Global Solar Photovoltaic Development: Why do countries start and stop developing PV?

Gaurav Daswani
4276493
Sustainable Energy Technology
Faculty of Electrical Engineering, Mathematics, and Computer Science

TU Delft Delft University of Technology

MSc Thesis in the faculty of Electrical Engineering, Mathematics, and Computer Science

Gaurav Daswani
Student Number: 4276493

Thesis Committee Members
1st Supervisor: Prof. Dr. Kornelis Blok
2nd Supervisor: Dr. Nihit Goyal

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I am grateful for my family and friends, who always supported my decisions because they believed in me.

Executive Summary

Fossil fuels play an important role as an energy source in the world. The high use of fossil fuels does not come without environmental and climate challenges. The development of renewable energy technology is seen as one of the solutions to tackling these challenges because of its non-carbon-emitting characteristic. Renewable energy technologies required governmental support to grow because of their high costs compared to their fossil fuel counterpart.

Countries adopted different renewable policy strategies, resulting in different photovoltaic development trajectories. When observing these photovoltaic development trajectories in countries, a recurring pattern occurs in which development starts and stops. One of several examples of this pattern was when photovoltaic development in Germany began to increase in 2003 with an annual capacity added of 175 MW, then peaking at 8161 MW in 2012 and decreasing to 2633 and 1190 MW, respectively, over the following two years. Another instance was in Spain in 2006. Photovoltaic development started to take off with an annual capacity added of 78 MW, peaking at 2890 MW in 2008 and decreasing to 39 MW the year after. This pattern results in development stagnation and harms the country's markets, jobs, and investor confidence.

If the renewable policy strategies adopted by countries result in stop-and-go patterns of development, causing the aforementioned negative impacts, why do countries adopt them? The process of policy-making across countries is believed to be subject to different factors such as the country's natural resources, culture or beliefs, history, pressure groups, or external events. What could be considered an important reason for one government to adopt or cease a renewable policy may not be important for another country, given the different factors and external events. What are the reasons these different countries adopt these stop-and-go policies?

To understand the underlying cause of the stop-and-go policies in different countries, we take a closer look at the photovoltaic development trajectory in several countries. First, we identify the reasons countries started and stopped developing solar PV in the literature. After identifying these reasons, we analyze each country to determine which of these reasons were important for the countries to start or stop developing solar PV. Last but not least, we compare which of these reasons were important for starting or stopping the support of solar PV across countries. Data was collected through literature review and desk research. This thesis analyzed seven countries, nine go events, and four stop events. The countries analyzed in this thesis were France, Germany, Italy, Japan, Spain, the United Kingdom, and the USA. The volume of data analyzed consisted of approximately 277 documents. The analyzed documents were governmental policy documents, peer-reviewed scientific papers, and reports from global organizations such as the IEA, IRENA, REN21, and GWEC.

The findings indicated that improving the security of supply and stimulation of the economy were extremely important reasons countries developed solar PV. Countries with abundant domestic fossil fuel resources developed solar PV to stimulate their economies, while countries with scarce domestic fossil fuel resources developed to improve their security of supply. Improving the security of supply as a reason alone was enough in some instances for countries to start developing solar PV. Countries stopped developing solar PV due to an economic crisis or the prioritization of other economic sectors or energy technologies. However, the same economic crisis that caused certain countries to stop developing solar PV was the reason for some countries to stimulate their economy.

When countries decided to stop support of PV, some countries took a more aggressive approach to reduce support than others, causing PV capacity added to decrease at a different pace.

Nuclear disasters were initially thought to be a reason why countries started developing solar PV though the evidence was limited. However, upon further investigation, it became evident that PV development started before the accident to improve the security of supply and create an industry but was accelerated after the accident.

Stop-and-go policies can occur in different countries because the countries can be triggered by the same external events that influence energy policy, for example, the 1970s oil crisis, the 2008 economic crisis, and the reduction of PV costs. Stop-and-go policies also occur due to the election/appointment of new governments that reduce or increase support for solar PV.

As a recommendation for policymakers, policymakers should monitor PV capacity added and PV cost trends in the short term to amend PV support policies. PV development increased between 2008-2010 due to falling PV

costs and lagging policy amendments leading to explosive growth. This explosive growth happened during an economic crisis. In the context of an economic crisis, the levies on electricity bills for PV support received increasing negative attention. On the other hand, taking a too-aggressive approach to decrease solar PV support may negatively impact investor confidence and the future development of PV in a country. Thus, countries must monitor developments closely and adjust support accordingly. Recommendations for further research on this topic are provided in the conclusion.

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1 Introduction

Fossil fuels were the dominant energy source and currently remain the dominant energy source. In 1987 the total primary energy supply of fossil fuels was 87%, and in 2019 it was 81% (IEA, 2021). Fossil fuels contributed 63% of the total electricity supply in 2019. This high use of fossil fuels does not come without environmental and climate challenges. Due to greenhouse emissions that occur while burning fossil fuels, the concentration, and emissions of greenhouse gases in the atmosphere have reached a historical high driven mainly by our continued high usage of fossil fuels (IPCC, 2022). Greenhouse gases are the root cause of climate change, and without climate action, our ecosystems and human societies across the globe will be catastrophically and irreversibly altered.

The development of renewable energy technology is seen as one of the solutions because of its non-carbon-emitting characteristic. In 2021 annual capacity additions of renewable energy technology broke a new record increasing to 295 GW (IEA, 2022).

This record-breaking development did not manifest without its challenges and complications. Renewable energy technology was at an early stage when development started meaning these technologies required governmental support to grow because of their high costs compared to their fossil fuel counterparts (Jacobsson & Lauber, 2006) (Breetz, Mildenberger, & Stokes, 2018). If renewable technology was going to play a significant role in climate action, sound policy was required.
Countries adopted different renewable energy policy strategies resulting in different renewable development trajectories. Countries chose strategies such as adopting a feed-in tariff, adopting an RPS portfolio, or issuing tax credits to promote renewable development (Gallagher, 2013)(Sahu, 2015). As a result of the adopted renewable energy policy strategies, photovoltaic development increased globally in a smooth upward trend, as observed in Figure 1. In Figure 2 the share of solar generation in electricity production can be seen. However, when observing the photovoltaic development trajectory in the countries, a recurring pattern occurs in which development starts and stops. This pattern results in development stagnation and harms the country's markets, jobs, and investor confidence.
If the renewable policy strategies adopted by countries result in stop-and-go patterns of development, causing the aforementioned negative impacts, why do countries adopt them? The process of policy-making across countries is believed to be subject to different factors such as the country's natural resources, culture or beliefs, history, pressure groups, or external events (Jacobsson & Lauber, 2006) (Huenteler, Schmidt, & Kanie, 2012) (Schmid, Sewerin, & Schmidt, 2020). What could be considered an important reason for one country to adopt or cease a renewable policy may not be important for another country, given the different factors and external events.

This stop-and-go pattern in the development of solar photovoltaics occurs in different countries; however, the underlying cause has not yet been studied in detail. To understand the underlying cause of the stop-and-go policies in different countries, we will closely examine photovoltaic development in several countries. We start by identifying the reasons countries started and stopped developing solar PV in the existing literature. After identifying these reasons, we analyze each country to determine which of these reasons were important for the countries to start or stop developing solar PV. Last but not least, we compare which of these reasons were important for starting or stopping the support of solar PV across countries. This thesis focuses mainly on the electricity sector for two reasons. In many countries, the electricity sector is where most carbon dioxide emissions occur and where most progress can be achieved in the short-term (Geels, 2014) (IEA, 2021). We focus on the countries France, Germany, Italy, Japan, Spain, the United Kingdom, and the United States. For this thesis, nine go events and four stop events were investigated.

In order to understand the stop-and-go pattern, we try to understand why countries stop and start developing renewable energy. Gallagher explored the reasons why and how the governments of Denmark, Germany, China, and certain US states develop renewable technology by comparing four factors for each case. The four factors explored for each case were the economic motive, the renewable source potential or availability of non-renewable sources, the political system, and the culture/attitude (Gallagher, 2013). The findings were that economic motives played an important role in all these countries supporting renewables. The availability of domestic resources (renewable and nonrenewable) combined with the dependence on fossil fuel imports explained the motivation to support renewables. Jacobsson & Lauber applied the advocacy coalition framework to Germany to explain the diffusion of renewable energy technology, specifically wind power and solar PV (Jacobsson & Lauber, 2006). The external events, advocacy coalitions, and policies that influenced wind and solar PV development in Germany were discussed. Del Rio analyzed the FIT policy in Spain. He tried to answer what the reasons for success were behind the solar PV policy and reforms in the policy and discussed the interactions between the main actors (Del Río González, 2008). Sklarew applied the ACF in Japan and focused on the powerful influence of electric utilities on policymaking in the energy sector (Sklarew, 2018). Cherp et al. analyzed the energy transitions in Germany and Japan by comparing the paths of development of nuclear, wind, and solar PV in the two countries (Cherp, Vinichenko, Jewell, Suzuki, & Antal, 2017). This analysis compared the relevant actors and events influencing renewable energy policy in both countries. The annual REN21 Global Status Report discussed annual global trends and highlighted renewable energy policy, renewable technology market and industry trends, and investment trends across countries (REN21, 2022). The annual Renewable Energy Market Update presented forecasts for capacity additions by analyzing technology trends, key uncertainties, and policy implications that may affect the development of renewables in the following year (IEA, 2022). In the annual IEA-PVPS national survey reports on solar PV capacity additions, the policy that contributed to the increase or decrease in development was discussed (IEA-PVPS, 2022). However, the reports do not mention why the government introduced the policy, nor are countries compared because each report focuses on the individual country. In the PV Status Report 2019, various countries' solar PV capacity additions and the main policy responsible for development were briefly discussed.

Solar photovoltaic development is part of a country's national renewable energy policy that is subject to different forces such as the different governments over time, public opinion, the influence of the incumbent energy industry, events such as nuclear accidents or natural disasters, or external policies such as pollution policy. Which past events and actors have shaped today's renewable energy policy? Which forces cause the stop-and-go policies in different countries affecting the development of solar photovoltaics? Can we explain the stop-and-go dynamics by analyzing these countries based on the reasons for starting and stopping support of solar PV found in the existing literature?

This research was conducted as part of the study program Sustainable Energy Technology at the Delft University of Technology as part of the Economics & Society track. This research embraced the study of the relationship between the introduction or ceasing of governmental policies, external events, competing energy technologies, and the capacity added of solar PV and compares this across countries. This thesis does not aim to focus on the diffusion of solar PV technology across countries. Instead, it seeks to discover the reasons governments supported or stopped the support of solar PV.

This thesis is structured in the following way. In Section 1.1, the goal and objectives of this research are discussed, followed by the research question in Section 1.2. In Section 1.3, the sub-questions and thesis approach are discussed. In Chapter 2 we first define the framework used to analyze the countries by identifying the reasons countries started and stopped developing solar PV in the literature. We then discuss the methodology in Chapter 3. In Chapter 4 we analyze the seven countries individually using the framework to determine which reasons were important for countries to start or stop developing solar PV. In Chapter 5, we present our results by comparing the analyses across the countries. Ultimately, we present the discussion and conclusion.

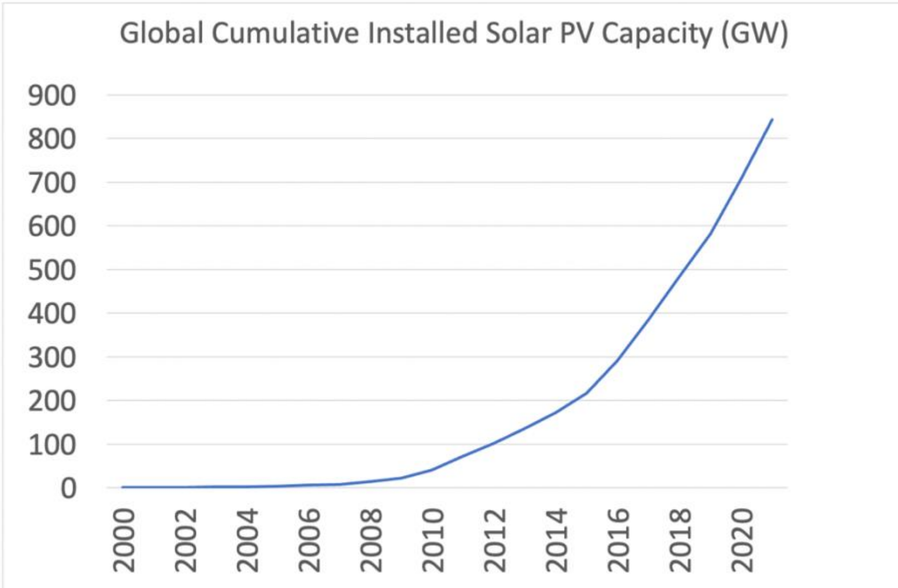

Figure 1. Global Cumulative Installed Solar PV Capacity Source: (BP, 2022)

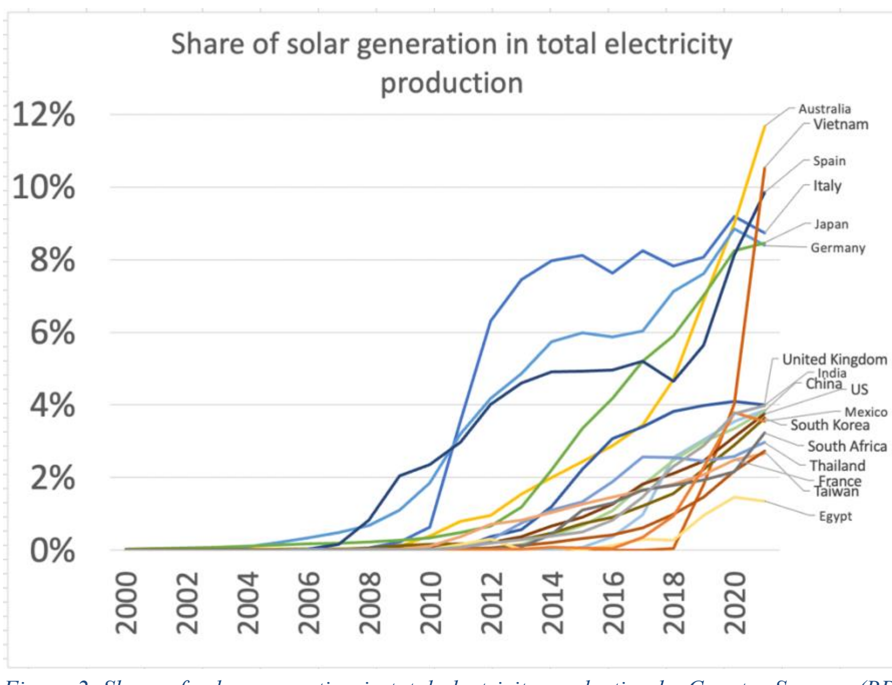

Figure 2. Share of solar generation in total electricity production by Country Source: (BP, 2022)

1.1 Goal and objectives

The purpose of this research is to *develop a better understanding of the underlying causes of stop-and-go policies in the development of solar PV.* By understanding the underlying causes, we can determine how to prevent the stop-and-go from occurring to accelerate the energy transition of the power sector.

We try to do so by identifying the reasons countries started and stopped developing solar PV in the literature. After identifying these reasons, we analyze each country to determine which of these reasons were important for countries to start or stop developing solar PV. Last but not least, we compare which of these reasons were important for starting or stopping the support of solar PV across countries. A better understanding and assessment of why countries stop and start supporting solar PV would help policymakers understand what causes the stop-and-go in the development of renewables.

1.2 Research question

To achieve the research objective, we formulate the main research question:

Why do stop-and-go policies in solar photovoltaic development occur in different countries?

1.3 Thesis approach and structure

The research approach of this thesis was to develop a framework by identifying which reasons were important for countries to start and stop developing solar PV in the literature, then use this framework to analyze the countries individually and ultimately compare the results across countries.

The main research question is: *Why do stop-and-go policies in solar photovoltaic development occur in different countries?*

In order to try to answer the main research question, we try to answer the following sub-questions:

The sub-questions are:

1. What reasons have been identified in the literature for countries to start supporting solar PV?
2. What reasons have been identified in the literature for countries to stop supporting solar PV?
3. For each country: What reasons were important for the country to start supporting solar PV?
4. For each country: What reasons were important for the country to stop supporting solar PV?
5. Across countries: What reasons were important for countries to support solar PV?
6. Across countries: What reasons were important for countries to stop supporting solar PV?

The countries analyzed were:

1. France
2. Germany
3. Italy
4. Japan
5. Spain
6. UK
7. USA

Countries were pre-selected based on the presence of the stop-and-go pattern. From these pre-selected countries, preference for research was given to countries with larger cumulative capacity. For further elaboration on the selection of the countries, see Section 3.2. For this thesis, nine go events, and four stop events were analyzed. The timeframe countries analyzed in this thesis was 2000-2020. The research was conducted on a country basis to investigate what is already known about solar PV development trends in the selected countries. For each stop-and-go event, peer-reviewed publications, reports by international bodies, NGO documents, and government policy documents from the selected country were examined.

The structure is as follows: In Chapter 2 we first define the framework used to analyze the countries by identifying the reasons countries started and stopped developing solar PV in the literature. We then discuss the methodology in Chapter 3. In Chapter 4 we analyze the seven countries individually using the framework to determine which reasons were important for countries to start or stop developing solar PV. In Chapter 5, we present our results by comparing the analyses across the countries. Ultimately, we present the discussion and conclusion.

2 Framework

The purpose of this chapter is to introduce and discuss the framework consisting of reasons for countries to start and stop developing solar PV identified in the literature. The reasons for stop-and-go identified in the literature are discussed in Section 2.1, followed by the advocacy coalition framework in Section 2.2.

2.1 Reasons for stop-and-go

This section presents the reasons countries started and stopped developing solar PV found in the literature. The purpose of this review was to find reasons countries started and stopped developing solar PV. This literature review was conducted by examining peer-reviewed scientific papers and reports done by organizations such as the IEA, IRENA, and REN21. Research on renewable energy development on an individual country basis was analyzed by consulting academic literature and policy documents. Research in which the energy transition of countries was compared was also analyzed.

The two sub-questions answered in this section are:
1. What reasons have been identified in the literature for countries to start supporting solar PV?
2. What reasons have been identified in the literature for countries to stop supporting solar PV?

The process of policy-making across countries is believed to be subject to different factors such as the country's natural resources, culture or beliefs, history, pressure groups, or external events (Jacobsson & Lauber, 2006) (Huenteler, Schmidt, & Kanie, 2012) (Schmid, Sewerin, & Schmidt, 2020). What could be considered an important reason for one country to adopt or cease a renewable policy may not be important for another country, given the different factors and external events.

The reasons presented in this section can be seen as hypotheses for reasons why countries have started or stopped developing solar PV. The author acknowledges that the presented reasons are not independent or disconnected. The dependence or relations between the reasons is out of the scope of this research due to time constraints but can be an interesting topic for further study.

Energy Crisis / Security of Supply
High dependence on fossil fuel imports can be a reason for countries to support the development of renewables. (Gallagher, 2013). Gallagher's findings indicated countries with scarce domestic fossil fuel resources and renewable potential develop renewables in order to improve energy security. In Gallagher's findings, this was the case for Denmark. During energy crises such as oil shocks, countries with high fossil fuel import dependence support solar PV to improve the security of the supply (Moe E. , 2015) (Jacobsson & Lauber, 2006). Moe claims this was the case for Japan after an energy crisis in the 1970s. Likewise, the work of Jacobsson & Lauber claimed this for Germany. Jacobsson & Lauber analyzed policies that contributed to the diffusion of solar PV and wind from 1974-2003.

Create an industry / Stimulate the economy

Economic motives can play an important role in countries to support the development of solar PV (Gallagher, 2013) (Moe E. , 2015). The findings of Gallagher were that countries with abundant fossil fuel resources support renewables to stimulate the economy. On the other hand, even in countries with scarce domestic resources, solar PV policy was introduced for industrial development, as shown in Japan in the findings of Moe. Scaling up the renewable energy technology industry creates business opportunities for small and large companies and export businesses for the country. After an industry reaches a critical size, it makes it opportune for politicians along the political spectrum to support it. The work of Grover indicates that a government can choose to stimulate the economy shortly after a recession (Grover, 2013).

Nuclear accident
To respond to a nuclear accident, a country can decide to support renewables (Huenteler, Schmidt, & Kanie, 2012). The findings of Huenteler et al. showed that the regulatory framework of the country increasingly focused on nuclear energy before the nuclear accident in the case of Japan. In addition, no stringent regulatory framework had been implemented to support renewables before the accident, concluding that the government was impeding the use of renewables rather than increasing it. After the disaster, the country supported renewables to compensate for the supply shortage after the accident. The work of Jacobsson & Lauber showed political support in Germany for renewables increased due to public pressure after a nuclear accident in 1986 (Jacobsson & Lauber, 2006).

Emission Reductions
Countries that are heavily reliant on coal support renewables in order to reduce emissions (Schmalensee, 2012). In the findings of Schmalensee, the strongest argument to support the development of renewables in the United States was to reduce CO_2 emissions due to the country's heavy dependence on fossil fuels. Fischer & Preonas compare the effectiveness and interaction of different renewable energy support policies. One of the motivations for increased support for renewable development was to reduce emissions (Fischer & Preonas, 2010).

Energy diversification
Seriño discusses energy diversification as a motivation for countries to develop renewables (Serino, 2019). More evidence for this hypothesis is rather limited in the literature. Although related, this reason is not to be confused with the previously discussed reason developing for energy security. An example could be when a country is heavily dependent on nuclear technology while not relying on foreign sources for energy. This reason assumes the country is not dependent on foreign energy sources.

EU Pressure/Renewable Targets
Member countries of the EU can be pressured to reach renewable energy generation targets. In France, a national survey report mentions the main reason driving photovoltaic policy implementation was the EU renewables target (IEAPVPS, 2008). Bocquilon & Evrard believed it was EU pressure that pushed France to implement its first photovoltaic support policies (Bocquillon & Evrard, 2017). In another instance, the IEAPVPS report discussed how Spain organized tenders to meet renewable target goals (IEA-PVPS, 2018).

