A comparative study of photovoltaic (PV) technology diffusion in Japan and Germany, 1990-2011: Importance of policy, incentives and R&D investments for cost reduction and energy system transformation

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Abstract

The world is moving into a new era, the Go Green Revolution (GGR) because of the earth's current global warming and rising seas. Renewables have long occupied a branch within energy policies. Photovoltaic (PV) has the highest cost reduction potential among all renewable energy sources (RES) and has experienced rapid growth. In order to overcome institutional barriers, develop the technology, and create an initial market, public policies are needed. To design efficient policy instruments, one needs knowledge about what challenges face the growth of the new technology. Comparative case studies of Japan and German PV sector from 1990 to 2011 were developed considering the government energy policy, environmental policy and PV cost reduction.

Japan was dominating the PV industry business globally during the decade 1994~2004. During this period Japan PV market increased 41 times from 7MW in 1994 to 290MW in 2005. After 2005 Japan's PV market decreased and became 210 MW in 2007 and world cumulative installed PV share decreased from 30.5% in 2003 to 7.3% in 2011. On the other side, since 2000, German PV market increased abruptly and it increased from 44MW in 2000 to 7.5 GW in 2011.

A comparative analysis of these cases suggests that the main reason for Japanese PV market decline was the unaligned energy policy and insufficient incentives. German policy is long term and the incentives are more generous than Japanese incentive program. The termination of incentive policy is the key reason for the Japanese market decline.

Moreover, Japanese environmental policy was not favorable for the growth of the renewable energy. The instruments that environmental economists have expected to be the most effective emission-reduction tools have not been introduced due to strong opposition from Japanese industry. Japan considering controlling CO_2 emission through energy saving, waste reduction and low CO_2 emission energy specially increasing nuclear energy production not the renewable energy like PV energy. On the other hand, to satisfy the environmental obligation as reduction of CO_2 emission Germany is promoting renewable energy and continued to support the policy to stay away from nuclear energy. German policy concerning environment promote the renewable energy specially a large growth of PV energy during last few years.

The levelized cost of electricity (LCOE) in Japan decreased from 260 yen in 1993 to 46 yen in 2004. The LCOE had decreased by 83% compare to 1993. Price gap between LCOE and grid

electricity in 1993 was 230 yen and it decreased to 22 yen in 2004. From 2005-2008 it was almost constant. By 2004, the LCOE in Germany had decreased 49% to 57 €ct/kWh and further decreased to 24.5 €ct/kWh in 2012. Recently Germany achieved grid parity in PV electricity. With a strong digression in recent years, the German feed-in tariff (FIT) has driven this development and the government reduced FITs with a stronger digression rate than expected.

The purpose of this research is to elucidate 1) how successfully the policies were implemented; 2) what the main reasons are behind successful cost reduction; 3) influences of policy on the diffusion of PV technology; and finally 4) what will be needed for the transformation process to be a success. This study compares the development and diffusion of PV (photovoltaic) in Japan with the situation of PV in Germany. Both cases were analyzed with the Technological Innovation Systems (TIS) framework, which focuses on a particular technology and includes all those factors that influence its development. This framework proposes seven system functions that need to be fulfilled for the TIS to function well. Both the fulfillment of each system function and the interaction dynamics between them are important. By observing positive and negative interactions, the fulfillment of each function can be determined which respectively support or hinder the functioning of the TIS. This study shows that different functional patterns occur for the PV Innovation Systems.

The goal of this study is to analyze the functional dynamics of the Japanese and German PV innovation systems, in order to understand the diffusion of PV, and more specifically to identify the inducing and blocking mechanisms in the diffusion process of PV. Finally, this study will point out key issues for diffusion and some solutions for the issues as well.

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Chapter 1

Introduction

The economy, consumers and the public purse are suffering increasingly from rising energy prices. The future competitiveness of a nation depends on its energy security. Fossil fuels constitute the dominant source of energy in the world. This dominance is associated with clear environment and climate challenges. The threat of nuclear disasters and problems with radioactive waste disposal are issues that have received much attention. As a response to the new awareness 'Green' energy is emerging. A wider use of renewable energy technology is seen as one way of meeting these challenges. Renewables have long occupied a branch within energy policies. However, greater technological dispersion has helped bring about a global trend in which exponential growth in renewables is emerging due to continuous innovation and decreasing costs.

Recently, much attention has been paid to the development of renewable energy in order to solve problem of energy and environment. Renewable energy is an energy generated from natural resources—such as sunlight, wind, rain, tides and geothermal heat. Photovoltaic (PV) is the most fascinating way to produce electricity. PV is environmentally friendly and has the biggest potential among all renewable energy sources (RES). Expected future world energy consumption shows that PV has the highest energy demand. PV is an expensive way to produce electricity from renewable energy sources but it has the highest cost reduction potential. Due to government subsidies and the rising cost of electricity, solar power has exploded in Europe, Japan and USA. However, the diffusion and implementation of PV technologies are going slowly. Policy makers, governments, utilities and customers are the major stakeholders for PV, and there are different motivations and arguments for PV deployment among each stakeholder group.

Policies are necessary in order to overcome institutional barriers, allow the technology to mature and create an initial market. In Japan interest is also in ally intensifying regarding the role renewables play in energy, climate change, and industrial policies. Policies like, Feed-in Tariff (FIT) law, which expanded from Europe to the rest of the world, helped renewables to achieve rapid growth. Such policies have created conditions in which renewables, such as wind and solar photovoltaic (PV), are emerging more and more as attractive new industries and markets.

To design efficient policy instruments, knowledge is needed about what mechanisms hinder the diffusion of the new technology. One method to analyze the development and diffusion of a technological innovation is to investigate its "technological innovation system" (TIS), i.e. what institutions (e.g. regulations, laws and culture) and actors (e.g. governmental bodies, companies and universities) relate to the technology, and what interconnections are there between the different actors. To understand, not only the structure of the system, but what processes that go on inside it, one can analyze its functional dynamics, i.e. look at the key processes that influence the development, diffusion and use of the technology. These functions can then be used to assess the innovation system, and determine the key inducement and blocking mechanisms. To determine the performance of a particular technological innovation system, it is particularly useful to compare it in functional terms with TIS in another country.

Today, Japan and Germany are the leading PV countries in terms of both market size and cumulative installed capacity. Combined, Japan and Germany accounted for about 80% of the total PV power that had been installed in IEA PVPS countries at the end of 2006. However, compared to other energy sources, PV makes only a marginal contribution to Japanese primary energy supply, which is dominated by oil, followed by coal, gas, and nuclear.

Photovoltaic (PV) has the highest cost reduction potential among all renewable energy sources (RES) and has experienced rapid growth. The current solar cell technologies are well established and provide a reliable product, with sufficient efficiency and energy output for at least 25 years of lifetime. This reliability, the increasing potential of electricity interruption from grid overloads, as well as the rise of electricity prices from conventional energy sources, add to the attractiveness of photovoltaic systems. Since 2000, total PV production increased more than 125 fold, with annual growth rates between 40 % and 80 %. Production data for the global cell production in 2011 increased up to 37 GW. This is again an increase of 37 % compared to 2010. In 2011 the photovoltaic cumulative installed capacities reached more than 67 GW (see Figure 1). A 10 fold increase of solar photovoltaic electricity generation capacity was observed between 2000 and 2011. The European Union is leading in PV installations with the exceptional development in the German market (7.5 GW). In Asia the largest market is Japan with 1.1 GW. In addition, most markets are still dependent on public support in the form of feed-in tariffs, investment subsidies or tax-breaks. The electricity generation costs are already at the level of residential electricity prices in some countries, depending on the actual electricity price and the local solar radiation level. But only if markets and competition will continue to grow, prices of the photovoltaic systems will continue to decrease and make electricity from PV systems for consumers even cheaper than from conventional sources. In order to achieve the price reductions and reach grid-parity for electricity generated from photovoltaic systems, public support, especially on regulatory measures, will be necessary for the next decade. Market conditions for photovoltaic differ substantially from country to country. This is due to different energy policies and public support programs for photovoltaic, as well as the varying grades of liberalization of domestic electricity markets (APERC, 2012).

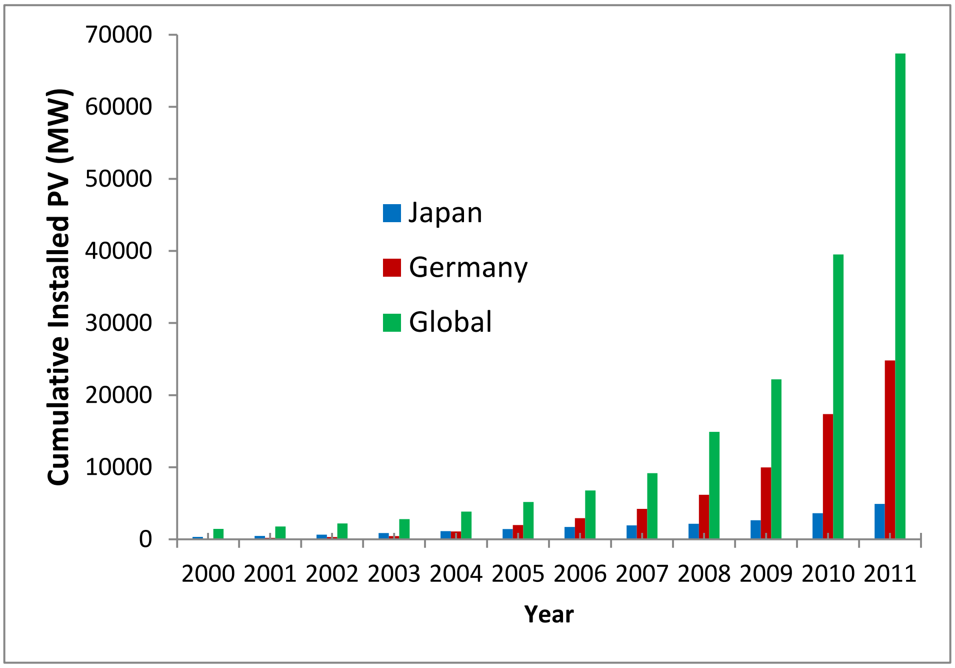

Figure 1. Cumulatively installed PV capacity in Japan, Germany and Global, 2000–2011. (Created by collecting data from: Chowdhury, S., 2012a, BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar 2011; BSW-Solar 2012; AGEE-Stat 2011; AGEE-Stat, 2012; IEA PVPS 2008; IEA PVPS 2011; IEA PVPS 2013; IEA, 2003; IEA, 2003a; IEA, 2004; IEA, 2004a; IEA, 2007; IEA, 2008; IEA, 2008a; IEA, 2010; IEA, 2010a; IEA, 2011; IEA, 2011a; IEA, 2012; IEA, 2012a; DBCCA, 2011).

The Japanese PV research and development program, as well as the measures for market implementation, which started in 1994, have ensured that Japan has become a leading PV nation world-wide. Japan was dominating the PV industry business globally during the decade 1994~2004. During this period Japan PV market increased 41 fold from 7MW in 1994 to 290MW in 2005. After 2005 Japan's PV market decreased and became 210 MW in 2007 and global PV production share decreased from 45.8% in 2005 to 7.3% in 2011. On the other side, since 2000, German PV market increased abruptly and it increased from 44MW in 2000 to 7.5 GW in 2011.

Comparative case studies of Japan and German PV sector from 1990 to 2011 were developed considering the government incentives, firms' long term production strategy, environment policy, research and development and cost reduction of PV system. The goal of this study is to analyze the functional dynamics of the Japanese PV innovation system, in order to understand the historical diffusion of PV in Japan, and more specifically to identify the blocking mechanisms facing the innovation system today, hindering further diffusion of the technology. Key policy issues, related to the blocking mechanisms, will be pointed out, which we hope will contribute to the general understanding of the diffusion of renewable energy technologies. The German PV innovation system has previously been studied by others, and their results will be used to compare the dynamics of PV innovation systems in Japan with the situation of PV in Germany. Both cases will be analyzed with the Technological Innovation Systems (TIS) framework, which focuses on a particular technology and includes all those factors that influence its development and diffusion. This framework proposes seven system functions that need to be fulfilled for TIS to function well: entrepreneurial activities, knowledge development, and knowledge diffusion, guidance of the search, market formation, resources mobilization, and support from advocacy coalitions. Both the fulfillment of each system function and the interaction dynamics between them are important. By observing positive and negative interactions, the fulfillment of each function can be determined which respectively support or hinder the functioning of the TIS. This study shows that different functional patterns occur for the PV Innovation Systems. And finally this study will lead to an assessment of the functionality of the Japanese PV system today.

We will compare and contrast the structure and functional dynamics of Japan and Germany. First we will study the structures or the system components. After that we will study the functional dynamics, and what is hindering the diffusion of the technology. After finding the inducement of the technology, we will finally identify the blocking mechanisms. At the end of this study, we will point out the key issues for diffusion.

Chapter 2

Theoretical framework: Technological Innovation System (TIS):

Introduction

Technological innovation is defined as a process that includes the research and development, commercialization, industrial production, marketing, application and diffusion of the technology. Gaining profit from the innovation is emphasized because it marks the success or failure of technological innovation. Sustained growth can occur only with the continuous introduction of truly new goods and services-radical technological innovations that disrupt markets and create new industries. Radical technological change, in turn, is a function of the capacity to turn science based ‘inventions’ into commercially viable ‘innovations’. Understanding the invention to innovation transition is essential in the formulation of both public policies and private business strategies designed to more efficiently convert the research assets into economic assets.

The process by which a technical idea of possible commercial value is converted into one or more commercially successful products –the transition from invention to innovation- is highly complex, poorly documented, and little studied. In order to understand technological change, one needs insight in how the innovation system around a new technology is built up. Thus insight in the dynamics of the innovation system is necessary.

