders (e.g., prosumer storage solutions by consumers). Are existing financial incentives sufficient to stimulate the application of technical solutions? If not, stakeholders should work together towards adjusting the regulatory framework setting the economic conditions in order to allow for adequate financing to apply the optimal mix of technical solutions.

4. ASSESSMENT OF NATIONAL FRAMEWORKS FOR PV DEVELOPMENT

4.1. Research on National Administrative Frameworks

Supplementary to enhancing PV hosting capacity in distribution grids by favouring the adoption of available technical solutions, another area of PV GRID's research activities focused on the administrative frameworks for PV system development and operation in sixteen European countries. The primary research objective was to describe, both qualitatively and quantitatively, the procedures and requirements involved with the permitting, installation, connection to the grid and operation of a PV system. As a consequence, the research allows for identifying those barriers that investors and project developers face when setting up a PV project. Furthermore, the research aims at providing results in a standardised format, making them comparable across countries.

National PV markets are analysed focusing on three PV market segments: **residential systems** (PV systems up to 1 kWp in size), **commercial systems** (up to 1 MWp in size) and **industrial ground-mounted systems** (over 1 MWp in size). For the purpose of the analysis, the PV project development lifecycle is broken down into ten standard processes, which are then analysed both qualitatively and quantitatively:

1. **Site Selection:** the acquisition of the project site and any other action needed to make it legally suitable for further project development activities;
2. **Electricity Production Licence:** all actions necessary in order to obtain the license to produce electricity. This license may have different names, such as electricity generation license or exploitation authorization;
3. **Administrative Process:** all necessary administrative authorisation activities - such as the application for building or environmental permits - that need to be completed before the construction of the PV installation may start;
4. **Grid Connection Permit:** the formal procedure to obtain the permission to connect the PV installation to the grid;
5. **Support Scheme(s):** the formalities that must be taken care of in order to receive the most important support schemes for PV installations such as a feed-in tariffs or quota systems;
6. **PV System Construction:** The physical installation of the PV system and any administrative requirements associated with this process;
7. **Grid Connection and Commissioning:** The phase of realising the PV system's physical connection to the grid and its initial conformity verification;
8. **Financing:** The steps to be taken to acquire the necessary capital, equity or debt financing for the realisation of the PV installation;
9. **Corporate Legal-Fiscal:** All actions necessary to incorporate (if this is legally required), to become member of a certain association, to become liable for taxation, or to become exempted from it;
10. **PV System Operation:** The requirements and other activities involved with the operation of a grid-connected PV system over its 20 to 30 years of operational lifetime.

Qualitative and Quantitative Analysis

The initial phase of qualitative research was focused on all the permitting, grid connection and operation provisions that a PV system has to pass through and built on the market experience of national solar industry associations and their members. In a successive step, selected stakeholders (mainly PV project developers) were interviewed in each country to verify and refine the previously researched data and to quantify each process according to the following indicators:

- **Duration:** the total time (measured in weeks) needed to complete a specific process or the sequence of all processes (for the Overall Project);
- **Waiting time:** the total idle time (measured in weeks) spent waiting for authorities, administrations or grid operator feedback or action, thereby obviating further action in the process;

- **Legal-administrative Cost Share:** the average share of legal-administrative costs in total project development costs, excluding PV equipment (measured in %);
    - **Barrier severity:** the qualitative assessment of the gravity of market barriers hampering or blocking PV system development;
    - **Legal-administrative Labour Requirements:** the amount of time (measured in man-hours) invested for complying with legal-administrative requirements during a process;
    - **Non Legal-administrative Labour Requirements:** the amount of time (measured in man-hours) that needs to be invested for a process, excluding the time spent complying with legal-administrative requirements.

The results based on the research methodology outlined above are documented in the PV GRID database. The required procedures for developing and operating a PV system in sixteen European countries are illustrated by a practical step-by-step approach, complemented with a set of quantitative indicators that allow for comparing the lead times and administrative burdens faced by PV project developers and investors across countries.

The PV GRID database is accessible online at http://www.pvgrid.eu/database/.

4.2. Barriers to PV System Development and Operation

A large part of the research carried out within PV GRID relates to the assessment of barriers encountered in the development and operation of PV systems. As previously outlined, these barriers have been identified and verified by means of qualitative research performed by national solar industry associations and further investigated by means of interviews with national stakeholders, principally taking into account the perspective of PV system developers and operators.

In total, more than 200 barriers have been identified. Even though the focus of the research is on administrative frameworks, it is natural that both national industry associations and interviewed stakeholders also tend to highlight barriers that are not purely administrative, but rather deal with technical requirements, regulatory matters and economical profitability issues. This information is deemed valuable and is therefore also included in this report.

The collected barriers have undergone a review process to identify possible similarities and group them in larger categories. As a result, four main categories have been identified:

1. Permitting Procedures
2. Grid-related
3. Support-related
4. Operation & Maintenance

Below, a description of the four barrier categories is provided, along with some examples.

Permitting Procedures

Administrative permitting procedures affect PV projects quite differently, depending on the market segment and on the regulations that apply to systems belonging to that segment.

In the **residential segment**, the administrative permitting process is in most cases simple and requires only a building permit or a simple notification to the municipality stating that the PV system will be installed. In the **commercial segment**, the administrative permitting process can become more challenging. Planning permissions and environmental impact assessments are more frequent and in some countries an electricity production license may also be required. In the **industrial ground-mounted segment**, the administrative permitting process is usually complex and time consuming. Given the typical large size of these plants, compliance with local land or urban development plans needs to be ensured. Furthermore it is commonly necessary to undergo an environmental impact assessment and to verify the acceptance of the new plant by the local communities. The administrative lead times are normally in the range of one year or more.

Grid-related

Grid-related barriers represent, together with those in permitting procedures, one of the two main groups of barriers that have been identified by the PV GRID research. Such barriers appear in the grid connection permit and in the grid connection and commissioning process.

Within the PV GRID assessment of national frameworks, the barriers in these processes are seen from the perspective of PV developers, while within the scope of PV GRID's work of enhancing grid hosting capacity, the same barriers are discussed from the DSO's and PV owners' points of view.

These processes may vary largely in the three market segments, in terms of requirements and in terms of administrative procedures, going from a mere notification for **residential systems** to a more complex procedure for **commercial systems**. Often, barriers are encountered in the case of larger plants, given the additional complexity involved.

In general, for **industrial ground-mounted systems**, the grid connection process consists of an initial request phase, during which a request for a connection point is sent either to the competent distribution or transmission system operator. After internal consultations and the opportune technical verifications, the grid operator will reply to the system developer confirming the access point and presenting an offer for the realisation of the connection works, or refusing the access point request. In the latter case, the grid operator is normally required to provide an alternative access point and connection works offer. Once the PV system developer accepts a connection offer, a provisional connection contract is signed between the two parties, a deposit is paid to the operator and usually the works for installing the PV systems can start. Once the PV system construction and installation has been finally completed, the PV developer will contact the grid operator and request that the connection works are executed. Finally, after a brief test and commissioning phase, the PV system will be connected to the grid and will begin feeding electricity into it. At this point, the PV system owner and the grid operator generally conclude the process signing a connection contract.

Support-related

Although the goal of PV GRID is not specifically to analyse and report on support schemes, administrative requirements linked to this issue are considered relevant in the context of project development, and as such are assessed in this project. Regardless of the market segment, these issues are relevant in two contexts: administrative requirements and financial aspects.

Operation & Maintenance

A minor group of barriers identified within the framework of PV GRID relates not to the development of the installation itself, but rather to its operation. There may be certain regulatory changes or existing requirements that create particular difficulty in terms of the day-to-day management of the installation.

4.3. Summary of national frameworks

The market for **residential systems** is active in all analysed Member States with the exception of Spain, where the current legislative framework de facto blocks the development of any photovoltaic systems. In most of the remaining countries, however, it appears that the sector is in good health, with fast procedures and no major barriers. The only two countries where more severe barriers are encountered in this segment are Bulgaria and Sweden. On average, the project lifecycle for a residential PV system in the analysed countries takes about 20 weeks. At the beginning of 2013 the timeline for such a project was about 24 weeks on average. This is mainly due to a steep decline in the overall duration for Austria, the Netherlands and Poland. The overall project duration strongly increased in Bulgaria, however this does not completely outbalance the overall positive effect. Figure 4.1 provides a graphic representation of the current situation.

In comparison, PV projects' lifecycles in the **commercial segment** are showing much higher values in terms of duration and administrative hurdles than the residential segment. Nevertheless commercial systems are still active throughout Europe (with the exception of Czech Republic, where the market is frozen). However, in some cases there are project durations reported lasting for as long as 92 weeks (Sweden). On the other hand, shorter project durations also have been reported, such as the UK (8 weeks) and Germany (9 weeks). On average, the analysed countries project lifecycle duration is of 40 weeks, slightly less than the value calculated in 2013 (41). This slight decrease is partially attributable to the halting of the Spanish market, whose former high value is not taken into account anymore. In fact, there has been some slight decline in the overall project duration in a few countries (Austria, Italy, the Netherlands, and Portugal), but also a strong increase in two countries (Bulgaria increased by 23 weeks, Poland increased by 14 weeks). Below, a graphic outline of the current situation is provided in Figure 4.2.