Economic Crisis
The findings of Del Rio and Mir-Artigues discussed how Spain retracted support for solar PV because of increasing costs of solar PV support during a broader economic downturn (Del Río & Mir-Artigues, 2014). Mahalingam & Reiner compare two European countries and discuss how both scaled back support for renewables during the Global Financial Crisis of 2008 (Mahalingam & Reiner, 2016). Economic income often leads to less government income and to a need to cut budgets and therefore reduce support for renewable energy.

Prioritizing other sectors
Governments can choose to stop developing renewables to invest in energy alternatives or other policy sectors though evidence in the literature is limited. This can happen after an election of a new government or president. Moore and Roberts discussed the slashing of the solar PV budget while spending on defense increased in the USA (Moore, 1982) (Roberts, 1983). Miller discusses how support for renewables decreased and other sectors, such as coal, oil, and gas, increased after a new administration came into office (Miller, 2018).

Coalition shift
Governments can support solar PV due to a shift in advocacy coalition dominance. Advocacy coalitions are comprised of actors who share equal belief systems concerning a particular policy. The shift of dominance from one coalition to another coalition can lead to policy change. We discuss the advocacy coalition framework in more detail in the next section.
Schmid et al. used discourse network analysis to identify the advocacy coalitions in three different periods allowing us to see the growth or decline of the coalitions over the periods in Germany and explained this phenomenon as a result of the policy-induced feedback (Schmid, Sewerin, & Schmidt, 2020). Certain aforementioned reasons can also impact coalition shifts, such as nuclear disasters, as was observed by Schmid et al. For this reason, we will dive into the advocacy coalition framework in the next section.
The findings of Jacobsson & Lauber showed how dominance shifted from nuclear and coal coalitions to renewable coalitions over time (Jacobsson & Lauber, 2006). The findings discuss the early formation and growth of a renewable advocacy coalition, lobbying by the minority advocacy coalition for institutional support, and the attempts of the dominant advocacy coalition to oppose the shift. Support for the dominant coalitions decreased while support for renewables increased.

2.2 Advocacy Coalition Framework

The Advocacy Coalition Framework (ACF) was developed by Sabatier to understand and describe factors influencing policy processes (Sabatier P. , 1998)(Weible, Sabatier, & McQueen, 2009) (Cairney, 2011). ACF focuses on the actors and external events that influence policy change. The ACF key research questions focus on whom advocacy coalitions are formed by, what the reasons were for their creation, and which external events were responsible for their creation and growth or decline. These key questions contribute to our understanding of coalition shifts as a reason for countries to start and stop developing solar PV. The advocacy coalition framework was chosen to determine whether or not coalition shifts were an important reason for a country to start or stop developing solar PV.

The ACF framework tries to describe policy action within a complex policymaking system by simplifying it. The system is comprised of five components, as seen in Figure 3. The five components are the policy subsystem, relatively stable system parameters, external events, and long-term opportunity structures for coalitions.

Subsystem
Policy subsystems consist of policy participants seeking to influence policy in a specific policy domain for an extended period, often decades. Within the subsystem, coalitions compete and use resources to obtain their desired policy outcome.

Advocacy Coalitions
An advocacy coalition is comprised of actors who share equal belief systems concerning a particular policy. Actors can be from multiple levels of government as well as the private sector. This ranges from government officials, journalists, and researchers, to the general public. Actors with equal beliefs are grouped into a coalition. Coalitions compete to influence policy to their desired policy outcome and objectives. These actors regularly try to actively influence the policy of the specific domain.

Long-term opportunity structures for coalitions
Long-term opportunity structures for coalitions relate to the process and actors of the political system. How centralized is the decision-making process? Does the government need to cooperate with other parties?

Belief system
The advocacy coalition framework divides beliefs into three categories: deep core beliefs, policy core beliefs, and secondary beliefs. Deep core beliefs are based on normative values and worldviews that are difficult to change.Policy core beliefs are positions towards a specific policy in terms of salience and the role of the state. Secondary beliefs are specific measures and policies to be implemented.
Relatively stable parameters

Relatively stable parameters are defined as stable exogenous factors such as basic attributes of the problem area, basic distribution of natural resources, fundamental socio-cultural values, social structures, and basic constitutional structures. Relatively stable parameters establish constraints and resources in how policy participants operate in the subsystem. These parameters are less likely to change.

Policy change
ACF distinguishes between minor and major policy changes. A minor policy change means adaptations of policies and measures. A major change is defined as new or fundamentally different policy goals, programs, and measures. A minor change is seen as a difference in secondary belief, while a major change is seen as a difference in shifting core beliefs.

Policy-oriented learning
An aspect of policy change is the policy-oriented learning (Sabatier P. , 1988). Changes in policy core beliefs can occur through policy-oriented learning. Policy-oriented learning occurs when coalitions compete against each other in order to further their policy objectives. Coalitions will seek knowledge and resist knowledge not in line with their beliefs to further their policy objective. This type of learning, however, is not neutral because coalitions keep their policy objectives in mind.

External and internal events
Shifting core beliefs do not change voluntarily. ACF attributes the change of core beliefs and policy change to external events that trigger external shocks or internal shocks in the policy subsystem.
External events could be changes in socioeconomic conditions, changes in public opinion, environmental disasters, and changes in the governing coalition (not the advocacy coalition).
Internal and external shocks are triggered by external events, but the difference lies in the way the coalitions respond to the external event (Cairney, 2011). An internal shock occurs after an external event when coalition actors change their beliefs and consequently leave the coalition due to the failure of the policy they supported or a crisis of confidence in their belief system. An external shock occurs when there is an element of competition, the minority coalition exploits the external event to show that its belief system is superior.

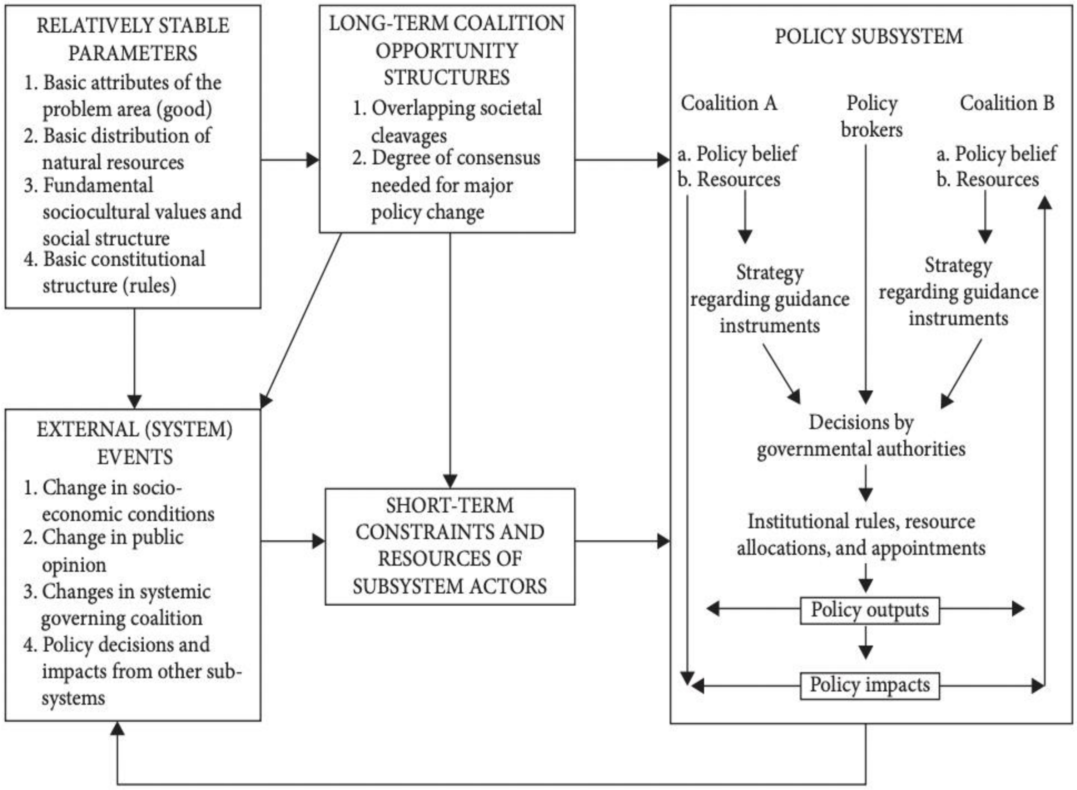

Figure 3. ACF Framework (Weible, Sabatier, & McQueen, 2009)

3. Methodology

In this section, we first define the stop-and-go event. Following this, we present the selected countries and the stop-and-go events. Subsequently, we discuss the method for data collection. Last but not least, we discuss how we determine if a reason for starting or stopping solar PV development is important.

3.1 What is a stop-and-go event?

This subsection discusses the method for identifying the stop-and-go events and in which countries they occur.

A stop-and-go situation occurs when there are periods of activity in the development of renewable energy technology, quickly followed by periods of inactivity or a steep decrease in the development rate of renewable energy technology. Before researching the underlying cause of the stop-and-go pattern in the development of solar PV first, the stop-and-go pattern must be defined. After defining the stop-and-go pattern, the next step is to analyze the development data of solar PV in all countries globally to identify the stop-and-go patterns.

To identify a stop-or-go event, we define capacity-added growth or CAG.

Capacity added growth or CAG is defined by the following equation:
$$CAG_t = ((Capacity_t - Capacity_{t-1}) / Capacity_{t-1}) * 100\%$$

CAG_t is the capacity added growth in % in year t
$Capacity_t$ is the capacity added in MW in year t

Go event definition: the first year of a period of at least two years where CAG is greater than 50%. The CAG of the first year must be at least 100%. Capacity added in the first year must at least be 50 MW. This 50 MW limit was introduced to avoid the inclusion of volatility at smaller capacities.

Stop event definition: the first year of a period of at least two years where CAG is less than -25%. The CAG of the first year must be less than -50%. Capacity added in the first year must be at least 50 MW. This 50 MW limit was introduced to avoid the inclusion of volatility at smaller capacities.

3.2 Selected countries

According to the definition in 1.3, the countries where stop-and-go events occur were pre-selected. Of these pre-selected countries, preference was given to countries with larger cumulative solar PV capacity.

Countries:
1. France
2. Germany
3. Italy
4. Japan
5. Spain
6. UK
7. USA

Firstly, these seven selected countries were all in the top 15 countries with the largest GDP (World Bank, 2022). The results of this thesis could differ in countries with smaller GDPs.
Secondly, Italy, Japan, Spain, and the USA are roughly between 25-50°N. The UK is between 50-60°N, France is between 40-50°N, and Germany is between 47-55°. Countries between 25°S and 25°N receive more irradiation than the selected countries. This may have different implications for the development of solar PV

because of the higher amount of solar energy.
Thirdly, France, Germany, Italy, Spain, and the UK (until February 2020) were all part of the EU, subject to EU policies. EU directives and targets for renewable energy influenced the development of renewable energy technology in the member countries. Japan and the USA were the only cases that were not subject to EU policy. Furthermore, out of these countries, Japan is the only one without international interconnection of the electricity system. The other six countries all have international connections between electricity grids. The capability of international electricity trade plays a role in energy policymaking.

3.3 Stop-and-go events

In this section, stop-and-go events in the development of solar PV in the selected countries are presented. Stop-and-go events are shown in Table 1 and Table 2. The annual capacity added to solar PV by the selected countries is illustrated in Figure 4.

Table 1. Go events in selected countries

Go event	Country	Year
1.	France	2008
2.	Germany	2003
3.	Germany	2009
4.	Italy	2007
5.	Japan	2009
6.	Spain	2006
7.	Spain	2019
8.	United Kingdom	2010
9.	USA	2009

Table 2. Stop events in selected countries

Stop event	Country	Year
1.	Germany	2013
2.	Italy	2012
3.	Spain	2009
4.	United Kingdom	2017

Preference was given to countries with larger cumulative solar PV capacity. This resulted in the selection of seven countries France, Germany, Italy, Japan, Spain, the UK, and the USA.

In Figure 4, the capacity added by the seven countries is illustrated during the period 2000-2020. Spain was the first country where solar PV development peaked in 2008. The peak in annual PV capacity added occurred later in France, Germany, and Italy. A peak occurred even later in the UK, Japan, and the USA. In Germany and Spain, we observe solar PV development increasing more recently again.

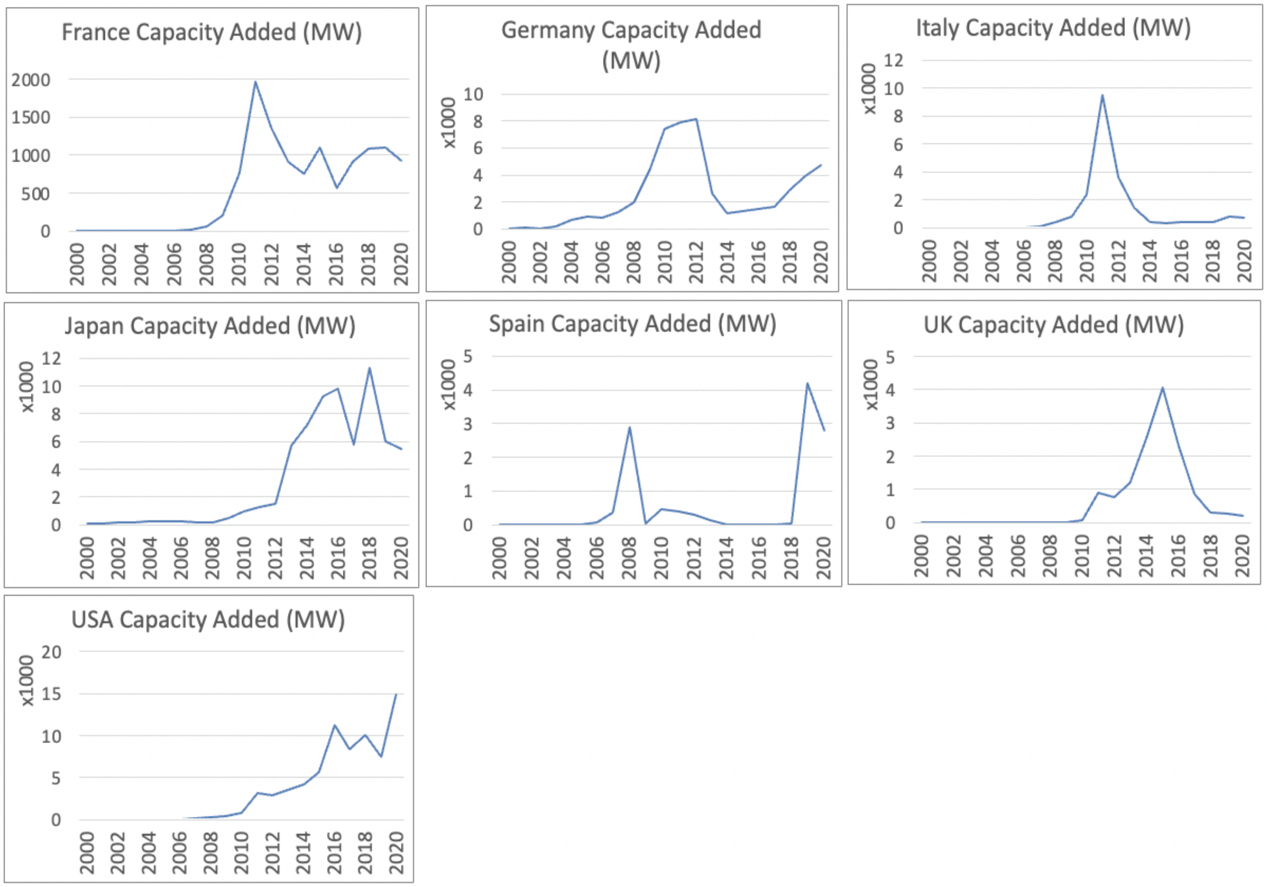

Figure 4. Annual solar PV capacity added of selected countries Source: (BP, 2022)

3.4 Data Collection

The case analysis was conducted by examining peer-reviewed scientific papers and reports from global organizations such as the IEA, IRENA and REN21, and GWEC. Academic and policy literature about multiple countries and individual countries were examined. Policy documents in the country's native language were translated to English using Google Translate.

Furthermore, the research was conducted using databases such as Google Scholar, ScienceDirect, and Research Gate to gather relevant articles. Keywords were used to narrow down the results. The relevance of an article was determined based on the number of citations. Backward snowballing was used to extend the literature study.

Keywords including the following and combinations of the following were used: 'solar PV', development', 'photovoltaic', 'renewable', 'energy policy', 'renewable energy'. When analyzing country-specific literature, the country name was added to the keywords.

To understand the decisions of governments in the policymaking process, peer-reviewed publications by organizations such as IEA, IRENA, and REN21 were reviewed because they conduct in-depth reviews of their member countries and analyze the energy policies and energy sector of the countries. Information was sought related to solar PV development, energy policy, energy transition, renewable energy policy, solar PV policy, and energy policy of competing technologies of the selected countries.

The history of solar PV technology in the countries was researched during data collection. The policy schemes that led companies to start investing or the ceasing of the policies that led companies to stop investing in solar PV and the details of the supporting policy schemes in each country were researched.
Secondly, the reason governments introduced policies was researched by investigating coalition agreements and policy introduction documents published by governmental bodies. Information regarding new governments in office and their stance towards RET and solar PV and increasing or decreasing support for solar PV was sought. In addition, affiliations of political parties or government bodies with actors in the energy industry sectors were sought in governmental and scientific literature.
Thirdly, the cost trend of solar PV and competing technologies in the countries and globally during the analyzed period was researched. The increase and decrease of policy support incentive rates over time in the countries were also investigated.
Furthermore, dependence on energy sources such as fossil fuels were researched, and the dependency on competing technologies in the countries was explored. The actors and influence of the competing technologies were explored. Lobbying activities by relevant actors influencing energy policymaking in each country were sought.
External events affecting solar PV and competing technologies policies were also sought.
Last but not least, differences between the electricity system, the energy policy, solar PV development, renewable energy development, and competing technologies of the different countries were also researched.

Methods compared to the existing literature
Gallagher explored the reasons why and how the governments of Denmark, Germany, China, and certain US states develop renewable technology by comparing four factors for each of these cases (Gallagher, 2013). The four factors explored for each case were the economic motive, the renewable source potential or availability of non-renewable sources, the political system, and the culture/attitude. According to our study, the first two factors can be considered motives for governments to support solar PV. Namely to create an industry or support the economy and improve energy security. In this thesis, we expand the motives to develop solar PV to include nuclear accidents, emission reductions, energy diversification, EU pressure, and coalition shifts. Furthermore, we expand to include reasons to stop developing solar PV, such as an economic crisis, prioritizing other sectors or alternative energy technologies, and, last but not least, coalition shifts.

3.5 How do we determine if the proposed reason is important?

Energy Crisis / Energy Security
To determine if an energy crisis or energy security was an important reason for a country to start developing solar PV, we look at the sources utilized for electricity generation over the analyzed period. If a country heavily depends on imported fossil fuels, energy security can be considered an important reason for developing solar PV.

Create an Industry / Support the economy
To determine if a government supported PV to create an industry or to support the economy, we researched the state of the country's economy when the policies were introduced. For example, was the unemployment rate relatively high? Were the policies introduced as a response to an economic crisis? Was the country investing in R&D for solar PV before the more direct solar PV support policies (such as feed-in tariffs)? Did a network of actors form in the country?

Nuclear Accident
To determine if a nuclear accident was an important reason for solar PV support, we researched the PV support policies before and after the nuclear accident. If PV support policies were already in place, we would consider the nuclear accident less important.

Emission Reductions
To determine if emission reductions were an important reason to support solar PV, we researched the sources of electricity generation in the country. If a country relies heavily upon fossil fuels such as coal, emission reductions can be an important reason to support solar PV.

Energy Diversification
To determine if energy diversification was an important reason to support solar PV, we researched the sources of electricity generation in the country. If a country relies heavily on one source for electricity generation, diversification can be a reason to develop solar PV. This is not to be confused with the reason for improving energy security where a country relies heavily on imported fossil fuels. In the case of energy diversification, the relied-upon source for electricity generation is domestic.

Economic Crisis
To determine if an economic crisis was an important reason to stop support for solar PV, we researched when the solar PV policies were introduced and when support started to decrease. When did the first amendments to the support policies take place? Was it before the recession or during the recession? What were the costs associated with the solar PV support policies?

Prioritizing other sectors
To determine if prioritizing other sectors was an important reason for decreasing support for solar PV, we researched what the government prioritized. For example, if government spending on solar PV support decreased, for which alternative energy technology or sector did government spending increase?

Coalition change
To identify coalition shifts, first, we searched the literature for an existing ACF analysis regarding the electricity system in the country, and if the ACF analysis existed, it was taken into account. If we could not find an ACF analysis for the electricity system in the country, we searched the literature for other analyses of the electricity system where relevant energy actors are identified, such as energy transitions in the country. In these analyses, we search for organized groups competing to influence policies and further their policy objectives. If these organized groups exist, we then search how they evolved over the analyzed time periods. Did actors appear, disappear or dissociate from the advocacy coalitions? Which external events caused these coalitions to grow or decline? In the end, we try to conclude whether or not there was a coalition shift based on the development of the sizes of the advocacy coalitions over time.

4 Country Analysis

In this chapter, we analyze each country to determine which of the reasons identified in Section 2.1 were important for countries to start or stop developing solar PV. For each country, we identify the advocacy coalitions and events that contributed to coalition growth or decline. We then discuss the reasons for companies to start or stop investing in solar PV, followed by the reasons for governments to start or stop supporting solar PV. The countries were analyzed in the following order: France, Germany, Italy, Japan, Spain, the United Kingdom, and last but not least, the USA.

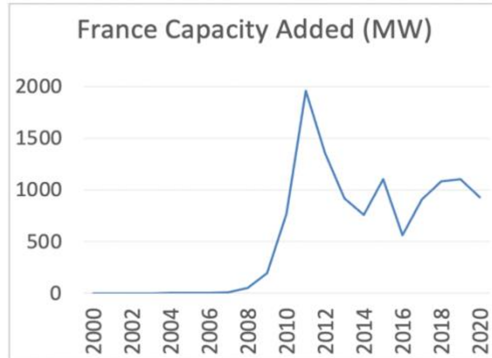

Figure 5. Annual Solar Capacity added in France Source: (BP, 2022)

4.1 France

France is home to 67.5 million people and has a GDP of 2.9 trillion euros (World Bank, 2022). Nuclear energy has played an important role in the electricity sector of France. Power consumption between 2000-2020 has grown slightly from 440 TWh to 449 TWh (IEA, 2022).