2.1 Structures of Technological Innovation System

The system components of a Technological Innovation System are called structures. These represent the static aspect of the system, as they are relatively stable over time (Carlsson, B. and Stankiewicz, R. 1991; Jacobsson, S., Johnson, A. 2000). Three basic categories are distinguished:

Actors: Actors involve organizations contributing to a technology, as a developer or adopter, or indirectly as a regulator, financer, etc (Bergek, A. et al. 2008). It is the actors of a Technological Innovation System that, through choices and actions, actually generate, diffuse and utilize technologies. The potential variety of relevant actors is enormous, ranging from private actors to public actors and from technology developers to technology adopters. The development of a Technological Innovation System will depend on the interrelations between all these actors. For example, entrepreneurs are unlikely to start investing in their businesses if governments are unwilling to support them financially. Vice versa, governments have no clue where financial support is necessary if entrepreneurs do not provide them with the information and the arguments they need to legitimate policy support.

Institutions: Institutional structures are at the core of the innovation system concept. It is common to consider institutions as 'the rules of the game in a society. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by some authority, and informal institutions being more tacit and organically shaped by the collective interaction of actors. Informal institutions can be normative or cognitive (Jacobsson, S. and Bergek, A. 2004; Bergek, A. et al. 2008). The normative rules are social norms and values with moral significance, whereas cognitive rules can be regarded as collective mind frames, or social paradigms. Examples of formal institutions are government laws and policy decisions; firm directives or contracts also belong to this category.

Technological factors: Technological structures consist of artifacts and the technological infrastructures in which they are integrated. They also involve the techno-economic workings of such artifacts, including costs, safety, and reliability. These features are crucial for understanding the feedback mechanisms between technological change and institutional change. For example, if R&D subsidy schemes supporting technology development should result in improvements with regard to the safety and reliability of applications, this would pave the way for more elaborate support schemes, including practical demonstrations. These may, in turn, benefit technological improvements even more.

The structural factors are merely the elements that make up the system. In an actual system, these factors are all linked to each other. If they form dense configurations they are called networks. An example would be a coalition of firms jointly working on the application of a fuel cell, guided by a set of problem-solving routines and supported by a subsidy program. An analysis of structures typically yields insight into systemic features - complementarities and conflicts - that constitute drivers and barriers for technology diffusion at a certain moment or within a given period in time.

All activities that contribute to the TIS processes are considered system functions and are necessary for TIS build-up. System functions are the key determinants of innovative performance. A functional analysis consists of mapping activities within TIS over time.

2.2 Dynamics of Technological Innovation System

Structures involve elements that are relatively stable over time. Nevertheless, for many technologies, especially newly emerging ones, these structures are not yet (fully) in place. The central idea of this approach is to consider all activities that contribute to the development, diffusion, and use of innovations as system functions. These system functions are to be understood as types of activities that influence the build-up of a Technological Innovation System (Hekkert, M. P. 2007, 2008). Each system function may be 'fulfilled' in a variety of ways. The following are the definition of seven system functions and there are also examples of each system function from Japan and German PV innovation system.

Seven system functions

F1. Entrepreneurial Activities: The classic role of the entrepreneur is to translate knowledge into business opportunities, and eventually innovations. The entrepreneur does this by performing market-oriented experiments that establish change, both to the emerging technology and to the institutions that surround it. The Entrepreneurial Activities involve projects aimed to prove the usefulness of the emerging technology in a practical and/or commercial environment. Such projects typically take the form of experiments and demonstrations. Example of this function; Japan: Many companies, researchers, universities participate in different NEDO projects through PVTEC; (total members in 2001: PVTEC committees (8), companies (29), universities (16) and national research institution (1).

Germany: In 1991, 100,000 roofs program started to drive further expansion of the industry. The program aimed to drive down the price of solar PV and invited private entities to participate.

F2. Knowledge Development: The Knowledge Development function involves learning activities, mostly on the emerging technology, but also on markets, networks, users etc. There are various types of learning activities, the most important categories being learning-by-searching and learning-by-doing. The former concerns R&D activities in basic science, whereas the latter involves learning activities in a practical context, for example in the form of laboratory experiments or adoption trials. Example of this function; Japan: In 1993, the Sunshine Program merged with the "Moonlight Program" and the "R&D Project on Environmental Technology" started.

Germany: The Federal Ministries (BMBF, BMWA) started support program for R&D on PV projects in 2000.

F3. Knowledge Diffusion / Knowledge Exchange: The characteristic organization structure of a Technological Innovation System is that of the network. The primary function of networks is to facilitate the exchange of knowledge between all the actors involved in it. Knowledge Diffusion activities involve partnerships between actors, for example technology developers, but also meetings like workshops and conferences. The innovation system approach stresses that innovation happens only where actors of different backgrounds interact. Quantitative ways of measuring this function is to look at indicators that are related to the creation of new knowledge – patents, R&D projects, published articles etc. Example of this function; Japan: Since 1990, PVTEC holds a joint research presentation meeting in cooperation with NEDO once a year calling researchers in the fields of government, industry and academia. This meeting held to obtain broad information's, member companies, or national institutions take part in PVTEC projects to present their research results and collect and exchange information.

Germany: Every two years BMU invites renowned experts to a photovoltaic strategy meeting in Glottertal to discuss research priorities and draw up guidelines and exchange information.

F4. Guidance of the Search: The Guidance of the Search function refers to activities that shape the needs, requirements and expectations of actors with respect to their (further) support of the emerging technology. Guidance of the Search refers to individual choices related to the technology but it may also take the form of hard institutions, for example policy targets. It also refers to promises and expectations as expressed by various actors in the community. Guidance of the Search can be positive or negative. A positive Guidance of the Search means a convergence of positive signals - expectations, promises, and policy directives - in a particular direction of technology development. If negative, there will be a digression, or, even worse, a rejection of development altogether. Example of this function; Japan: MITI Energy Outlook, 1990; Ambitious targets for PV installation; by the year 2000, 250 MW and by 2010, 4,600 MW.

Germany: In 1994 the German federal government confirmed its objective of cutting CO_2 emissions by 25-30% by 2005.

F5. Market Formation: Emerging technologies cannot be expected to compete with incumbent technologies. In order to stimulate innovation, it is usually necessary to create artificial (niche) markets. The Market Formation function involves activities that contribute to the creation of a demand for the emerging technology, for example by financially supporting the use of the emerging technology, or by taxing the use of competing technologies. Market Formation is especially important in the field of sustainable energy technologies, since, in this case, there usually is a strong normative legitimation for the intervention in market dynamics. Example of this function; Japan: Monitoring program for residential PV systems; Aimed at stimulation of the PV market. 50% of PV installation costs were subsidized between1994 to 1996.

Germany: The main market introduction initiative, the 100,000 Roofs Solar Power Program, providing low interest loans of 1. 91% since 1st January 1999.

F6. Resource Mobilization: Resource Mobilization refers to the allocation of financial, material and human capital. The access to such capital factors is necessary for all other developments. Typical activities involved in this system function are investments and subsidies. They can also involve the deployment of generic infrastructures such as educational systems, large R&D facilities or refueling infrastructures. The Resource Mobilization function represents a basic economic variable. Its importance is obvious: an emerging technology cannot be supported in any way if there are no financial or natural means, or if there are no actors present with the right skills and competences. Example of this function; Japan: 1994 national budgets for photovoltaic were 2030 MJPY for market incentives.

Germany: 100,000 roofs program was implemented in January 1999, with an initial goal of installing 300 MW by 2004. Funded with EUR 560 million (~$500 million), the program provides 10-year low interest loans.

F7. Support from Advocacy Coalitions: The rise of an emerging technology often leads to resistance from actors with interests in the incumbent energy system. In order for a Technological Innovation System to develop, other actors must counteract this inertia. This can be done by urging authorities to reorganize the institutional configuration of the system. The Support from Advocacy Coalitions function involves political lobbies and advice activities on behalf of interest groups. This system function may be regarded as a special form of Guidance of the Search. The concept stresses the idea that structural change within a system is the outcome of competing interest groups, each representing a separate system of values and ideas. The outcome is determined by political power. Example of this function; Japan: Local government initiated in drawing up their PV introduction plan under the vision for Regional New Energy in 1995.

Germany: In 2001, German government decided to phase out nuclear power for expanding electricity generation from renewable sources.

For the innovation system approach to be of use for policy makers, it is preferable to continue the analysis with an assessment of how well the system is functioning, or in other words to assess the functionality of the innovation system (Jacobsson, S. and Bergek, A. 2004). The method chosen in this study is to compare and contrast the functional pattern of the primary system with that of another technological innovation system. The contrasting system should have some similarities, but can be in for instance another geographical area. By a comparison of the functional pattern of the two systems, one may find commonalities and differences, which leads to an assessment of the primary system's performance. This study compares the development and diffusion of PV (photovoltaic) in Japan with the situation of PV in Germany. Both cases were analyzed with the Technological Innovation Systems (TIS) framework, which focuses on a particular technology and includes all those factors that influence its development. The assessment of the functionality will be a guide in finding inducement and blocking mechanisms of the technology, which in turn can lead to suggestions of key policy issues. It is important to remember that the method described in Bergek et al. (2008) is primarily focused on identifying "system failures" or weaknesses, in functional terms, to be of use for policy makers. The assessment can thus be a bit biased towards the negative aspects of the performance of the system. This should not be interpreted as the system being "dysfunctional", but viewed as an analysis of improvement potential.

For successful implementation of a technology, sufficient knowledge and skills must be available to implement, maintain, and if necessary repair the technology. The relevant network of actors should be involved from the beginning. Networks of actors develop and implement new knowledge and technology; the local institutional context should fit with the technology including policy programs, financial incentives, levels of education, etc. The Indicators of functions used in this thesis helps to understand the fulfillment of each system function (Table 1). With the help of the indicators for each system function, we will find out the fulfillment of each system functions of Japanese and German PV innovation system. We will categorize all the events and information's of each function from Japan and Germany, based on the above indicators. Finally we will rank the system functions according to the indicators we have made to measure each system function in the spider diagram.

Table 1. Indicators of functions (Kamp, L.M. 2009)

Functions	**Indicators**
Function 1: **Entrepreneurial Activities** *to translate knowledge into business opportunities and eventually innovations*	• Type of entrepreneur • Change in the number of entrepreneurs • Recent activities • Future (announced) activities
Function 2: **Knowledge Development** *function involves learning activities*	• Type of organization performing research • Type of research activities (basic/applied) • Start of national research project • International recognition • Start of production • Production cost changes • Market size indication • Feedback from market
Function 3: **Knowledge diffusion** *through networks*	• Partnerships between actors • Collaboration between organizations on R&D • Formalized exchange methods
Function 4: **Guidance of the search** *activities that shape the needs, requirements and expectations of actors*	• Targets set by government or industry • Type of targets (research/ market/ installation) • Support for goals • Technological expectations • Expected continuation of development and diffusion
Function 5: **Market formation** *to create artificial (niche) markets*	• Market size • Consumer motivation • Financial market incentives
Function 6: **Resources mobilization** *allocation of resources*	• Availability of venture capital • Availability of (research) employees • Availability of specialized education programs • Availability of raw materials
Function 7: **Advocacy Coalitions**	• Availability of venture capital • Availability of (research) employees • Availability of specialized education programs • Availability of raw materials

Chapter 3

3. Methodology

In a business that aims to create value, the diffusion of a technology may be the key to its success (OECD, 1974). This study will analyze the diffusion process of PV by using the framework of an innovation system that integrates a process with structural theory. The advantage or disadvantage of an innovation system will be objectively evaluated in terms of profit gained and value added. This research will also analyze the diffusion process in PV systems by focusing on the value chain and interaction between technology and markets, and to explore the diffusion factors that contribute to technology, social and energy policy recommendations.

To understand the performance of a technological innovation system, i.e. its strengths and weaknesses, one cannot simply look at its structure. One of the main reasons for this is that two systems with different structures could have the same output, implying that there are many "ideal" ways to organize an innovation system for it to perform well. One must therefore look at the process that goes on within the system itself – the *functional dynamics* of the technological innovation system. Various methods have been proposed to assess the performance of a technological innovation system, such as determining the phase of the technology and thus comparing its functional pattern to an "ideal" system in the same phase.

This study uses the functional dynamics approach of technological innovation systems in order to understand the historical development of PV and determine blocking mechanisms for further PV diffusion. The analysis follows the steps described in Bergek et al. (2008), from mapping the structure of the innovation system to specifying key policy issues. An additional motivation was that, although the development and diffusion of PV in Japan had been studied before, it had as far as we know never been analyzed using the functional dynamics approach specifically.

Looking at PV in Japan is interesting, since it has been one of the leading countries in recent years, in terms of cumulative installed capacity, market size and production. PV research was also initiated at an early stage in Japan, which makes a historical outlook interesting in order to understand the current situation. The spatial boundary was chosen to be a single country, although many companies and other organizations act on a regional or global level, since many of the relevant institutions (energy policies, regulations, laws, etc.) vary at the country level. Today, the German market for PV is the world's largest, after overtaking Japans position in 2004. The two technological innovation systems have developed in a similar time frame, but under different conditions, which made the German case suitable as the reference for an assessment of the performance of the Japanese PV innovation system. An additional reason to use Germany was that the case had previously been studied by Swedish researchers using the same analytical framework, reducing the time needed to investigate it. The Japanese case could thus be investigated more thoroughly to give a deeper and more accurate picture. Qualitative and quantitative data used in the study are collected through a literature study and through interviews. The key actors of the PV innovation system will be identified through a preparatory survey of literature, conference papers, etc.

Technological Innovation System: To acquire insight in how the PV technology is going through these phases a theoretical framework is needed that maps the involved actors, institutions, networks and technological conditions. The Innovation System (IS) framework is able to do this. In 1987 Freeman was the first to describe an IS:

"…The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies " (Freeman, 1987)

For this research however we need to look at only one technology (PV) for which the Technological Innovation System (TIS) was defined by Carlsson and Stanckiewicz (1991). The TIS focuses on all the structural elements (institutions, actors and networks) surrounding a specific technology with all its strengths, weaknesses and dynamics (Jacobssen and Johnson 2000).