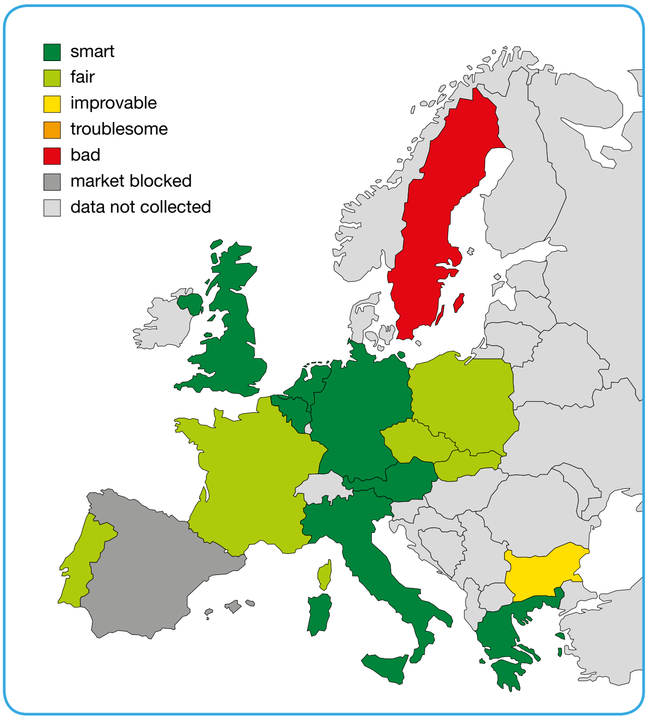

Figure 4.1 – Status of the residential systems segment

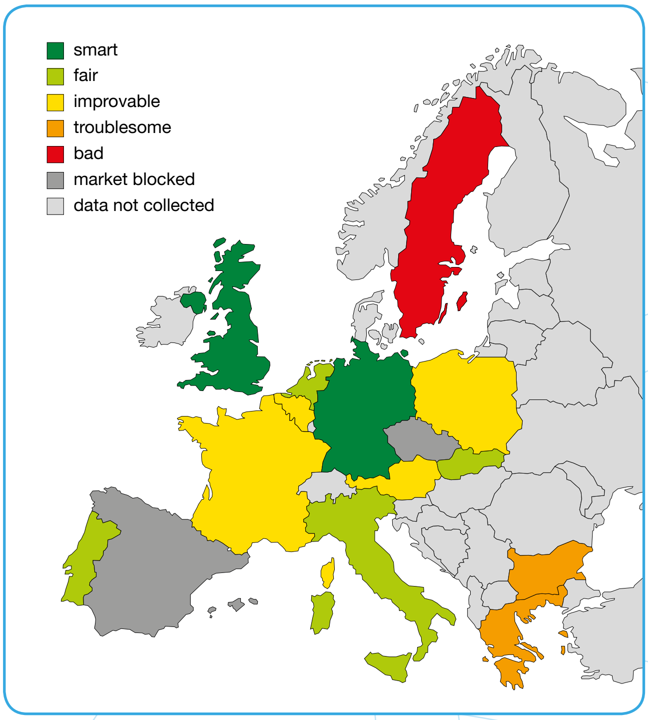

Figure 4.2 – Status of the commercial systems segment

The most notable change in the analysed countries' PV market is the steep decline in the **industrial ground-mounted systems** segment, as it appears to only remain active in three of the sixteen analysed countries: Germany, Greece and UK. This situation might be due to different factors such as the interruption of support schemes (Italy), the lack of a legislative framework (Portugal), or to legislative changes (Spain). Figure 4.3 provides a graphic representation of the current situation.

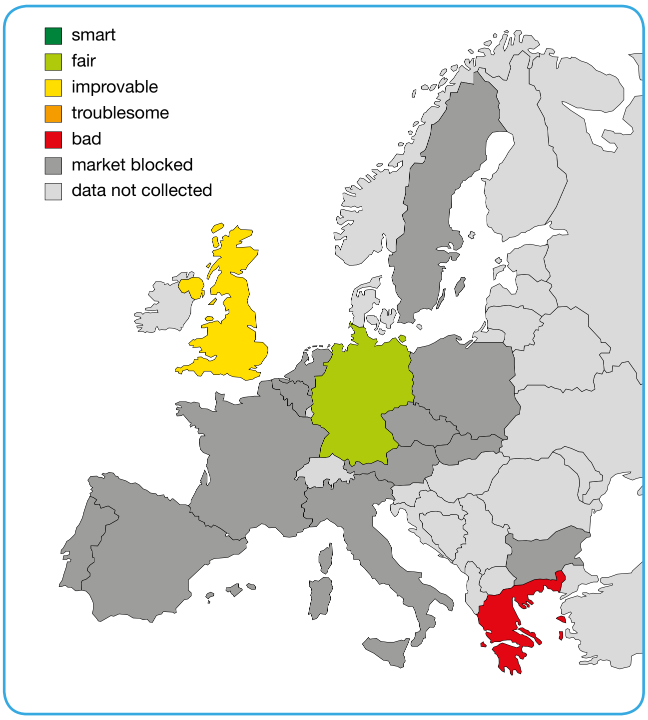

Figure 4.3 – Status of the industrial ground-mounted systems segment

While the market decline of industrial ground-mounted systems is easily identified, it is not as immediate to pinpoint the reasons accounting for this decline. Our consortium has observed, however, that all the different causes for this decline can be somehow rooted to three main factors:

1. A decline in support schemes or presence of unattractive support schemes for this segment;
2. A lack of a legal framework to allow for such installations;
3. Cases of policies or public authorities adverse to the development of photovoltaic.

These factors have been reported in several countries and are present to a different extent in the analysed countries. Clearly, reducing the whole PV industry status to three causes may seem too much of a simplistic approach. The PV GRID consortium does agree with that point of view, and the above points are simply meant to provide a snapshot of the situation. For detailed information about the current status of Segment C in each country, our suggestion is to consult the national assessments in section 6 and to refer to the online PV GRID database.

5. CONCLUSIONS AND OUTLOOK

PV GRID consisted of two areas of activity: on the one hand, the continuous assessment of national frameworks for the development of PV installations, and on the other hand, the project was focusing on the relation between certain legislative, regulatory and normative frameworks and the identified technical solutions available to increase distribution grid hosting capacity. The second area of activity derived largely from the fact that PV GRID's predecessor project, PV LEGAL, which already had assessed national PV development frameworks and thereby focused on barriers resulting from legal-administrative processes and procedures, identified grid-related barriers as one of the main groups of barriers hampering PV development. For this reason, PV GRID primarily focussed on the **enhancement of PV hosting capacity in distribution grids while overcoming regulatory and normative barriers hampering the application of available technical solutions**.

As for the assessment of national frameworks for PV development, a few conclusions can be drawn based on the continuous monitoring of national PV development frameworks reflected in the PV GRID database. In particular, as discussed in section 4, a decline of utility-scale ground-mounted PV systems can be observed all over Europe, while residential and commercial applications continue to grow steadily.

European Advisory Paper: Key Results

With hindsight and compared to other EU projects, PV GRID had a rather wide scope. As presented in section 3.1, this has led to the development of an **overall framework for different categories of technical solutions**, depending on the area of responsibility for implementing them (DSO, Prosumers or both). Based on two indicators developed by the project consortium, identified technical solutions have been prioritized for low voltage and medium voltage grids. In general and despite the different levels of effectiveness, the list of solutions has to be seen as toolbox that contains solutions addressing different technical problems. The selection of the best solutions may differ in each planning process, depending on network regional specifics and/or local feeder constraints. Furthermore, and as schematically illustrated in Figure 5.1, a **systematic framework for barrier analysis** relating to the application of technical solutions has been created.

Figure 5.1 – Systematic Framework for Barrier Analysis with respect to Application of available Technical Solutions

As detailed in section 3.2, broad **recommendations** were formulated with respect to overcoming those barriers hampering the application of available technical solutions and adjusting the European and national frameworks in order to support the transition towards integrating higher shares of electricity from PV and other distributed generation facilities. The project consortium was able to agree on rather generic compromises on a whole range of issues, but due to their complexity and interdependencies none of these issues could be addressed in great detail.

The barrier analysis framework in combination with the recommendations has also led to the development of an **overall assessment structure pertaining to increasing PV hosting capacity** in a given national context. The so-called **"PV GRID Roadmap"**, as presented in section 3.3, aims at providing policy makers and other stakeholders with a first and easy indication on where their country is positioned with regards to PV hosting capacity and what needs to be done to actually help increasing penetration levels of PV. The roadmap offers general ideas and advice on how to structure the analysis and then find a course of action, if the national strategy does indeed call for a strong increase in the penetration of PV or of other RES in the distribution networks.

One important lesson learnt from PV GRID is that the process of analysing the current situation, identifying suitable technical solutions as well as barriers in the regulatory and normative framework that may have to be overcome, will need to be carried out together by all stakeholders, including DSOs, PV industry representatives, policy makers, regulators and other important stakeholders. Applying this inclusive approach will allow for reaching a common ground, developing mutual understanding and helping people share ways of finding answers to the tough questions regarding the integration of solar into the larger energy delivery system.

Open Issues to Explore in the Future

A detailed technical analysis, including modelling of different options, as well as a detailed cost benefit analysis focussing on the different technical solutions and the recommendations provided by PV GRID, is still to be undertaken. With the limited resources available in the project, this immense task couldn't be carried out and has to be delivered by future endeavours. In addition, it is highly recommendable to check whether the existing barrier assessment is also broadly valid for other RES/DG technologies, such as wind or biomass.

A consistent and detailed regulatory and economic framework for using Demand Response, storage solutions, smart metering and Smart Grids needs to be further developed, especially if the potential provided by DSO storage should be exploited on a broader scale. The current ancillary services market design should be advanced and adjusted in order to accommodate for new products delivered by RES generators and storage devices.

PV GRID has strictly focused on identifying technical solutions to solve voltage and thermal issues in distribution networks. In the context of applying those solutions, one important aspect to be researched, defined and developed further is the overall future role of the DSO. This future role includes the coordination between DSOs and TSOs under new requirements set by high penetration of RES and DG. While several issues related to the role of DSOs (access to DG capabilities, Demand Response facilitation, Smart Grid functionalities, etc.) have been treated in PV GRID and have eventually given rise to recommendations, the latter has also surfaced at various points within the project. For example, when discussing the EU Network Codes, but it wasn't addressed in more detail as it was out of the scope of the project, and therefore needs further investigation.

Another relevant topic with additional need for further work is the national implementation of EU Network Codes. Furthermore and in light of the new role of DSOs, it will be important to align and adapt the education and training for the DSO workforce in order to equip staff with the required competences to master the future challenges of system operations.

PV GRID Outcomes in the Framework of other European Initiatives

A number of other research projects funded by the European Commission are looking into similar issues as those examined and discussed within PV GRID, but with a different focus or perspective. PV GRID outcomes certainly can provide structured input to those projects or even be used as justification for other projects, such as *IGREENGrid* or *DISCERN* for example. Some projects, such as *INCREASE* or *evolvDSO*, are already working on advancing or solving the open issues outlined above. Furthermore, there are projects whose scope of analysis is rather complementary to PV GRID, such as *REserviceS* or *metaPV* for example. Overall, linking the results of the different projects will be important in the endeavour to develop the electricity networks of the future in Europe enabling high penetrations of a mix of distributed and variables sources, storage and responsive users.