During 2000-2020 investment and support for photovoltaic technologies from French companies and the French government influenced installed PV capacity in France. Capacity added started to grow in 2008. The event to be analyzed is 2008.

First, advocacy coalitions in the French electricity sector are introduced. Secondly, the events and policies that formed, grew, or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason the French government supported solar PV are discussed. In France, two coalitions were identified, namely the Nuclear and RET coalition.

Nuclear Coalition
France relied on nuclear technology for 77% of its electricity generation in 2000 (EdF/Observ'ER, 2001). The nuclear coalition consisted of utilities, nuclear development actors, and governmental actors. Electricité de France (EdF) was the publicly monopolized utility company in France. Areva and EdF were the main actors in France in nuclear reactor design construction and use (Szarka, 2013).
The Corps des Mines was a technocratic body of the French government consisting of state industrial engineers that controlled the nuclear policy in France. Members from the Corps des Mines held key positions in the government, EdF, or CEA, allowing them to be important in the decision-making process (Schneider, 2008). The members held their positions long-term, so elections did not influence their abilities to influence nuclear policy.

RET Coalition
In the 1990s, an advocacy coalition for renewables emerged consisting of the SER (association of renewable energy) and the French Wind Energy Association (FEE), environmental NGOs, and the Green Party (Les Verts) (Bocquillon & Evrard, 2017). Renewable energy policy was the responsibility of the Ministry of Economy, Finance, and Industry (Zoeten-Dartenset, 2002). The ENGIE group controlled the National Company of the Rhone and the Hydro-Electric company of the Midi SHEM, which produced electricity using hydropower.

1970s Oil Crisis
In France, the nuclear coalition grew rapidly during the 1970s. France was dependent on fossil fuels, especially oil. As a consequence of the oil shocks in the 1970s, France decided to invest heavily in nuclear technology. Between 1973 and 1984, the government ordered 48 nuclear reactors. The success of the quick transition was the result of the Corps des Mines having strong power in developing nuclear policy and coordinating between nuclear reactor developers and the government (Grubler, 2010). The EdF, the state nuclear R&D organization

Atomic Energy Commission (CEA), and the government worked together in a well-coordinated way to develop nuclear technology (Grubler, 2010).

Nuclear Accidents
Nuclear development declined in the late 1980s due to concerns about safety after the Three Mile Island accident in 1979 and the Chernobyl accident in 1986 (Szarka, 2013). Due to regulatory tightening construction of plants was delayed, and costs were increased. Despite the accidents, the nuclear coalition remained dominant.

Why did France start RET development?
In 2000 France passed legislation to begin liberalization of the electricity market. Even after liberalization, EDF remained a large producer of electricity in France. The weight EdF holds in France as an actor in the electricity system is one of great significance. In a context of highly centralized decision-making, the nuclear lobby delayed the development of renewable energy technologies to maintain its dominance (Feurtey, Sakout, Saucier, & Ilinca, 2016). Another barrier to development was that wind and solar PV technology were more expensive than nuclear technology.
It was the EU that gave France the first impulse to start RET development. The green socialist government introduced the first renewable support policies and targets along with the feed-in tariff for RET in 2001 (Bocquillon & Evrard, 2017).

Solar PV development in France

Start: 2009
Why did companies in France invest in solar PV?
In 2002 a feed-in tariff for photovoltaics was introduced in France. However, solar PV development remained low. The feed-in tariff was 15 Eurocent/kWh. This feed-in tariff did not lead to the high development of PV because it was not high enough to ensure profitability to investors.
Afterward, in 2006 the feed-in tariff was increased to 30 Eurocent/kWh. However, capacity added remained low at 11 MW (MEFI, 2006). Installations in mainland France received 30 Eurocent/kWh and could receive a 25 Eurocent/kWh premium if the solar system was building integrated. For overseas territories, the feed-in tariff rate was 40 Eurocent/kWh with a premium of 15 Eurocent for building integrated systems. The majority of cumulative PV installations in France were building integrated installations (Schuetze, 2013). Other countries did not offer extra financial compensation for the technically constructional and/or formally creative integration of photovoltaics in buildings, whereas France did (Schuetze, 2013). The feed-in tariff was available to installations up to 250 kW. Instead of rates that would decrease over time as other countries utilized, this tariff increased annually to account for inflation (MEFI, 2006). The compensation cap was increased from 1200 hours to 1500 hours.
Comparing Germany to France, crystalline silicon module prices in 2009 were both around 2 EUR/kW, but the turnkey price was higher in France (IEA-PVPS, 2012). For example, looking at the turnkey price of a 3 kW system: the turnkey price was 4 Euro/kW in Germany and 7.5-8.2 Euro/kW in France in 2008. In order to benefit from the higher feed-in tariff, investors accrued higher installation costs.
Although the feed-in tariff was increased in 2006, capacity started increasing later in 2008 after delays and falling turnkey prices the year after, as seen in Table 3. The annual capacity added to solar PV in France is illustrated in Figure 5. PV installers have faced delays in connecting photovoltaics to the grid since 2006 (IEAPVPS, 2009). These delays were attributed to the lack of skilled installers. Another reason was legal procedures with non-technical and administrative organizations involved in construction or modification that have not yet dealt with PV systems. Long wait times to obtain gridconnection were also part of the reasons for the delay.
Additionally, a tax incentive to support PV development was introduced in December 2008. The tax credit for PV was introduced called Crédit d'Impôt. Investors received a tax reimbursement of 50% of the costs of PV systems capped at 8000 EUR. Developers also benefitted from a reduced VAT charge of 5.5% instead of 19.6% on PV system costs. Capacity in 2008 increased due to the feed-in tariff and tax credit for PV (IEAPVPS, 2009). In short, capacity added from 2008 grew due to generous incentives, namely the feed-in tariff and the Crédit d’Impôt followed by the decrease in solar PV turnkey costs.

Table 3. Turnkey prices for different applications of solar PV Source: (IEA-PVPS, 2012)

Application	2006	2007	2008	2009	2010	2011
Residential building-integrated	8,6	8,4	8,2	6,9	5,9	3,9
Large roof integrated	7,6	7,8	7,6	6,4	5,5	2,6
Centralised production	6,3	6,3	6,2	5,2	4,5	2,0

Source: IEA-PVPS NSR France 2010 up to 2010 and SER 2011.

Subsequently, the annual capacity added to solar PV after 2012 was stagnant, as illustrated in Figure 5. In 2013 the ministry of Ecology set an annual target for PV installations of 800 MW (IEAPVPS, 2014). This target would remain in effect till 2017. Tenders were introduced for systems over 100 kW. Between 2013 and 2020 annual capacity added remained between 800 – 1100 MW.

Why did the French government support solar PV?
Firstly, the reason for developing renewables was to diversify energy generation and combat climate change, as stated in the national energy plan (Programme fixant les orientations de la politique énergétique, 2005). According to the national energy strategy guidelines, the energy policy of France is based on energy independence, guaranteeing the security of supply and preservation of the environment. However, France depended largely on nuclear energy, which does not produce CO_2. The reason for developing solar PV for climate change holds less weight than developing for energy diversity.

In a statement made in May 2006, prime minister Villepin mentioned that solar energy would take off in France. The prime minister mentioned that the price of oil reached 70 USD per barrel and that preparation must be made for the post-oil era however the French electricity system is not largely dependent on oil but rather on nuclear technology (Villepin, 2006).

Furthermore, the Minister of Industry Loose explained that the reason for increasing the rates in 2006 was to stimulate a photovoltaicmarket and an industry that created jobs (Debourdeau, 2011).

According to the IEAPVPS 2007 report, the main reason for supporting PV is the European Commission's target to have 21% of electricity from renewable sources before 2020 (IEAPVPS, 2008). As mentioned, it was the EU that gave the government the push to implement the first RET support policies in 2001. The EU pressure was an external perturbation from another subsystem influencing the decision to start support of solar PV.

The coalition shift was not a reason for France to start developing solar PV. Since the emergence of the nuclear coalition in the 1970s, a coalition shift has not occurred however, the RET coalition has grown.

In summary, EU pressure, stimulating an industry, creating jobs, and diversifying energy generation were important reasons for the French government to support solar PV in 2009. Emission reduction, security of supply, and coalition shift were not important for the French government to support solar PV.

In summary, the 1970s oil crisis was an external event (external shock) that led to the creation of a nuclear technology coalition. Although nuclear accidents happened during the nuclear expansion, these were not enough to overthrow the dominance of the nuclear coalition because of the coalition's strong influence.

Due to EU pressure, France implemented a feed-in tariff, a tax incentive, and targets for renewable energy development. Another event that contributed to the development of PV was the decrease in PV turnkey prices starting in 2009. However, the nuclear coalition remains an important player in the electricity sector. In conclusion, the French government supported photovoltaics to diversify energy generation, to create an industry, because of EU pressure, and not reduce emissions or increase the security of supply.

4.2 Germany

Germany is home to 83.1 million people and has a GDP of 4.2 trillion euros (World Bank, 2022). Coal and nuclear energy have played an important role in the electricity sector of Germany. Power consumption between 2000-2020 has declined slightly from 545 TWh to 535 TWh (IEA, 2022). The introduction of the feed-in law, the Erneuerbare-Energien-Gesetz (EEG) or Renewable Energy Sources Act, and the Atomausstieg in Germany were pivotal policies resulting in major changes in the German electricity sector.

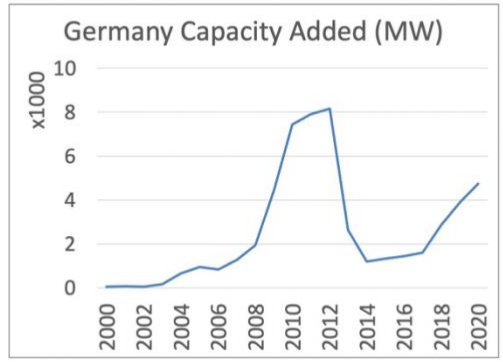

Figure 6. Annual Solar Capacity added in Germany Source: (BP, 2022)

During 2000-2020 support for photovoltaic technologies from the German government started and stopped, influencing installed PV capacity in Germany. Installed PV capacity started to increase significantly in 2003 and exploded after 2009. After 2013 capacity added in Germany decreased. We investigate what reasons were important for German PV support and the withdrawal of support after. The events to be analyzed in Germany are 2003, 2009, and 2013.

First, advocacy coalitions in the German electricity sector are introduced. Secondly, the events and policies that formed, grew or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason the German government supported solar PV are discussed.

In Germany, three advocacy coalitions were identified in the periods 1998-2002 and 2009-2013, namely the nuclear coalition, the coal technology coalition, and the RET coalition (Schmid, Sewerin, & Schmidt, 2020). The coal coalition and nuclear coalition were the dominant coalitions.

Nuclear Coalition
In 1967 the first commercial nuclear power plant opened in Germany. Siemens and the General Electricity Company (AEG) were important nuclear power plant developers. However, in the 1970s, AEG discontinued nuclear development. The political parties CDU, SPD, and FDP supported nuclear power (Hake, Fischer, Venghaus, & Weckenbrock, 2015). SPD supported nuclear power until the Chernobyl accident.

Coal Coalition
Since the 1950s both East and West Germany relied heavily on domestic coal. Coal was responsible for 90% of total final energy consumption in 1950 in Germany (Renn & Marshall, 2016). Most of the coal industry was located in West Germany. The coal coalition had a powerful union of coal mining workers called IG Bergbau und Chemie. This union had close ties with the SPD party (Renn & Marshall, 2016). The German steel and coal industry had a strong alliance (von Hirschhausen, Gerbaulet, Kemfert, Lorenz, & Oei, 2018).

RET Coalition
Initially, the RET advocacy coalition consisted of environmental interest groups. The Green Party was established in the 1970s as a result of the environmental movement (against coal) and public protest against nuclear power (Renn & Marshall, 2016). German Solar Energy Industries Association, Fordervein Solarenergie, and Eurosolar and solar cell manufacturers ASE and Shell were also part of the RET coalition and lobbied to introduce PV support programs. The Öko-Institut was an actor that developed renewable energy policies. Renewable Industry associations such as Bundesverband Solarwirtschaft, Bundesverband Wind Energie and Bundesverband Erneubare Energien were formed and influenced policymaking (Bosman, 2012). Universities and research institutes in Germany and the Renewable Energy Agency funded by the Ministry of Environment and Agriculture, and later on, households with PV installations joined the RET coalition.

1970s Energy Crisis

During the 1970s energy crisis, nuclear technology and coal received increased support from the West and East German government. The fossil fuel coalition received incentives from the government during the crisis to use domestic coal that was otherwise non-competitive. Germany expanded nuclear rapidly in the following years; however, this became a controversial topic with the public. As a result of the crisis, the nuclear technology coalition and fossil fuel coalition grew.
Meanwhile, the government decided to increase investment in R&D for renewables which were 20 million DM in 1974 and in 1982 peaked at 300 million. The public opinion was that the development of renewables and investment in energy efficiency was a better solution than the nuclear technology (Jacobsson & Lauber, 2006).

Chernobyl and the creation of the RET coalition
Afterward, in 1986 the Chernobyl accident happened. This event reinforced an already negative public opinion about the nuclear coalition causing it to decline. After the accident, the public and the parliament increased pressure on the government to support RET. Eventually, the government decided to introduce the first market formation policies for RET in 1988, the 250 MW program for wind, and in 1990 the 1000 roof program followed by the feed-in law or Stromeinspeisungsgesetz (Lauber & Metz, 2006). The introduction of these first market formation policies for wind and solar PV was the beginning of the formation of a RET coalition.

Feed-in law
In the mid-1990s, when the RET coalition started to grow as a result of the feed-in law, specifically wind power, the big utilities (part of the nuclear coalition and coal coalition) tried to roll back the 1991 feed-in law. This rollback attempt was both political, and in court however, both attempts were unsuccessful. The government proposed to reduce the tariffs however this led to demonstrations by the public and wind and solar associations in 1997.
Despite the feed-in law not being as successful for solar PV as it was for wind due to the high cost of solar PV at the time, local governments supported solar PV by facilitating feed-in tariff agreements with local rates between PV generators and municipality utilities after the 1000 roof program (Jacobsson & Lauber, 2006). In addition, these local governments had their own initiatives, such as market introduction programs, for example, subsidizing local PV projects for schools.
Through these initiatives, small firms entered the market, and more importantly, these initiatives triggered lobbying and interest by other organizations. Organizations such as German solar cell manufacturer ASE intensified their lobbying (Jacobsson & Lauber, 2006). Shell and ASE decided to invest in the solar cell manufacturing industry in Germany in 1998 (Jacobsson & Lauber, 2006).

Nuclear phase-out
On the other hand, the nuclear coalition declined when the Red-Green coalition was formed in 1998, and the parties agreed on a nuclear phase-out (Renn & Marshall, 2016). This external event was a change in the systemic governing coalition that led to an internal shock within the nuclear coalition. Before the Red-Green coalition, the energy policy seemed to have been in the interests of utilities (Lauber & Metz, 2006). During 1998 - 2002 many actors from the nuclear coalition and the coal coalition disappeared or dissociated from these coalitions. For example, the nuclear branch of Siemens, Areva NP disappeared. An example of actor dissociation was the SPD who aligned themselves with the nuclear coalition before but dissociated from the nuclear coalition after 1998. The SPD was aligned with the coal industry. Nuclear and coal were competing for the baseload power (Cherp, Vinichenko, Jewell, Suzuki, & Antal, 2017).
After the Fukushima disaster, nuclear technology gained attention again, and the conservative-liberal government decided to make a second nuclear phase-out decision in 2011. This caused an internal shock in the nuclear coalition. An important actor, Siemens nuclear technology department, which had built all nuclear plants in Germany, disappeared in 2011.

To sum up, it was the 1970s energy crisis that led to the growth of the nuclear coalition (external shock) and the coal coalition through increased subsidies and increased investment in R&D for RET. The Chernobyl event led to the creation of market formation policies that led to the formation of a RET coalition (external shock). The initiatives to support solar PV by local governments of Germany attracted organizations and firms to invest in the solar PV manufacturing industry, strengthening the RET coalition. The formation of the Red-

Green government in 1998 and their decision to phase out nuclear was an important external event causing the nuclear coalition to decline (internal shock). Last but not least, it was the Fukushima disaster that once again led to the decline of the nuclear coalition (internal shock) because of the nuclear phase-out decision in 2011.

Solar PV development in Germany

Start: 2003

Why did companies in Germany invest in solar PV?

The capacity added of solar PV in Germany in 2000 and 2001 was 44 and 81 MW, respectively. In 2002 capacity added was 65 MW. The annual capacity added to solar PV in Germany is illustrated in Figure 6. Capacity added remained low because of the total feed-in tariff cap and limit for maximum PV plant size.

In 2000 the solar feed-in tariff was introduced under the Renewable Energy Sources Act or the Erneuerbare-Energien-Gesetz (EEG). Feed-in tariffs were originally introduced in 1991 as part of Stromeinspeisungsgesetz or StrEG. The StrEG tariff ranged between 7.89 - 8.13 Eurocents (Lauber & Metz, 2006). The EEG feed-in tariff for solar PV was 51 Eurocents/kWh (Hoppmann, Huenteler, & Bastien, 2014). The difference between the feed-in tariff of StrEG and the EEG was that the tariff of the EEG was guaranteed for a period of 20 years, and the tariff of StrEG was not (Stefes, 2010). Under the EEG, generated renewable energy received "preference to the grid over fossil fuels and nuclear energy. Thus, utilities could not reject purchasing renewable energy unless the grid was overloaded. The StrEG feed-in tariff was not high enough to cover the cost of generating solar energy, but the EEG tariff was (Lauber & Mez, Three Decades of Renewable Electricity Policies in Germany, 2004) (Hoppmann, Huenteler, & Bastien, 2014). Although the feed-in tariff of 51 Eurocents/kWh introduced in 2000 was significantly higher than the StrEG tariff, it did not increase PV development significantly.

Hereafter, companies started to invest in solar PV in 2003 when the EEG was amended. The capacity added in 2003 was 175 MW. In this amendment, the size limit of 5 MW for roof-mounted solar PV and 100 kWp for other installations to receive the feed-in tariff was removed. The total feed-in tariff cap available to 1000 MW of installed capacity was removed, and the feed-in tariff was increased to 57.4 Eurocent/kWh for rooftop PV (Hoppmann, Huenteler, & Bastien, 2014).

The reason why companies started to invest in solar PV was due to the increase in the remuneration for rooftop PV and the removal of the ceilings for maximum plant-size (Hoppmann, Huenteler, & Bastien, 2014) (Lauber & Mez, 2004). Development increased due to the removal of the 100 kWp limit for the installations (Vasseur & Kemp, 2011). In 2004 and 2005, capacity added grew to 670 MW and 951 MW, respectively.

In summary, the increase of the feed-in tariff in 2000 and 2003, the removal of the ceilings for maximum plant size, and the removal of the feed-in tariff cap were important for the increase in capacity added after 2003.

What were the drivers for the German government to support solar PV?

The Red-Green coalition consisting of the SDP and the Green Party was formed in 1998. Previous governments supported coal and nuclear. This governing coalition remained in office till 2005. Since the inauguration of the Red-Green coalition, both parties agreed on the phase-out of nuclear power. The Green Party was established in the 1970s as a result of the environmental movement (against coal) and public protest against nuclear power (Renn & Marshall, 2016). Before the Red-Green coalition, the energy policy seemed to have been in the interests of the utilities (Lauber & Metz, 2006). The previous governments were under the influence of a minister of economic affairs that protected the interests of utilities. With the formation of the new government, the dominance of the nuclear coalition and the coal coalition began to decline.

An important reason for supporting solar PV was to reduce unemployment, as the unemployment rate reached a record high in 1998 (Regierungskabinett der Bundesrepublik Deutschland, 1998). The reason for developing solar for Germany was to create a solar industry (and create jobs) while trying not to hamper the current installations of fossil fuel technology and nuclear technology. Organizations started lobbying for PV support strengthening the position of the RET coalition. German PV manufacturing firms started moving to the US. The government felt pressure to create a market because they had promised large solar cell companies to support (Lauber & Metz, 2006).

The EEG explanatory memorandum act aims to reduce emissions and create jobs in small and medium-sized enterprises, which were crucial for the German economy. In addition, these SMEs supported the engineering industries of Germany. Furthermore, it states that renewable energy can reduce dependence on energy imports. However, the majority of electricity produced came from local coal and nuclear in the early 2000's (IEA, 2003).

In Germany, the formation of the Red-Green government in 1998 and their decision to phase out nuclear was an important external event causing the nuclear technology coalition to decline. Due to this decline in the following years, a coalition shift occurred, causing actors to leave the dominant nuclear coalition. In short, the important drivers for the German government to support solar PV were to create an industry to tackle unemployment, reduce emissions from coal, and the coalition shift.

Go: 2009

Why did German companies invest in solar PV?

Capacity added grew from 951 MW in 2005 to 4447 MW in 2009. In 2010 and 2011, the capacity added was 7440 MW and 7907 MW, respectively. Capacity added increased exponentially starting in 2009. The price of PV modules dropped significantly from the end of 2008 (Hoppmann, Huenteler, & Bastien, 2014). The EEG amendment of 2009 reduced the feed-in tariff (discussed in Stop: 2013), but this was not enough to reduce the annual capacity added (Hoppmann, Huenteler, & Bastien, 2014). The reductions in the feed-in tariff could have had the opposite effect where installed capacity accelerated before the feed-in tariff was reduced, especially since the reduction was in the near future (Leepa & Unfried, 2013). In conclusion, PV system prices dropped quicker than the feed-in tariffs between 2009 and 2011, causing companies to invest and resulting in a boom in the capacity added (Hoppmann, Huenteler, & Bastien, 2014).

Stop: 2013

Why did German companies stop investing in solar PV?