Technological Innovation System (TIS) is a process that involves the generation, diffusion and utilization of the technology. TIS can be analyzed in terms of its structural elements (actors, institutions and technological factors) and its dynamics. Structures represent states of the TIS which are subject to change; system functions represent these changes of the structures. All activities that contribute to the TIS process are considered as system functions. Functions are necessary for TIS buildup. System functions are key determinants of innovative performance. A functional analysis consists of mapping activities within the TIS over time. These system functions are to be understood as types of activities that influence the build-up of a Technological Innovation System (Hekkert, M. P. 2007, 2008). Each system function may be 'fulfilled' in a variety of ways.

System Functions: To gain insight in these dynamics the relevant activities within the TIS need to be mapped. In this method activities are analyzed on their influences on the development of the TIS. These influences are categorized in a number of system functions that can be fulfilled within TIS. The Fulfillment of each system function will be analyzed by using the indicator of that function. The events and information's of each system function from Japan and German PV innovation system will be categorized based on the indicators mentioned before.

Allocation to function: The seven system function has been categorized into 5 levels. Each level has its own parameter that will define the level of that function. Considering the events and activities from 1990- 2011, we will determine the rating of each system function of Japan and German PV innovation system in the context of the year 2011. This will give us a rough insight in the overall fulfillments of seven system functions. The rating we get from each system function will measure the strength or weakness of that function.

3.1. Measuring System Functions of PV:

F1: Entrepreneurial Activities:

Indicators:

A. Existence of entrepreneur types and change in their number:

1. Production of cells and modules
2. Material and equipment suppliers
3. Balance-of-system (BOS) component manufacturers
4. Project development, system integration and installation companies
5. Number research and development centers at company, university and institutes)
6. PV industry total workforce

B. Types of activities (what kind of activities took place and to what extent)

1. The realization of PV production/year
2. Milestone of future PV production capacity increase: Rapid increase production capacity based on domestic and international market
3. Project activities, like large solar power plants
4. Expand company activities: like some company transform to fully integrated PV Company; expand company activities from domestic market to international market.

Parameters chosen for measuring the levels are:

Level 1:

1. Production of cells and modules: <5 companies
2. PV industry total workforce: <1000 workforce

Operationalization of Level 1:

In this level few companies are active in the PV sector. PV is very low (1-5MWp/year). In this level, total workforce in PV industry is below <1000 people.

Level 2:

1. Production of cells and modules: 5-15 companies
2. PV industry total workforce: 1000-10,000 people

Operationalization of Level 2:

Even though there are entrepreneurial activities, there is no relatively significant outdoor market in this level. Looking at this level, it becomes clear that the main industrial players involved in PV are still large established firms, and not many new players enter. PV production is low (<100 MWp/year). In this level, the total workforce in PV industry is in the range of 1000-10,000 people. Milestone of future PV production capacity increase based on domestic market.

Level 3:

1. Production of cells and modules: 15-50 companies
2. PV industry total workforce: 10,000-50,000 people

Operationalization of Level 3:

In this level, there is much growth in PV production. PV production becomes increased (100-500 MWp/year). In this level, the total workforce in PV industry is in the range of 10,000-50,000 people. Milestone of future PV production capacity increase based on domestic market. Project activities, like large solar power plants also increase in this level.

Level 4:

1. Production of cells and modules: 50-100 companies
2. PV industry total workforce: 50,000-150,000 people

Operationalization of Level 4:

Productivity of PV firms in general experienced strong growth in this level. Furthermore, there has been a growth in labor places. The PV market at this level is at a much more mature stage than in the previous level, and growing. PV production increase in the range of 500-1000 MWp/year. In this level, the total workforce in PV industry is in the range of 50,000-150,000 people. Milestone of future PV production capacity increase based on domestic market. Project activities, like large solar power plants also increase in this level. Expand company activities is observed: like fully integrated PV company form; expand company activities from domestic market to international market.

Level 5:

1. Production of cells and modules: >100 companies
2. PV industry total workforce: >150,000 people

Operationalization of Level 5:

In this level, PV industry is capable of expanding its activities in order to provide for the growing demand. Expansion of company activities markedly observed in this level: like some company transform to fully integrated PV Company; expand company activities from domestic market to international market. PV production increase >1000 MWp/year. In this level, the total workforce in PV industry will become >150,000 people**.**

Considering the information from 1990-2011, we will rate the level of fulfillment of entrepreneurial activities (F1) for Japanese and German PV innovation systems in the year 2011.

F2: Knowledge Development

Indicators:

Function involves learning activities: learning-by-searching, learning-by-doing and learning-by-using

1. Type of organization performing R&D activities
2. Type of research activities (basic/applied)
2. Development of the number of articles/year on PV technologies
3. Development of R&D budget
4. Development of national research project

5. Development of PV system price changes

6. Comparison of PV electricity price (LCOE) and grid electricity price: >10 times

7. Monitoring program project (Feedback from market)

Parameters chosen for measuring the levels are:

Level 1:

1. Development of the number of articles/year on PV technologies: <50
2. Comparison of PV electricity price (LCOE) and grid electricity price: >10 times

Operationalization of Level 1:

Public R&D spending on PV in this level slowly started to pick up. The funding was almost exclusively restricted to promotion of research, development and for a small part also demonstration. The development of the number of papers on PV in this period is very low. The price is very high and the demand production volume low, economies of scale did not exist and there were no significant cost reductions. In this early period learning by using did only take place on a very limited scale (due to the limited application); mainly financed by government. Results of the demonstration project led to the further expansion of the scope of PV technology. The program eventually resulted in new knowledge on the application of PV technology.

Level 2:

1. Development of the number of articles/year on PV technologies: 50-100
2. Comparison of PV electricity price (LCOE) and grid electricity price: 5-10 times

Operationalization of Level 2:

In this level, research is carried out by universities, industry and research institute. Research funding is increased markedly. Research in this period is done regarding all parts of the production chain through demonstration projects, as well as handheld appliances. In this phase research funding is also allocated for a variety of topics relating to the application of PV technology, such as inverters. In this level, research focus on basic research (new material development), minimizing PV cell cost and increase the cell efficiency.

Level 3:

1. Development of the number of articles/year on PV technologies: 100-300
2. Comparison of PV electricity price (LCOE) and grid electricity price: 2-5 times

Operationalization of Level 3:

In this phase as well, research on PV get high levels of funding. Research programs are focused on lowering the production costs of PV cells, increasing the efficiency, optimization of systems, applications engineering and funding pilot installations. In this level the research picked up, which is indicated by the overall amount of papers that increased. The main goals of monitoring projects are to learn by using and to gain know-how on installation, and to optimize the components of the system.

Level 4:

1. Development of the number of articles/year on PV technologies: 300-600
2. Comparison of PV electricity price (LCOE) and grid electricity price: <2 times

Operationalization of Level 4:

In this level, a steady increase in the number of papers on PV is observed. The cost of modules and systems is slowly reduced. Research mainly focus on elucidation of obstacles that hindered further diffusion of PV: solar cell costs reduction through increasing efficiency and reducing manufacturing costs, using PV to generate network independent and decentralized energy supply, and optimizing the technology. A reduction in price is significant in this level due to increase of market and PV production. In this level, the number of monitoring projects is increase.

Level 5:

1. Development of the number of articles/year on PV technologies**:** >600
2. Comparison of PV electricity price (LCOE) and grid electricity price: ≤1 (almost same)

Operationalization of Level 5:

Like level 4, a steady increase in the number of papers on PV is observed. The cost of modules and systems is slowly reduced. Research mainly focus on elucidation of obstacles that hinder further diffusion of PV; solar cell costs reduction through increasing efficiency and reducing manufacturing costs, using PV to generate network independent and decentralized energy supply, and optimizing the technology. Grid parity is achieved in this level and the number of monitoring projects increase.

Considering the information from 1990-2011, we will rate the level of fulfillment of knowledge development (F2) for Japanese and German PV innovation systems in the year 2011.

F3: Knowledge Diffusion

Indicators:

Function involves knowledge diffusion through networks

1. Partnerships between actors
2. Collaboration between organizations on R&D
3. Formalized exchange methods
4. Workshop, Conferences
5. Development of national/international collaborative research projects
6. Development of the number of collaborative research articles/year
7. Development of PV cluster

Parameters chosen for measuring the levels are:

Level 1:

1. Total public R&D and collaborative projects budget: <10MUS$
2. Development of the number of conference articles/year: <50

Operationalization of Level 1:

In this level, knowledge diffusion is initiated through the cooperation of industry with research institutes. An important aspect of the cooperation is the transfer of the research from the laboratory to an industrially exploitable production process. A collaborative research projects usually involved many research institutes and industrial partners. It is therefore likely that this cooperation starts in order to combine expertise on different issues in PV and bring out a joint paper for comparison. International cooperation furthermore took place between universities or institutes mainly on basic research.

Level 2:

1. Total public R&D and demonstrative projects budget: 10-50MUS$
2. Development of the number of conference articles/year: 50-100

Operationalization of Level 2:

1. Partnerships between actors
2. Collaboration between organizations on R&D

3. Workshop, Conferences

Level 3:

1. Total public R&D and collaborative projects budget: 50-250MUS$
2. Development of the number of conference articles/year: 100-200

Operationalization of Level 3:

1. Partnerships between actors
2. Collaboration between organizations on R&D
3. Workshop, Conferences

Level 4:

1. Total public R&D and collaborative projects budget: 250-500MUS$
2. Development of the number of conference articles/year: 200-400

Operationalization of Level 4:

1. Partnerships between actors
2. Collaboration between organizations on R&D
3. Formalized exchange methods
4. Workshop, Conferences
5. Development of PV cluster

Level 5:

1. Total public R&D and collaborative projects budget: >500MUS$
2. Development of the number of conference articles/year: >400

Operationalization of Level 5:

1. Partnerships between actors
2. Collaboration between organizations on R&D
3. Formalized exchange methods
4. Workshop, Conferences
5. Development of PV cluster

Considering the information from 1990-2011, we will rate the level of fulfillment of knowledge diffusion (F3) for Japanese and German PV innovation systems in the year 2011:

F4: Guidance of the search

Indicators:

Function involves activities that shape the needs, requirements and expectations of actors with respect to their further support of the emerging technology.

Expectations for the market growth (next 10 years) considering following activities: MW

1. Environment policy target/goal: % CO_2 reduction
2. Renewable energy target/goal: % electricity supply
3. PV energy target/goal: % electricity supply
4. PV market target/goal
5. Decrease of nuclear electricity dependence
6. Support for goals

Considering the above future targets how much the market is expected to grow for the next 10 years will determine the level of the function.

Parameter chosen for measuring the levels is:

Level 1:

Expectations for the market growth (next 10 years) considering following activities: <100 MW

Operationalization of Level 1:

When PV energy target or goal, renewable energy target or goal and environment policy target for the next ten years will make the expected market to grow less than 100 MW, at that time F4 will be in level 1.

Level 2:

Expectations for the market growth (next 10 years) considering following activities: 100-1000 MW

Operationalization of Level 2:

If PV energy target or goal, renewable energy target or goal and environment policy target for the next ten years will make the expected market to grow about 100-1000 MW, at that time F4 will be in level 2.

Level 3:

Expectations for the market growth (next 10 years) considering following activities: 1-20 GW

Operationalization of Level 3:

If PV energy target or goal, renewable energy target or goal and environment policy target for the next ten years will make the expected market to grow about 1-20 GW, at that time F4 will be in level 3.

Level 4:

Expectations for the market growth (next 10 years) considering following activities: 20-60 GW

Operationalization of Level 4:

When PV energy target or goal, renewable energy target or goal and environment policy target for the next ten years will make the expected market to grow about 20-60 GW, at that time F4 will be in level 4.

Level 5:

Expectations for the market growth (next 10 years) considering following activities**:** >60 GW

Operationalization of Level 5:

When PV energy target or goal, renewable energy target or goal and environment policy target for the next ten years will make the expected market to grow about >60 GW, at that time F4 will be in level 5.

Considering the information from 1990-2011, we will rate the level of fulfillment of guidance of the search (F4) for Japanese and German PV innovation systems in the year 2011.

F5: Market formation

Indicators:

In order to stimulate innovation, it is usually necessary to create artificial (niche) markets. The Market Formation function involves activities that contribute to the creation of a demand for the emerging technology, for example by financially supporting the use of the emerging technology, or by taxing the use of competing technologies.

Market size developments (annual installation capacity) considering following activities:

1. Financial market incentive (govt. support program)

2. Consumer motivation due to favorable tax regimes and environmental or moral principles

3. Providing low interest loans

4. Buy-back system

5. Feed-in-tariff (FIT) / Renewable portfolio standard (RPS)

Parameters chosen for measuring the levels are:

Level 1:

Market size developments (annual installation capacity) considering following activities: < 10 MW/year

1. Financial market incentive (govt. support program)
2. Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS)

Operationalization of Level 1:

The cost of producing solar cells in this level is very high and efficiencies are low, as a result of which solar cells are only attractive in particular niches or applications that are isolated such as a wrist watch. Demonstration program for the application of PV in decentralized applications enlarged the scope of the PV market. An important aspect of market formation in this period is the initiative of government incentive/subsidy program. The program focused on private households and their power generation. Although the program comes down to large scale testing, it is considered by many as the first stages of the market launch. The government incentive/subsidy program in this level created a small market space for PV manufacturers. During the program, supplementary programs from the states are initiated. The duration of these programs is limited and thus their influence has only been supportive rather than having a key impact on the diffusion.

Level 2:

Market size developments (annual installation capacity) considering following activities: 10-100 MW/year

1. Financial market incentive (govt. support program)
2. Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS)

Operationalization of Level 2:

The funding took place in this level is that, government pays some percent of the investment costs in the PV systems that are between 1 and 5 kW in capacity. The utilities are subsequently legally obliged to purchase the electricity fed into the grid at a certain rate /kWh. It is also possible to involve these private home owners through the environmental friendly “green” image that they would acquire through putting a PV system on a clearly visible place on their roofs. Feed-in payments initiated by the government, although these are much too low due to the high costs involved at this level. Thus the impact of the act is small, but nonetheless it has a positive influence on the developments: It created an important condition, as now the PV systems had a guaranteed connection to the grid, which is an important contextual condition for the further development of the technology, and it communicated a positive signal towards the PV sector. The growth in this level is low and in the range of 10-100 MW/year. The costs are still high. In this level, the market goes through a phase of weak and fluctuating growth. The government or utility do not provide compensation that cover all the costs of PV. Although the aim is to learn with regards to installation, integration and operation of the network, this initiative amongst others contributed to the limited growth in this level. The demand in this level can be explained through the pioneering attitude of the initial users of PV that do not have profit as their main concern. Instead, they invest in PV due to environmental or moral principles, but the prospect of coming policies and programs will give them an extra boost to put this into action.