In addition, the transformation of today's electric grid to the future electric grid will require conducting more focused research, data development, and demonstration projects. Last but not least, in an increasingly complex and dynamic environment, the transition will also require improved coordination efforts between all stakeholders participating in the electricity industry and markets.

6. ANNEXES

6.1. Summary of National Frameworks for PV development

In this section, we present a summary of the situation of administrative frameworks and of the national PV markets in each of the sixteen participant countries, offering a glance at the main PV GRID indicators, the situation in each market segment and the major current market barriers.

This collection of information is based on the research carried out by national solar industry associations, complemented with interviews with national PV system developers and operators.

More detailed and up to date information is available online in the PV GRID database:
http://www.pvgrid.eu/database/.

Austria

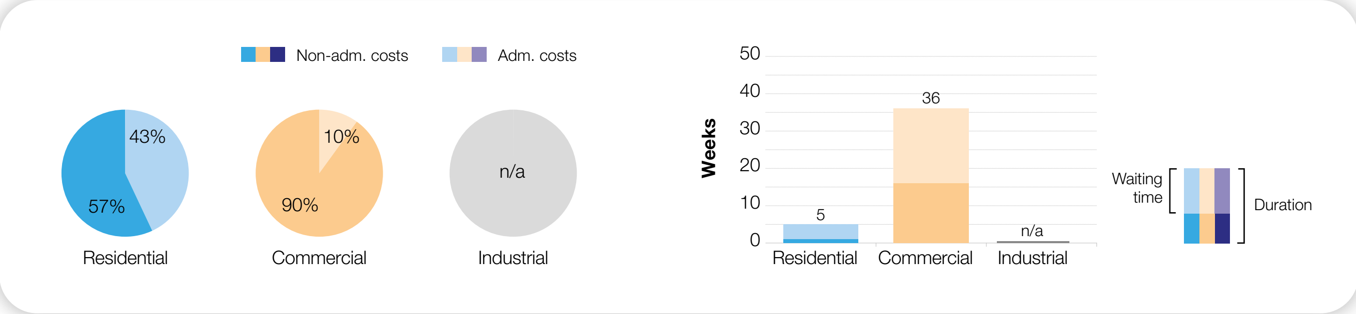

Figure 6.1 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

In the Austrian legal-administrative system, the overall framework is set at national level, whereas implementation takes place at federal level. As a result, there are 9 different federal Electricity Management and Organization Acts and a number of implementation rules, released either by single network operators or by all federal network operators in a harmonized common document. In this context, the main barriers appear to be uncertainties about costs for the grid connection, the limited budget for the promotion of PV systems and the long and costly approval procedures.

About one third of the installed PV capacity in Austria is made up by **residential systems** smaller than 5 kWp. This percentage used to be higher, but because of changes in the budget for the feed-in tariff for bigger plants (since 2012 more money is available) a large amount of larger plants has been built. **Commercial systems** (around 5-100 kWp) represent about 50% of the total installed capacity. When a PV system is planned and operated in the context of a commercial property, specific approval procedures apply, which may represent a barrier for PV system planners, even for the most experienced ones.

Generally, the segment of industrial ground-mounted systems sized larger than 0.5 MW has developed poorly since 2013, as the Green Energy Act (GEA) does not support projects with more than 350 kW anymore. Due to the current lack of opportunities and a missing market for this sector, no interviews were carried out in this update round. There are, however, a few projects in operation, which were implemented under promotion policies of earlier editions of the Green Energy Act (GEA).

Barrier Type	Name	Process	Description
Permitting Procedures	Electricity production	Electricity Production License	The Federal Electricity Acts requires an electricity permit procedure. Whether an electricity permit is necessary, depends on the peak power of the PV system and on the federal limits. For small-scale plants a simple procedure is allowed without an on-site approval meeting. Larger systems need to be approved within an on-site negotiation meeting. Sometimes also several experts are required which cost money and cause delay.
Permitting Procedures	Request of green power feed-in tariff and limited promotion budget	Support Scheme(s)	Project applicants can apply for a green power feed-in tariff on a specific website. Due to the limited overall promotion budget of 8 million €, not all project applicants can be supported. Request for feed-in tariff support has to be entered very quickly in order to get properly queued. Thus, the speed of handling this web interface is a crucial success factor.
Grid-related	Grid capacity constraint	Grid Connection Permit	According to the Electricity Management and Organization Act, network operators are obliged to connect PV systems with priority to the grid. Upon verification of the grid capacity, the network operator either approves by sending a contract, or makes it dependent on successful commissioning. If sufficient grid capacity at the nearest possible connection point is not available, the network operator claims to reinforce the grid at the cost of the project applicant.

Table 6.1 – Most severe market barriers in Austria

Belgium[9]

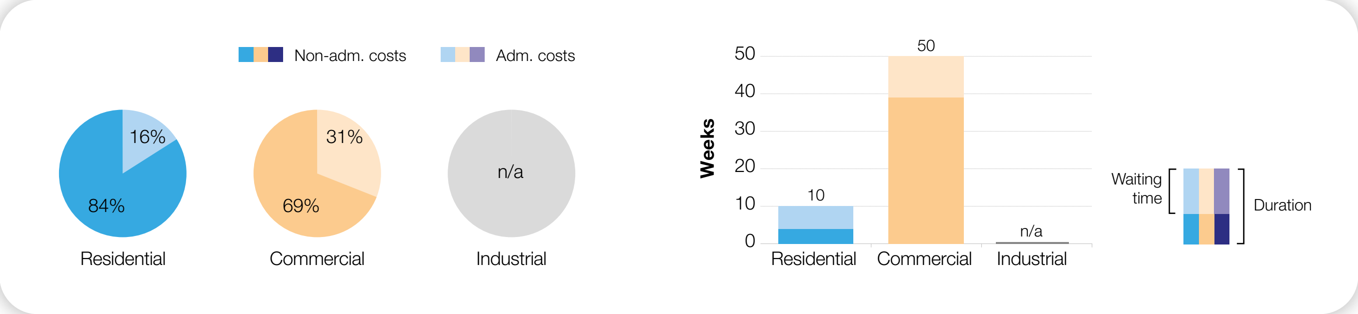

Figure 6.2 - PV project development : share of administrative costs, duration and waiting time

Summary of market status

The majority of the PV market in Belgium is composed of residential and commercial systems. Industrial ground-mounted systems are not present.

The segment of **residential systems** in Wallonia (maximum 10 kVA) and in Brussels (maximum 5 kVA) is well developed and growing. These systems represent 97% of the total installed PV systems in Wallonia and 39% of the ones in Brussels and are mostly installed on rooftops, or sometimes are ground-mounted (in gardens). Administrative procedures are simple. In March 2014, the green certificates scheme has been replaced by a new mechanism called Qualiwatt. Due to its novelty, details on the scheme's functionalities are still unavailable.

Commercial systems represent about 3% of total installed PV capacity in Wallonia and 61% of the total installed PV capacity in Brussels. In Brussels, this segment has increased up to August 2013, when the level of support decreased. Additional difficulties are linked to the historical context of the city (listed buildings) which can induce administrative obstacles.

Industrial ground-mounted systems are neither installed in Wallonia nor in Brussels. There is no support scheme for PV systems larger than 250 kVA. Moreover, the dense urban character of the Brussels region makes it very hard for this sector to be developed.

Barrier Type	Name	Process	Description
Grid-related	The criteria for the connection analysis are not transparent, slow process	Grid connection permit	Legal deadlines are not always met and there are differences in treatment between different DSOs. Criteria leading to the technical solution of connection are not always transparent, so it is difficult to ensure that the suggested connection is optimal with respect to the financial interests of the developers.
Support-related	Unguaranteed green certificates price	Support schemes	The repurchase price of green certificates depends on the market for green certificates. As such, if the demand is not sufficient in relation to the supply, prices can collapse and endanger the financial viability of the PV system.
Support-related	Support level conditioned to 50% self-consumption	Support Schemes	Up to a PV system capacity of 250 kWp it is possible to receive four green certificates per MWh produced, with the condition that the self-consumption of electricity is at least equal to 50% of the production every three months.

Table 6.2 – Most severe market barriers in Belgium

9 Not including Flanders

Bulgaria

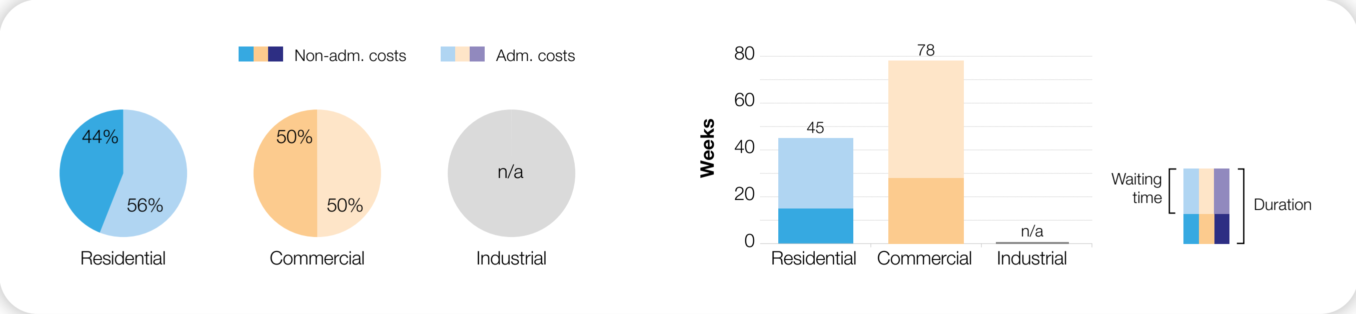

Figure 6.3 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The development of PV systems in Bulgaria is facing several barriers that impede the development of the overall sector. In general, an unclear political framework prevents foreign investments. Disproportionate requirements hamper in particular the sector for small systems, while large ground-mounted systems are affected by recent changes of the legal-administrative framework.

The installation of **residential systems** on buildings is mainly hampered by numerous complicated procedures. A simple notification of construction is not allowed; instead developers have to undergo a full building permit process – although some regulations for smaller plants have recently been lifted.