Since 2009, when a new conservative government consisting of a coalition with the FDP instead of the SPD was formed, support for PV decreased (Hoppmann, Huenteler, & Bastien, 2014). The new coalition made amendments to the EEG. Annual degression rates for tariffs were increased further than initially planned from 6.5% to 8-10%, and an additional degression rate was introduced to control annual added capacity. The target of this amendment was to keep the annual installed capacity between 1000 – 1500 MW. These targets were referred to as corridors. The corridors were not effective starting from 2009 because the update times of the feed-in tariff were up to 6 months which was too long (IEA-PVPS, 2013). The feed-in tariff rates can be seen in Table 4. The level of the feed-in tariff or the adjustment mechanism was inappropriate to meet the target corridor (Leepa & Unfried, 2013).

Eventually, feed-in tariff reductions caught up to the falling PV system prices, as can be seen in Figure 7 which led to companies stopping investing in PV (Tews, 2016). Capacity added in 2012 peaked at 8161 MW. In 2013 capacity added decreased to 2633 MW, and 1190 MW in 2014. The feed-in tariff was decreased twice in July 2011 and January 2012. The June 2012 amendment introduced new size classes: up to 10 kW, 10-40 kW, and 40 – 1000 kW. Before the amendment, size classes were defined as up to 30 kW, between 30-100 kW, between 100-1000 kW, and larger than 1000 kW. The amendment reduced the FIT by 20-29% for new installations and included a monthly 1% degression rate for FIT. An additional degression rate was introduced ranging from 1-2,8% if growth corridors of 2500-3500 MW were exceeded. In September 2012, installations larger than 10 MW stopped receiving feed-in tariffs. The update period between the feed-in tariffs was reduced to one month. In other words, the decrease in capacity added was the result of decreasing feed-in tariff rates and more frequent tariff updates.

To summarize, a decrease in remuneration rates led to a decrease in confidence and uncertainty for both strategic investors and private owners, resulting in a decline in capacity added. Eventually, falling system prices could not keep up with the decrease in remuneration, leading companies to stop investing in PV.

Table 4. Development of feed-in tariff in Germany Source: (IEA-PVPS, 2014)

YEAR	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013*	2014*
EURcents/ kWh	50,6	48,1	45,7	57,4	54,5	51,8	49,2	46,75	43,01	39,14	28,74	24,43	17,02	13,68

** adjusted by a flexible monthly degression rate between 1 – 2,8 % throughout the year*

Why did the German government stop supporting solar PV?
As mentioned before, in 2009, when a new conservative government consisted of a coalition with the FDP instead of the SPD, support for PV decreased (Hoppmann, Huenteler, & Bastien, 2014). The cost of the EEG rose from 0.19 Eurocent/kWh in 2000 to 6.24 Eurocent/kWh in 2014 (Brunn & Sprenger, 2014). Total costs of the EEG were roughly 20 billion euros in 2013 (Bohringer, 2014). The coalition agreement stated that the EEG has to be made more cost-efficient because it has reached a level where it has become a burden for private households and medium-sized companies (Bundeskabinett Deutschland, 2013). The coalition agreement stated that the government would invest in other sectors, such as research and development, digitize the economy, and invest in industries such as education and infrastructure.
In this stop event, a coalition shift was not a reason for the German government to stop support for solar PV. The newly formed governing coalition with FDP instead of SPD was the external perturbation leading to decreased support for PV. Furthermore, the government wanted to invest in other sectors.

In conclusion, the formation of the new governing coalition in 1998 with the Green party and SPD was the external event that led to increased support for solar PV. The important drivers for the German government to support solar PV in 2003 were to create an industry and tackle unemployment, reduce emissions from coal, and a coalition shift. The decrease in the price of PV systems in 2009 contributed to the growth of the RET coalition. The formation of a new conservative government coalition in 2009 was the reason for decreased support for solar PV. The new coalition formed with FDP instead of SPD decreased support for PV because of the high costs of the EEG and to invest in other sectors. The coalition shift was not a reason for decreased solar PV support.

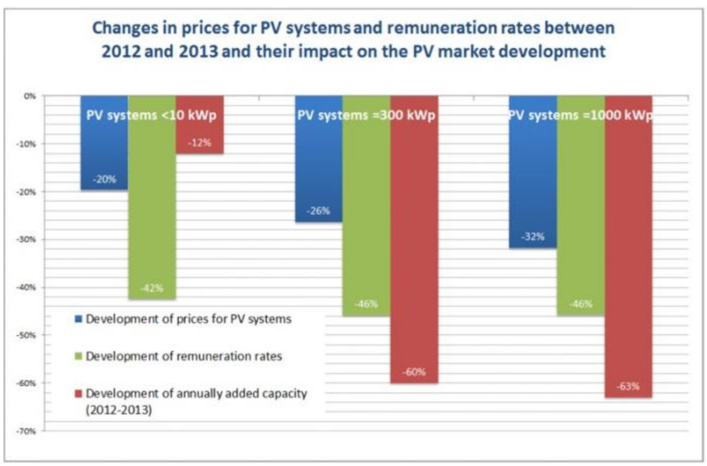

Figure 7. Changes in prices for PV systems, remuneration rates, and PV market development Source: (Tews, 2016)

4.3 Italy

The population of Italy is 59 million people. Italy has a GDP of 2.1 trillion euros (World Bank, 2022). Oil and natural gas have played an important role in the electricity sector of Italy. Power consumption between 2000-2020 has declined slightly from 301 TWh to 295 TWh (IEA, 2022).

During 2000-2020 support for photovoltaic technologies in Italy started and stopped, influencing installed PV capacity. Capacity added started to increase significantly in 2007 but decreased considerably in 2012 and after. What reasons were important for Italian PV support and the withdrawal of support after? The events to be analyzed in Italy are 2007 and 2012.

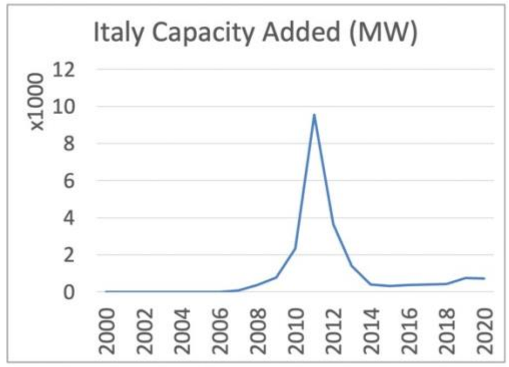

Figure 8. Annual Solar Capacity added in Italy Source: (BP, 2022)

First, advocacy coalitions in the Italian electricity sector are introduced. Secondly, the events and policies that formed, grew, or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reasons the Italian government supported solar PV are discussed.

Oil & Gas Coalition

ENI, the multinational state-owned oil and gas company, and the state-owned electricity company ENEL played a role in influencing energy policy in Italy (Di Nucci & Prontera, 2021).

RET Coalition

Due to the absence of an industrial or financial lobby, there has been less pressure on authorities to promote the development of RET (Farinelli, 2004). Limited information is available in the academic literature indicating the creation or presence, or growth of a RET coalition in Italy, lobbying activities related to RET policies, or political party affiliation with the promotion of RET.

The Italian Electricity Sector in the 1960s

The Italian electricity sector was nationalized in 1962, and the monopolist electricity company ENEL was created. The ENI and ENEL played key roles in forming the electricity policy of Italy until the liberalization of the electricity sector in 1999 (Di Nucci & Prontera, 2021). Prior to the nationalization of the electricity sector, 80% of electricity in Italy was generated by hydropower (Di Nucci M. , 2006).
ENI grew in political and economic power, and political forces pushed for an energy policy that favored the massive use and exploitation of oil for power generation (Di Nucci & Russolillo, Energy Governance in Italy, 2019). Hydropower generation was substituted by oil use in the 1960s. Due to powerful petroleum lobbying by ENI, the role nuclear power played in Italy was limited, and more focus was put on the hydrocarbons (Di Nucci & Prontera, 2021).

During the 1970s oil crisis, the vulnerability of electricity generation became apparent; however, oil use was substituted with natural gas and diversification of foreign producers.

CIP6

The CIP6 was introduced in 1992 as the first support policy for RET in Italy. The compensation for the CIP6 was the sum of avoided costs the utilities would have incurred using conventional generators and an additional component depending on the type of RET. The first component of the CIP6 was guaranteed for 15 years, and the second was for 8 years. CIP6 did not support solar PV (Marcantonini & Valero, 2015).

Liberalization and Green Certificates

In 1999 the Bersani decree was passed. This decree liberalized electricity generation in Italy to introduce competition in electricity generation. Hereafter in 2001, green certificates were introduced for renewable energy generation substituting the CIP6. The average price of green certificates between 2004 - 2007 was 13.3

Eurocents/kWh (IEA, 2010). Since the liberalization of the electricity market, ENEL remains a big actor in the electricity system however, other generators, including RES, are now able to participate in the market.

Market Creation for solar PV
In 2003 the first support policy for PV, called "10,000 roofs" was introduced. PV systems between 1-20 kW received capital subsidies of 60-70% of installation, design, and purchase costs. This decree was introduced in 2003 but only became operationally active in 2005.

To sum it up, the monopoly ENEL and the state-owned oil and gas company ENI played a key role in shaping energy policy until liberalization in 1999. The oil and gas lobby kept nuclear technology from becoming a competitor. After liberalization, the first market-creation policies for solar PV were introduced.

Solar PV development in Italy

Start: 2007
Why did Italian companies start investing in solar PV?
Conto Energia (2005)

When Conto Energia was introduced in July 2005, companies did not show high interest yet. The program incentivized the generation and self-consumption of solar energy. Plants had to be between 1 kW and 1 MW and be grid-connected to be eligible for the compensation (Italian Ministry for Economical Development, 2005). The tariffs were guaranteed for 20 years and ranged from 44.5-49 Eurocents/kWh. This tariff was only for self-consumed electricity. The rate for feeding into the network was the electricity market price (Bianco, 2021). Renewables were granted priority dispatch to the grid over fossil fuel sources under this legislation. In 2006 the Conto Energia was amended, and the limit of annual installed capacity to be incentivized was raised from 100 MW to 500 MW (Italian Ministry for Economical Development, 2005). In 2006 the added capacity was only 11 MW. The annual capacity added to solar PV in Italy is illustrated in Figure 8. The reason why the first Conto Energia did not see success is that the incentives were only available for the self-consumption (Sgroi, Tudisca, Trapani, Testa, & Squatrito, 2014) (Shimada & Dong, 2017).

Conto Energia II (2007 - 2010)

The first reason companies started to invest in solar PV was the introduction of the feed-in tariff when the Conto Energia was amended in 2007. Capacity added started to increase in 2007, 2008, and 2009 due to the feed-in tariff introduced in Conto Energia II (IEAPVPS, 2008) (Cuchiella & D'Adamo, 2012). The feed-in tariff rates ranged from 36-49 Eurocents/kWh depending on system size. Before the 2007 Conto Energia amendment, the costs of panels were too high, the administrative procedure too uncertain, and the political situation played a role in the lack of PV development (Antonelli, 2014).

Besides this, the amendment included a simpler bureaucratic procedure and increased the 500 MW capacity limit to 1200 MW, and removed the 1000 kW limit for installations. Utilities would be penalized for delays in connection to the grid. The annual decrease rate of the feed-in tariffs was 2%. This year 65 MW was installed, and the year after, 373 MW. A bonus was awarded if the PV system replaced a roof with asbestos.

The second reason companies invested was because the simpler procedure introduced in Conto Energia II allowed companies to apply for feed-in tariff remuneration only after the plant was in operation and did not require permission for plant installation. Another change was that utilities were penalized for delays regarding grid connection. The AAEG (National Authority for Electricity and Gas) also simplified the process for the grid connection (IEAPVPS, 2008).

Thirdly farmers implemented PV to make their farms more competitive and sustainable while diversifying their income (Sgroi, 2013). The incentive for replacing the asbestos roof with PV systems was used in industry areas (Di Dio, Favuzza, La Cascia, Massaro, & Zizzo, 2015)

To sum up, companies in Italy invested in solar PV because of the generous FIT, a simpler application procedure, to make farms more competitive, diversify income, and the asbestos roof replacement incentive.

Conto Energia III (2010)
In 2010 Conto Energia III was introduced. In this amendment, feed-in tariff rates were cut however costs of PV

decreased further, as can be seen in Figure 9. The capacity added in 2010 was 2333 MW.

Conto Energia IV (2011)
The fourth Conto Energia was introduced in 2011. This update reduced tariffs and simplified the installation categories to two sizes of systems. At the end of this year, the capacity added was at an all-time high of 9534 MW. A compensation cap was introduced of 6 billion euros. The rates for the feed-in tariff decreased by over 70% in the period from 2008 - 2012, yet installed capacity still increased. This is because module prices dropped quicker than tariff rates, as can be seen in Figure 9 (Antonelli, 2014). Falling module prices caused companies to invest in solar PV.

In short, the reason Italian companies invested in solar PV was due to generous feed-in tariff rates, to diversify income, and the asbestos roof replacement incentive. Although the government decreased feed-in tariff rates over the years, the cost of PV declined at a higher rate resulting in a boom in PV investments in 2011.

Why did the Italian government support solar PV?
The Italian government introduced Conto Energia because of binding agreements with the EU regarding capacity development as part of the 20-20-20 strategy Italy was implementing (Standish, 2012) (Bianco, 2021). The electricity sector of Italy was heavily dependent on imported natural gas. Most importantly, renewables were developed to decrease the dependence on imports of fossil fuels (Autorità per l'energia elettrica e il gas, 2005). The coalition shift was not a reason for Italy to support solar PV.

Stop: 2012
Why did Italian companies stop investing in solar PV?
Following the peak of capacity added in 2011 of 9534 MW, the annual added capacity in 2012 decreased to 3654 MW. The capacity added in the years to come also decreased substantially.

Conto Energia V (2012)
The fifth Conto Energia was introduced in 2012 and ended in July 2013. During the previous Conto Energia, generators received compensation for all electricity generated and contemporarily received compensation for electricity fed into the grid at market price. With the Conto Energia V, a premium tariff was introduced for the electricity fed into the grid (Sgroi, 2013). At the end of this year, annual added capacity dropped to 3654 MW. The compensation cap was increased from 6 to 6.7 billion euros.

Spalma Incentivi (2014)
Spalma Incentivi introduced retroactive adjustments for feed-in tariffs reducing existing feed-in tariffs.

The compensation cap for the Conto Energia IV was almost used up by the end of 2011 which meant the remaining compensation could only be used for smaller installations (Di Dio, Favuzza, La Cascia, Massaro, & Zizzo, 2015). The decrease in capacity added from 2011 to 2012 was primarily in installations above 20 kW (GSE, 2011) (GSE, 2012). Due to the compensation cap, investors stopped investing. Investors had the idea new PV investments were not worth it because of a lack of incentives going forward (Orioli, Franzitta, Di Gangil, & Foresta, 2016).

Eventually, feed-in tariff reductions caught up to falling module prices, as can be seen in Figure 9. FIT rates were reduced to 21-25 Eurocents/kWh. LCOE of solar PV in Italy was 22 Eurocent/kWh in 2012 (IRENA, 2020).

Why did the Italian government stop supporting solar PV?
An important reason the Italian government stopped supporting solar PV was that after the 2009 financial crisis, the costs of renewable energy incentives started gaining more negative attention (Di Nucci & Prontera, 2021). In 2010 the incentives for PV support amounted to 773 million euros (GSE, 2011). In 2011 the yearly cumulative cost of incentives provided to photovoltaics amounted to 3.65 billion euros (GSE, 2012). In

2011 the government was under pressure to reduce the budget for renewables (Standish, 2012). In the 2012 National Energy Strategy, it was stated that spending on renewable energy must be contained.

Secondly, support for solar PV was reduced because the government prioritized an alternative energy source. Investment in thermal renewable energy was prioritized because of its lower specific costs, growth potential, and greater environmental return (Ministero dello Sviluppo Economico, Ministero dell'Ambiente, 2012).

Moreover, in March 2012, the government decided to reduce the tariffs to invest in other sectors such as heating, transport, and energy efficiency (Ministero dello Sviluppo Economico, Ministero dell'Ambiente, 2012).

Furthermore, actors such as the state-owned utility ENI and small business organizations mobilized against PV development. As a consequence of the economic crisis, electricity demand decreased while PV expansion continued resulting in overcapacity for PV. State-owned utility company ENI influenced the decision-making of the government because of its important position in the past (Prontera, 2021). The company felt its position was being challenged because 98% of total PV installations were small operators, and it was leading to overcapacity and losses for the large utilities. Small business organization Confidustria also mobilized against the support for renewable energy because the electricity bills of SMEs were increasing (Prontera, 2021). Although a coalition shift did not occur, the existing dominant oil and gas coalition mobilized against the RET coalition. The 2009 financial crisis was an external perturbation that caused a policy shift.

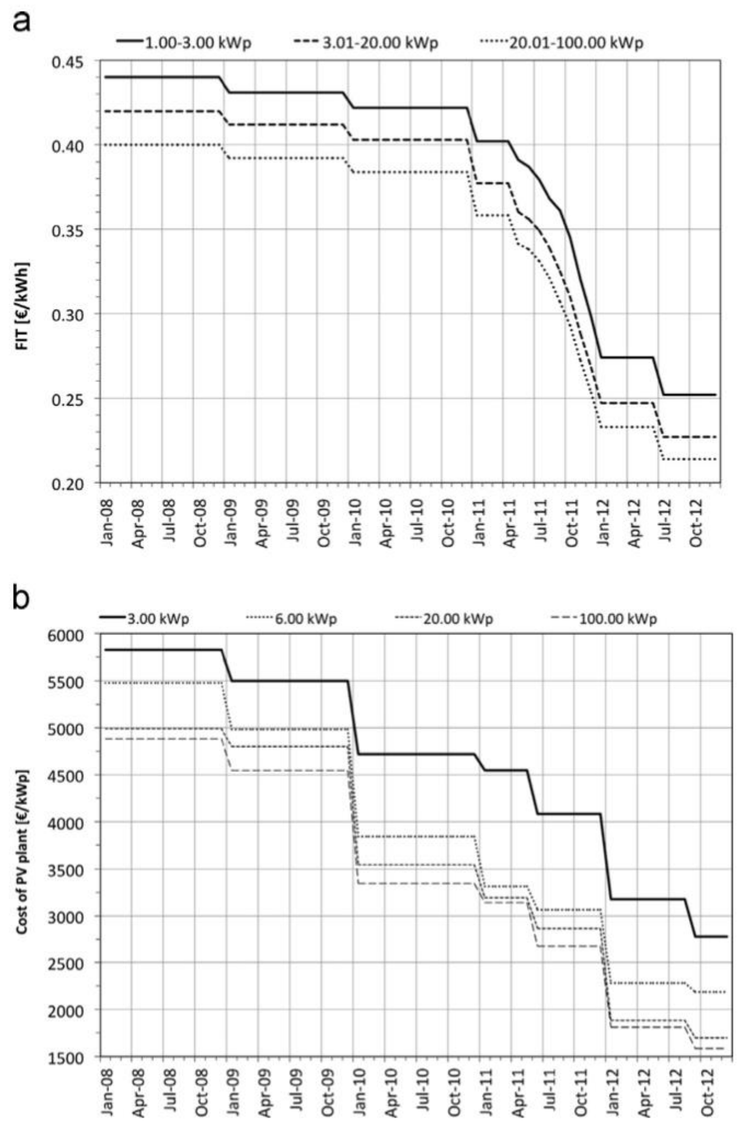

Figure 9. Changes in FIT and costs of PV during 2008 – 2012 in Italy Source: (Antonelli, 2014).

To summarize, the Italian government stopped support for solar PV because of the economic crisis, to prioritize investing in alternative renewable sources and other sectors, and due to opposition from different relevant actors.

The Italian government supported PV in 2007 to decrease dependence on imports of fossil fuels, specifically natural gas, and because of binding EU agreements. The economic crisis caused the shrinkage of the RET/solar coalition. After the economic crisis, the oil and gas coalition mobilized against the smaller RET/solar coalition to try to stop the development of solar PV. The Italian government withdrew support in 2012 due to the economic crisis and to invest in alternative renewable sources and other sectors.

4.4 Japan

Japan is home to 126 million people and has a GDP of 4.9 trillion euros (World Bank, 2022). Nuclear energy and fossil fuels have played an important role in the electricity sector of Japan. Power consumption between 2000-2020 has declined from 1029 TWh to 987 TWh (IEA, 2022).

During 2000-2020 the Japanese government supported photovoltaic technologies, increasing the installed PV capacity in Japan. Capacity added started to increase significantly in 2009. The event to be analyzed in Japan is 2009.

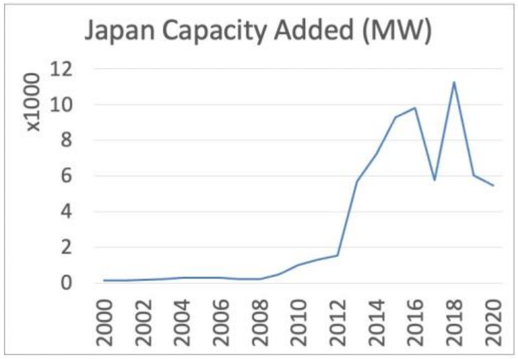

Figure 10. Annual Solar Capacity added in Japan Source: (BP, 2022)

First, advocacy coalitions in the Japanese electricity sector are introduced. Secondly, the events and policies that formed, grew or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason the Japanese government supported solar PV are discussed.

Nuclear Technology Coalition
The iron triangle in Japan is known as the cooperation between utility companies, politicians, and bureaucrats protecting the interests of nuclear technology. The LDP has been the dominant political party in Japan since 1955, with the exception of 1993. The triangle consisted of METI (Ministry of Economy, Trade, and Industry), known before 2001 as MITI (The Ministry of International Trade and Industry), the political party LDP, and the utility companies. TEPCO, or Tokyo Electric Power Company, was Japan's most powerful utility.

Solar PV Coalition
Companies such as Sharp, Sanyo, and Kyocera formed the Japan Photovoltaic Energy Association (JPEA) in 1987 and lobbied for support from the government (Umemora, 2015). The political party DPJ was part of the solar PV coalition and was in office between 2009 – 2012.

1970s Oil Crisis and the Coalitions
As a response to the 1970s oil crisis, the government shifted focus from fossil fuels to nuclear technology. The government relied on the utility companies to construct additional power plants and invest in the expanded infrastructure needed leading to the empowerment of the utilities. This cooperation between the government and the utilities strengthened the ties between utilities and policymakers (Moe E. , 2015) (Sklarew, 2018).