Level 3:

Market size developments (annual installation capacity) considering following activities: 100-1000 MW/year

1. Financial market incentive (govt. support program)
2. Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS)

Operationalization of Level 3:

In this level, the market develops independently and shows more growth. The aim of the government program is to support the shift of PV to the stage of mass production. In this level policy initiatives are to be introduced that cause a take-off of the market. A long term government support program come into effect in this level. These support programs will provide investment grants to PV industry and low-interest loans for those that installed PV systems. This program will give a considerable impulse to the market introduction of PV. PV market growth in this level is high and in the range of 100-1000 MW/year.

Level 4:

Market size developments (annual installation capacity) considering following activities: 1-5 GW/year

1. Financial market incentive (govt. support program)
2. Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS)

Operationalization of Level 4:

In this level vital policy measures are taken at a federal level, which signified the end of the uncertainty in the previous level and led to a considerable positive boost in the development of PV. The support program for PV in this level is thus not directly compensating the initial investment, but rather the electricity generated by the investment. In this level, the support program made the generation of electricity through PV economically feasible. A sign of the new economic feasibility can be seen in the increase of installed capacity. Obviously, PV technology is still very much dependent upon financial support. The growth in this level is high and in the range of 1-5 GW/year. The price gap between grid electricity and PV electricity continuously decrease.

Level 5:

Market size developments (annual installation capacity) considering following activities: >5 GW/year

1. Financial market incentive (govt. support program)
2. Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS);

Operationalization of Level 5:

In this level, all kind of restriction on the market volume increase is removed which led to greater investment security. An essential feature that can be seen in this level of government policy is its consistency. So that PV will remain a viable economic option for investors. The growth in this level is high and become >5 GW/year. PV system price continuously decrease due to rapid growth of PV market and finally PV will achieve grid parity.

Considering the information from 1990- 2011, we will rate the level of fulfillment of market formation (F5) for Japanese and German PV innovation systems in the year 2011.

F6: Resources mobilization

Indicators:

Resource Mobilization refers to the allocation of financial, material and human capital.

1. Availability of venture capital
2. Availability of (research) employees
3. Availability of specialized education programs
4. Availability of raw materials
5. Subsidies (deployment support),
6. Investments support for manufacturing plants
7. Funding for R&D

Parameters chosen for measuring the levels are:

Level 1:

1. Public investment (R&D, subsidy and FIT): (<US$100 million)
2. Availability of (research) employees: <1000 people

Operationalization of Level 1:

In this level, the entrepreneurial activities are still risky from an economic perspective, as there is only a small market and prospective growth is only just emerging. None of them is specialized in PV, but rather PV is a small part of their business. Such companies are subsequently able to take the risk of engaging in this developing market; they have their own capital. With regard to research employees, it appears that these are available through the related industries which are established already in many countries. This level is characterized by a small niche market which only existing firms could afford to engage in as part of their business. Since the PV market is still at an infancy stage, no education programs existed with a focus on PV. In this level, PV is not a completely new stand-alone technology, but rather strongly related to existing technologies, for example semiconductor technology. Thus in this early period the existing knowledge complemented by research is sufficient to start development of PV applications. In this level, the market is small size that raw materials are sufficiently available.

Level 2:

1. Public investment (R&D, subsidy and manufacturing plants): (US$100-500 million)
2. Availability of (professional) employees: 1000-5000 people

Operationalization of Level 2:

In this level, R&D on PV technologies is mainly conducted by large established firms that get funding from the government for their research. It thus seemed that there is sufficient funding to conduct research on PV. With regard to physical resources, at this early time the demand from the PV sector for raw materials is still relatively small and there were no indications found of any material constraints.

Level 3:

1. Public investment (R&D, subsidy and manufacturing plants): (~US$500-1000 million)
2. Availability of (professional) employees: 5,000-10,000 people

Operationalization of Level 3:

Resources in this level are mobilized mainly from government subsidy. In this level there appeared to be a shortage of raw materials supply, due to the increasing demand, which led to rising prices difficulties for cell manufacturers. Although the growth in this level is limited, there is a boom of startups at the end of this level, triggered by the prospects offered by the coming strong incentive program. However, in order for this boom to happen, a new phase of corporate financing emerged in this level.

Level 4:

1. Public investment (R&D, subsidy and manufacturing plants): (US$1- 10 billion)
2. Availability of (professional) employees: 10,000-30,000 people

Operationalization of Level 4:

In this level, high demand for PV is generated by government incentive/subsidy program. A large number of specialized employees are required for the rapid diffusion of PV. Many university degree courses focus on PV technologies. High demand and a shortage of raw material caused the prices of modules to rise. It will have an extra motivation for research into different technologies. In this level, deployment support seems to be high relatively to the investment support for manufacturing plants and R&D support. Investment from PV industry also increases in the construction, expansion and modernization of solar production factories.

Level 5:

1 Public investment (R&D, subsidy and manufacturing plants): (>US$5billion)

2. Availability of (professional) employees: >30,000 people

Operationalization of Level 5:

Resources in this level are mobilized through national/local government incentive/subsidy program, investments from financing organization and PV industries. In this level, high demand for PV is generated by generous government incentive/subsidy program. With regard to human resources, a large number of specialized employees are required for the rapid diffusion of PV. Specialized employees are partially available from the semiconductor industry, an industry that is highly related. Many specialized training facilities are open inside PV cluster to fulfill the rapid growth of specialized employees demand. Many university degree courses focus on PV technologies. Close cooperation between the electronics and semiconductor industry and the PV industry lead to an employable workforce. In this level, deployment support seems to be high relatively to the investment support for manufacturing plants and R&D support. Investment from PV industry rapidly increases in this level.

Considering the information from 1990-2011, we will rate the level of fulfillment of resource mobilization (F6) for Japanese and German PV innovation systems in the year 2011.

F7: Advocacy Coalitions

Indicators:

Advocacy coalitions involve political lobbies and advice activities on behalf of PV technology.

1. Existence of advocacy coalitions
2. Activities of coalitions
3. Recent results of activities

Level 1: Formation of activist group /interest group(s) to represent RE/PV for lobbying activities

Operationalization of Level 1:

In this level a variety of actors entered the scene and these actors later become key players in advocating PV. The actors are scientists, companies, associations and citizens from different occupational sectors. Interest group for PV is formed. Such associations represent the most important force in lobbying. This groups' objective is to diffuse information to politicians and industry. A presidium undertakes most of the discussions with policy makers and this group is present on the advisory groups on energy within the different political parties.

Level 2: Create positive impression on PV; create a public climate interest within society that would enable to tear down the walls in people's minds and founding non-profit organization/association which lobbies within the political structure, but is not affiliated to any political parties or interest group.

Operationalization of Level 2:

This association/ group's activities made important contributions to the diffusion of PV and create PV friendly institutional structures in future. Political parties become more and more interested in PV. Furthermore, the organizations (group/actors) help shape measures at national and local level and played a major role in conveying the potential of photovoltaic. As the network companies have regional monopolies it becomes a question of legitimacy to convince the Political parties to gain attention. In the public sphere, renewables will. In this level, public and political support for PV grows. To replace nuclear and fossil energy entirely with renewable based energies, the activist group does so by developing political and economic concepts for the implementation of renewable energies, which in turn will have a major impact on the diffusion of PV.

Level 3: The interest groups form networks within society and political parties. Through lobbying activities influence the government to make strong policies in favor of PV which will have major impact on PV diffusion.

Operationalization of Level 3:

In this level, PV technology finds advocates at a number of levels. They gradually branch off in different directions within society and political parties and form networks. The ground-breaking work of associations and societies provided a particularly firm basis for the development of PV. Furthermore, advocacy coalitions lay a basis for what would later on prove to be essential policy instruments, important steps will be taken that would facilitate large scale diffusion later on of PV. Take-off of PV took place through implementation of a long-run incentive program. In this level, resolutions for the parliament to prioritize solar energy in research and development policy are submit. To manage the strong forces from the antagonizing advocates (nuclear and fossil fuel), it is necessary to find and strengthen some sort of counterforce. The TIS (PV) specific advocacy coalition is a central part of this counterforce and a policy option is to strengthen it.

Level 4: Creating consensus among the politicians, induce large, and influential, actors that can bring momentum to the legitimation process. This alliance will stress the needs for the expansion of the PV market (new act).

Operationalization of Level 4:

In this level, advocacy coalitions' most important activities is political consulting, which basically implies systematically lobbying for investment security and suitable market incentive programs. In this level, renewable energies enjoyed broad support from public and government, which is necessary as the public have to invest in these systems (FIT) for a significant part, while policy makers have to support financial market incentives. PV technology is still dependent upon financial support, which is partly granted by the government financial institutes in the form of low interest loans. Activities of advocacy coalitions are vital in this regard. In this level, a cross-parliamentary group alliance is made in collaboration with members from parliament and different interest groups. PV supporters have strong influence, and the important role played by advocacy coalitions during government energy budget. The advocacy coalitions will engage in removing institutional obstacles and lobbying for financial incentives.

Level 5: Creation of PV based advocacy coalition which is strong enough to fight against the antagonizing advocates (nuclear), and the incumbent technology. This advocacy coalition will be supported by a whole set of institutions, for instance in the form of legislation favoring the incumbent technology.

Operationalization of Level 5:

In this level, the advocacy coalitions will have broad support from public and government, which is essential in securing a consistent policy of financial incentives for PV technology. With the further spread of technology the advocacy coalitions will increasingly have to busy themselves with dealing with practical obstacles like creating or securing space for PV applications. In this level government law, environment policy and renewable energy policy support PV technology directly. This clearly indicates the strength of the advocacy coalition and creates PV friendly institutional structures. In this level the activities are also on an international level, as the member of the advocacy coalition group are also involved in international organization that represents PV industry. Even the government, the opposition will support the energy transition and the phase out for nuclear power. Therefore initiate or change laws in order to promote PV and ensure a reliable energy supply.

Considering the information from 1990-2011, we will rate the level of fulfillment of advocacy coalitions (F7) for Japanese and German PV innovation systems in the year 2011.

3.2. Functioning of the innovation system of PV

In this section, the data will be analyzed, based on the indicators and the parameters given for each levels of that function. The 5 levels of the spider diagram have its own parameters that will define the level of that function. The rate (level) of each system function will help us to draw the spider diagram (Figure 2). This diagram shows the relative fulfillments of the system functions and which function might need extra attention. TIS will be assessed for both Japan and Germany through the evaluation of the seven system function. All events and activities, from 1990-2011, of the system functions will be summarized. The system functions will be rated considering the activities of the year 2011. The function fulfillment of seven system functions of Japan and Germany will be ranked and compared in spider diagrams.

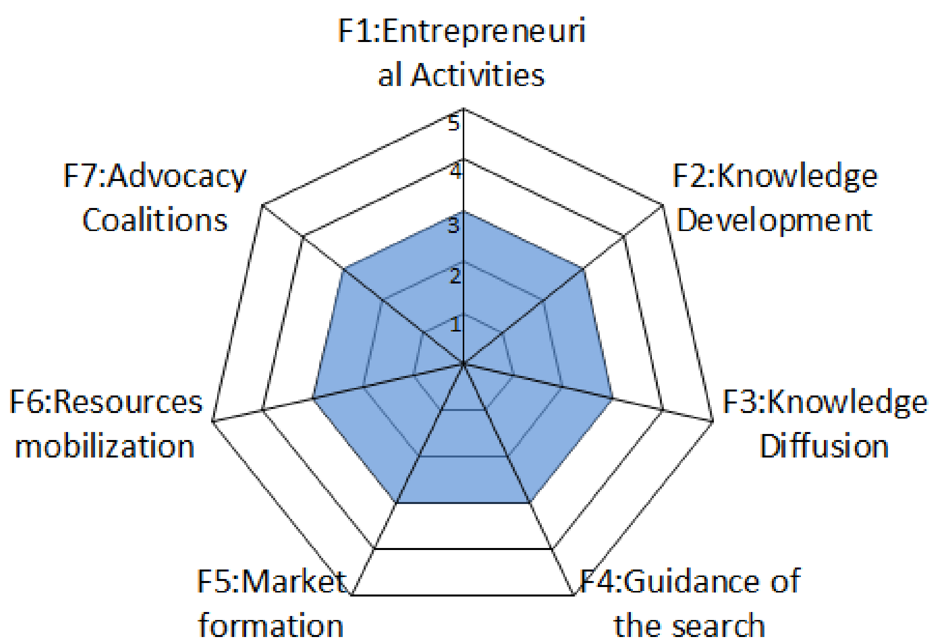

Figure 2. Functioning of the innovation system functions of PV

The above spider diagram shows the level of fulfillment of the seven system functions. Figure 2 shows an example of spider diagram where each system function has been rated 3. The events linked to the system functions and its scores are transformed into a narrative which tells how the TIS developed over time. In the end, blocking and inducement mechanisms for the functional dynamics of the Japanese PV innovation system will be summarized (Jelse, K., Johnson, H, 2008, Blommerde, J. 2011).

We will compare and contrast functional dynamics of Japan and Germany. First we will study the structures or the system components. After that we will study the functional dynamics, we will rate each system function and draw the spider diagram. We will draw the diffusion curve of innovation and point out the position of Japan and Germany. We will find out what is hindering the diffusion of the technology. After finding the inducement of the technology, we will finally identify the blocking mechanisms. At the end of this study we will point out the key issues for diffusion. In conclusion I'll try to give some suggestions for the issues.