Burdensome processes also impede the development of the **commercial systems** segment. Building permits are required and entail the need for a supervision company to monitor the construction of the PV system and of the required architectural, electrical, static and other designs, subject to special approval by the municipal administration. A recent transitional provision of the RES Act implements the rescheduling of the grid connection of large and middle scale PV plants after 2016. DSOs tend to interpret this rule very broadly, which affects the investment stability of many projects.

The **industrial ground-mounted systems** segment suffers in particular from recent legal reforms, among others an early interconnection fee, the change of the grid connection procedures, including postponement of the connection of all projects to after 2016 and annual determination of available capacities for new RES initiatives. In three consecutive years 2012, 2013 and 2014 there is no grid capacity available for ground-mounted systems.

Barrier Type	Name	Process	Description
Grid-related	Rescheduling of grid connection procedures	Grid Connection Permit	A decision of the National Electricity Company for rescheduling the grid connection of large and middle scale PV is broadly interpreted and currently applied to all segments. DSOs are postponing the time of grid connection for small installations to after 2016 or blocking the grid connection procedure.
Operation & maintenance	Unpredictable Limitation of Generation	PV System Operation	As the limitations are during the day hours, they affect PV plants at most. The installations work with 40% of their capacity, which added to all the retroactive measures takes away 100% of their income.
Grid-related	Unavailable grid capacity for new installations	Grid Connection Permit	Temporary restriction for development of new RES projects due to the annual decision for maximum available grid capacity for new PV/RES projects. The decisions from 2012, 2013 and 2014 provided NO available capacity. Thus no new PV projects (except rooftop installations up to 200 kWp) have access to the electricity grid until the next decision of the Regulator in July 2015.

Table 6.3 – Most severe market barriers in Bulgaria

Czech Republic

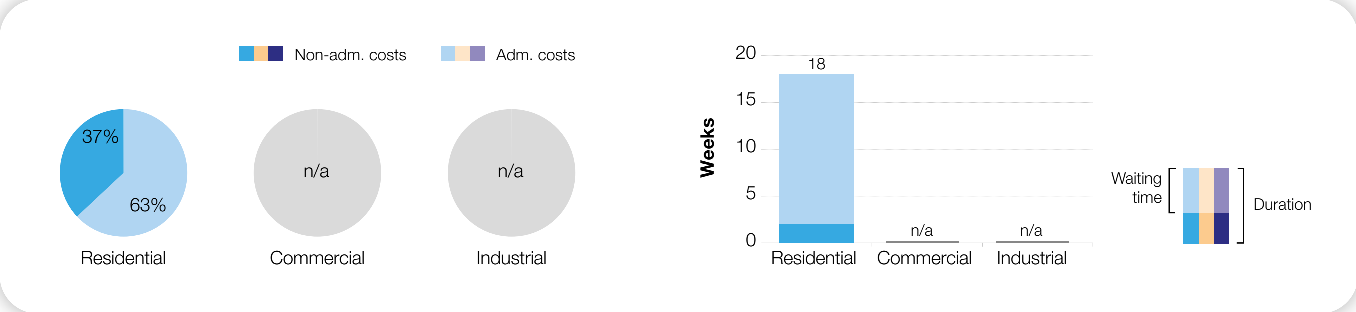

Figure 6.4 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The Czech PV market has undergone quite strong changes in the past years. At present, smaller systems appear to be still developing, but larger ones seem to suffer from the current situation. In fact, there is no economic support scheme for PV systems above 30 kWp. Currently, **residential rooftop systems** represent the only segment that still experiences project development. At present, there are more than 12,000 PV systems operating in the country. By the end of 2012, the cumulative installed capacity had reached 80 MWp (PV systems under 20 kWp). The main barriers for this market segment relate to the attitude of the grid operators, which may hinder obtaining the connection permit and commissioning; and the technical difficulties, which tend to delay, or even block, higher grid penetration.

The installed capacity of **commercial rooftop systems** reached 107 MWp by the end of 2011. There are currently about 2,400 commercial rooftop PV installations. This segment is strongly influenced by the lack of support (officially cancelled on 1 January 2014), the difficulties in grid connection outlined for residential rooftop systems and a solar tax imposed on systems larger than 30 kWp.

Installation of new **industrial ground-mounted systems** has stagnated by March 2011. At the end of 2011, 1,600 licences were granted to PV plants above 100 kWp, for a total capacity of more than 1,800 MWp. These numbers were almost the same as in 2010. The most significant changes of the legal framework that came into effect since 2011 were the cancellation of the 5-year tax exemption, the introduction of a special taxation on production, the amendment of support (resulting in more than 5% decrease of FiT levels per year), the extension of the depreciation period to 20 years and the introduction of recycling fees. Obtaining the connection permit and the concrete commissioning for a large PV system is currently rather unlikely. A special authorisation from the Ministry of Industry and Trade is required for PV systems above 100 kWp. Furthermore, these systems suffer heavily because of the cancellation of the support scheme.

Barrier Type	Name	Process	Description
Grid-related	Refusal to connect lacking substantial explanation	Grid Connection Permit	There is a risk that grid operators refuse the connection approval. It is often not clear what the true reasons are, although the operator usually argues they are of purely technical nature. Usually, distributors argue there is insufficient grid capacity in the respective location and thus another generation plant with non-linear production could cause a serious damage to it.
Operation & Maintenance	Retroactive changes of the support scheme	Support scheme	The support scheme is unstable and there has been a retroactive reduction of the FiT as well as the introduction of new taxes and fees.
Grid-related	Heterogeneous approach to the applicants	Grid Connection Permit	DSOs show a non-standard approach towards applicants, applying different requirements without justification.

Table 6.4 – Most severe market barriers in Czech Republic

France

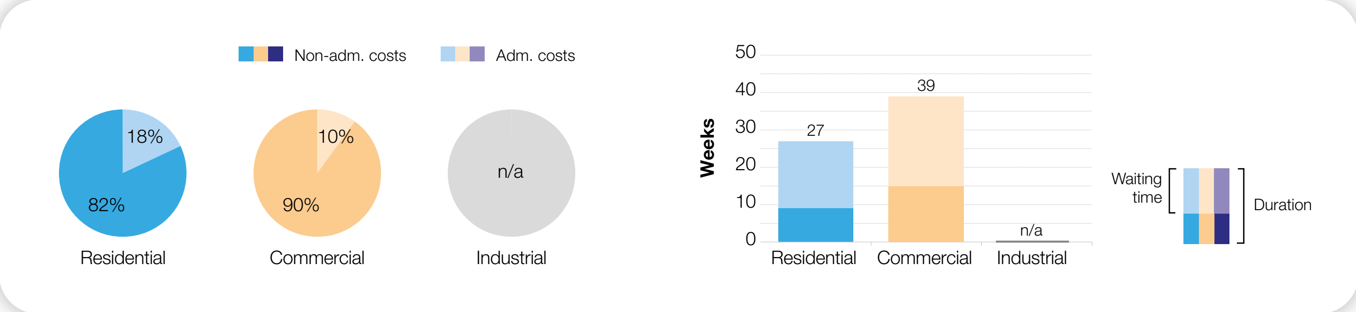

Figure 6.5 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The largest part of the market in France is composed of residential and commercial PV systems, whereas industrial ground-mounted systems are less developed, also due to the fact that the feed-in tariff is not very attractive for larger systems and that the related regulatory framework is quite restrictive and laborious.

Most of the French PV market in the **residential systems** segment is made up of rooftop installations of less than 3 kWp in size. These installations are supported by the tax credit and the feed-in tariff. Building integrated PV installations on residential houses up to 9 kWp are eligible for the highest FIT level. The main barriers to the development of these kinds of PV projects are related to obtaining the administrative permissions and to the grid connection costs.

Commercial rooftop systems with a capacity of up to 100 kWp are essentially supported by the feed-in tariff. The main obstacles for the development of this segment are the grid connection procedure and the vagueness of certain regulations. A call for tenders is available every four months for rooftop PV projects between 100 and 250 kWp.

The feed-in tariff is attractive only for installations less than 100 kWp in size, thus not covering large industrial PV system on roofs or **industrial ground-mounted systems**. This is severely limiting the profitability of larger installations. This segment is practically undeveloped at the time being, even if a call for tenders has been opened in 2011 and another one was open from March to September 2013 (results still pending). The most severe barrier regarding this sector is the administrative procedure.

Barrier Type	Name	Process	Description
Grid-related	Grid capacity constraint	Grid Connection Permit	Often, technical constraints exist relatively to the grid hosting capacity in some areas. If the installation is too far from the grid, or if the grid is overloaded, sometimes, specific grid expansion works must be carried out by the DSO.
Grid-related	Waiting times	Grid Connection Permit	Waiting times for obtaining the permit may be extremely time-consuming.
Grid-related	Deadline for grid connection	Grid Connection Permit	When the grid connection is asked, the developer has 18 months to build the PV system and be connected to the grid. If this deadline is exceeded, the Feed-In Tariff (FIT) contract is reduced by 3 times the exceeding period. Responsibility of such excess delay would be charged to the developer if he doesn't finish the installation construction within 18 months.

Table 6.5 – Most severe market barriers in France

Germany

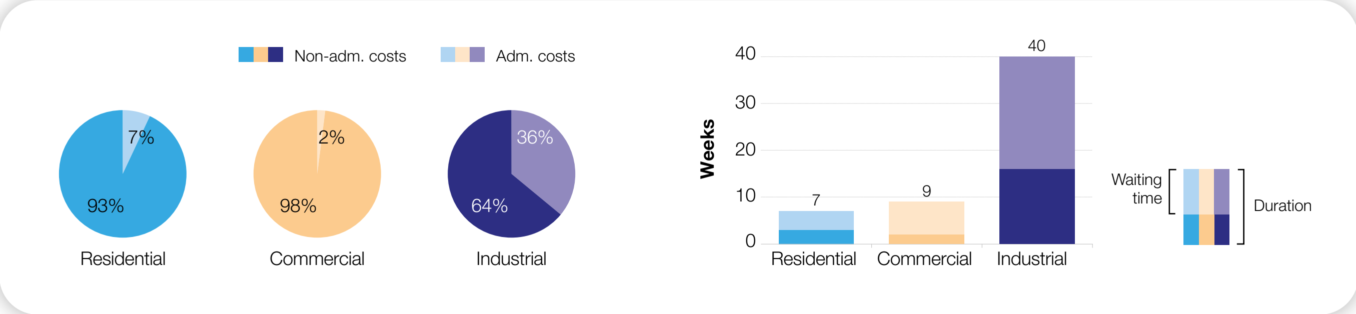

Figure 6.6 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

Residential systems up to 10 kWp in size are usually installed on building rooftops and in most cases benefit from an exemption from planning permissions. For installations up to 30 kWp it is legally defined that the connection point of the plot with the grid is regarded as the most favourable connection point. When applying for grid connection, the experiences with the individual grid operators differ. The application is often easy and quick. Sometimes, however, PV system developers report that the process takes too long and involves high connection fees.