As a second response to the crisis, similar to Germany, Japan launched an R&D program in 1974 called the Sunshine Project to support PV as an alternative energy source and to create an industry (Moe E. , 2015). In addition, the development of solar PV was part of a commercial strategy to create new exports. This new program attracted collaboration with R&D departments of companies leading to the creation of the solar coalition (Moe, 2010).

Anti-nuclear movement
Before the 1986 Chernobyl accident, the anti-nuclear movement in Japan consisted of NIMBY participants. After the Chernobyl accident, the movement grew. Between 1960 and 2000, nuclear development increased significantly, and more nuclear accidents occurred in Japan (Kotler & Hillman, 2000). Along with increasing nuclear development, opposition from the public grew.

After almost 20 years of solar R&D, during the 1990s, MITI introduced the first market creation policies for solar PV. It was around this time the JPEA intensified its lobbying (Kimura & Suzuki, 2006). The solar PV coalition lobbied to influence regulatory barriers regarding the installation and grid connection permissions. In 1995 the 70,000-roof subsidy program was introduced and contributed to growing the industry by means of technological progress and economies of scale however, the cost of solar PV was still high (Umemora, 2015).

Hereafter, between 2003 and Fukushima, the main policy supporting RET was the Renewable Portfolio Standard (RPS). The targets for the RPS were set at 1.35% of electricity from renewables by 2010. The target was low because of the influence of the utilities on the government (Moe E. , 2015).

In parallel, during the expansion of nuclear technology, between 1991 and 2007, a series of nuclear accidents and scandals happened in Japan. These were not serious enough to overturn the dominance of the nuclear coalition, and thus the nuclear technology expansion continued. Japan relied on nuclear for 30% of its electricity generation before Fukushima (Komiyama, 2017).

Fukushima

In 2011 the Fukushima accident occurred. This was an event that would be followed by the rethinking of Japan's reliance on nuclear technology. The ties between the iron triangle were challenged, and fear was instilled in the public. Major anti-nuclear protests took place in Japan in 2011, and Japan started to shut nuclear reactors down (Koppenborg, 2020). Nuclear generation would be substituted, at least in the short term, by increased generation from coal and natural gas and increased development of solar PV.

The Nuclear Regulation Authority (NRA) was created in September 2012 after Fukushima and challenged the nuclear coalition. The NRA possessed regulatory independence and introduced more stringent safety standards, performed safety checks, and had the power to revoke the operating license of a nuclear plant. In addition, new safety precautions introduced by the NRA required additional investment in nuclear plants. Utilities hesitated to invest additionally in older plants for the new safety precautions (Koppenborg, 2020).

In summary, the 1970s oil crisis was the event that triggered the prioritization of nuclear technology and the initial steps for solar PV development. This also led to the formation of these two coalitions; however, the nuclear coalition grew at a rapid rate due to the close cooperation between utility, METI, and LDP. The solar coalition lobbied successfully and got market introduction policies introduced for solar PV. After Fukushima, the NRA was introduced and challenged the nuclear coalition.

Solar PV development in Japan

Start: 2009

Why did companies in Japan start investing in solar PV?

Before solar PV capacity added started to increase significantly in Japan, between 2003 and 2011, the Japanese government supported renewables through Renewable Portfolio Standard. However, it was ineffective because it lacked economic viability for generators (Ito, 2015). The annual target for the RPS started at 7.32 TWh in 2003 and was meant to rise incrementally. By 2009 renewable generation was 8.84 TWh falling short of the 10.38 TWh target (Shimada & Dong, 2017).

The reason households supported solar PV initially was because of the subsidy program for residential PV systems and the fixed PV purchase scheme. Before 2009 annual capacity added was below 300 MW. The annual capacity added to solar PV in Japan is illustrated in Figure 10. It was not until 2009 that the annual capacity added increased to 483 MW, as seen in Figure 12. The government started a subsidy scheme in January 2009 of 538 EUR / kW installed for household installations called the subsidy program for the residential PV systems (IEAPVPS, 2011) (Chowdhury, Sumita, Islam, & Bedja, 2014). The government introduced the Fixed PV Purchase scheme in November 2009, providing compensation for 37 Eurocent/kWh for excess electricity from households, and 18.5 Eurocent/kWh for excess from commercial entities, over a period of 10 years. This tariff was available for installations below 500 kW. Along with the subsidy, this caused an increase in capacity added in 2011 (Chowdhury, Sumita, Islam, & Bedja, 2014).

Hereafter, companies invested in solar PV because of the feed-in tariff. After the Fukushima disaster in March 2011, the Renewable Energy act was introduced. The feed-in tariff was introduced by METI in July 2012 under this act. This feed-in tariff compensated all generation from PV, not only excess. The feed-in tariff boosted non-household installations larger than 10 kW and paid 30.7 Eurocent/kWh for commercial installations for 20 years (Kuramochi, 2015). Before 2012 85% of installations were residential. After the introduction of the FIT, non-residential installations grew significantly (Wen, Gao, Kuroki, & Ren, 2021). Growth in capacity added came mainly from non-residential installations due to high tariffs. The high price of FIT attracted private investors and large enterprises (Wen, Gao, Kuroki, & Ren, 2021). The feed-in tariff rates in Japan can be seen in Figure 11.

To sum up, companies and households in Japan invested in solar PV due to the incentives such as the subsidy program for residential PV systems, the fixed PV purchase scheme, and the feed-in tariff.

Why have investments in solar PV by companies in Japan leveled off recently?

The first reason solar PV development in Japan leveled off was due to the introduction of tenders for installations at the end of 2017. The Japanese government introduced tenders for installations larger than 2 MW to control costs (IRENA, 2021). Costs for the FIT were expected to reach 28 billion euros by 2030 when the FIT was introduced in 2012. However, it was projected to reach much sooner, specifically in 2019, due to rapid deployment (Ministry of Economy, Trade and Industry, 2018). Before this, the FIT did not have a limit on installation size for eligibility. In September 2019, this threshold was reduced to installations larger than 500 kW and in 2020 to installations larger than 250 kW.

Secondly, the reason for limited PV development was the "connectable amount" of PV (Matschoss, Kochems, Grashof, Guss, & Iinuma, 2017) (Matsubara, 2018). The connectable amount is the limit of renewables utilities claim is needed to balance supply with demand. The connectable amount is determined annually by METI and by the Grid Working Group. Utilities may curtail an installation for 30 days without compensation if supply exceeds demand. The connectable amount was determined by local utilities and METI to balance the grid. In certain areas of Japan connectable amount has dropped to 0. This means new capacity cannot be added to the grid. To be eligible for the FIT, the installation must be connected to the grid.

What were the drivers for the Japanese government to support PV?

The first driver for solar PV support was to develop an alternative energy source after the 1970s oil crisis. In the 1970s, Japan started investing in R&D and manufacturing solar PV as an alternative source because of the two 1974 and 1979 oil crises and to create an industry. By introducing the new Sunshine Program in 1993, the Japanese government wanted to create a Japanese solar industry and a national market for solar power (Chowdhury, Sumita, Islam, & Bedja, 2014).

The second driver was when the government showed renewed interest in energy security because of record-high oil prices in 2008 (Vivoda, 2012). Japan imports all of its fossil fuels, making the security of supply an important aspect of the electricity sector (IEA, 2016) (Chapman & Itaoka, 2018).

This 2009 fixed PV Purchase scheme was introduced after the DPJ government was elected in 2009. The power utilities and pro-nuclear lobby of the METI actively lobbied against the introduction of this scheme (Abin, 2021).

Furthermore, the grid of Japan is isolated and fragmented, making interconnection relatively limited. East- and West Japan operate in different frequencies making the grid less flexible. Before the Fukushima accident, nuclear energy was meant to play a growing role to solve the energy security problem. The Strategic Energy Plan of 2010 aimed to increase nuclear generation for the security of the supply (Skea, Lechtenbohmer, & Asuka, 2013).

Thirdly solar PV was used to compensate for electricity generation as a result of the nuclear shutdown after Fukushima. After the Fukushima accident, Japan started to shut its nuclear reactors down. The Strategic Energy Plan of 2014 mentioned nuclear safety as a key priority for the reason to develop renewables (Ministry of Energy Trade and Industry, 2014). Before the accident, Japan relied on nuclear for 30% of its electricity generation (Komiyama, 2017). Nuclear generation was substituted with the increase of fossil fuel usage and increased development of renewables resulting in increased support for these two coalitions. After Fukushima, a coalition shift occurred. Due to the heavy reliance on fossil fuels, the power sector was the largest emitter in Japan (Zhu, Mortazavi, Maleki, Aslani, & Yousefi, 2020).

The feed-in tariff was introduced in 2012, replacing the RPS. The Renewable Energy Act mentioned renewable sources were important to secure a reliable energy system to deal with economic and social situations in Japan and abroad. The act mentioned another reason is to reduce the environmental load from the energy sector (Government of Japan, 2011).

The 1970s oil crisis was an external perturbation that led the government to build the foundation for the solar industry. The 2008 oil crisis and the election of the new DPJ government were external events that contributed to the reasons the government supported solar PV in 2009. The Fukushima accident was an external perturbation that accelerated the development of solar PV (external shock) after 2012. A coalition shift occurred in the case of Japan after the Fukushima accident resulting in the decline of the nuclear coalition and increased support of the fossil fuel coalition and the solar coalition.

In conclusion, the Japanese government supported solar PV to increase energy security and create an industry after the 1970s oil crisis. Hereafter, the government supported solar PV because of the 2008 record-high oil prices and limited grid interconnection, and last but not least, to substitute nuclear electricity generation after the Fukushima accident. The Fukushima disaster caused a shift in coalition dominance from the nuclear coalition to the solar coalition and fossil fuel coalition. The reduction of emissions was not a reason for Japan to support solar PV.

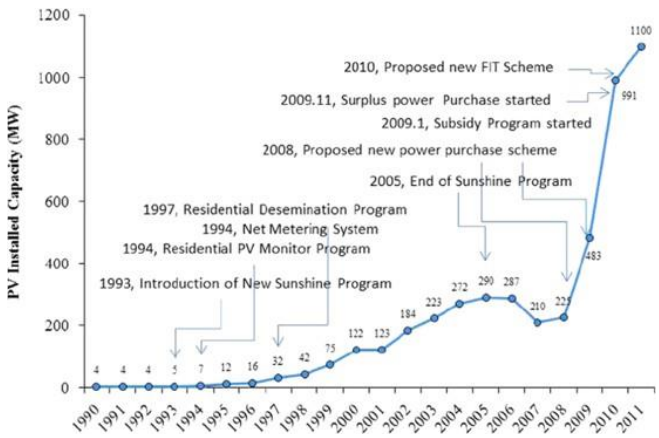

Figure 11. PV Capacity and Policy Schemes in Japan Source: (Chowdhury, Sumita, Islam, & Bedja, 2014).

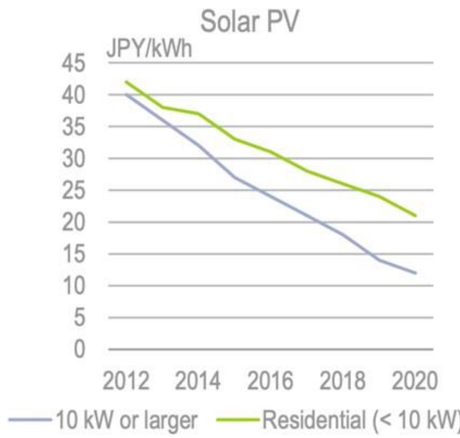

Figure 12. Japan Solar feed-in tariff (IEA, 2022)

4.5 Spain

Spain is home to 47 million people and has a GDP of 1.4 trillion euros (World Bank, 2022). Fossil fuels have played an important role in the electricity sector of Spain. Power consumption between 2000-2020 has increased from 209 TWh to 240 TWh (IEA, 2022).

During 2000-2020 support for photovoltaic technologies from the Spanish government started, stopped, and started again influencing installed PV capacity in Spain. Shortly after installed capacity started to grow significantly in 2006 it halted in 2009. After a period of PV market paralysis, the market was revived in 2019. The events to be analyzed in Spain are 2006, 2009, and 2019.

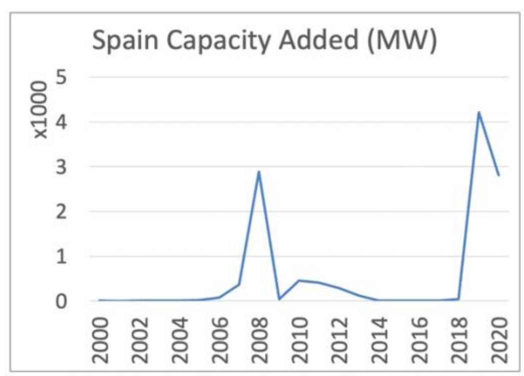

Figure 13. Annual Solar Capacity added in Spain Source: (BP, 2022)

First, advocacy coalitions in the Spanish electricity sector are introduced. Secondly, the events and policies that formed, grew, or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason governments supported solar PV are discussed

Nuclear Coalition
Forum Atomico Espanol (FAE) was an industry association part of the nuclear advocacy coalition. The FAE

consisted of actors such as the main electric companies in Spain, nuclear facilities, nuclear component manufacturers, private engineering companies, and the Spanish nuclear energy board. The Nuclear Energy Board (Junta de Energıa Nuclear, JEN) was a governmental agency in charge of nuclear policy in the 1950s.

Utility Coalition

Endesa and Iberdrola were large utility companies in Spain. In 1944 the UNESA association was created, composed of electric companies and utilities and lobbied for electric companies in the government. UNESA had close ties with the Ministry of Industry. Historically the utility coalition maintained a close relationship with the government because they were organized around banks. Banks in Spain maintain a powerful lobby on economic policy in Spain that utilities benefit from due to their ownership structure (Arocena, Kuhn, & Regibeau, 1999).

RET Coalition

The RET coalition consisted of large and smaller RES generators. The large generators are linked to the traditional utilities, Iberdrola owned a large share of the hydropower capacity of Spain (Arocena, Kuhn, & Regibeau, 1999). The smaller generators are part of the Association of Small Renewable Energy Producers (APPA), founded in 1987, consisting initially of small hydropower producers.

Formation of the Nuclear Coalition

During the 1950s, the support for nuclear development by the Franco regime increased after the discovery of uranium deposits and the Spanish market opened to private American nuclear plant construction companies (Sanchez-Vazquez & Menendez-Navarro, 2014).

The Nuclear Energy Board (Junta de Energıa Nuclear, JEN) was responsible for nuclear management until the 1960s when the private industry gained importance in the nuclear development of Spain. In the 1960s the JEN and private industry cooperated and crafted policies. Similar to Japan's iron triangle, politicians, bureaucrats, and industry worked together to promote nuclear development (Sanchez-Vazquez & Menendez-Navarro, 2014).

Since the 1960s and after the 1970s energy crisis nuclear development increased significantly. The FAE was founded to increase the penetration of nuclear energy and influence energy policy in the early 1960s when development started to increase.

1970s Oil Crisis

After the first oil crisis of 1970, Spain invested in coal-fired and nuclear power plants. The government supported the national coal industry by imposing minimum coal requirements for electricity generation (Arocena, Kuhn, & Regibeau, 1999). The government of Spain supported the coal industry though domestic coal was more expensive than imported coal, similar to the case of Germany.

The emergence of the anti-nuclear movement and the decline of the Spanish Nuclear Industry

The anti-nuclear movement emerged in 1975 after a significant amount of new power plants were planned in the first National Energy Plan (NEP). The protests of the anti-nuclear movement prevented most of the 11 new nuclear power plants that were planned to be built after the energy crisis of 1973. The anti-nuclear organization Coordinadora Estatal Antinuclear (CEA) was created in 1977.

Due to major anti-nuclear events taking place at the construction sites of new nuclear power plants, the nuclear issue gained more attention. The first draft of the second NEP, meant to be introduced in 1979, planned a significant increase in nuclear generation, which was met with increasing public and political opposition. The Three Mile Island accident occurred in 1979 in the US, causing major anti-nuclear demonstrations in Spain. The socialist party PSOE and communist party PCE requested the Ministry of Industry revise the second NEP. The revision of the NEP gave priority to other sources, such as coal and hydropower.

The late 1970s and early 1980s financial crisis

During the late 1970s and early 1980s, Spain went through a financial crisis. Under government guidance, the electricity sector was transformed from municipality utilities to 10 regional vertically integrated utilities. The collaboration between UNESA and the government during the financial crisis of the 1980s to stabilize the industry strengthened the ties between UNESA and the government (Arocena, Kuhn, & Regibeau, 1999).

Following this, In the 1990s, the Spanish electricity market was transformed through mergers. The resulting industry was a duopoly of dominating firms Endesa and Iberdrola. The Spanish government converged the market so the firms could compete internationally (Arocena, Contın, & Huerta, 2002).

Liberalization and market creation for renewables

Liberalization of electricity generation took place under the EU directive through the Electricity Sector Act of 1997. In 1998 the first market creation policy for renewables was introduced under the Aznar government, namely the FIT under Royal Decree 2818/1998. RES generators lobbied for the introduction of the FIT under this decree (Del Río González, 2008).

To summarize, the nuclear coalition was formed because of the cooperation between the government, private industry, and bureaucrats. The 1970s oil crisis was supposed to lead to increased nuclear development. However, public opposition to planned increased nuclear development increased, which was followed by the TMI accident, ultimately leading to the decline of the nuclear coalition.

The utility coalition was strengthened after the 1970s oil crisis. The financial crisis of the late 1970s and early 1980s led to close cooperation between the government and utilities. Ultimately the utility industry converged into two dominating firms Endesa and Iberdrola.

Last but not least, due to liberalization and lobbying by the RET coalition, the first market formation policies were introduced for RET.

Solar PV development in Spain

Start: 2006

Why did Spanish companies start investing in solar PV?

Although the new feed-in tariff was introduced in 2004, it was not until 2006 that capacity added grew significantly to 78 MW. The annual capacity added to solar PV in Spain is illustrated in Figure 13. The Royal Decree 436 was introduced in 2004, providing compensation to generators for the surplus of electricity either by trade with electricity companies or directly to the daily market. The compensation could be chosen as either a feed-in tariff calculated based on the average electricity price (40 Eurocents/kWh in 2004) or a premium based on the average electricity price for participating in the daily market (Del Río González, 2008). Before this decree, the feed-in tariffs offered to RES did not yield significant development because the support levels were too low (Sahu, 2015). In addition, the duration of compensation of the previous feed-in tariff was uncertain, and tariffs could be adjusted annually. In the 2004 scheme, tariffs were guaranteed for the lifetime of the plant, and tariffs were to be adjusted every 4 years, providing more certainty to investors (Duffield, 2020).

The reason companies started to invest in the solar PV market was as an alternative investment to the stagnant housing market (Del Río & Mir-Artigues, 2012). Small investors had easy access to credit and low-interest rates, and the government was eager to grant permits with little delay (Del Río & Mir-Artigues, 2012). The capacity added in 2007 was 364 MW.

The second reason companies invested in solar PV, causing capacity added to explode to 2890 MW in 2008, was the entry of a stop decree RD1578/2008. Investors took advantage of this by rushing to lock in the rates of the previous decree, causing a boom in installations (Del Río & Mir-Artigues, 2012) (Movilla, Miguel, & Felipe Blázquez, 2013). The tariffs were going to be lowered to 34 Eurocents/kWh from up to 44 Eurocents/kWh depending on system size.

To summarize, companies in Spain invested in solar PV as an alternative investment to the housing market and due to easy access to credit and low-interest rates. Companies invested because of the feed-in tariff.

What were the drivers for the Spanish government to support solar PV?

Under the new Zapatero government in 2004, the energy policy was directed toward nurturing niches (Gabaldon-Estevan, Penalvo-Lopez, & Alfonso Solar, 2018). The Spanish government introduced RD436/2004 to protect the environment (Ministerio de Economia, 2004).

Most importantly, improving the security of supply was the reason for Spain to support PV. Spain imported all of its gas and oil and 75% of its coal. The electricity sector was 63% dependent on these 3 sources.

Nuclear energy provided 20% of the energy for the electricity sector. The Spanish electricity sector is heavily dependent on imported fossil fuels, which made PV an attractive alternative (IEA, 2005) (IEA, 2009). Another key point is that the Spanish electricity grid does not have much interconnection capacity compared to total demand.

Other reasons for developing PV were the reduction of greenhouse gas emissions and job creation (Ministerio de Industria, Turismo i Comercio, 2005) (Del Río & Mir-Artigues, 2014).

The coalition shift was not a reason for the Spanish government to support solar PV for this event.

In short, the security of supply was an extremely important reason for Spain to develop PV because of the fossil fuel import dependence and low grid interconnection capacity. Reduction of greenhouse gas emissions was also important due to the high dependence on fossil fuels. Job creation was a less important reason.

Stop: 2009

Why did companies in Spain stop investing in solar PV?

The reason companies stopped investing in solar PV was because of the reduced profits under the 2008 stop decree (Movilla, Miguel, & Felipe Blázquez, 2013). Following the boom in capacity added, the Spanish government introduced a new decree in late 2008. The new tariffs varied between 32-34 Eurocent/kWh. Difficult access to credit and the economic crisis hindered investment.

The reason for the dramatic decrease in capacity added after the boom was due to a delay in publication for the first call of the new preregistration system, paralyzing the PV market from October 2008 to March 2009 (Del Río & Mir-Artigues, 2012) (K Garbe, 2012). The following year after capacity added exploded, the market was paralyzed, with capacity added dropping to 39 MW.

Furthermore, companies stopped investing in solar PV because, in 2010, the government introduced Royal Decree 1003/2010, decreasing remuneration for both existing and new installations and damaging investor confidence (Mahalingam & Reiner, 2016). A cap for the total number of hours of operation for remuneration was introduced (Ministerio de Industria, Turismo y Comercio, 2010). All plants, including existing ones, would receive compensation for 25 years instead of their lifetime.

In short, companies in Spain stopped investing in solar PV due to reduced feed-in tariff rates, difficult access to credit, and the economic crisis.

Why did the Spanish government stop support for solar PV?