Chapter 4

4. Background of the study

4.1. Energy sector of Japan

Japan has virtually no domestic oil or natural gas reserves and is the second-largest net importer of crude oil and largest net importer of liquefied natural gas in the world (Japan Energy Data, 2011). Including nuclear power, Japan is still only 16% energy self-sufficient. Japan has a strong energy research and development program that is supported by the government. Among the large developed world economies, Japan has one of the lowest energy intensities, as high levels of investment in research and development of energy technology since the 1970s substantially increased energy efficiency in the country. The industrial sector in particular has become much more efficient. Japan had 282 GW of total installed electricity generating capacity in 2010, the third largest in the world behind the United States and China. Since experiencing the two oil crises of the 1970s, Japan began increasing energy supply from gas, coal and nuclear, as well as increasing energy efficiency and investing in "new energy" development, such as solar, wind and geothermal energy. Although the low oil prices in the 1980's decreased the level of public attention on energy development and conservation, emergence of the climate change issue required the government to work even more on developing clean and efficient energy technologies. As a result, its dependence on petroleum declined from 77.4 % in fiscal 1973 to 43.7 % in fiscal 2010. In fiscal 2010, the total primary energy supply in Japan was 23,123 petajoules. Its breakdown was: 43.7 % in petroleum, 21.6 % in coal, 17.3 % in natural gas, 10.8 % in nuclear power, and 3.1 % in hydro power (Figure 3) (Statistics Bureau, 2012; EIA, 2012; Duffield, J.S., Brian Woodall, B., 2011). Other sources were also used, though only in small quantities, including energy from waste, geothermal, and natural energy (solar energy, wind power, biomass energy, etc.). Japan is the third largest consumer of nuclear power in the world, after the United States and France. Renewable energy accounts for a relatively small percentage of total energy consumption in the country. Electricity output in Japan totaled 1,157 billion kWh in fiscal 2010. Of this total, thermal power accounted for 66.7 %; nuclear power, 24.9 %; hydro power, 7.8 %; and other sources, 0.6 % (Statistics Bureau, 2012) (Figure 3). The EIA forecasts that Japan will consume 1,151 TWh of electricity by 2030.

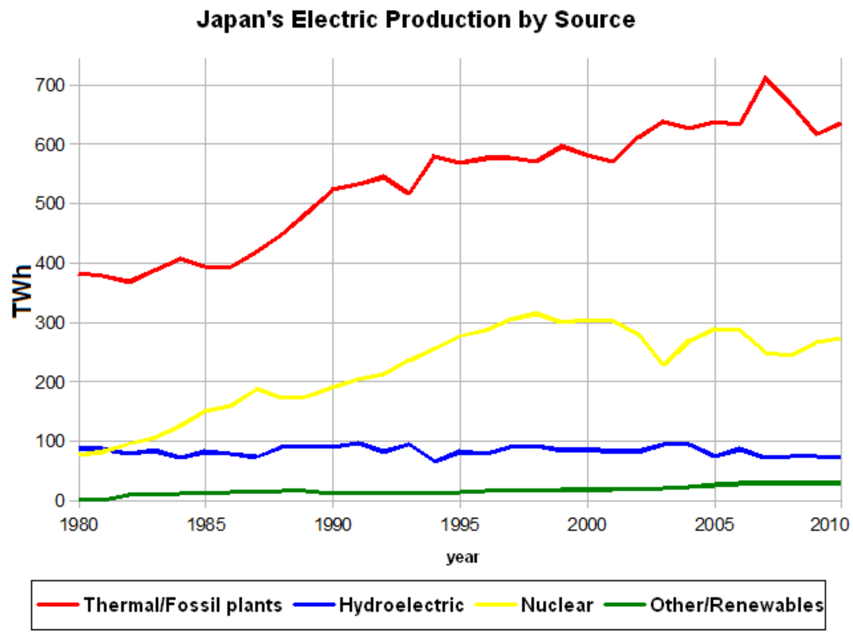

Figure 3. Japan electricity generation, from 1980-2010
(Source: Wikipedia 2013, <http://en.wikipedia.org/wiki/Energy_in_Japan> (Accessed on June 13, 2013))

4.2. Energy sector of Germany

In the 1970s, Germans were faced with soaring energy prices. Successive oil crises had sent price shocks throughout Europe, while heightening energy security concerns. In the next two decades, increasing pollution and the Chernobyl nuclear disaster made the environment a central concern for the German public. Germany's demand for energy is met by imports of up to 74%. In the European Union, the share of imports will rise from 50% at the end of the 1990s to 70% in 2020. This perilous dependence can only be solved in the long term by renewable, supply of which is virtually limitless and the costs of which are continually falling. Germany has focused on the development of renewable energy sources so as to decrease fossil fuel consumption and the dependence on fossil fuel imports (Jacobsson, S., Lauber, V., 2006). In fiscal 2010, the total primary energy supply in Germany was 21,752 petajoules, its breakdown was: 36% in oil, 24% in coal, 23% in natural gas, 10% in nuclear power, 1.0% in hydro power and 6 % in renewable power (GEGS, 2011). Germany has defined a planned policy of phasing-out nuclear power by 2022. Comparing 2010 to 2000, nuclear power production share has declined from 29.6% to 23% of total power production, partly being substituted with a rise in renewable electricity: wind power, biomass and solar power. The electricity sector in Germany in the year 2010: fossil fuel power produced 60%, nuclear power produced 23% and renewable energy 17% (including wind + solar + hydro). Germany is the world's first major renewable energy economy (GEGS, 2011; GEA, 2007; GEA, 2007a). In fiscal 2011, the gross electric power generation in Germany was 615 TWh: lignite (24.9%), hard coal (18.6%), natural gas (13.7%), nuclear energy (17.6%) and renewables (wind, water, biomass, photovoltaic) 20.1% (Figure 4).

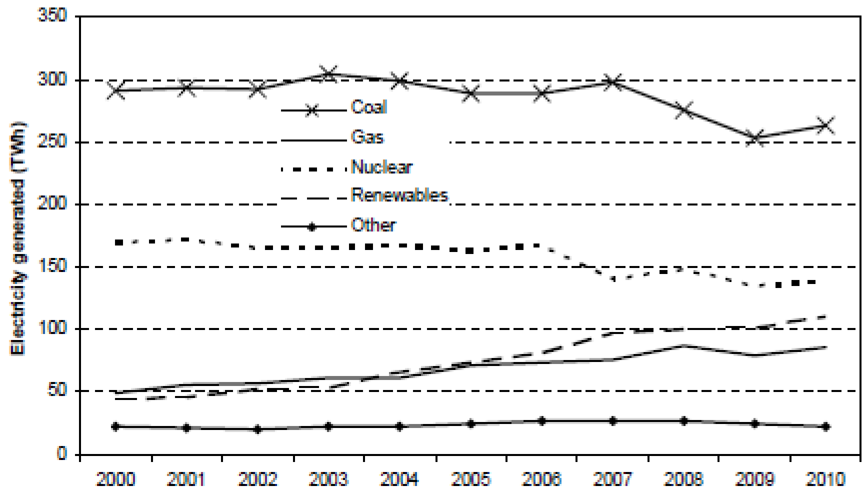

Figure 4. Germany's electricity generation by source, 2000-2010 (Source: Germany's Electricity Generation Sector (GEGS), 2011, page 3; <http://www.pc.gov.au/__data/assets/pdf_file/0006/109923/15-carbon-prices-appendixf.pdf> (Accessed on June 13, 2013))

4.3. History of PV

In 1956, solar photovoltaic (PV) cells were far from economically practical. Electricity from solar cells ran about $300 per watt. The "Space Race" of the 1950s and 60s gave modest opportunity for progress in solar, as satellites and crafts used solar paneling for electricity.

It was not until 1973 that solar leapt to prominence in energy research. The Arab oil embargo demonstrated the degree to which the Western economy depended upon a cheap and reliable flow of oil. As oil prices nearly doubled over night, leaders became desperate to find a means of reducing this dependence. In addition to increasing automobile fuel economy standards and diversifying energy sources, government invested heavily in the PV business. The hope in the 1970s was that, through massive investment in subsidies and researches, PV costs could drop precipitously and eventually become competitive with fossil fuels. By the 1990s, the reality was that costs of solar energy had dropped as predicted, but costs of fossil fuels had also dropped—solar was competing with a falling baseline. However, huge PV market growth in Japan and Germany from the 1990s to the present has reenergized the PV industry. In 2002 Japan installed 25,000 solar rooftops. Such large PV orders had created economies of scale, thus steadily lowering costs. The PV market is currently growing at a blistering 30 percent per year, with the promise of continually decreasing costs.

4.4. Photovoltaic power generation and different PV technologies

The photovoltaic (PV) cell is a technology that converts incoming solar radiation to an electric current. The first photovoltaic module was built by Bell Laboratories in 1954. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current - that is, electricity.

A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module (Figure 5). Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module. Multiple modules can be wired together to form an array. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination. Several solar modules, together with some additional components, such as inverters, form a PV system. In the case of off-grid applications, an energy storage system, such as a battery, is often included. When the PV modules are exposed to sunlight, they generate direct current ("DC") electricity. An inverter then converts the DC into alternating current ("AC") electricity, so that it can feed into one of the building's AC distribution boards ("ACDB") without affecting the quality of power supply. A PV system can either connect to the electricity grid or used in as off-grid in places where it is not practically or economically possible to build connections to existing power lines (Figure 6).

Solar cells are classified into three generations which indicates the order of which each became important. At present there is concurrent research into all three generations while the first generation technologies are most highly represented in commercial production. Solar cells can be made out of many different materials and through different production technologies, which produce cells with different characteristics. The “family tree” in Figure 7 gives an overview of these technologies available today. About 90% of today’s production consists of wafer-based silicon cells (c-Si) (first generation), which can be divided into mono-crystalline (Mono c-Si) and polycrystalline (or Multicrystalline) (multi c-Si) silicon cells, their efficiency ranges between 12% and 17% (Table 2).

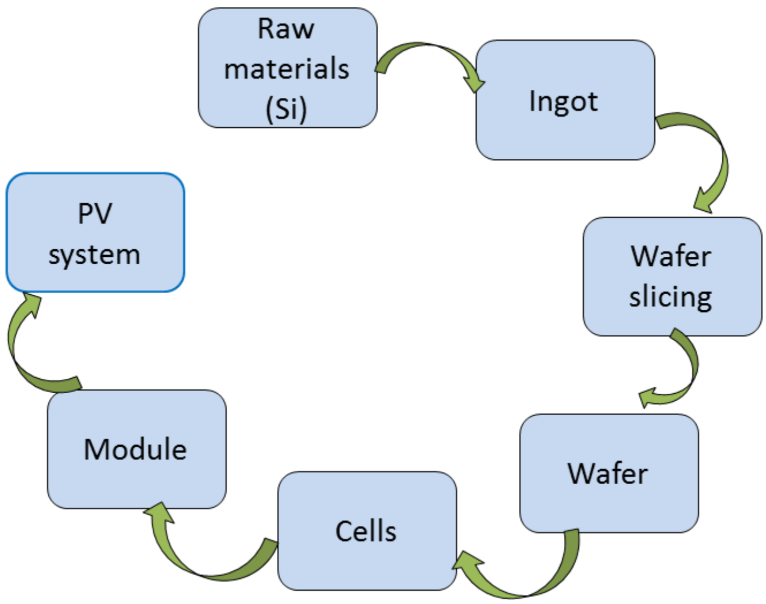

Figure 5. Different steps of production of a photovoltaic system (crystalline-based PV)

Table 2. Conversion efficiencies of various PV module technologies

Technology	**Module Efficiency**
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%
Amorphous Silicon (a-Si)	5-7%

Other solar cell technologies that are either being researched or commercialized include silicon based thin film, compound based (second generation) cell like GaA, CdS, CdTe, and CuInGaSe, and new material based (third generation) cell like dye-sensitized, thin-film polymer, and quantum dot solar cell.

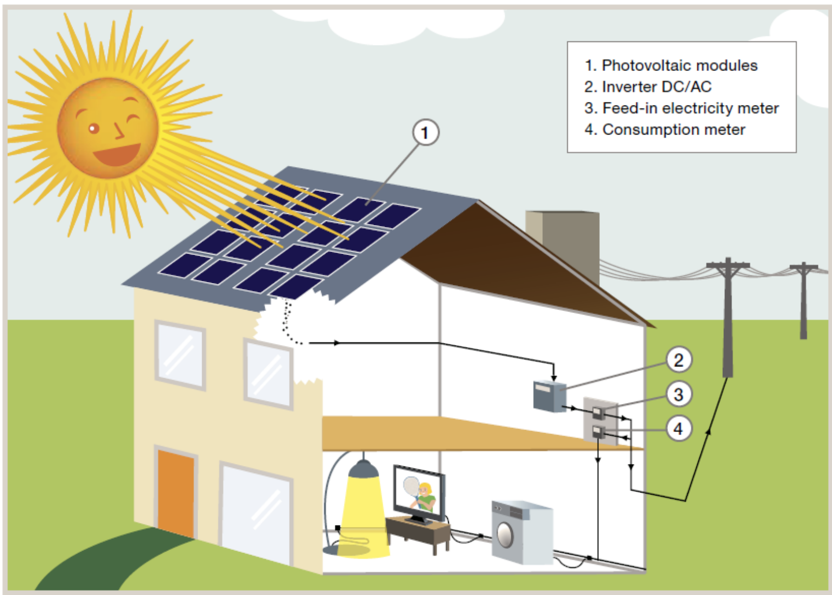

Figure 6. Grid-connected domestic solar PV system configuration
(Source: "Photovoltaic Energy - Electricity from the Sun"; European Photovoltaic Industry Association (EPIA) report; page-7; <http://www.epia.org/about-us/about-photovoltaics/solar-photovoltaic-technology/> (Accessed on June 13, 2013))

Thin film modules, which is newer and growing in popularity, are constructed by depositing extremely thin layers of photosensitive materials onto a low-cost backing such as glass, stainless steel or plastic. Thin film manufacturing processes result in lower production costs compared to the more material intensive crystalline technology, a price advantage which is currently counterbalanced by substantially lower efficiency rates (from 5% to 13%). Thin-film technologies reduce the amount of material required in creating the active material of solar cell. Thin-film solar technologies have enjoyed large investment due to the success of First Solar and the largely unfulfilled promise of lower cost and flexibility compared to wafer silicon cells, but they have not become mainstream solar products due to their lower efficiency and corresponding larger area consumption per watt production. Cadmium telluride (CdTe), copper indium gallium selenide (CIGS) and amorphous silicon (a-Si) are three thin-film technologies often used as outdoor photovoltaic solar power production. CdTe technology costs about 30% less than CIGS technology and 40% less than a-Si technology in 2011.