The segment of **commercial systems** up to 1 MWp in size represents the highest share of the German PV market. The grid connection application is often a significant obstacle. For systems with power of more than 30 kWp the grid connection point is defined in EEG (section 8 para. 1 sentence 1). This paragraph stipulates that the network operator has to connect EEG generators immediately and with priority to the grid connection point which is suitable in terms of the voltage and which is at the shortest linear distance from the location of the installation if no other grid system has a technically and economically more favourable grid connection point. The definition of the systems up to 30 kWp is therefore more precise than the definition for systems of more than 30 kWp. Thus, more disputes between the PV system developer and the grid operator occur with respect to the grid connection point of installations higher than 30 kWp. In the PV system developer's point of view, the process takes too long and involves too high connection fees.

The eligibility of **industrial ground-mounted systems** larger than 1 MWp insize has been restricted in the past years. Whether the criteria are met is not always obvious. Drafting or amending a land development plan and urban development plan is necessary in most cases in order to be granted feed-in tariff payments. The involved proceedings are slow and expensive. The application of a connection point often turns out to be a major obstacle. The allocation of the technically and economically most favourable connection point by the grid operator is often disputed.

Barrier Type	Name	Process	Description
Permitting Procedures	"Change of use" induced by the installation of a PV system on a building	Administrative Process	The exemption of PV systems from the requirement to obtain planning permission does not cover the possible change of use of non-commercial buildings induced by the installation of a commercially used PV system on the building. In that case, the developer has to apply for permission for change of use of the building.
Grid-related	Technical grid connection conditions	Grid Connection Permit	The relevant technical connection conditions for PV systems are created by a committee (FNN), in which the grid operators have the majority. The connection conditions contain regulations that make the connection of renewable energy systems difficult. Moreover, the value of the FNN standards as recognised rules of technology is in part criticised by planners, installers and operators.
Permitting Procedures	Difficulties finding locations for ground-mounted systems	Site Selection	Suitable areas for PV ground-mounted systems have become rare and require the approval of municipalities. Project developers must invest a lot of time to identify areas and subsequently negotiate with the owners of the areas and the municipalities in order to implement a project.

Table 6.6 – Most severe market barriers in Germany

Greece

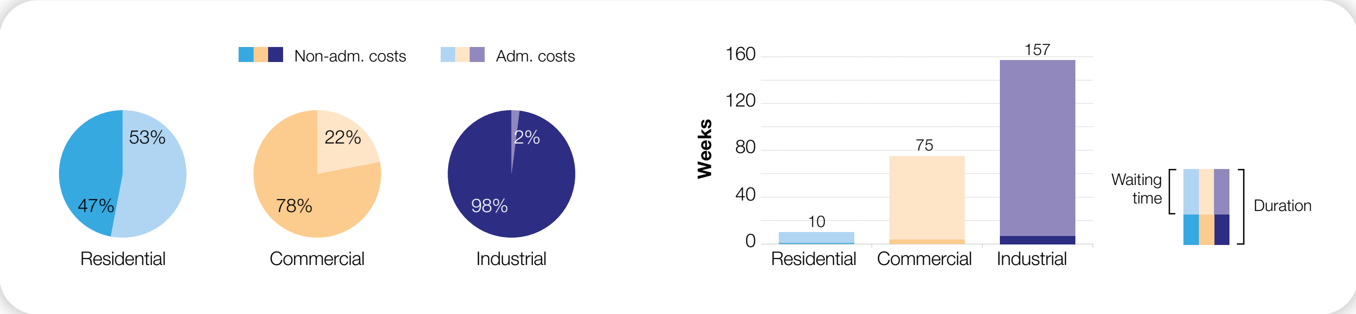

Figure 6.7 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The PV Market in Greece is currently in a transition phase. New support schemes such as net-metering are being introduced, while feed-in-tariffs have been reduced to unsustainable levels. The market in the coming years will mainly be composed of residential and industrial ground-mounted systems, whereas commercial systems are facing some difficulties in deployment due to lack of adequate incentives.

Thanks to a program for the installation of **residential systems** sized up to 10 kWp on building rooftops, most barriers have now been lifted for this segment. Hence, this segment has been a very dynamic one. A new self-consumption scheme (based on net-metering) has been agreed upon and is currently being developed by the authorities in parallel with the existing feed-in-tariffs.

The installation of **commercial systems** follows a relatively easy process, especially since mid-2010 when new legislation came into force removing most of the existing barriers. The most severe barrier in this segment is the delayed response of the grid operator to applications for grid connection offers. From August 2012 until April 2014, there was a suspension of new applications in this segment. A new support scheme based on net-metering for this segment is currently under consideration.

Since 2010 the permitting procedures do not constitute a barrier anymore for **industrial ground-mounted systems**. From August 2012 till April 2014, a suspension on new licensing of this segment was in place. Only old applications holding a grid connection contract and having already applied for a Power Purchase Agreement could proceed while the freeze in licensing was in place. This segment represented one-third of all installed capacity in mid-2012. This segment has a prosperous future outlook on the condition that adequate incentives will be applied. However, this is currently not the case.

Barrier Type	Name	Process	Description
Support-related	Inadequate incentives; Delays in signing the PPA contract	Support Schemes	Compensation offered has been reduced to unsustainable levels in most cases. Furthermore, there are considerable delays by the Market Operator (which is understaffed) regarding the signing of Power Purchase Agreement. The date of the contract though is the date that a complete file was delivered to the Operator, no matter when the contract was signed.
Grid-related	Grid connection bottleneck	Grid Connection Permit	Grid connection offer was a serious barrier until recently as the Grid Operator was not able to comply with deadlines set by the legislation with the excuse that there were too many applications.
Permitting Procedures	Exclusion of prime agricultural land for PV installation.	Site Selection	New installations of ground-mounted systems (having filed an application with the Grid Operator after 21-9-2011) are no longer allowed on prime agricultural land. This barrier was not in place in the period June 2010 - Sep. 2011.

Table 6.7 – Most severe market barriers in Greece

Italy

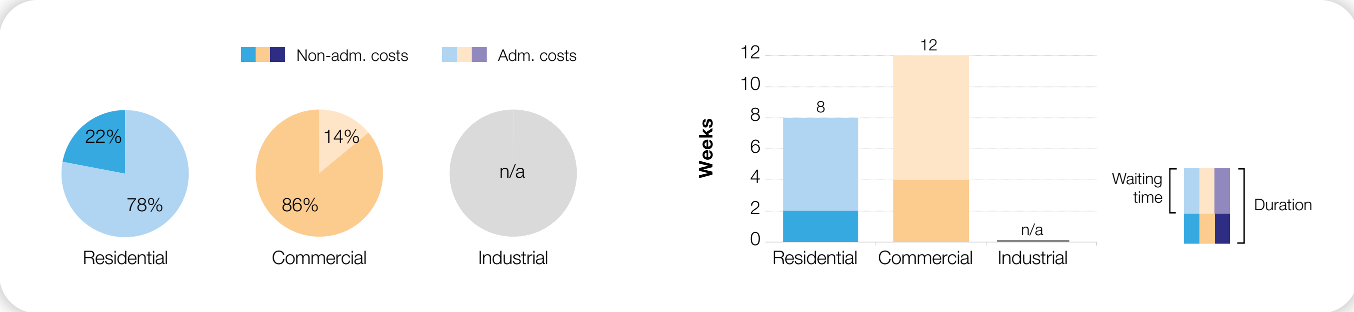

Figure 6.8 - PV project development: share of administrative costs, duration and waiting time[10]

Summary of market status

The feed in tariff mechanism in Italy, called "*Conto Energia*", ended in July 2013. Now PV plants (<200 kW) can request net metering's convention (called "Scambio sul posto") and tax concession for investments below € 96.000. **Residential systems** are typically installed on rooftops. Authorization procedures are simple enough, even though there can be differences at territorial level. In some cases restrictions that might require longer procedural steps are possible.

Commercial systems have been highly penalized in 2012 by the introduction of the registries for all systems above 12 kWp. Authorization procedures are relatively simple, even though also in this case there can be differences at regional level or restrictions that might require longer procedural steps. These systems are probably the ones mostly affected by the new registry system.

Currently, the market for **industrial ground-mounted systems** is frozen. Although installation is possible, a great uncertainty (restrictions and lengthy authorization process), high costs involved and an increasingly difficult access to credit greatly discouraged the market for this segment.

Barrier Type	Name	Process	Description
Grid-related	Grid operators: delays	Grid connection permit	With much less frequency than in the past, there might be delays and cases of difficult communication with the local grid operators. In case of delays, monetary compensation is foreseen. See art. 14 of the TICA - Integrated Text for Active Connections, further specified by Deliberation ARG/elt 187/11 of the AEEGSI (the Authority for Gas and Electric Energy and water system).
Permitting Procedures	Lengthy permitting process	Administrative Process	Restrictions relating to protection of the environment, landscape and historical/artistic heritage can be imposed by various administrations. The permission from regional Superintendencies, when necessary, can lead to considerable delays. The conduct and waiting times can vary according to the territorial offices concerned.
Permitting Procedures	Electric-ity Production Licence	Electricity Production	For the Electricity Production Licence request, procedures and paperwork might differ a lot according to the territorial offices involved. The legal-administrative as well as the technical workload may not be uniform.

Table 6.8 – Most severe market barriers in Italy

10 Results for Italy are not available at the time of publishing. Please check the PV GRID database for up to date information.