The main reason the Spanish government stopped support for solar PV was due to the economic crisis (IEA, 2015). The government introduced a new decree RD 1578/2008 to control the annual volume of PV and costs because of the economic crisis (K Garbe, 2012) (Del Río & Mir-Artigues, 2014) (Jäger-Waldau, 2016). In 2009 photovoltaic support costs accounted for 45% of the total renewables support but were responsible for only 9% of electricity generation (Instituto Espanol de Estudios Estrategicos, 2014). Total subsidies paid to PV generators in Spain were 194 million euros in 2007, 990 million euros in 2008, and 2.6 billion in 2009 (Del Río & Mir-Artigues, A Cautionary Tale: Spain's Solar PV Investment Bubble, 2014).

To control costs eventually, feed-in tariffs were abolished, which were applied to generators with existing installations, eventually paralyzing solar PV development. In 2012 capacity added was 286 MW. In 2013 and 2014 capacity added was 128 MW and 7 MW, respectively.

Hereafter in 2015, a new decree was introduced affecting PVSC, which prevented economic viability for PVSC (JL Prol, 2020) (Mir-Artigues, Del Río, & Cerdác, 2018). This decree introduced a “sun tax” and stated that residential installations would not receive any remuneration for electricity exported to the grid, and industrial and commercial installations would receive a backup charge for PVSC. Industrial/commercial installations above 10 kW were charged a fee per kWh consumed, also known as the “sun tax”.

In conclusion, the Spanish government stopped support for solar PV because of the economic crisis and the increasing costs of the support scheme. The coalition shift was not an important reason for the Spanish government to stop supporting solar PV.

Start: 2019

Why did companies in Spain start investing in solar PV again?

The reason small businesses and households started to invest again was due to the removal of the sun tax for PVSC in RD 15/2018 under the new Sanchez administration (IEA, 2021). ln 2018 capacity added started

to increase again with 41 MW. The year after, the capacity added exploded to 4209 MW. Administrative procedures for PVSC were simplified in RD 244/2019, leading to a reduction of soft costs and information barriers for household installations (JL Prol, 2020). Systems under 100 kW did not need to be registered in the electricity production facilities registry (RAIPEE) and did not need access, and connection permits (IEA-PVPS, 2018). In July 2017, a renewable energy auction was organized, and 4000 MW was assigned to companies to be installed before 2020 (Feijoo, et al., 2020).
In conclusion, the removal of the sun tax and simplification of administrative procedures for PVSC led to an increase in PV development again.

What were the drivers for the government to support solar PV again?

Rising prices of oil, gas, and coal and an increase in the price of CO_2 emission rights led to the introduction of RD 15/2018 and RD 244/2019.

More importantly, the security of supply remained an important reason to develop renewables because of Spain's heavy reliance on imported oil and gas alongside the phase-out of nuclear, closure of coal mines, and limited interconnectivity with other countries (IEA, 2021).

The coalition shift was not an important reason for the Spanish government to support solar PV.

Another reason Spain supported solar PV was to meet EU energy and climate targets, and the Paris Agreement targets (IEA-PVPS, 2018). The Paris Agreement's target was to meet 42% of electricity from renewables by 2020. In 2017 the share of electricity generated from renewables was 32% (Red Electrica De Espana, 2022).

In short, the security of supply was once again an important reason to develop solar PV, followed by rising prices of oil, gas, and coal, and last but not least, EU and Paris Agreement targets.

In conclusion, the government supported photovoltaics in 2006 for the security of supply. During the 2009 event, the government stopped support of PV to control costs during the economic crisis. Ultimately in the event of 2019, the security of supply remained an important reason for the government to develop solar PV, followed by the EU energy and climate targets.

4.6 United Kingdom

The UK is home to 67 million people and has a GDP of 3.2 trillion euros (World Bank, 2022). Fossil fuels, namely natural gas and coal, have played an important role in the electricity sector of the UK. Power consumption between 2000-2020 has declined from 360 TWh to 303 TWh (IEA, 2022).

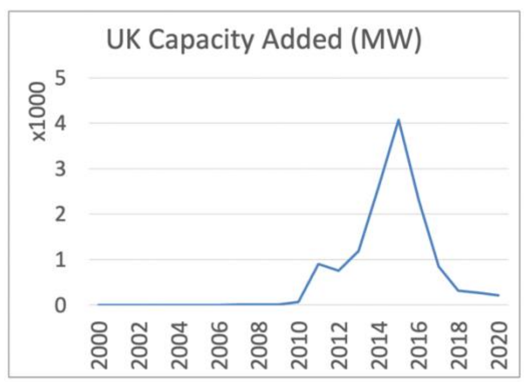

Figure 14. Annual Solar Capacity added in UK Source: (BP, 2022)

The UK electricity system was a state-owned monopoly with 12 regional utilities until it was privatized in 1990 under the Thatcher government and liberalized in 1998. After privatization majority of the electricity sector converged into the big 6 (E-ON, EDF, SSE, Scottish Power, British Gas, and N-Power) (Littlecott, Burrows, & Skillings, 2018).

During 2000-2020 support for photovoltaic technologies from the UK started and stopped, influencing installed PV capacity in the UK. Installed capacity started to increase significantly in 2010 but decreased considerably in 2017 and after. This section investigates what reasons were important for UK PV support and the withdrawal of support after. The events to be analyzed in the UK are from 2010 and 2017.

First, advocacy coalitions in the UK electricity sector are introduced. Secondly, the events and policies that formed, grew, or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason governments supported solar PV are discussed.

Coal coalition

The UK has been reliant on coal since the beginning of the 19th century for heating and transport steel production, but since the 1980s, coal has been used for power generation. At the beginning of the 1980s, coal accounted for 80% of electricity generation in the UK (Brauers, Oei, & Walk, 2020). The UK had domestic coal; the mining industry was also part of this coalition. Unions supported coal and lobbied against coal mine and coal plant closures.

Nuclear Coalition

The Central Electricity Generating Board (CEGB) was the central authority coordinating the supply side of the electricity sector before the liberalization of the electricity sector in 1990. The CEGB was created to progress nuclear development and owned all commercial nuclear power plants in England/Wales (Winskel, 2002). The CEGB had monopoly rights in generation and transmission and supplied the 12 regional utilities to distribute electricity to end consumers. The United Kingdom Atomic Energy Authority (AEA) was the principal policy advisor to the government and was in charge of research design and development of nuclear technology.

1970s Oil Crisis

Due to the oil crisis, the government increased support for coal by imposing minimum domestic coal usage requirements for the electricity sector, although domestic coal was more expensive than imported coal, similar to the case of Germany and Spain (Turnheim & Geels, 2012). Nuclear and coal generation were upscaled in the 1970s and 1980s.

In the mid-1970s, R&D for onshore and offshore wind power was limited, and collaboration between scientific institutions and industry was weak (de Carvalho, 2018). The CEGB was in charge of the research and development strategy, but it had close ties to the nuclear coalition and coal coalition (Suck, 2002). The Science Research Council (SRC) provided small grants for wind energy inventions (Simmie, Carpenter, & Sternberg, 2014). Most of the funding went to wave-, geothermal energy, and vertical axis wind turbines, all of which were not successful (Suck, 2002). R&D for renewables was underinvested and lacked coordination hampering the development of the technology (Simmie, Carpenter, & Sternberg, 2014).

Privatization of the electricity sector and coalition shifts

The electricity sector was privatized in 1990 under the Thatcher government. The Thatcher government privatized other industries, such as telecom as well. After privatization, electricity companies started increasing coal imports as there was no regulated dependence on domestic coal anymore. In addition, utilities increased the use of natural gas for generation, referred to as the 'dash for gas.' For these two reasons, the coal coalition declined (Turnheim & Geels, 2012). The nuclear power plants initially remained public but were later privatized. After privatization, electricity prices began to decline, and the nuclear industry struggled financially (Hewlett, 2004).

After the Non-Fossil Fuel Obligation (NFFO) program was introduced in 1990 to support the struggling nuclear industry, the first RET development unintentionally began. The NFFO was a competitive bidding system that provided a premium to non-fossil fuel sources. The NFFO was available between 1990 and 1998. This program resulted in the capacity added of on-shore wind. Solar PV was still too expensive at the time (Lipp, 2007). Support from this program for renewables was initially almost non-existent, but the portion for RET grew significantly in the last two years, ultimately reaching 49% of the budget (Suck, 2002).

Following this, the first market creation policy for renewables, called Renewables Obligation (RO), was introduced in 2002. The RO required utilities to meet annual renewable targets. The RO was favorable for large-scale technologies such as on-shore wind.

Meanwhile, lower prices of coal led to increased coal use between 1996-2006 (Geels, 2014). After 2006 the Carbon Price Floor and the Emission Performance Standard (EPF) were introduced. These policies declined the coal coalition further. The EPS restricted the future construction of new coal plants without carbon capture, and the CPF made coal for electricity production less competitive, and older coal plants were forced to close.

In summary, two advocacy coalitions existed in the electricity sector of the UK, namely the coal coalition and the nuclear coalition. Due to the external event of the 1970s oil crisis, support for coal and nuclear increased. In

1990 privatization led to the decline of the two coalitions because of competition with natural gas. Following privatization, the first market creation for renewables was introduced. The coal coalition declined further due to climate change policies to control emissions, such as the Carbon Price Floor and the Emission Performance Standard.

Solar PV Development in the UK

Start: 2010

Why did companies in the UK start investing in solar PV?

The reason households and companies started investing in solar PV was due to generous feed-in tariffs, compensation for surplus electricity generated, and the self-consumption (Department of Energy & Climate Change, 2015). Feed-in tariffs were introduced in April 2010, ranging from 40-57 Eurocent/kWh depending on the installation size (Muhammad-Sukki, et al., 2013) (Department of Energy & Climate Change, 2015). After the introduction of the feed-in tariff, capacity added increased from 4 MW in 2009 to 68 MW in 2010. The annual capacity added to solar PV in the UK is illustrated in Figure 14.

Before the feed-in tariff, photovoltaic development was supported by Renewable Obligation Certificates (ROC) awarded to renewable energy generators and required electricity supply companies to cover a certain percentage of their supplied electricity with ROC. The RO price was 8.4-9.8 Eurocent/kWh in 2003, which was too low for solar PV (Mitchell & Connor, 2004).

Another reason companies started investing in solar PV was due to falling PV costs. In 2011 capacity added exploded to 905 MW. Between October 2011 and April 2012 costs of PV dropped significantly, causing a rapid increase in the development (Department of Energy & Climate Change, 2015).

In 2011 the government introduced a levy control framework (LCF) to prevent overspending on renewable support. The total support for low carbon generation available was 7.6 billion GBP by 2020. In April 2012, tariffs were decreased and ranged from 12-28 Eurocents/kWh depending on the installation size (Department of Energy & Climate Change, 2015). However, the capacity added was still 753 MW by the end of the year. LCOE for solar PV in 2013 in the UK was 23 Eurocents/kWh (IRENA, 2020).

Despite cuts in tariffs, from 2013 to 2014, capacity added grew from 1184 MW to 2591 MW due to falling costs of PV and the increasing popularity of rent the roof business model where the installation owner receives FIT payments, and the homeowner receives generated electricity (Ofgem, 2014). It is surprising that despite the FIT rates decreasing significantly, the capacity added was still increasing. Domestic installations smaller than 4 kW formed 95% share of all solar PV installations and 62% of cumulative installed PV capacity up till 2015 in the UK (Department of Energy & Climate Change, 2015). The reason for capacity added increasing although tariffs decreased could be that rooftop installers consider the payback period based on annual savings compared to buying electricity and not LCOE. LCOE is considered for large-scale installations (Reid & Wynn, 2015).

In 2014 the government promoted community energy by launching an Urban Community Energy Fund and Rural Community Energy Fund. Institutional investors such as the UK local authority pension funds, insurance, and pension funds played a role in investing in the solar development (Sovacool, et al., 2021). Schools and community projects used the feed-in tariff as a reliable source of income (Department of Energy & Climate Change, 2015).

Furthermore, community energy organizations benefitted from tax relief structures such as the Enterprise Investment Scheme (EIS), Seed EIS (SEIS), Venture Capital Trust (VCT), and the Social Investment Tax Relief (SITR) (Sovacool, et al., 2021). In October 2014, the government introduced a contract for difference scheme to support projects above 5 MW to replace the renewable obligation scheme. The first auction was held in February 2015, in which 71 MW was awarded to PV. This new scheme was not important for the development of solar PV in the UK.

In January 2015, the government introduced new classes to the feed-in tariff to support building-integrated PV and stand-alone PV, causing a surge in installations between January and March by generators applying for the higher tariff (Ofgem, 2015). The renewables obligation scheme closed on 1 April 2015 for capacity greater than 5 MW PV projects and closed on 1 April 2016 for installations smaller than 5 MW causing a surge in capacity added (EurObservER, 2016).

Deployment caps were introduced to control costs effective from January 2016, causing a rush in applications for feed-in tariffs in 2015 as can be seen in Figure 15 (Ofgem, 2016). The capacity added by the end of 2015 was 4073 MW.

In summary, companies in the UK invested in solar PV, most importantly due to generous feed-in tariffs, self-consumption, and last but not least, falling PV costs. The Renewable Obligations scheme was not as successful for PV as it was for wind. The planned feed-in tariff reduction in January 2016 caused a peak in installations.

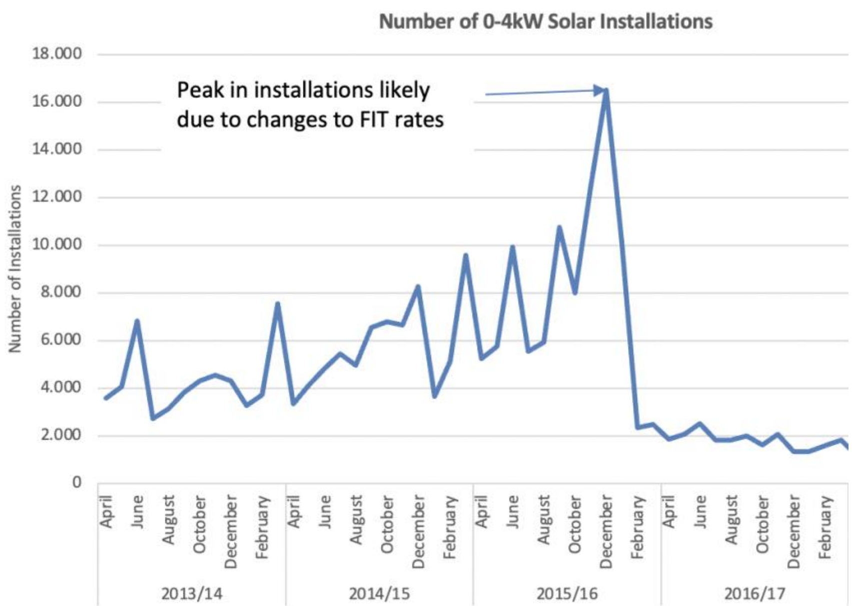

Figure 15. Number of 0-4 kW Solar Installations in the United Kingdom during 2013-2017
Source: (Department for Business, Energy & Industrial Strategy, 2022)

What were the drivers for the government to support solar PV again?

The reason the UK government supported solar PV was to achieve the renewable energy target of 15% of final energy consumption by 2020 and engage the broader public to partake in the generation of low-carbon technology (Department of Energy & Climate Change, 2010). The UK Renewable Energy Strategy mentions climate change and the security of supply are increasingly urgent concerns.

Another reason for the support was economic and employment development after the financial crash (Secretary of State for Energy and Climate Change and by command of Her Majesty, 2009) (Grover, 2013).

Moreover, the depletion of North Sea oil and gas reserves was a reason to start developing renewables (Secretary of State for Energy and Climate Change, 2009) (Committee on Climate Change, 2008). Depletion of these reserves and the dependence on imports that depletion might lead to were a reason to develop renewables (Grover, 2013).

Furthermore, old coal-fired power plants contribute significantly to the emissions of the electricity sector (Committee on Climate Change, 2008). The electricity sector is responsible for roughly 37% of all UK CO_2 emissions. Most UK coal-fired power plants are old, with the newest one opened in 1974 (Grover, 2013). Before 2020 the majority of coal plants need to be retired because they cannot comply with EU Large Combustion Plants Directive (IEA, 2012) (Grover, 2013). Around 19 GW of capacity is scheduled to be closed before 2020.

Due to emission standard policies, the coalition dominance of the coal coalition declined prior to 2010. However, there is no evidence of whether or not this resulted in the formation or growth of a RET coalition. The financial crash was an external perturbation influencing the policy subsystem.

In summary, the UK government supported solar PV to achieve the renewable energy target, engage the broader public to partake in energy generation, support the economy after the financial crash, because of the depletion of the North Sea oil and gas reserves, and reduce emissions from coal.

Stop: 2017

Why did companies in the UK stop investing in solar PV?

The main reason companies stopped investing in solar PV was because tariffs were cut. Under the Cameron government, which came into office in May 2015, subsidies for PV were significantly cut (Sovacool, et al., 2021). Tariffs were reduced between 87% for small installations and 76% for larger installations. Feed-in tariffs ranged from 1.06 Eurocent to 5.35 Eurocent/kWh in March 2016, depending on the installation size (Department of Energy & Climate Change, 2015) (Ofgem, 2016). LCOE for solar PV in the UK was 23 Eurocents in 2016 (IRENA, 2020).

Another reason investments in solar PV declined was because the tax relief structures were ended. In 2015 the government excluded community energy organizations from receiving the tax relief EIS, SEIS, and SITR. These benefits were important for the project financially (Sovacool, et al., 2021).

Furthermore, the renewables obligation scheme closed on 1 April 2015 for high-capacity greater than 5 MW PV projects and closed on 1 April 2016 for installations smaller than 5 MW.

Hereafter, investor confidence declined when tariffs were decreased, and the introduction of deployment caps caused a decrease in installations in 2017 and 2018 (Ofgem, 2018). Deployment caps were introduced to control costs effective from January 2016. The deployment cap for 2016 was 540 MW. Costs of the feed-in tariff amounted to 1.1 billion GBP in 2016 (Ofgem, 2016). Capacity added in 2017, 2018, and 2019 decreased to 846 MW, 316 MW, and 273 MW, respectively, after the introduction of the deployment caps. These policy changes were made after the new government was elected in May 2015 (Lockwood, 2016).

In conclusion, the reduction of feed-in tariffs and the introduction of deployment caps were important reasons for companies to stop investing in solar PV.

What were the drivers for the government to stop supporting solar PV?

The main reason for stopping the support of PV was to invest in other sectors. The government prioritized investing in national security and international aid and planned to spend more on national health services, social care, and education (HM Treasury, 2015). The government planned to reform and modernize public services.

In 2015 the Office for Budget Responsibility released a report projecting the levy control framework to reach 9.8 billion by 2020, surpassing the goal of 7.5 billion. The reason for anticipating overspending was threefold. The decrease in fossil fuel prices globally would lead the government to compensate more in the CFD scheme.

Another reason was quicker than expected development in renewables due to the high FIT and higher load factor than expected for offshore wind leading to more compensation (Department for Business, Energy and Industrial Strategy, 2016). The anticipated overspending led the DECC to adjust the policy (Lockwood, 2016).

In summary, the UK government supported solar PV to achieve the renewable energy target, engage the broader public to partake in energy generation, support the economy after the financial crash, because of the depletion of the North Sea oil and gas reserves, and reduce emissions from coal. The main reason the government stopped the support of PV was to invest in other sectors.

4.7 USA

The USA is home to 331 million people and has a GDP of 23 trillion euros (World Bank, 2022). Coal has played an important role in the electricity sector of the USA. Power consumption between 2000-2020 has increased from 3857 TWh to 4055 TWh (IEA, 2022).

After years of low capacity added for solar PV in the USA, capacity added started to increase in 2009. This section investigates what reasons were important for the US PV support. The event to be analyzed in the US is 2009.

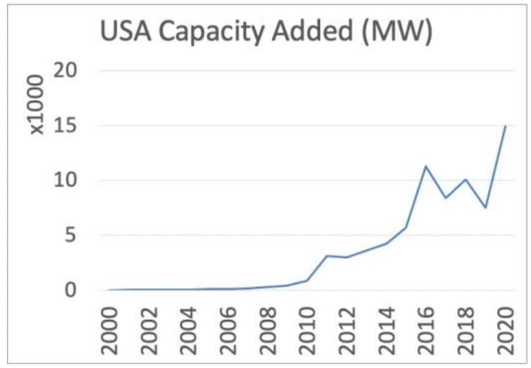

Figure 16. Annual Solar Capacity added in USA Source: (BP, 2022)

First, advocacy coalitions in the US electricity sector are introduced. Secondly, the events and policies that formed, grew, or declined these coalitions are discussed. Last but not least, the reasons companies invested in solar PV and the reason governments supported solar PV are discussed.

Coal Coalition

Historically coal played an important role in electricity generation in the United States. In 2005 coal was responsible for 50% of the electricity generation (IEA, 2008). The coal industry supported the Republican party and elected officials in coal-producing states with political spending (Popa, et al., 2016).
The top 5 coal-producing companies were Alpha Natural Resources, Cloud Peak Energy, Rio Tinto, Peabody Energy, and Arch Coal. AEP (American Electric Power), and Duke Energy were large utilities that used coal for electricity generation. The main coal associations are the American Coal Council (ACC), and the National Mining Association (NMA).

Oil and Gas Coalition

The large oil and gas companies that form a part of this coalition are Shell, Exxon Mobil, BP, and Chevron. Associations formed by oil and gas companies are the American Petroleum Institute (API), the American Natural Gas Association (ANGA), and the Independent Petroleum Association of America (IPAA). The Gas Research Institute was a nonprofit organization funded by the gas industry.

RET Coalition

Advocates for RET varied by state. Organizations were funded through The Energy Foundation. Actors of the RET coalition were The American Wind Association (AWEA), the Environmental Protection Agency, California Solar Energy Industry Association (CALSEIA), and wind power companies such as Kenetech and ENRON Wind. Solar manufacturing companies in the US were Shell Solar, AstroPower, and BP Solar.

1970s Oil Crisis

As a response to the oil crisis, the US government increased investment in energy R&D from 114 million USD to 1.43 billion USD. In the late 1970s, the government supported drilling for shale gas by providing tax credits and increasing support for R&D. These R&D programs resulted in technological innovations for drilling shale gas (Wang & Krupnick, 2015).