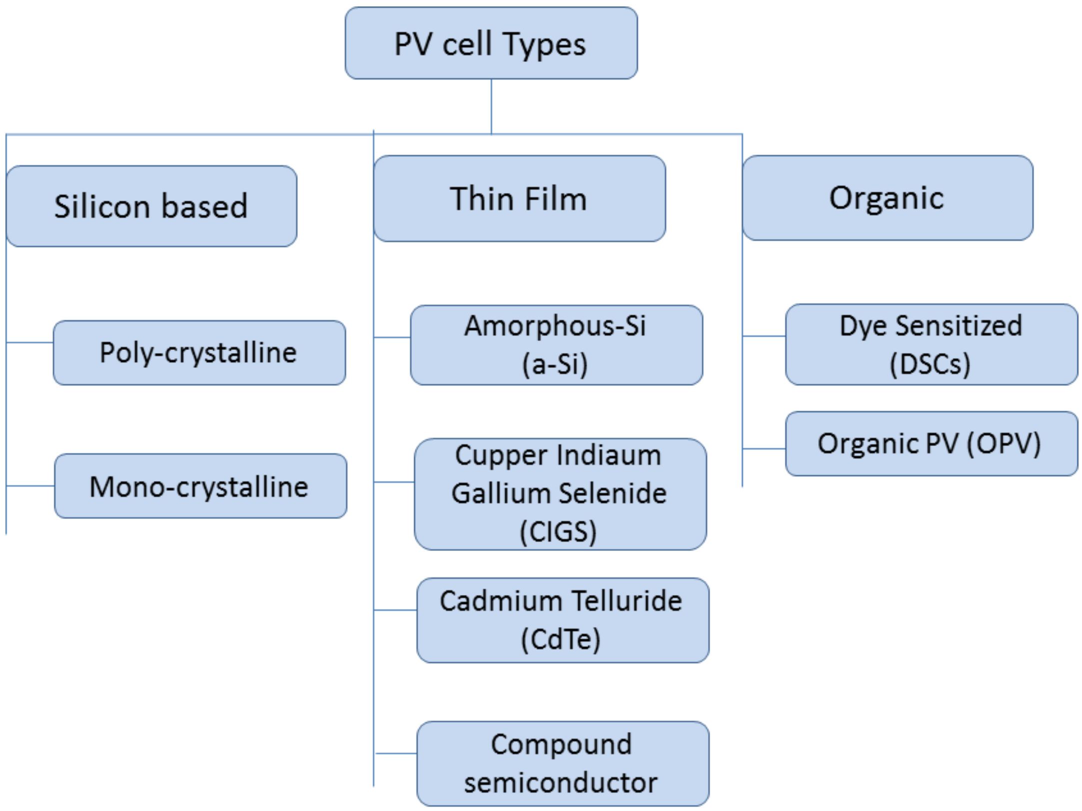

Figure 7. PV technology family tree

Dye-sensitized solar cells (DSSCs) are made of low-cost materials and do not need elaborate equipment to manufacture, possibly allowing players to produce more of this type of solar cell than others. In bulk it should be significantly less expensive than older solid-state cell designs. DSSC's can be engineered into flexible sheets, and although its conversion efficiency is less than the best thin film cells.

Organic solar cells and polymer solar cells are built from thin films (typically 100 nm) of organic semiconductors including polymers, such as polyphenylene vinylene and small-molecule compounds like fullerenes and fullerene derivatives. Energy conversion efficiencies achieved to date using conductive polymers are low compared to inorganic materials. These cells could be beneficial for some applications where mechanical flexibility and disposability are important.

In 2010 the market share of thin film declined by 30% as thin film technology was displaced by more efficient crystalline silicon solar panels (the light and dark blue bars). In 2007, CdTe production represented 4.7% of total market share, thin-film silicon 5.2% and CIGS 0.5% (Figure 8).

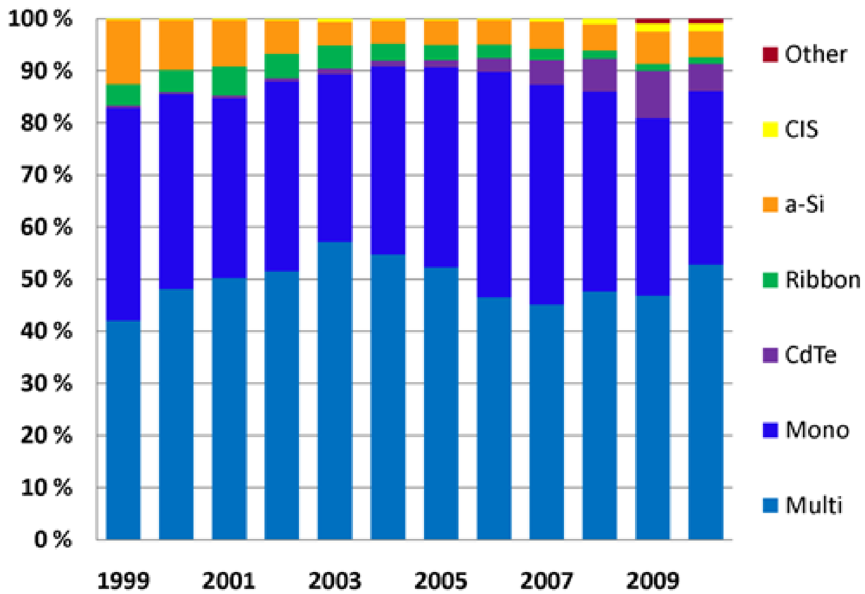

Figure 8. Market share of the different PV technologies, 1999-2009 (Source: Wikimedia < http://en.wikipedia.org/wiki/File:PV_Technology.png>, (Accessed on June 2011))

Categories of companies involved in the production and installation of PV system

1. Raw material suppliers
2. Solar cell manufactures
3. Solar module manufacturers
4. Manufacturers of additional components
5. Installers and housing companies

Raw material suppliers: since most solar cells are made out of crystalline silicon wafers, this category consists mainly of silicon raw material miners and company's refining and purifying the material into solar-grade silicon. The output product from this step is usually in the form of silicon ingots or wafers. For other types of solar cells, this category would instead consist of suppliers of gallium, cadmium, etc.

Cell manufacturers are the companies involved in making solar cells from the raw materials. In some places, it is common that the solar cell manufacturer also handles the module assembly step.

Module manufacturers take solar cells, connect them and encapsulate them in weather-protecting material. This produces a solar module, which is ready to be used as a part of a PV system.

Other solar system component manufacturers supply the electrical components and mounting structure that are needed to use the solar module as a part of an electricity-generating system. If the system is connected to the electricity grid, one important component is the inverter, which is used to transform the direct current from the solar cell into alternating current. For off-grid applications, a supplier of storage batteries might also be included in this category.

Installers and construction companies' takes care of the installation and maintenance of a PV system according to the rules and regulations in the country in question. This ranges from architects and engineering firms that design skyscrapers to electricians installing a single PV system on a private home.

Chapter 5

PV diffusion in Japan and Germany

PV development in Japan was started just after the Bell Institute invented silicon solar cells in 1953. In response to the first Oil Crisis, the government launched the *Sunshine Program*, a national R&D program aiming at providing substantial amount of new non-fossil fuel energy by 2000. This ambitious program formed the backbone of both public and private activities to develop new energy technologies. Sunshine Program was formulated and expanded between 1974-1981 which was being conducted by the Ministry of International Trade and Industry (MITI) with the initial budget of JPY 2.5 billion. The second Oil Crisis in 1979 urged the government even more to invest in alternative energy development, so the target and funding for the Sunshine Program was intensified. The original target to supply 1.6% of the total energy demand in 1990 was raised up to 5% in 1990 and 7% in 1995. In addition, "*Alternative Energy Act*" was enacted in 1980, which established *New Energy Development Organization (NEDO)*, a quasi-governmental organization, was established as the central actor responsible for new energy development. The center pillar of the Sunshine Program was solar energy.

One important result of the expansion of the Sunshine Program was the abundant, stable budget for PV development. The level of PV budget keeps around the level of US$ 6 billion during the 1980's and 90's. This provided a desirable R&D environment for researchers in the national laboratories. The establishment of the Sunshine Program was the biggest stimulus for major appliance producers firms to expand their activities of PV development. The strong commitment by the government to develop and adopt PV very much stimulated private investments, which rose well over governmental subsidies. Substantial progress of PV had been made in the Sunshine Program. The Program promoted not only basic R&D but also a number of demonstration projects. These demonstrations created an indispensable demand of solar cells. NEDO demonstrations provided PV producers the *only* market in the 1980's, where producers could accumulate production experience and improve process technologies through learning-by-doing. The cost reduction target by NEDO was a strong incentive for firms to reduce production cost. The NEDO demonstration projects had strong buy-down effect. The result was the steady improvement of conversion efficiency and economics of PV in the 1980's.

The energy crises of the 1970s produced major rethinking in Germany as in Japan. The main response of the German government to the oil crises consisted in the promotion of nuclear and coal. Since 1979, there were also first efforts to stimulate demand for electricity from renewable energy sources (RES-E) by use of the tariff. The accident in Chernobyl in 1986 had a deep impact in Germany. Within two years, opposition to nuclear power increased to over 70% and the government committed themselves to gradually phasing out nuclear power. Also in 1986, reports warning of an impending climate catastrophe received much attention. An inter-ministerial working group for CO_2 reduction was also established. The commission worked very effectively and recommended a goal of 30% reduction of 1987 CO_2 and methane emissions by 2005, and of 80% by 2050. A series of proposals were formulated which included an electricity feed-in law for generation from renewables.

In Germany, the solar energy industry has continuously increased from 2002 to till now. Germany is developing technologies for producing low cost solar cells. Renewable energy can also be used as a decentralized source for providing power in remote locations. To increase solar energy consumption in domestic electricity and heating applications, Germany is promoting integration of solar energy systems in constructions. This will help to decrease the pollution resulting from conventional power generated for domestic applications. To support the generation of renewable energy especially solar, Germany has introduced feed-in tariff and the green energy certificate system, and is conducting the sustainable energy campaign. A number of financing schemes for the development of renewable energy projects have also been introduced. In addition, a number of regulations providing subsidies and tax rebates have been introduced. In Japan interest is also in ally heightening regarding the role renewables play in energy, climate change, and industrial policies. Japan can also be said to have at long last joined in this competition. However, Japan's renewable energy market has remained in a grounded state due to market policies for renewable not been sufficiently examined or implemented.

For about a decade and a half, renewable energy policy consisted almost exclusively in the promotion of research. Yet, in this largely unfavorable political context, institutional changes occurs which began to open up a space for wind and solar power; a space which proved to be of critical importance for the future diffusion of these renewables. In the period 1977-1989, many universities, firms and research institutes received federal funding. The major part of the research funding was directed towards cell and module development. In addition, R&D funds were allocated to the exploration of a whole range of issues connected to the application of solar cells, such as the development of inverters. As a consequence, and in spite of the fringe status of that

R&D, a broad academic cum industrial knowledge base began to be built up about 25 years ago for solar cells.

In 1983, the first German PV demonstration project took place under financed by the federal government and had an effect of 300kWp. In 1986, it was followed by a demonstration program, which by the mid-1990s had contributed to building more than 70 larger installations for different applications. Yet, by 1990, the accumulated stock amounted to only 1.5MWp. Although the demonstration program had only a minor effect in terms of creating a 'protected space', it was effective as a means of enhancing the knowledge base with respect to application knowledge. In sum, this formative phase was dominated by institutional change in the form of an R&D policy that began to include, at the fringe, R&D in renewables. Although small in relation to R&D in nuclear and other energy technologies, it allowed for a small space to be opened for wind and solar power in which a range of firms and academic departments began a process of experimentation and learning. Small niche markets were formed and a set of firms were induced to enter. In addition to these firms and universities, a range of other organizations such as the Institute of Ecology, Forderverein Solarenergie, and Eurosolar were set up, organizations which later were to become key actors in advocacy coalitions for wind and solar power.

Figure 9 shows the trend of PV installation in Japan and Germany from 1990 to 2011, from which we can distinguish three phases in its history:

1st Phase- Technology development and market creation (1982-1994): The market was very small due to the lack of demand for power applications. In Japan, substantial progress had been made in the Sunshine Program. Many demonstration projects were also implemented. In Germany, installations of residential PV systems have started under 1000 roofs and Feed-in tariffs subsidy program.

Second Phase- Market development (1994-2004): Installations of residential PV systems, in Japan, have been rapidly increasing since 1994 due to simplified procedures of PV installation, technical guidelines for grid-connection, the investment subsidy for residential PV systems, and the net-metering system provided by electric power companies. So far 94% of the PV installed in Japan is grid-connected residential PV systems with governmental subsidies. Until 1999, installations of residential PV systems in Germany were increased slowly. From 1999, PV installations increased rapidly under subsidy program of 100,000 roofs and Erneuerbare-Energien-Gesetz (EEG).