The Netherlands

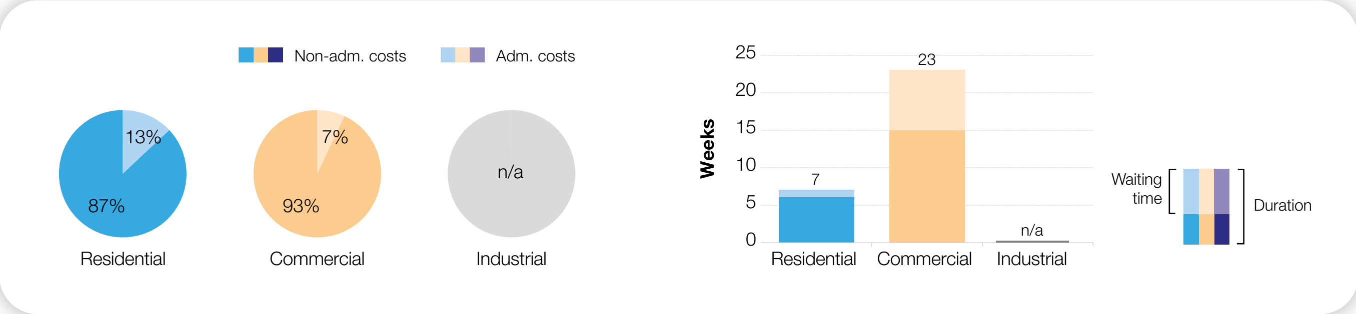

Figure 6.9 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

Residential systems continued to strongly increase in number in the Netherlands over the last year, thanks to their economical attractiveness in comparison with prices of electricity obtained by local electricity retail companies and the many collective PV system purchasing initiatives. The organisations behind these initiatives have achieved this success by offering a 'one-stop-shopping' service, easing the legal and administrative barriers for the buyers. Presently, the most important barriers for this market segment result from the financial support scheme and the administrative process related to requesting for grid connection.

The market for **commercial systems** has started to develop in the last few years, thanks to the increased awareness created by the original SDE support scheme. In the 2013 and 2014 version of the support scheme (SDE+) some of the earlier administrative barriers were reduced. Unfortunately, the financial support was reduced as well, both in terms of the available tariff and the certainty to obtain the grant. Obtaining a grant is often not financially sufficient for realising a PV project in this segment. New commercial initiatives (e.g. co-operative local PV system developments) might give this segment a boost over the coming years. PV project developers also still find it cumbersome to establish grid connections for the larger PV systems.

The market segment for **industrial ground-mounted systems** is almost non-existing in the Netherlands. With the SDE+ and the inclusion of solar in some regional urban development plans, projects have started to appear. So far, only a small number of systems of relatively small size have been realised. An increase can however be expected in the future.

Barrier Type	Name	Process	Description
Permitting Procedures	Denied approval of land development plan amendment	Administrative Process	A Municipality may eventually decide to not make an amendment to the land development plan (or not issue an exemption to the plan) in favour of a planned PV project. The reasons for such decision can be manifold.
Permitting Procedures	Lack of designated land for solar usage	Site Selection	As the segment for ground-mounted systems is new for the Netherlands, and notwithstanding the goodwill of regional authorities, the practical reality is that land designated for solar is scarce.
Operation & Maintenance	Potential impact of changes in net-metering conditions	PV System Operation	As with all support schemes, it is likely that the economical conditions for net-metering will change over time. The government stated already its intention to replace the present net-metering mechanism by a different one by 2017. This will most likely have an impact on the return on investment of the PV system.

Table 6.9 – Most severe market barriers in the Netherlands

Poland

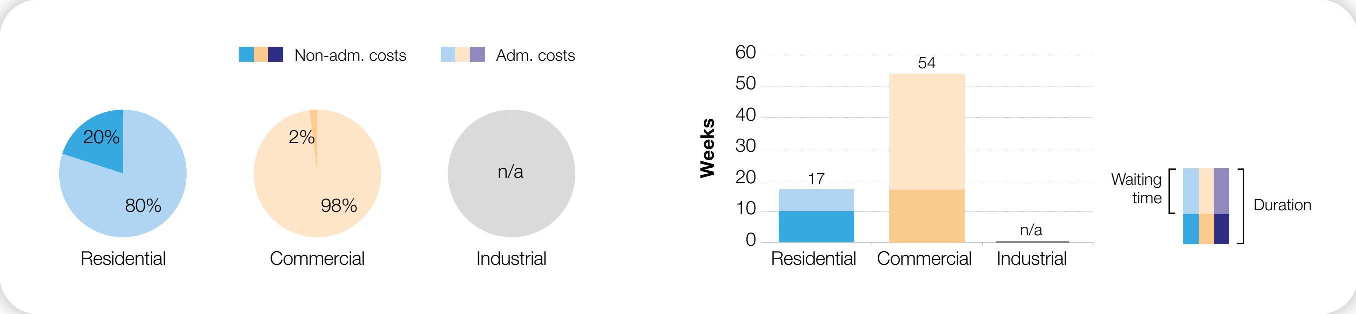

Figure 6.10 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The Polish PV market is hardly developed, as there are only a few systems above 10 kWp. Furthermore, from the administrative and grid connection point of view there is no segmentation: all PV systems, regardless of their size are treated in the same way.

Residential systems are poorly developed in Poland. With regards to **commercial systems**, the amendment to the Energy Law on 11 Sept. 2013 introduced changes in the installation of PV power above 40 kW: all installations above 40 kW are required to obtain a building permit. It is required to obtain a concession for the production and sale of electricity, therefore the electricity producer must establish a company. It is also required that in the local development plan or in the building conditions the source of renewable electricity, e.g. photovoltaic system, is explicitly named. The company can sell electricity at a price equal to the average wholesale price of electricity on the competitive market in the previous year. Companies can further apply for "green certificates ", which are traded on the Polish Power Exchange (POLPX), however, this current system of support is deemed unprofitable.

As for **industrial ground-mounted systems**, the segment is hardly developed and is not expected to grow in the coming years due to the low incentives offered by the state. The procedures applying to this type of PV system are in principle the same as in the commercial segment. The problem on the regional level may arise from municipal zoning plans.

Barrier Type	Name	Process	Description
Support-related	Costs of the PV system	Financing	Existing financing mechanisms: national and regional provide small grants and are not sufficient for the implementation of PV systems.
Permitting procedures	Conformity with the grid development plan	Site selection	It is required that in the local development plan or the building conditions the source of renewable electricity, e.g. photovoltaic system, is explicitly named. In case the above mentioned requirements are not fulfilled, changes in the plan are necessary. This takes at least 12 months and there is no guarantee that the query will end successfully for the investor.
Support-related	Costs of documentation and monitoring	Support schemes	Current methods of financing for photovoltaic systems are not very cost effective, when produced electricity is sold at a price equal to 80% of the average electricity wholesale price on the competitive market.

Table 6.10 – Most severe market barriers in Poland

Portugal

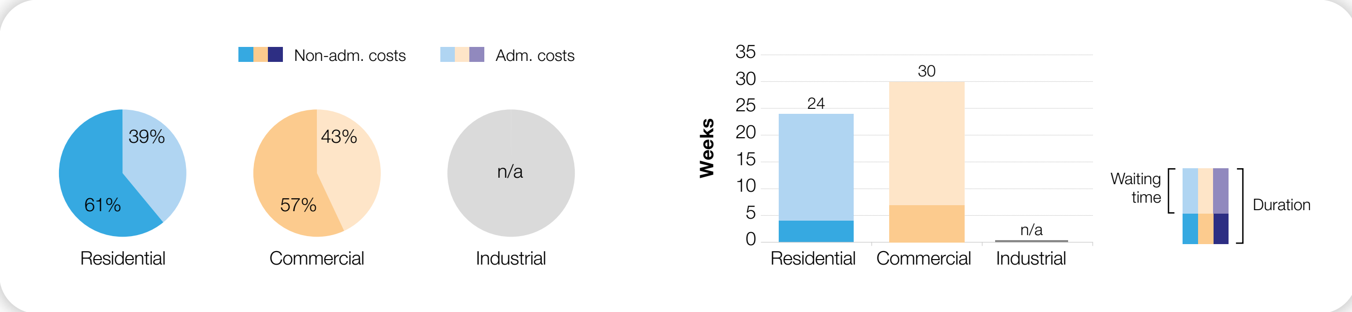

Figure 6.11 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

Despite Portugal being one of the sunniest countries in Europe, the PV market has not reached its actual potential. Since February 2013 both Mini- and Microgeneration are subject to the same legislation, the DL 25/2013. A new legislation for the whole PV-market is expected before the end of 2014. The draft has been discussed between the government and the associations/industry already. It will permit self-consumption systems up to 1 MW capacity with a low FIT for the exceeding production.

Residential systems on buildings are allowed with a maximum capacity of 3.68 kWh (nominal inverter capacity). Each consumer may install a PV system, but there are grid connection capacity restraints and an annual market cap in place. Until 2012, the annual cap was 25 MWn, which represents approximately the requested capacity, but was then limited to 10 MWn. This restriction has created serious problems for the PV sector, as the demand for licenses goes well beyond it. Another serious barrier is the application of technical requirements, which leads to high costs for the upgrade of existing grid connections. In the **commercial systems** segment, installations are relatively small and range from 20 to 250 kWn inverter capacity. The annual quota for this segment is 30 MWn. Again, this limit has created serious problems for the PV sector since it limits market demand consistently.

At present, the segment for **industrial ground-mounted systems** is inactive. The decree that used to support this PV segment (DL 312/2001) assumes the attribution of a specific kind of license (PIP - Project of Public Interest) as mandatory. However, these licenses have been blocked since 2006. As a consequence, it is theoretically possible to develop a plant of more than 250kWn. However, since the Government blocks the licenses, the legal framework does not apply. Regardless of the law from 2006, there was an open public tender of a total of 150 MWn. This was however an exceptional situation and it isn't expected to happen again in the next years.

Barrier Type	Name	Process	Description
Grid-related	Transformer capacity	Site selection	Total energy production in the medium voltage transformer area cannot exceed 25% of the transformer capacity, otherwise the license is rejected.
Grid-related	Technical barriers in construction and connection phase	PV System Construction	The technical guidelines are not adequate for a PV installation. The required installation is much more expensive and the labour costs increase significantly. The technical support by the utilities is insufficient.
Grid-related	Alteration to branch line	PV System Construction	An EDP (Energias de Portugal) technician must be called for alteration of branch lines. However, EDP may not respond to alteration requests for several weeks. This may cause serious problems because the time limit for project implementation is 120 days. There is no rule that specifically determines the time frame for an answer from EDP.