Nuclear Energy in the US

Nuclear development increased in the USA through nuclear programs initiated in the 1960s and 1970s. No lobby was needed for nuclear development because of the close cooperation between politics, the military, and the nuclear industry (Heffron, 2013).
However, new nuclear development (not ongoing) declined after 1975 for various reasons (Hultman & Koomey, 2013). Firstly, an economic contraction was caused by the 1970s oil shock affecting the demand for electricity. In addition, financing costs for nuclear were high, the interest rate was 20%, and construction was delayed. Last but not least, the Three Mile accident decreased public support for nuclear energy.

RET Development from the late 1970s to the late 1990s
The RET coalition in the US consisted mainly of wind actors because wind development was successful early on. The Public Utility Regulatory Policies Act (PURPA) was federally introduced in 1978 in response to the 1973 oil crisis to promote renewable and domestic energy generation. The PURPA intended to increase competition by requiring utilities to purchase electricity from independent generators. The PURPA tariff was calculated as the cost the utility would have incurred had the utility generated the equivalent amount using fossil fuels. In other words, the avoided cost or the wholesale cost of fossil fuel. Development increased mostly for wind with PURPA in California, followed by other renewables (Martinot, Wiser, & Hamrin, 2005). The Production Tax Credit was federally introduced for wind energy in 1992 under the Energy Policy Act of 1992. The initial credit was set at 1.5 cents/kWh. The introduction of the Production Tax Credit also contributed to increasing wind development.
In the early 1990s, the PURPA faded away due to falling fossil fuel costs, namely natural gas costs from $7/MBTU in the 1980s to less than $1.50/MBTU by 1993 (Martinot, Wiser, & Hamrin, 2005). Power sector restructuring at federal and state levels also led to a decline in capacity added. This stagnation in development lasted till 1997.
Solar PV received state support in the late 1990s through net metering (NEM) and RPS schemes that were implemented in several states. NEM policy was adopted by several states in the late 1990s. Once these policies were enacted and electricity sector restructuring was complete, the RET industry began growing. Key actors in promoting the RPS in different states were the AWEA and the Energy Foundation again (Stokes, 2015).

Coal Coalition Decline
During the 1990s, climate change began to gain more attention. The Clean Air Act was amended, and tighter emission controls were introduced for nitrogen oxide, sulfur dioxide, and mercury. As discussed before, the US has been investing in unconventional natural gas R&D programs since the 1970s. The US Shale gas revolution has been an important driver for the substitution of coal in power generation since 2008 (Popa, et al., 2016). The main driver for the decline of electricity generation using coal has been the decline in costs of generation using solar, natural gas, and wind (Jacob & Steckel, 2022).

To summarize, historically, coal has played an important role in power generation. In the US power sector, three coalitions can be identified, namely, the coal coalition, the oil and gas coalition, and the RET coalition. After the 1970s oil crisis, the US invested in R&D for unconventional natural gas and RET. The 1970s oil crisis was an external event that the oil and gas coalition, and the RET coalition grew from. Nuclear development decreased after 1975 for reasons such as the contraction of the economy, high financing costs, and the TMI accident. The RET coalition consisted initially of early wind development and actors in the wind industry. The solar coalition began to emerge after several states adopted RPS and NEM policies.
Ultimately, the coal coalition declined throughout the decades after policies for pollution regulation and cheaper and cleaner alternatives substituted generation such as solar, natural gas, and wind. The pollution regulation was a policy from another subsystem causing the decline of the coal coalition.

Solar PV development in the USA

Go: 2009
Why did companies in the USA start investing in solar PV?

Solar ITC (2006 – Present)
The Solar ITC entailed a dollar-for-dollar reduction in taxes equal to 30% of the total system costs invested in a solar system. The first reason companies started to invest in solar PV was the ITC. Before 2006 capacity added remained below 100 MW. The capacity added in 2006 was 105 MW. The annual capacity added to solar PV in the US is illustrated in Figure 16. In 2006 the Solar Investment Tax Credit (ITC) was introduced as part of the Energy Policy Act of 2005. The Solar Investment Tax Credit played a significant role in the installed capacity of solar (Comello, 2015).
In 1986 the Solar Modified Accelerated Cost Recovery System was introduced. The Solar Modified Accelerated Cost Recovery System allowed investors to depreciate their system costs in 5 years to reduce tax liability. This

program was paired with the ITC allowing investors to save up to 56% of the installed cost of a solar project (IEAPVPS, 2014).

Lower prices of PV Technology

Costs for installing PV in the USA over the years have reduced by over 70% between 2010 and 2021 (Tabassum, et al., 2021). In 2010 LCOE for utility PV was 0.27 USD/kWh, and by 2017 it was 0.06 USD/kWh (IEA, 2020). Capacity added grew to 11274 MW by 2016.

1603 Grant Payments-In Lieu-Of-Tax-Credits program (2009 – Dec 2011)

Another reason companies started to invest in solar PV was the introduction of the 1603 grant program allowing developers to not have to rely on tax equity investors. In 2007 and 2008, capacity added grew to 160 MW and 298 MW, respectively. In 2009 and 2010, capacity added grew to 435 MW and 852 MW, respectively. In 2009 1603 Grants Payments 1603 Grant Payments-In Lieu-Of-Tax-Credits program was introduced as part of the American Recovery and Reinvestment Act. The 1603 program offered a cash grant payment instead of a tax credit for 30% of the capital of the project. Before this program, the capital was provided by tax equity investors in exchange for the tax benefits of the solar programs. After the introduction of this program, solar developers did not have to rely on tax equity investors anymore (National Renewable Energy Laboratory, 2012).

The 1603 program supported significant and dramatic development in the deployment of renewable energy (National Renewable Energy Laboratory, 2012). The program ceased in December 2011 however, projects that were approved for funding before 2011 were allowed to complete the project until 2016 (IEAPVPS, 2013). In 2011, 2012, and 2013, capacity added grew to 3132 MW, 2965 MW, and 3622 MW, respectively.

1705 Loan Guarantee Program (2009 – Sep 2011)

Furthermore, in 2009 the government introduced the 1705 program under the American Recovery and Reinvestment act. Large-scale renewable energy technologies were prevented from being deployed using grants available before the 1705 Loan Guarantee program because the DOE required the projects to be ‘’innovative’’ and ‘’new or improved. This changed with the introduction of the 1705 program (Gunn-Wright, 2020). The 1705 guarantee program was not as successful because it focused on a few large-scale solar projects, many of which were not realized. The 1705 program was less successful because it required more staff to administrate, awarded grants slower, and supported less installed capacity than the 1603 (Aldy, 2013).

To summarize, when the solar ITC was introduced in 2006, solar PV development did not take off. When the 1603 program was introduced, solar PV took off. Lower prices of PV technology played an important role in the increase in PV development.

What were the drivers for the government of the USA to support solar PV?

In 2009 the Obama Administration introduced the American Recovery and Reinvestment Act (ARRA) to promote jobs for economic recovery, assist the ones most impacted by the recession, provide investment for technological advances in science and health to increase economic efficiency, invest in environmental protection to provide long-term economic benefits (Government of the United States of America, 2009).

Most importantly, the act was introduced because of widespread fear of the American economy falling into a depression after the 2008 recession (Reid, 2012). ARRA had a significant impact on investing in clean energy projects (IEA, 2014). Under this act, investments and programs to stimulate investment in solar and wind energy were included. The ARRA investment had a dual purpose which was to provide the American economy with more jobs and to invest in a sustainable future (Executive Office of the United States of America, 2016). ARRA funded clean energy projects to address environmental externalities from the burning of fossil fuels, innovation market failures, and capital market failures.

Furthermore, the reason the US developed renewable energy was to reduce emissions by shifting away from fossil fuels (Schmalensee, 2012). Historically, coal provided 50% of electricity generation, but due to tighter emission restrictions from EPA, this has gone down and been replaced by natural gas and renewable energy sources. (IEA, 2014). However, the decrease in coal use was due to the lower natural gas prices and the shale revolution, stagnant US electricity demand, and not because of policy-supported growth in the wind and solar generation (Gruenspecht, 2019).

In the case of the USA, a coalition shift was an important reason the government supported solar PV. Dominance shifted from the coal coalition to the competing coalitions. As mentioned before, the US Shale gas revolution since 2008 and the decline in costs of generation using solar and wind were important drivers for the substitution of coal in the power generation (Jacob & Steckel, 2022).

In conclusion, the government of the USA supported solar PV to stimulate the economy after the 2008 recession, to reduce emissions, and because of the coalition shift.

5 Results

In this chapter, the results of the research are presented. The purpose of this research is to *develop a better understanding of the underlying causes of stop-and-go policies in the development of solar PV.* After identifying the reasons countries started and stopped support for solar PV in the literature, we analyzed each country to determine which of these reasons were important for countries to start or stop developing solar PV. In this section, we compare the findings across countries.

The reasons governments started developing solar PV can be seen in Table 5. Firstly, the most important reason for countries to support solar PV was to improve the security of supply. Countries developed solar PV because of their high dependence on imported fossil fuels in order to improve the security of supply. Improving the security of supply was a reason that manifested independently (in three instances). In the other events except for Germany in 2009, a combination of reasons was found to be important. Secondly, an extremely important reason countries with abundant domestic fossil fuel resources support solar PV is to stimulate their economies, with the exception of Japan. In some cases, this was during or following a recession. Coalition shift and emission reduction were important reasons for countries that relied heavily on coal to support solar PV. Though the evidence was limited, nuclear disasters were provided as a reason why countries started developing solar PV in Section 3.1. However, this was not a reason we observed in the country analysis. Last but not least, a reason that was not proposed in Chapter 3 for the go events was observed. In Germany, a significant decrease in the cost of solar PV technology was an independent reason for the go event of 2009.

Table 5. Reasons for go events

Government	**Year**	**Security of supply**	**Stimulate Economy**	**Energy diversification**	**Emission reduction**	**EU Renewables Target**	**Coalition shift**	**Nuclear accident**
France	2008	○	•	•	○	•	○	○
Germany	2003	○	• •	○	•	○	•	○
Germany	2009	○	○	○	○	○	○	○
Italy	2007	• •	○	○	○	○	○	○
Japan	2009	• •	• •	○	○	N/A	○	○
Spain	2006	• •	○	○	○	○	○	○
Spain	2019	• •	○	○	○	○	○	○
United Kingdom	2010	•	•	○	○	•	○	○
USA	2009	○	• •	○	•	N/A	•	○

Extremely important = • •
Important = •
Not important = ○

The reasons governments stopped developing solar PV can be seen in Table 6. Economic crises were an extremely important reason for countries to stop developing solar PV. Although the same economic crisis was the reason for both Italy and Spain to stop the support of solar PV, we observed the stop events in different years. The reason for this was the different approaches taken by the two governments to reduce PV support. We also observed that all stop events are after 2008. This has to do with the costs of solar PV dropping significantly after 2008. In order to control explosive PV development, countries implemented stop policies after 2008 to limit policy costs. Last but not least, the coalition shift was not an important reason for countries to stop developing solar PV.

Table 6. Reasons for stop events

Governments	**Year**	**Economic crisis**	**Prioritizing other sectors instead of solar**	**Coalition shift**
Germany	2013	○	● ●	○
Italy	2012	● ●	○	○
Spain	2009	● ●	○	○
United Kingdom	2017	○	● ●	○

Extremely important = ● ●
Important = ●
Not important = ○

The reasons companies invested in solar PV can be seen in Table 7. In all countries, feed-in tariffs were an extremely important reason for investors to invest in solar PV, with the exception of the USA. In our findings, feed-in tariffs and reduction of PV costs were the only reasons that manifested independently and were enough for companies to invest in solar PV. For other instances, a combination of reasons was required. We observed reduction of PV costs played an extremely important role in investors investing in solar PV after 2008.

Table 7. Reasons companies invested in solar PV

Companies from	**Year**	**FIT (incl. FIT design)**	**Reduction of PV costs**	**PV Self-consumption**	**Form of alternative investment**	**Loan Programs**	**Tax incentives**	**Access to credit, low interest rates**
France	2008	● ●	● ●	○	○	○	○	○
Germany	2003	● ●	○	○	○	○	○	○
Germany	2009	○	● ●	○	○	○	○	○
Italy	2007	● ●	○	○	○	○	○	○

Japan	2009	• •	○	○	○	○	○	○
Spain	2006	• •	○	○	• •	○	○	• •
Spain	2019	○	• •	• •	○	○	○	○
United Kingdom	2010	• •	• •	○	○	○	•	○
USA	2009	○	• •	○	○	•	•	○

Extremely important = • •
Important = •
Not important = ○

The reasons companies stopped investing in solar PV can be seen in Table 8. Feed-in tariff amendments and deployment caps were extremely important reasons for investors to stop investing in solar PV across countries. Deployment caps and feed-in tariff amendments are both reasons that can manifest independently and would be enough for companies to stop investing in solar PV, according to our findings. The reason the end of schemes renewables obligations, contract differences, and tax incentives are not assigned for the countries in Table 8 is that they were not implemented at the time.

Table 8. Reasons companies stopped investing in solar PV

Companies	**Year**	**Feed-in tariff amendments**	**Deployment caps**	**End of Renewables Obligation**	**End of Contract for Difference Scheme**	**End of tax incentives**
Germany	2013	• •	• •	N/A	N/A	N/A
Italy	2012	○	• •	N/A	N/A	N/A
Spain	2009	• •	○	N/A	N/A	N/A
United Kingdom	2017	• •	• •	○	○	○

Extremely important = • •
Important = •
Not important = ○

In Table 9 the countries can be seen with their availability of domestic fossil fuels and if the reason to support solar PV was to stimulate the economy or to increase the security of supply. We observe that in countries with an abundance of domestic fossil fuels, the reason to support solar PV to stimulate the economy was extremely important, with the exception of Japan. Though it must be noted that this is a small number of countries. Although domestic fossil fuels were scarce in Japan, an extremely important reason Japan supported solar PV was to create an industry or stimulate the economy. In countries with scarce fossil fuels, an extremely important reason solar PV was supported was to increase the security of supply, with the exception of France due to their availability of nuclear energy.

Table 9. Countries that supported solar PV to stimulate the economy or increase their security supply with their domestic fossil fuel resources. Source for country reserve rankings: (BP, 2022).

Countries	**Supported solar PV to stimulate the economy**	**Supported solar PV to increase the security of supply**	**Domestic coal**	**Domestic oil**	**Domestic natural gas**
Germany	• •	○	++	-	-
USA	• •	○	++	++	++
Japan	• •	• •	-	-	-
Italy	○	• •	-	-	-
Spain	○	• •	-	-	-
United Kingdom	•	•	-	±	-
France	•	○	-	-	-

Abundant = ++ (Global reserve ranking 10 or below)
Available = ± (Global reserve ranking between 11 - 30)
Scarce = - (Global reserve ranking 31 or above)

Extremely important = • •
Important = •
Not Important = ○

6 Discussion and Conclusion

6.1 Discussion

In this section, we compare our findings to the reasons identified in the literature for countries to start and stop support for solar PV. Following this, we discuss the contribution of this thesis to the research topic, the limitations of this research, and ultimately recommendations for future policymakers.

Comparison to prior research

Gallagher explored the reasons why and how the governments of Denmark, Germany, China, and certain US states develop renewable technology by comparing four factors for each of these cases (Gallagher, 2013). The four factors explored for each case were the economic motive, the renewable source potential or availability of non-renewable sources, the political system, and the culture/attitude.
While the majority of previous literature that was analyzed focused on a single or few reasons for PV development, we focus on analyzing the countries using multiple proposed reasons to determine which of these reasons were important or were not important for countries to start or stop developing PV. Furthermore, to our knowledge, the existing literature focused on single or dual-country analyses while we compare these reasons across seven countries. The analyzed literature consisted of individual country analyses or country comparison analyses until the time of the writing of the research. This thesis analyzes the countries within the time frame of 2000-2020.
To the best of our knowledge, previous literature did not focus on the reasons companies started or stopped investing across countries. This research discusses the policies that were important or not important for companies to invest or stop investing and for the capacity added of solar PV in a country to increase or decrease.

Create an industry / Stimulate the economy
Reflecting on the findings of Gallagher, economic motives played an important role in countries supporting renewables (Gallagher, 2013). Gallagher showed states was the case for Germany and our findings are in line with this. The findings of Gallagher were that countries with abundant domestic fossil fuel resources support renewables to stimulate the economy. However, our results showed that Japan did not possess abundant domestic fossil fuel resources but still supported PV to create an industry. However, generally, this thesis supports the findings of Gallagher.

Energy Crisis / Security of Supply
Furthermore, this thesis supports the findings of Gallagher that high dependence on fossil fuel imports can be an important reason for countries to support the development of renewables (Gallagher, 2013). Gallagher's findings indicated that countries with scarce domestic fossil fuel resources develop renewables in order to improve energy security. In Gallagher's findings, this was the case for Denmark. According to our findings, improving the security of supply was an extremely important reason for countries to develop solar. This was also the case for Italy, Japan, and Spain. In addition, a new finding is that the security of supply manifested independently as a reason for countries to develop solar PV.

Nuclear accident
In response to a nuclear accident, Japan and Germany decided to support solar PV (Huenteler, Schmidt, & Kanie, 2012). However, in our findings, Japan began to support solar PV prior to the nuclear accident and had accelerated solar PV support after the accident. Our findings imply that the nuclear accident itself was not the reason for solar PV support but the reason to accelerate PV development.

Emission Reductions
The strongest argument for the USA to support renewables was in order to reduce emissions due to their heavy reliance on coal, according to Schmalensee (Schmalensee, 2012). One of the motivations for increased support for renewable development was to reduce emissions (Fischer & Preonas, 2010). This thesis supports the findings

of Schmalensee. In countries heavily reliant on coal for electricity generation, solar PV was developed to reduce emissions.

Energy diversification
Seriño discusses energy diversification as a motivation for countries to develop renewables (Serino, 2019). Energy diversification was a reason for only a single country in our analysis to develop solar PV because of its heavy reliance on nuclear technology. Therefore, we conclude that it is not an important reason for countries to develop solar PV.

EU Pressure / Renewable Targets
Bocquilon & Evrard believed that EU pressure pushed the member countries to implement their first photovoltaic support policies (Bocquillon & Evrard, 2017). This thesis supports the findings of Bocquilon & Evrard. EU Pressure can be an important reason to develop solar PV. In our findings, we observe this in France and the United Kingdom, two of the five EU-member countries analyzed.

Economic Crisis
Support for solar PV is believed to decrease because of the need to decrease government expenditures during a broader economic downturn (Del Río & Mir-Artigues, 2014) (Mahalingam & Reiner, 2016). In our findings, there are instances that support this argument. However, in our findings, there are also instances where countries have decided to increase support during or shortly after a broader economic downturn. This relates to the reason discussed above for stimulating the economy.

Prioritizing other sectors
Prioritization of other sectors or alternative energy is believed to be a reason for a decrease in support for solar PV (Moore, 1982) (Roberts, 1983) (Miller, 2018). This thesis supports these findings. We observe in our research two instances where support for solar PV decreased because other sectors or alternative energy were prioritized.

Coalition shift
Prior work on this topic by Schmid et al. and Jacobsson & Lauber argued how coalition shift could be a reason for an increase in solar PV support. (Schmid, Sewerin, & Schmidt, 2020) (Jacobsson & Lauber, 2006). This thesis supports coalition shift as a reason for supporting solar PV. However, a coalition shift was not observed as a reason to stop support for solar PV.

Decrease in costs of solar PV technology
In the analysis, a reason for go events that we did not come across in the prior literature discussed in Chapter 3 was observed. A significant decrease in the cost of solar PV technology during 2008-2011 was the reason for the go event. Based on our findings decrease in costs of solar PV technology was an independent reason for a go event.

Other reasons
We expected countries to support solar PV for other reasons, such as combatting climate change. However, other than the countries mentioning fighting climate change as a goal in their energy policy, we did not find any evidence to support this reason.

Contribution of this thesis to the research topic

Gallagher's analysis was performed on the countries Germany, China, Denmark, and specific states in the USA (Gallagher, 2013). This thesis expanded the analysis of the countries by adding Japan, France, Italy, Japan, Spain, and the United Kingdom. By analyzing a more extensive set of countries, we were able to determine that some of the reasons were generalizable.
Furthermore, the specific policies, external events, and advocacy coalitions that contributed to the increase or decrease in the capacity of solar PV were also analyzed. On the other hand, this thesis added the reasons countries stopped developing solar PV.

To our knowledge, prior research has analyzed countries considering a single reason or few reasons for developing solar PV. By analyzing multiple proposed reasons, we were able to determine that some of the proposed reasons for PV support occurred independently and some in combination with each other.

Our new insights included that the security of supply manifested independently as a reason for countries to develop solar PV. In addition, our results showed a case where a country did not possess abundant domestic fossil fuel resources but still supported PV to create an industry, which is not in line with the findings of Gallagher. However, generally, this thesis supports the findings of Gallagher. We also found that the economic crisis and prioritization of other sectors or alternative energy technologies were important reasons for countries to stop developing solar PV. Furthermore, emission reductions were only important for countries that relied heavily on coal for electricity generation. Last but not least, for one go event, none of the aforementioned reasons were necessary. A decrease in the costs of solar PV technology was an independent reason for the go event.

Furthermore, our research provides new insights regarding the reasons companies started and stopped investing in solar PV. By investigating the reasons companies started and stopped investing in solar PV, our findings suggest there is a relationship between policies and why companies start and stop investing in solar PV. Feed-in tariffs (and FIT design) played an extremely important role in companies starting and stopping investing in solar PV. Feed-in tariffs and reduction of PV costs can manifest exclusively as a reason for companies to start investing in solar PV. Last but not least, feed-in tariff design and deployment caps can manifest exclusively as a reason for companies to stop investing in solar PV.

Limitations of the research

Firstly, multiple countries were studied, which positively impacts the generalizability of the findings. However, the selected countries were all in the top 15 countries with the largest GDP meaning the results do not reflect lower GDP countries. Furthermore, the geographical positioning of the selected countries should be considered. The selected countries were all positioned between 25-60°N, meaning the research results do not reflect countries between 25°S and 25°N. By analyzing countries with lower GDP and between 25°S and 25°N, generalizability can be improved.