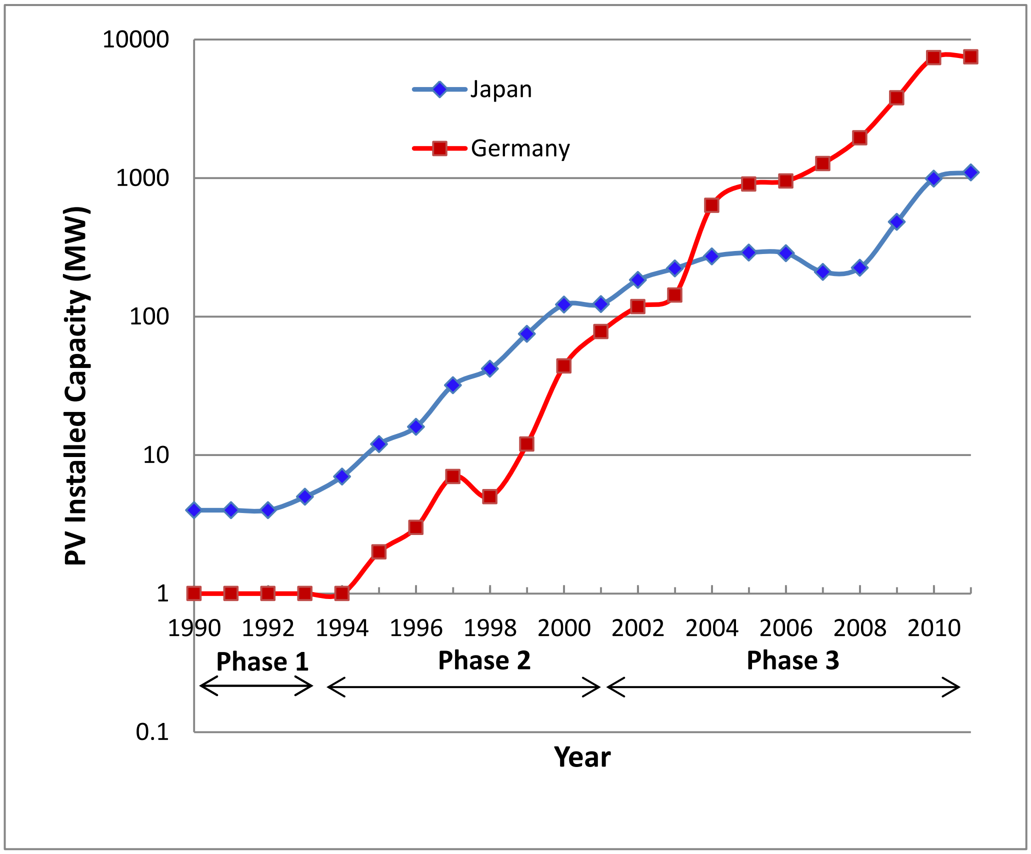

Figure 9. Trend of PV installation in Japan and Germany, 1990-2011
(Created by collecting data from: Chowdhury, S., 2012a; BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar, 2011; BSW-Solar, 2012; AGEE-Stat 2011; AGEE-Stat, 2012; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS, 2013; IEA, 2003; IEA, 2003a; IEA, 2004; IEA, 2004a; IEA, 2007; IEA, 2008; IEA, 2008a; IEA, 2010; IEA, 2010a; IEA, 2011; IEA, 2011a; IEA, 2012; IEA, 2012a; DBCCA, 2011)

Third Phase- Market development with and without subsidy (2005-2011): During 2006-2008, PV installation in Japan gradually decreased due to end of subsidy program. Since 2009 PV installation began to increase again due to new PV generated electricity purchase system, subsidy for new PV system installation and Feed-in Tariff Law. However, the March 2011 earthquake and tsunami have forced Japan to reevaluate its nuclear program and expected to undertake significant changes with respect to its energy program. German residential PV installation continuously increased under stable and modified EEG program in form of a Feed-in-tariff (FIT) (BSW-Solar, 2010).

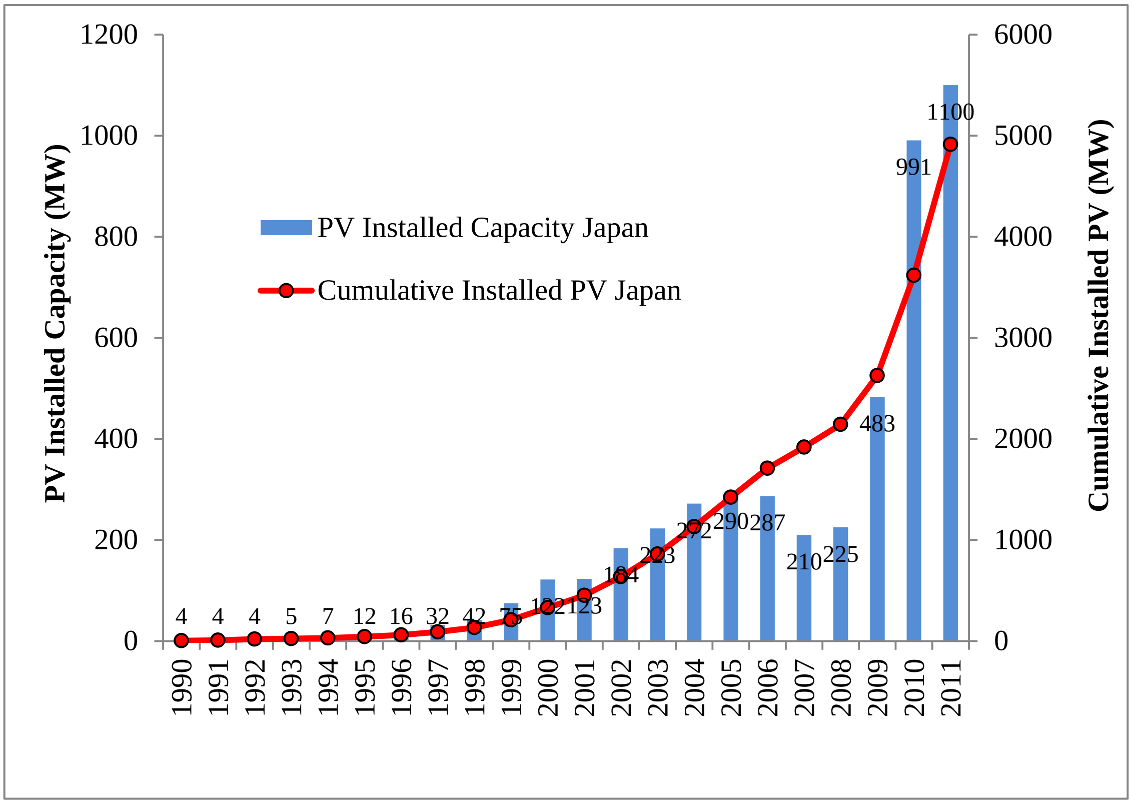

Figure 10. Installed capacity and cumulative installed PV in Japan, 1990–2011 (Created by collecting data from: Chowdhury, S., 2012a; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS 2013; IEA, 2003; IEA, 2004; IEA, 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012)

Figure 10 and Figure 11 show the installed capacity and cumulative installed PV 1990–2011in Japan and Germany, respectively. Figure 12 shows world cumulative installed PV share in Japan and Germany, 2000–2011. Japan was dominating the PV market globally during the decade 1994-2004. During this period Japan PV market increased 41 fold from 7MW in 1994 to 290MW in 2005. After 2005 Japan's PV market decreased and became 210 MW in 2007 and world cumulative installed PV share decreased from 30.5% in 2003 to 7.3% in 2011. On the other side, from 1990 to1999 German PV market did not grew at all but after 2000 it increased rapidly. Since 2000, German PV market increased abruptly and it increased from 40MW in 2000 to 7500MW in 2011. During 2000-2011, development of German cumulative installed PV market increased 196 fold from 126MW in 2000 to 24.7GW in 2011. During 2000-2011, Japanese cumulative installed PV market increased only 15 fold from 330MW in 2000 to 4.9GW in 2011. The Japanese market has stabilized at around 290MW/year in 2005, while the German market is increasing and exceeds 7.5GW/year in 2011. Recently, Japanese PV market is increasing again from 2009 and exceeded 1GW/year in 2011.

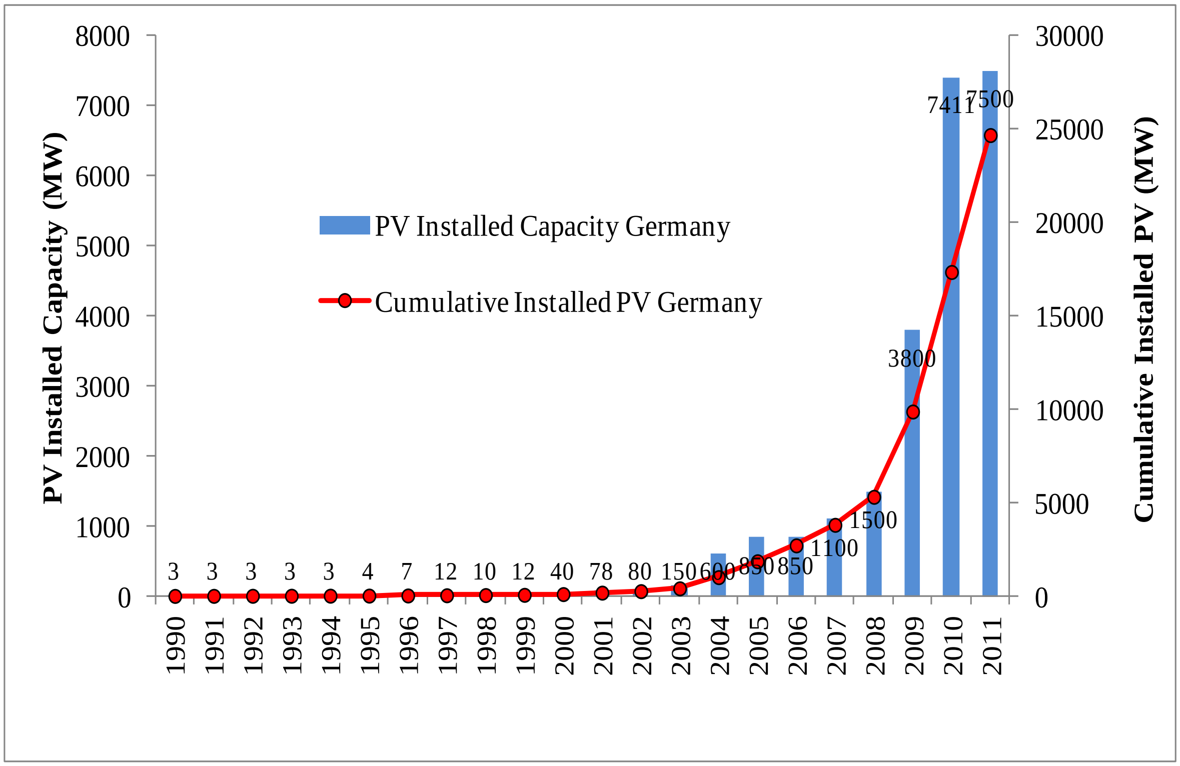

Figure 11. Installed capacity and cumulative installed PV in Germany, 1990–2011 (Created by collecting data from: Chowdhury, S., 2012a; BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar, 2011; BSW-Solar, 2012;; AGEE-Stat, 2011; AGEE-Stat, 2012; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS, 2013; IEA, 2003a; IEA, 2004a; IEA, 2008a; IEA, 2010a; 2011a; 2012a; DBCCA, 2011)

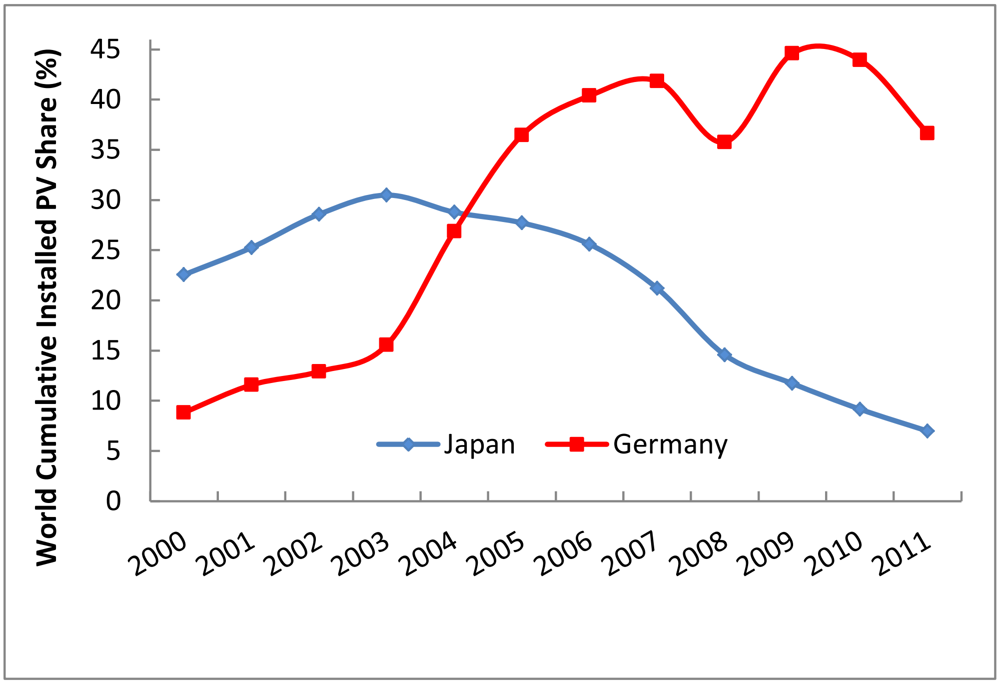

Figure 12. World cumulative installed PV share in Japan and Germany, 2000–2009 (Created by collecting data from: Chowdhury, S., 2012a; IEA PVPS 2008; IEA PVPS, 2011; IEA PVPS 2013; IEA, 2003; IEA, 2003a; IEA, 2004; IEA, 2004a; IEA, 2007; IEA, 2008; IEA, 2008a; IEA, 2010; IEA, 2010a; IEA, 2011; IEA, 2011a; IEA, 2012; IEA, 2012a; DBCCA, 2011)

Chapter 6

6. Government policy for renewable energy and their impact on the diffusion process of PV

6.1. Photovoltaic Promotion in Japan

In response to the first oil crisis, the government launched the *Sunshine Program* in 1974, conducted by the Ministry of International Trade and Industry (MITI), to promote research activities aiming at development of technologies from alternative energy by 2000. The target was to supply 7% of the total energy demand in 1995. In 1980, *New Energy Development Organization (NEDO)*, a quasi-governmental organization, was established as the central actor responsible for new energy development. Figure 13 and Table 3 shows the development of PV market in Japan from 1990-2011, showing all the incentive programs (METI, 2009).