Table 6.11 – Most severe market barriers in Portugal

Slovakia

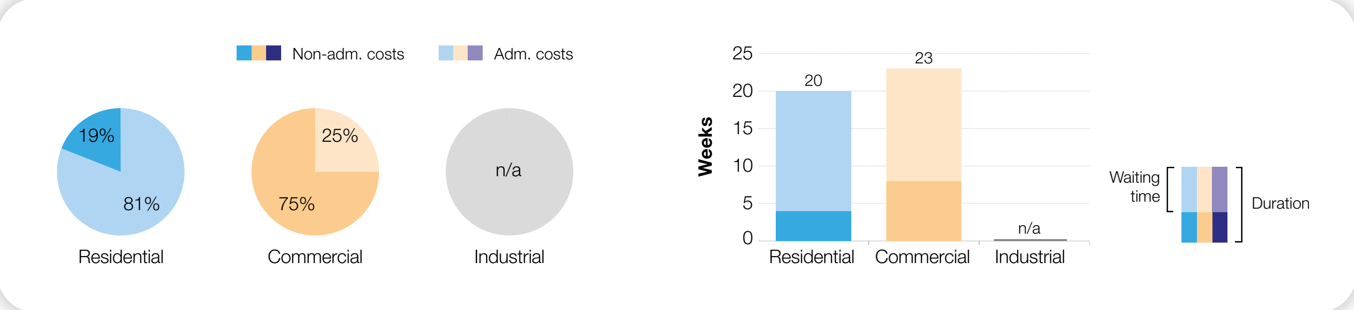

Figure 6.12 - PV project development : share of administrative costs, duration and waiting time

Summary of market status

The PV market in Slovakia is currently not thriving due to excessive administrative burdens, lack of governmental support and lack of competitiveness on the electricity market.

Residential systems represent the smallest share of PV systems installed in Slovakia. The only support scheme is the feed-in tariff. Due to its relatively low levels (0,08994 €/kWh), it results in a long investment return period. In addition, the legal-administrative and regulatory framework is unstable, changing a few times a year and involving excessive bureaucracy. As a consequence, the development process may take up to 10 months. The expectation for the near future is a decrease of new installations due to a lack of profitability and the complications resulting from the legal-administrative framework.

Commercial systems on building rooftops in Slovakia are allowed up to 30 kWp in size, after the PV boom up to 2012. Currently, there is no legal framework for these systems.

The **industrial ground-mounted systems** segment had seen a period of expansion in 2010 and 2011, when about 480 MWp were installed. Since early 2011, the installation of large systems is no longer allowed by the Slovakian legal-administrative framework : it is not possible to build a PV system sized larger than 30 kWp.

Barrier Type	Name	Process	Description
Support-related	Long waiting time for support contracts	Support Scheme(s)	The installer usually needs to wait for a long time to sign the contracts for FIT and Green energy due to an overload of work for the distribution system operators – very often only one person is responsible for the contracts.
Permitting Procedures	FiT certificate validation	Support Scheme(s)	The regional distribution system operator in central Slovakia (SSE-D) requires the validation of the FiT certificate. It means that once the producer gets the FiT certificate and signs the contract with the regulatory office, the regulatory office notifies the Ministry of Economy and both the producer and the ministry have 40 days to disclaim the contract. After this period the producer has to apply to the regulatory office to validate the FIT certificate. This step is uselessly prolonging the whole process.
Permitting Procedures	Bureaucracy	Administrative Process	It has been reported that there is an inappropriate amount of documentation and steps required by the regulatory office, such as the final inspection of the building where the PV system is installed, even in the case of small systems.

Table 6.12 – Most severe market barriers in Slovakia

Slovenia

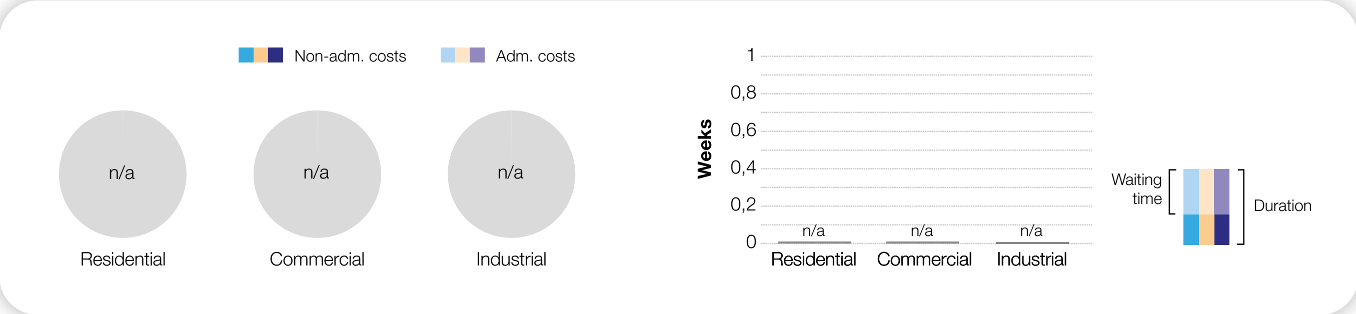

Figure 6.13 - PV project development: share of administrative costs, duration and waiting time[11]

Summary of market status

All three market segments appear to be developing quite strongly in Slovenia, although some regulatory issues still prove to be challenging for developers.

The sector of **small rooftop systems** on residential buildings in Slovenia pertains to the legislation of PV systems of up to 1MW and has been developing relatively well and fast since 2007 with the installed power almost doubling in each consecutive year. However, the recent change in the support mechanism has brought about almost a complete stop in terms of investments into the PV industry (year 2013).

The sector of **commercial PV systems** on buildings (50 kW) in Slovenia pertains to the legislation of PV systems of up to 1MW. The latter has been in sharp ascent since 2007. Due to the recent changes to the support scheme, however, the ascent has come to a near halt (year 2013). Despite this, PV systems sized up to 50 kW are still among the most popular.

Industrial ground-mounted systems are facing strong barriers to their development because of the 5 MWp cap for the FiT support system. Investors tend to split PV installations larger than 5 MW into groups of smaller ones. Furthermore, these systems are not considered simple constructions and thus the administrative authorization process may prove demanding.

Barrier Type	Name	Process	Description
Support-related	Annual cap for ground mounted PV systems	Support Scheme(s)	There is a 5 MWp yearly cap on ground-mounted PV systems up to which Borzen (power market operator) can provide the feed-in tariff. For 2014 the yearly cap is already reached.
Support-related	Digression rate of the FiT	Support Scheme(s)	Due to the changes in the feed-in support scheme for larger PV systems in late 2012, the year 2013 has seen a drastic drop of newly installed PV installations by a factor of 94% in the first 8 months. The overall installed power capacity amounted to only 32 MW (for comparison, the number in 2012 was around 122 MW). The relatively new support scheme foresees a digression rate of 2% on a monthly basis calculated on the previous month.
Permitting Procedures	Lack of administrative practice	Electric production	Due to the fact that there are currently no PV installations installed with a capacity of more than 1 MW in Slovenia, there is no practice in this field. For the building of a PV system larger than 1 MW also other administrative approvals need to be obtained (e.g. building permit, operating permit). In order to circumvent these special requirements the clients split their construction projects in multiple PV systems with a maximum capacity of 999 kW.

Table 6.13 – Most severe market barriers in Slovenia

11 Quantitative analysis of the Slovenian framework is not within the scope of the project.

Spain

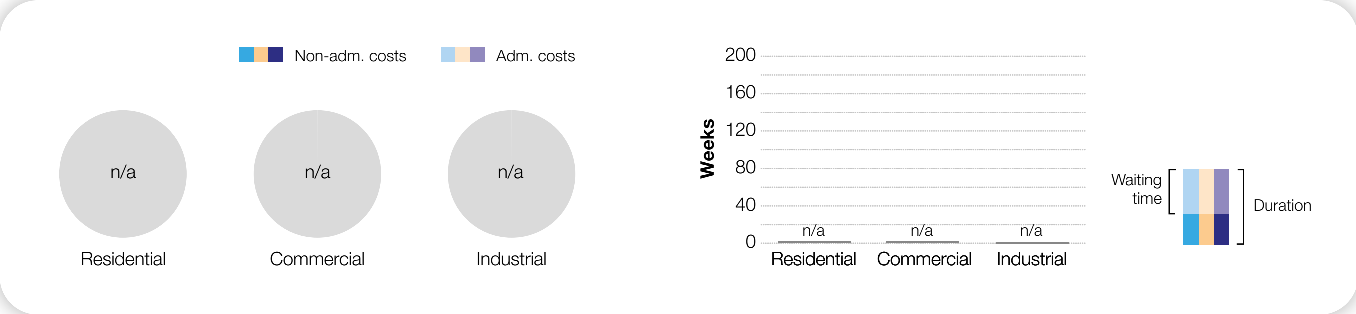

Figure 6.14 - PV project development : share of administrative costs, duration and waiting time

Summary of market status

A de facto moratorium is currently in place in Spain, all three market segments for PV are currently inactive – this process has started in 2012 with the then suspension of support schemes and progressed in 2013 and 2014 with a series of other measures that have radically changed the regulatory framework for PV.

Currently, there is no support scheme providing any incentives to PV systems. Support schemes, according to the new law of the electricity sector, would only be developed in exceptional situations and only in case achieving the 2020 EU goals without them prove impossible.

Residential and commercial systems are still not allowed to operate under a net metering scheme – although a legal framework for this was expected to be introduced in 2014. The type of systems allowed and the type of areas where a PV system installation is allowed have been reduced. Furthermore, the current legislation hinders self-production and consumption via the introduction of a "back-up toll", which renders the business model uneconomical.

Industrial ground-mounted systems have gone from representing nearly 100% of systems installed in Spain to a third of the total installed capacity in the country. Although theoretically allowed, industrial ground-mounted PV systems have not been built in Spain since the suspension of the support schemes.

Barrier Type	Name	Process	Description
Permitting Procedures	Connection Concession	Grid Connection permit	There are problems with the concession of access and connection to the corresponding transmission or distribution grid. The transmission or distribution grids can reach saturation level, affecting the lower voltage grids, in cases of energy evacuation towards the higher voltage grids
Permitting Procedures	High difficulties in accessing finance	Financing	Small systems face many difficulties when obtaining financing, unless they are guaranteed with personal belongings.
Grid-related	Lack of information	Grid Connection Permit	DSOs tend not to provide transparent information with regards to the grid capacity evaluation. Grid data and calculation tools are not available to connection point applicants.