Secondly, a limitation of this research was that only the literature available online was researched. This research focuses on reasons for starting or stopping the support of solar PV found only in the literature. The research can be strengthened by conducting interviews with policy experts, government officials, and investors from the countries that were analyzed. For example, by interviewing government officials that were in parliament during a stop-or-go event, empirical evidence for the reasons different countries started or stopped developing solar PV can be sought. In addition, since we used reasons for starting or stopping support of solar PV only found in the literature, perhaps by interviewing government officials and policy experts, we could come across reasons that have not yet been documented in the literature.

Last but not least, politicians or political parties can have vested interests (Moe E. , 2015) (Sklarew, 2018) (Schneider, 2008). The authenticity or validity behind the provided reasons for solar PV support in these government documents will always be questionable. The reasons for starting or stopping solar PV support in these government documents may not always be authentic and reflect the real reasons.

Recommendations for policymakers

In the context of the economic crisis, high levies for solar PV support gained increasing negative attention. This was the case in Italy and Spain. PV development increased between 2008-2010 due to falling PV costs and lagging policy amendments leading to explosive growth and high levies on electricity bills. As a recommendation for policymakers, PV capacity added and PV cost trends in the short term (quarterly and, in extreme cases, monthly) should be monitored closely by policymakers to amend PV support policies.

On the other hand, taking a too-aggressive approach to decrease solar PV support may negatively impact investor confidence and the future development of PV in a country. In the case of Spain and Italy, policy support for solar PV was withdrawn quicker than in Germany, which led to the stagnation of the PV industry. Thus, countries must monitor developments closely and adjust support accordingly.

6.2 Conclusion

This thesis explores the reasons why countries support and stop support for solar PV. The purpose of this research was to *develop a better understanding of the underlying causes of stop-and-go policies in the development of solar PV* as stipulated in 1.1. After identifying the reasons countries started and stopped supporting solar PV, we analyzed each country to determine which of these reasons were important for countries to start or stop developing solar PV and compared them across countries.

The research question was: Why do stop-and-go policies in solar photovoltaic development occur in different countries? To answer the research question, we formulated the following sub-questions:

SQ1: What reasons have been identified in the literature for countries to start supporting solar PV?
SQ2: What reasons have been identified in the literature for countries to stop supporting solar PV?
SQ3: For each country: What reasons were important for the country to start supporting solar PV?
SQ4: For each country: What reasons were important for the country to stop supporting solar PV?
SQ5: What reasons were important for countries to support solar PV?
SQ6: What reasons were important for countries to stop supporting solar PV?

In this section, we summarize the findings for the sub-questions. Since SQ5 and SQ6 encompass the findings of SQ3 and SQ4, we will not discuss the latter in this section.

SQ1: What reasons have been identified in the literature for countries to start supporting solar PV?

Knowledge from the scientific literature was accumulated to draft a framework of hypotheses of why countries started supporting solar PV. In the literature, seven reasons for supporting solar PV were identified. Countries supported solar PV to stimulate the economy, increase the security of supply after a nuclear accident, reduce emissions, diversify energy sources, and last but not least, due to EU pressure to reach renewable energy targets.

SQ2: What reasons have been identified in the literature for countries to stop supporting solar PV?

Knowledge from the scientific literature was accumulated to draft a framework of hypotheses of why countries stopped supporting solar PV. In the literature, three reasons were identified for decreasing support for solar PV. Countries decreased support due to an economic crisis, to prioritize other sectors, and due to a coalition shift.

SQ5: What reasons were important for countries to support solar PV?

After drafting the framework of hypotheses based on the literature on why countries start supporting solar PV, we analyzed the countries individually and concluded which reasons were important across countries. In summary, improving the security of supply and stimulating the economy were extremely important reasons countries developed solar PV. Countries with abundant domestic fossil fuel resources developed solar PV to stimulate their economies, while countries with scarce domestic fossil fuel resources developed to improve their security of supply. Nuclear accidents were not important for countries to start developing solar PV.

SQ6: What reasons were important for countries to stop supporting solar PV?

After drafting the framework of hypotheses based on the literature on why countries stopped supporting solar PV, we analyzed the countries individually and concluded which reasons were important across countries. Extremely important reasons for countries to stop developing solar PV were an economic crisis or the prioritization of other sectors or alternative technologies. However, the same economic crisis that caused certain countries to stop developing solar PV was the reason for some countries to stimulate the economy. When countries decided to stop support of PV, some countries took a more aggressive approach to reduce support than others, causing PV capacity added to decrease at a different pace. Coalition shifts were not important for countries to stop developing solar PV.

Why do stop-and-go policies in solar photovoltaic development occur in different countries?

At the beginning of this thesis, we mentioned how the development of renewable energy technologies is seen as one of the solutions to tackling climate change because of its non-carbon-emitting characteristic. Different renewable policy strategies adopted by countries resulted in stop-and-go patterns of stagnation in development and are harmful to the country's markets, jobs, and investor confidence.

To understand the underlying cause of the stop-and-go policies in different countries, we took a closer look at the photovoltaic development trajectory in several countries. We identified the reasons countries started and stopped developing solar PV in the literature. We analyzed and compared each country to determine which of these reasons were important to start or stop developing solar PV across countries.

Stop-and-go policies for solar photovoltaic development can occur in different countries because of the larger macroeconomic conditions (crises) that countries are subject to. As a response, countries could choose to start or stop developing solar PV. Countries choose to start or stop developing solar PV depending on the availability of domestic fossil fuel resources during these crises. In our findings, we observed go events for solar photovoltaic development can occur in different countries because countries highly dependent on imported fossil fuels desire to improve their energy security. Countries with abundant domestic fossil fuels choose to stimulate their economy. In the context of an economic crisis, countries can choose to stop support for solar PV. Last but not least, stop policies for solar photovoltaic development can occur in different countries because new governments prioritize other sectors or energy alternatives.

Recommendations for policymakers

As a recommendation for policymakers, PV capacity added and PV cost trends in the short term (quarterly and, in extreme cases, monthly) should be monitored closely by policymakers to amend PV support policies. PV development increased between 2008-2010 due to falling PV costs and lagging policy amendments leading to explosive growth and high levies on electricity bills in a period of economic crisis. On the other hand, taking a too-aggressive approach to decrease solar PV support may negatively impact investor confidence and the future development of PV in a country. Thus, countries must monitor developments closely and adjust support accordingly.

Recommendations for further research

In our findings, there were instances in which improving the security of supply, and decreasing costs of solar PV were independent reasons for go events. The reasons for starting or stopping support for PV are not entirely independent. For example, when a nuclear accident affects the dynamic between coalitions and causes a coalition shift. Another example could be the economic crisis and the energy crisis. The dependence or relation between reasons can be an interesting topic for further study.

Furthermore, as mentioned in the limitations, this research was conducted by researching only the literature available online. The research can be strengthened by conducting interviews with policy experts, government officials, and investors from the countries that were analyzed. For example, by interviewing government officials that were in parliament during a stop-or-go event, empirical evidence for the reasons different countries started or stopped developing solar PV can be sought. In addition, since we used reasons for starting or stopping support of solar PV only found in the literature, perhaps by interviewing government officials and policy experts, we come across reasons that have not yet been documented in the literature.

The results of our research reflect the reasons countries start or stop developing solar PV. Would these reasons for stop-and-go policies of solar photovoltaic development also apply to the development of other renewable technologies, such as off-shore or on-shore wind? Or perhaps there are more reasons for the stop-and-go events during the development of these technologies. Since on-shore and off-shore wind are not developed at the small scale of solar PV, it would be interesting to see if the results are different.

In our case analyses, we see multiple instances of uncontrolled growth resulting in high levies or where development completely stagnates, and the industry and investors suffer. Further research could be dedicated to designing policy-development feedback mechanisms to help future policymakers amend support policies. How do we optimally control solar PV development during times of exponential growth, and how do we reduce support without completely paralyzing the market?

In our findings, improving the security of supply played an important role for the one island we analyzed. I hypothesize that an extremely important reason for islands to develop solar PV is to improve their energy security because of their lack of abundant domestic resources. However, based on our analysis, we cannot conclude this because we have only analyzed one island. It would be interesting to extend the analysis to include more islands.

Developing solar PV to create an industry or stimulate the economy was important across several countries in our results. While we consider that the countries we analyzed have high GDPs, I hypothesize that this reason would not be important among lower GDP countries. It would be interesting to see if creating industry or stimulating the economy were important reasons, given the financial constraints of lower GDP countries.

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Appendix

A.1 Solar PV capacity of selected countries

France

Year	2006	2007	2008	2009	2010	2011	2012	2013
Installed Capacity (MW)	15	26	80	277	1044	3004	4359	5277
Installed Capacity Growth (%)	15%	73%	208%	246%	277%	188%	45%	21%
Capacity added (MW)	2	11	54	197	767	1960	1355	918
Capacity added growth (%)	0%	450%	390%	264%	289%	155%	-31%	-33%

Germany

Year	1998	1999	2000	2001	2002	2003	2004	2005
Installed Capacity (MW)	54	70	114	195	260	435	1105	2056
Installed Capacity Growth (%)	28%	29%	63%	71%	33%	67%	154%	86%
Capacity added (MW)	12	26	44	81	65	175	670	951
Capacity added growth (%)	-14%	+117%	+69%	+84%	-20%	169%	282%	41%

Year	2005	2006	2007	2008	2009	2010	2011
Installed Capacity (MW)	2056	2899	4170	6120	10567	18007	25914
Installed Capacity Growth (%)	86%	41%	44%	47%	73%	70%	44%
Capacity Added (MW)	951	843	1271	1950	4447	7440	7907
Capacity Added Growth (%)	+42%	-11%	+50%	+53%	+128%	+67%	+6%

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Installed Capacity(MW)	6120	10567	18007	25914	34075	36708	37898	39222	40677
Installed Capacity Growth (%)	47%	73%	70%	44%	32%	7%	3%	4%	4%
Capacity Added (MW)	1950	4447	7440	7907	8161	2633	1190	1324	1455
Capacity Added Growth (%)	+53%	+128%	+67%	+6%	+3%	-68%	-55%	+11%	+9%

Italy

Year	2006	2007	2008	2009	2010	2011
Installed Capacity (MW)	45	110	483	1264	3597	13131
Installed Capacity Growth (%)	32%	144%	339%	161%	184%	265%
Capacity added(MW)	11	65	373	781	2333	9534
Capacity addedgrowth (%)	+175%	+490%	+473%	109%	198%	309%

Year	2011	2012	2013	2014	2015	2016
Installed Capacity (MW)	13131	16785	18185	18594	18901	19283
Installed Capacity Growth (%)	265%	28%	8%	2%	2%	2%
Capacity Added(MW)	9534	3654	1400	409	307	382

Capacity Added Growth (%)	309%	-62%	-62%	-71%	-25%	24%

Japan

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Installed Capacity (MW)	2131	2611	3599	4890	6430	12107	19334	28615	38438
Installed Capacity Growth (%)		23%	38%	36%	31%	88%	60%	48%	35%
Capacity added(MW)	222	480	988	1291	1540	5677	7227	10811	9823
Capacity addedgrowth (%)	6%	116%	105%	30%	19%	268%	27%	28%	6%

Year	2016	2017	2018	2019
Installed Capacity (MW)	38438	44226	55500	61256
Installed Capacity Growth (%)	35%	15%	25%	10%
Capacity added(MW)	9823	5788	11274	5756
Capacity added growth (%)	6%	-41%	94%	-49%

Spain

Year	2003	2004	2005	2006	2007	2008
Installed Capacity (MW)	22	33	52	130	494	3384
Installed Capacity Growth (%)	29%	50%	58%	150%	280%	585%
Capacity added (MW)	5	11	19	78	364	2890
Capacity added growth (%)	25%	120%	72%	310%	367%	693%

Year	2008	2009	2010	2011	2012	2013	2014
Installed Capacity (MW)	3384	3423	3873	4283	4569	4690	4697
Installed Capacity Growth (%)	585%	1%	13%	11%	7%	3%	1%
Capacity added (MW)	2890	39	450	410	286	128	7
Capacity added growth (%)	693%	-98%	1000%	-9%	-31%	-55%	-95%

Year	2015	2016	2017	2018	2019	2020
Installed Capacity (MW)	4704	4713	4723	4764	8973	11785
Installed Capacity Growth (%)	0%	0%	0%	1%	88%	31%
Capacity added (MW)	7	9	10	41	4209	2812
Capacity added growth (%)	29%	11%	11%	310%	10,165%	-34%

United Kingdom

Year	2009	2010	2011	2012	2013	2014	2015	2016
Installed Capacity (MW)	27	95	1000	1753	2937	5528	9601	11914
Installed Capacity Growth (%)	17%	252%	952%	75%	68%	88%	74%	24%
Capacity added (MW)	4	68	905	753	1184	2591	4073	2313
Capacity added growth (%)	-20%	1600%	1230%	-17%	57%	218%	57%	-43%

Year	2015	2016	2017	2018	2019	2020
Installed Capacity (MW)	9601	11914	12760	13073	13346	13563

Installed Capacity Growth (%)	74%	24%	7%	3%	2%	2%
Capacity added (MW)	4073	2313	846	313	273	217
Capacity added growth (%)	57%	-43%	-64%	-63%	-13%	-21%

USA

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Installed Capacity (MW)	111	190	295	455	753	1188	2040	5172	8137
Installed Capacity Growth (%)	52%	71%	55%	54%	65%	58%	72%	54%	57%
Capacity added (MW)	38	79	105	160	298	435	870	3132	2965
Capacity added growth (%)	-16%	107%	33%	52%	86%	46%	100%	267%	-5%

Year	2013	2014	2015	2016	2017	2018	2019	2020
Installed Capacity (MW)	11759	15984	21684	32958	41357	51426	58924	73814
Installed Capacity Growth (%)	44%	36%	36%	52%	25%	24%	15%	25%
Capacity added (MW)	3622	4225	5700	11274	8399	10069	7498	14890
Capacity added growth (%)	22%	17%	35%	98%	-35%	20%	-25%	99%

A.2 Solar PV LCOE by country

Table 10. Solar PV LCOE by Country. To obtain cost in desired year correct for inflation then convert to euro if necessary Source: (IRENA, 2020)

Sector	Market	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
		2019 USD/kWh									
Residential	Australia	0.319	0.258	0.187	0.163	0.154	0.106	0.098	0.089	0.082	0.075
	Brazil				0.261	0.244	0.232	0.187	0.155	0.125	0.111
	China			0.162	0.144	0.139	0.107	0.103	0.096	0.079	0.067
	France		0.712	0.516	0.435	0.330	0.201	0.188	0.174	0.161	0.149
	Germany	0.301	0.261	0.204	0.185	0.174	0.144	0.141	0.138	0.144	0.138
	India				0.132	0.128	0.093	0.085	0.074	0.067	0.063
	Italy	0.405	0.360	0.248	0.228	0.162	0.137	0.128	0.121	0.113	0.109
	Japan	0.455	0.450	0.393	0.298	0.250	0.224	0.202	0.188	0.169	0.163
	Malaysia				0.185	0.185	0.161	0.151	0.127	0.109	0.095
	Republic of Korea				0.224	0.225	0.170	0.164	0.141	0.130	0.125
	South Africa				0.200	0.180	0.156	0.148	0.134	0.119	0.102
	Spain				0.181	0.158	0.122	0.116	0.109	0.106	0.104
	Switzerland				0.304	0.274	0.259	0.246	0.225	0.205	0.188
	Thailand				0.250	0.201	0.183	0.179	0.159	0.137	0.106
	United Kingdom				0.327	0.342	0.302	0.274	0.276	0.268	0.265
	California (US)	0.306	0.290	0.253	0.222	0.210	0.213	0.207	0.187	0.179	0.171
	Other US states	0.304	0.280	0.230	0.202	0.203	0.202	0.178	0.162	0.157	0.155
Commercial	Australia					0.131	0.107	0.097	0.086	0.082	0.078
	Brazil							0.155	0.123	0.104	0.093
	China		0.180	0.147	0.129	0.107	0.094	0.089	0.086	0.072	0.064
	France	0.625	0.324	0.237	0.240	0.237	0.194	0.166	0.186	0.176	0.154
	Germany		0.253	0.176	0.155	0.140	0.114	0.119	0.115	0.114	0.105
	India								0.071	0.066	0.062
	Italy	0.322	0.279	0.171	0.141	0.139	0.115	0.108	0.101	0.094	0.092
	Japan			0.335	0.276	0.213	0.172	0.169	0.164	0.153	0.147
	Malaysia					0.173	0.132	0.128	0.099	0.087	0.080
	Republic of Korea								0.137	0.125	0.115
	Spain		0.257	0.228	0.215	0.197	0.105	0.105	0.096	0.090	0.087
	United Kingdom							0.207	0.194	0.189	0.187
	Arizona (US)	0.279	0.249	0.222	0.180	0.152	0.162	0.147	0.135	0.120	0.112
	California (US)	0.259	0.251	0.203	0.191	0.156	0.152	0.157	0.150	0.138	0.134
	Massachusetts (US)	0.433	0.397	0.320	0.277	0.264	0.247	0.242	0.210	0.206	0.186
	New York (US)	0.439	0.397	0.337	0.268	0.243	0.227	0.213	0.189	0.181	0.171

Source: IRENA Renewable Cost Database.
Note: Unlike all other LCOE data presented in this report, the LCOE data in this table is calculated using a 5% WACC.

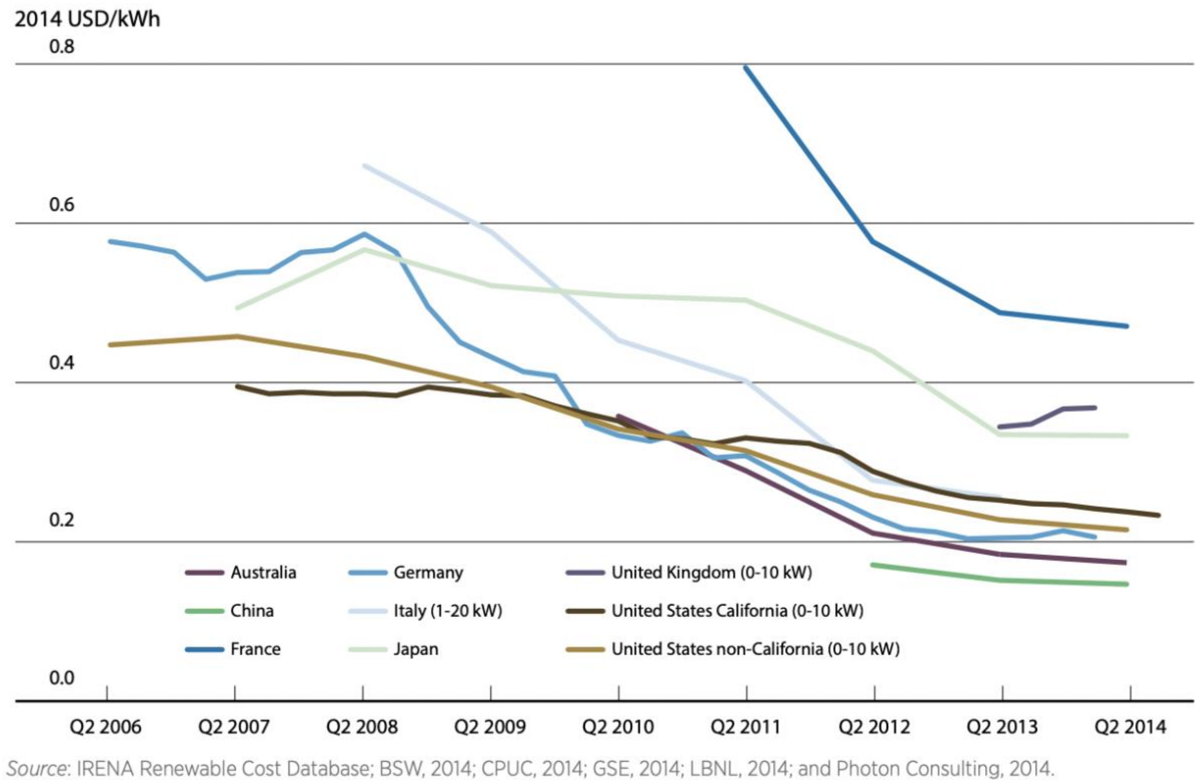

Figure 17. Solar PV LCOE by Country Source: (IRENA, 2015)

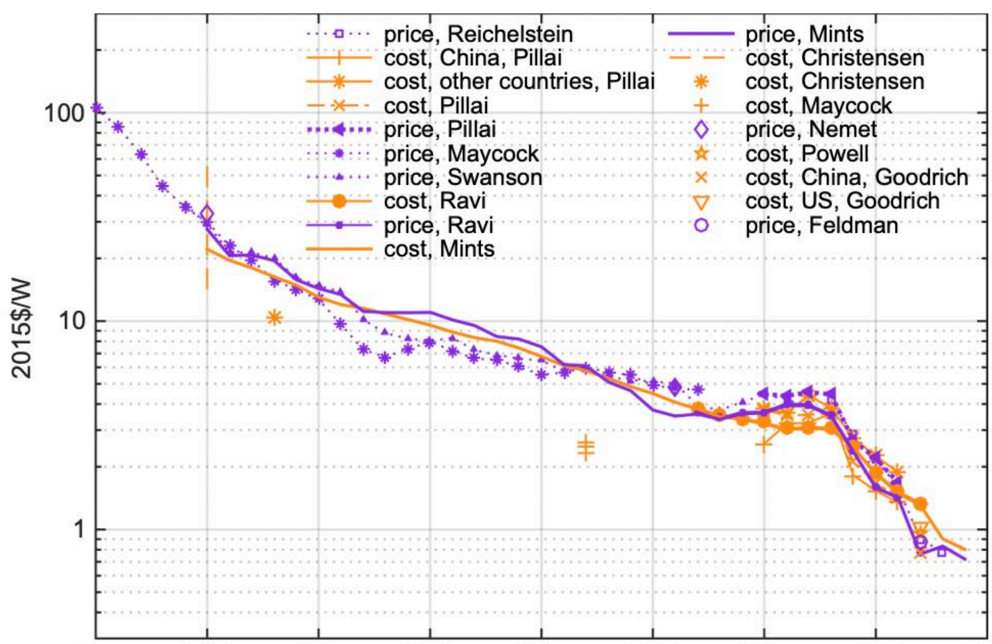

Figure 18. Solar PV module cost 1975-2015 Source: (Goksin Kavlak, 2018)