Table 6.14 – Most severe market barriers in Spain

Sweden

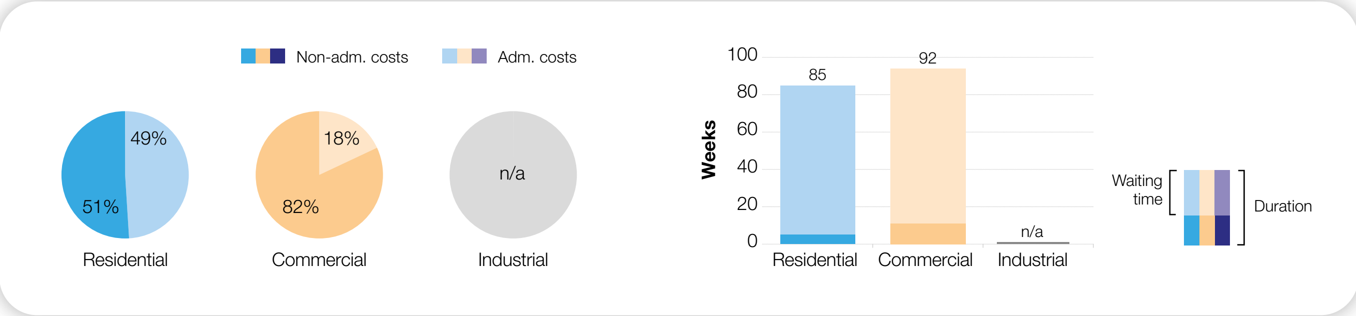

Figure 6.15 - PV project development: share of administrative costs, duration and waiting time

Summary of market status

The market for **residential systems** has existed just since July 2009 when a new investment subsidy was introduced. The subsidy has recently been prolonged until 2016, however, the total budget for the investment subsidy is limited to 24 million € for 2013-2016, of which 17 million € have already been distributed. On 30 January 2014 the government released a proposal offering tax deductions for excess electricity fed into the grid, but in early June 2014 no decision was taken by the parliament on this proposal. Whether and when this proposal may come back to the parliament for a vote is currently unclear. If the proposal is applied it will be positive for this segment. However, the limited investment subsidy will probably prevent this segment from growing.

The market for **commercial systems** is also mainly driven by the above mentioned investment subsidy. However, there is also a maximum subsidy of 139,000 € per property which sets an upper limit of the system size. The Proposal mentioned for residential system also partially applies to commercial ones, however it would have a more limited effect as it is suggested to be valid for a maximum of 30 000 kWh per year and for a maximum of 69 kW systems.

There is no market for **industrial ground-mounted systems** in Sweden, due to the inapplicability of the support system for large installations. Also, the production cost of PV electricity without subsidies is higher than the Nord Pool electricity spot market price. However, the interest for building larger systems has increased and the first 1 MW plant was inaugurated in February 2014.

Barrier Type	Name	Process	Description
Support-related	Complex electricity certificate system	Support Scheme(s)	The electricity certification system is not adapted to residential PV systems. The demand of hourly production measurements requires the producer to buy a service that is too expensive to make any profit from the certificates.
Support-related	Cap of investment subsidy budget	Support Scheme(s)	The total government budget for investment subsidies is limited to approximately €7 million (60 MSEK) in 2012, of which €0.3 million (2.5 MSEK) are used to cover administration costs of the authorities. The budget is too low to allow for funding of all applicants.
Grid-related	Grid capacity cap	Grid connection permit	At some grid operators a cap of total installation of intermittent power production (PV and wind power) may exist. That is for instance applicable on the island Gotland where the HVDC transmission to the mainland sets a limit of how much power can be installed and connected to the grid on Gotland. All installations planned on Gotland with a fuse higher than 63 Ampere are placed in an installation queue by the grid operator if they plan to feed electricity into the grid. These installations will not be allowed to connect before a new HVDC transmission cable to the mainland is in place, which will happen the earliest by 2017.

Table 6.15 – Most severe market barriers in Sweden

United Kingdom

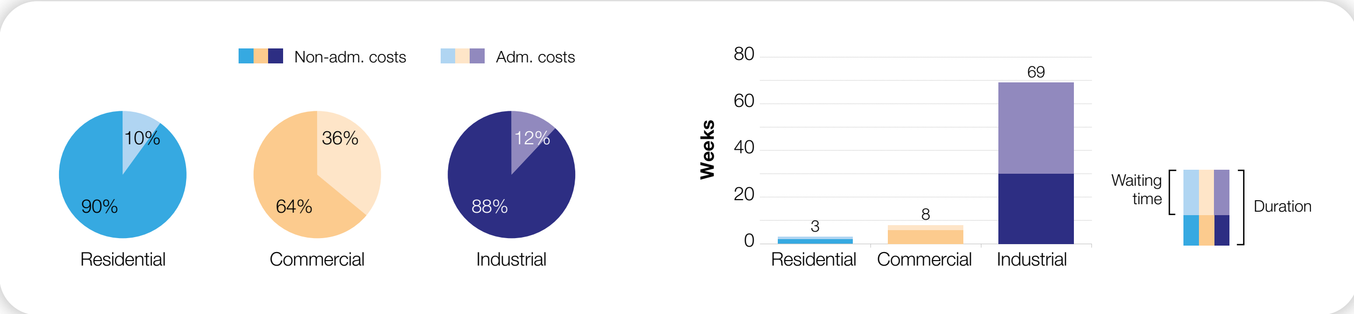

Figure 6.16 - PV project development : share of administrative costs, duration and waiting time

Summary of market status

The latest estimations (November 2013) of the amount of installed PV capacity in the UK by the Department of Energy and Climate Change indicated that there are about 2.6 GW of installed PV capacity in operation, mainly concentrated in the residential and commercial market segment. Larger installations are also present but to a lesser extent. **Residential systems** can count on a quite swift procedure with minor and relatively few barriers in the installation process, as it takes between 2 and 4 weeks to complete the whole process.

Commercial systems show slightly larger values in terms of overall process time and labour invested, but the segment appears to be in relatively good health. Installation of a commercial system takes 8 weeks on average. The biggest legal and administrative barriers occur at the site selection and grid connection stages of the process. These are not insurmountable, but the process could be made easier.

The project lifecycle of **industrial ground-mounted systems** takes 69 weeks on average and cases of processes lasting up to three years have been recorded. About half of this time is calculated as waiting time, that is time spent waiting for an answer from authorities. Usually, operators of industrial ground-mounted systems make use of the renewables obligation quota system instead of the feed-in tariff, following a drop of the latter in 2011.

Barrier Type	Name	Process	Description
Support-related	PV does not qualify for Enhanced Capital Allowances	Financing	Unlike some other renewable technologies, solar PV does not qualify for Enhanced Capital Allowances. This means that solar PV is not treated as favourably as other technologies with regard to corporation tax.
Grid-related	Cost of grid upgrade	Grid Connection Permit	Costs of grid upgrades charged on developers can be prohibitive.
Permitting Procedures	Change of land use	Administrative process	There may be objections to changing the use of the land e.g. from agriculture to power generation, leading to consistent lead times.

Table 6.16 – Most severe market barriers in the United Kingdom

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7. GLOSSARY

Booster Transformer is a transformer of which one winding is intended to be connected in series with a circuit in order to alter its voltage and the other winding is an energizing winding.

Closed-Loop Operation (or Closed Ring Operation) is the method of operation where each point of a given part of a network is fed from two sources along two distinct paths.

Electricity retailer is a company that is selling electricity to the final user.

Fast Voltage Deviations are defined as the variations that occur instantaneously in a network in case a generation plant suddenly disconnects.

Feeder is a power line transferring power between distribution substations and consumers.

Grid connection fees are to be paid for the connection of the PV system to the grid.

Grid operator: operator of transmission or distributions grids that transmits or distributes electricity within a designated area and co-ordinates its services with other grids.

Grid usage fees are to be paid for the use of the grid (e.g., for transport or storage of generated electricity).

Ground-mounted system: this term covers all PV systems that are installed on the ground.

Grid hosting capacity is the maximum DER penetration for which the power system operates satisfactorily.

Installed capacity is the sum of the PV modules' rated power of a PV system. The rated power is either calculated as sum of the nameplate capacity of the modules or the sum of the flashed power of the PV modules.

Installer: the person or company that installs the PV system.

Inverter is the device that converts direct current (DC) to alternating current (AC).

Land development plan represents the higher level in land use planning. Used for planning on town level.

Land use planning: Branch of public policy that encompasses various disciplines that seek to order and regulate the use of land in an efficient and ethical way.

Legal-administrative barriers are barriers that are caused by regulations stemming from government bodies or grid operators and which delay the authorisation or the installation of PV systems. This definition comprises bureaucratic barriers but also covers barriers that stem directly from the law and not only from its application by the administration.

Listed building: a building that has been placed on a list of Buildings of Special Architectural or Historic Interest. Usually, a listed building may not be demolished, extended or altered without permission from the local planning authority.

Maximum capacity: the highest possible output of a PV system under normal conditions.

On-Load-Tap-Changer (OLTC) is a device for changing the tapping connections of a winding, suitable for operation while the transformer is energized or on load.

Point of common coupling (PCC) is the point on the public electricity network at which customers are connected.

Project developer: a person or company that is in charge for the planning and development of the PV project.

PV system operator: a person or company that (owns and) operates a PV system.

Rooftop system: this term covers all PV systems that are installed on or in the roof of buildings.

Slow Voltage Deviations are defined as the variations that occur in voltage during normal operation, due to the behaviour of generation and load connected to a given network.

Static VAR Compensator (SVC) is an electrical device that provides fast-acting reactive power in an electrical network under various system conditions.

Supervisory control and data acquisition (SCADA) usually refers to centralized systems which monitor and control entire sites, or complexes of systems spread out over large areas (anything from an industrial plant to a nation).

Urban development plan: The lowest level in land use planning. Used for planning on local level and on parts of a town

PV GRID

Reducing barriers to large-scale integration of pv electricity into the distribution grid

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