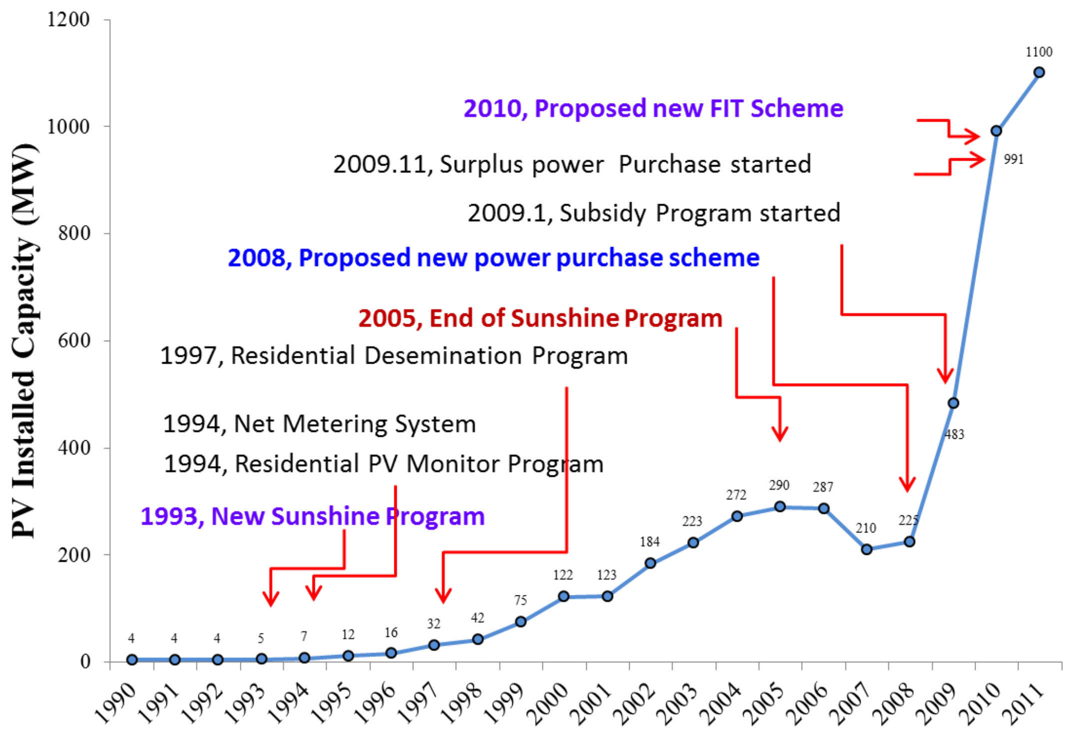

Figure 13. PV market development in Japan, 1990–2011
(Created by collecting data from: Chowdhury, S., 2012; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS, 2013; IEA, 2003; IEA, 2004; IEA, 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012)

Table 3. The Course of Photovoltaic Promotion in Japan

(Created by collecting data from: PV Status Report, 2011; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS, 2013; IEA, 2003; IEA, 2004; IEA, 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012)

Policy	Operating principle	Year of implementation
Sunshine Project	Promotion of research activities aiming at development of technologies from alternative energy	1974 - 1994
MITI Energy Outlook	Ambitious targets for PV installation By the year 2000, 250 MW and by 2010, 4,600 MW	1990
Electricity Utility Industry Law	simplified procedure to installation of PV Systems less than 500kW	1990
PV introduction project	electric utility companies announced; install 2.4MW of PV system by FY 1995	1991
Buy-back system	Buy-back system for the surplus PV power at the selling price has been implemented	1992
New Sunshine project	Successor of the aforementioned project, integrating the Sunshine, the Moonlight (Energy-saving technology R & D) and the Global Environment Technology Projects aiming at acceleration the market penetration of the technologies	1993 -2000
Monitoring program for residential PV systems	Aimed at stimulation of the PV market. 50% of PV installation costs were subsidized	1994-1996
Program for the development of the infrastructure for the introduction of residual PV systems	Successor of the aforementioned program with substantially increased funding facilities.	1997
PV Field Test Project for Industrial Use	Subsidy (50%) for private companies, local public organizations for installation of PV systems	1998
Projects for New Energies	(1) *Seed identification* – related to production technologies, industrialization and commercialization (up to 50% funding) (2) *Advanced PV Generation* - 100% sponsored development of pilot plants for new PV technologies	2001

Table 3. (Continued)

Subsidy program of local governments	Funding of up to 40% of the installation costs	
Renewable portfolio standard (RPS)	Legislation aiming at achieving a ratio of 3.2% for the renewable energy in the total energy supply till 2010. It requires each power retailer to set an annual sales target for six types of renewable energy (including PV)	1st April 2003
Action Plan for Dissemination of PV Power Generation	goals to set PV installations amounting to 14 GW by 2020 and 53 GW by 2030 Local governments to promote installation of PV systems: Tokyo Metropolitan: 1 000 MW of PV	2008
New Purchase System for Solar Power Generated Electricity	purchase excess PV power households: 48JPY /kWh schools and hospitals, etc.: 24JPY /kWh	November, 2009 starting in April 2010 and run for 10 years
Subsidy for Residential PV systems	70 thousand JPY/kWh	November 2009
Feed-in Tariff Law based on the "Renewable Energy Law"	PV systems with the capacity of 10 kW or larger, FIT, 42 JPY/kWh, for the period of 20 years For PV systems with the capacity of below 10 kW, FIT, 42 JPY/kWh for the period of 10 years; enforced in July 2012	2011

In 1990, procedure to installation of PV systems less than 500kW was simplified by the amendment of the Electricity Utility Industry Law. In 1991, electric utility companies announced PV introduction project aiming at installing 2.4MW of PV system by FY 1995. In 1992, buy-back system for the surplus PV power at the selling price has been implemented. PV field test project for public facilities by NEDO started. In1993, guideline of the technical requirements for PV grid-connection with reverse flow was prepared.

In 1993, the "Sunshine Program" merged with the "Moonlight Program" and the "R&D Project on Environmental Technology" to form the "New Sunshine Project" an effort to create a Japanese solar photovoltaic industry and a domestic market for solar power. Japanese government also initiates a long term goal for solar power sector. In "the basic guidelines for the new energy introduction" the government approved the overarching goal for PV that includes official target for cumulative installation will be 400MW by 2000 and 4600MW by 2020. From the perspective of 1993 these goal seems aggressive because in 1993 the cumulative base in Japanese PV was only 1.25MW. These goals and the strong growth rates they required were supported by the “New Sunshine Program”.

The Sunshine Program supported projects to accelerate technologies for which a virtuous cycle for PV development in Japan might be triggered. This virtuous cycle involved the expectation of technological improvement, decreasing cost, increasing demand, leading to mass production and further cost reduction. Due especially to the research program "New Sunshine Project" started in 1993 and the incentive program "Residential PV System Dissemination Program", as well as its predecessor "Residential PV System Monitoring Program" begun in 1994, the Japanese have been able to build up a self-supporting market. These programs are supported by Ministry for the Economy, Trade, and Industry (METI), while the concrete development is subject to the supervision of the New Energy and Industrial Technology Development Organization (NEDO). In 1995, Japan local government initiated in drawing up their PV introduction plan under the Vision for Regional New Energy. MITI’s Economic structure Plan in 1996, the target of new industry creation in the field of new energy was focused on fostering PV industry. In1997, the Law for New Energy Promotion Introduction was enacted. Residential PV System Dissemination Program started to deploy residential PV system on a large scale. Regional new energy introduction projects also started. In 1998, PV System Field Test Program for Industrial Use started. Policy on The Law Concerning “The Promotion of Development and Introduction of Oil Alternative Energy” was revised. Photovoltaic was placed one of Oil alternative energies.

Since 1999, Japan has been number one when it comes to PV business. Japan’s global PV production share exceeded 40% in the year 2000. One reason Japan achieved this solar prominence can be attributed to the uninterrupted federal assistance, which has been afforded mostly by the very influential METI. With the commercialization of photovoltaic at the forefront of the New Sunshine Project's objectives prior to the year 2000, the Japanese industry aims at mass production by 2005. Until 2007, Japan was the number one global market share holder by offering their products in other solar markets like Europe and the USA. By early 2004 there was general belief among Japanese policy makers and solar power executives that the goals of the “New Sunshine Program” were being achieved. Specially, creation of the initial market for PV system was viewed as complete and the government revised its “Long term energy demand and supply outlook”. With this revision, the programs under the New Sunshine Program were to be reduced and eliminated by 2005.

We can see that Japanese energy policy “New Sunshine Program” was generous and favorable for the growth of solar power sector from the year 1993 to 2005 (Figure 13). After the incentive program was eliminated, the Japanese PV market decreased, so we can say that this policy was not a long term program. It helped Japan to build up a self-supporting market for PV and in 2003 Japan became major global market share holder. But after the sunshine program was eliminated Japan began to lose its market share and became 4% by 2008. We can assume that the incentive program and the policy was the main support that helped Japan to occupy the top position for a long time. Their success can be attributed to Japan's embrace of coordinated public investment in each stage of the solar technology innovation pipeline, including not just funding for research and development, but also demonstration and early-stage deployment efforts. These efforts to support the demonstration and early-stage deployment of solar photovoltaic ensured a market for the emerging technology; without these policies photovoltaic would have faltered before reaching costs that were competitive with market electricity rates.

Against this background, in 2003, the Japanese government enacted legislation based on a Renewable Portfolio Standard (RPS) scheme that requires electricity retailers to supply a certain amount of renewable electricity to grid consumers. RPS mechanisms purportedly ensure that market implementation will result through competition, delivering renewable energy at the lowest possible cost. FIT schemes, on the other hand, guarantee purchase of all renewable energy, regardless of cost, as they are designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers.

Japan has been a long-time world leader in solar energy, primarily due to its highly successful “New Sunshine Program”, which enacted targeted policies to grow its solar PV industry and funded the installations of over 930 MW from 1992 to 2005. The government-initiated program was so successful that authorities were able to reduce the solar PV installation subsidy from 900 yen/Watt in 1994 to 20 yen/Watt in 2005. The government discontinued solar installation subsidies in 2005, however, and the PV market has stagnated since. As a result, Japan lost its solar market dominance to Germany, which has instituted generous price support mechanisms for their domestic PV industries.

Japan’s leaders have since recognized that boosting their domestic solar PV industry is an important step to increasing economic competitiveness in the burgeoning industry and the government has moved swiftly to regain its position as a leader in solar PV (NEDO, 2004). In 2009, Japan government declared national goal of increasing solar power generating capacity to twenty times 2005 levels by 2020, and 40 times by 2040. This would amount to a deployment of

28GW in 2020 and 56GW in 2040 (PV Status Report, 2011). For non-residential solar, the government has provided several hundred million dollars over the past two years to subsidize installation costs. The government aims to eventually make unsubsidized solar energy as cheap as conventional energy sources. The government has budgeted 20 billion yen for a 700,000 yen/kW PV installation subsidy available through 2009, and aims to have 70 percent of new homes equipped with solar panels by 2020. The public sector installation subsidy extends to utility-scale “mega solar” power generation facilities, and Japan has established a target for each of the country’s ten utilities to build a large-scale solar plant by 2020, for a total of nearly 140 MW.

Recently, the government implemented a new feed-in tariff for solar electricity production that is expected to dramatically increase solar energy adoption (PV Status Report, 2011). The “new purchasing system” would require utilities to purchase excess solar PV electricity at about twice the current (voluntary) price, 42 yen/kWh. The purchase term is 10 years and the cost of the whole system, including installation and actual infrastructure cost, is allocated to electricity users in the form of an additional charge on the utilities’ bill. The PV fixed price purchase system became an incentive for households to install PV. The impact of the system was soon obvious, as can be seen in the Figure 13, which show a dramatic increase in installed PV generating capacity after introduction of the scheme. Together with subsidy and tax reduction programs for residential PV systems, the PV fixed price purchase system became the main driving force for an increase in PV cell demand. It pushed up the installation of residential PV systems, with 1.1GW/year in 2011.

6.2 Photovoltaic Promotion in Germany

Germany began solar cells research in 1960 and it was greatly expanded after the first oil crisis, when German green movements caused government to start funding solar cell R&D. This funding was kept stable for many years. Figure 14 and Table 4 shows the development of PV market in Germany from 1990-2011, showing all the incentive programs. The German solar photovoltaic (PV) industry began with the passage of the "1000 roofs program" in 1991, in which the government gave subsidies to individuals to cover the cost of installing a PV rooftop system. The aims of the program were to gain experience with solar installations, make new housing compatible with renewable electricity generation needs, and stimulate consumer usage of solar power. By the mid-1990s, 2,000 grid-connected PV systems had been installed on the

Germany's rooftops. This successful initiative soon expanded into the 100,000 roofs program to drive further expansion of the industry. The program aimed to drive down the price of solar PV and invited private entities to participate. Each participant was given a loan of 6,230 €/kW (peak) for PV systems with an output less than 5MW and 3,115 €/kW if the output was higher. The program ended after 2004, with the successful installation of 100,000 grid-connected rooftop solar systems. By its end, Germany's solar PV industry had moved beyond niche markets to become capable of mass manufacture. The German government also supported the nascent solar industry and the solar roofs programs by establishing a policy known as a feed-in tariff (FIT) (DBCCA, 2011). The feed-in tariff guarantees a higher-than-market price for electricity generated by solar PV which is fixed for 20 years beyond the installation date, providing investment certainty for firms and individuals. The tariff, a component of the country's renewable energy law, has been a part Germany's energy policy since 1991 and continues to this day. In 2000, with the demonstrated success of the 100,000 roofs program, the new government increased the feed-in tariff rates for solar PV. Part of the updated tariff, however, was a 5% decrease each year in reimbursement for newly installed systems, providing a clear incentive for the solar industry to develop more cost effective panels (CPI, 2011).

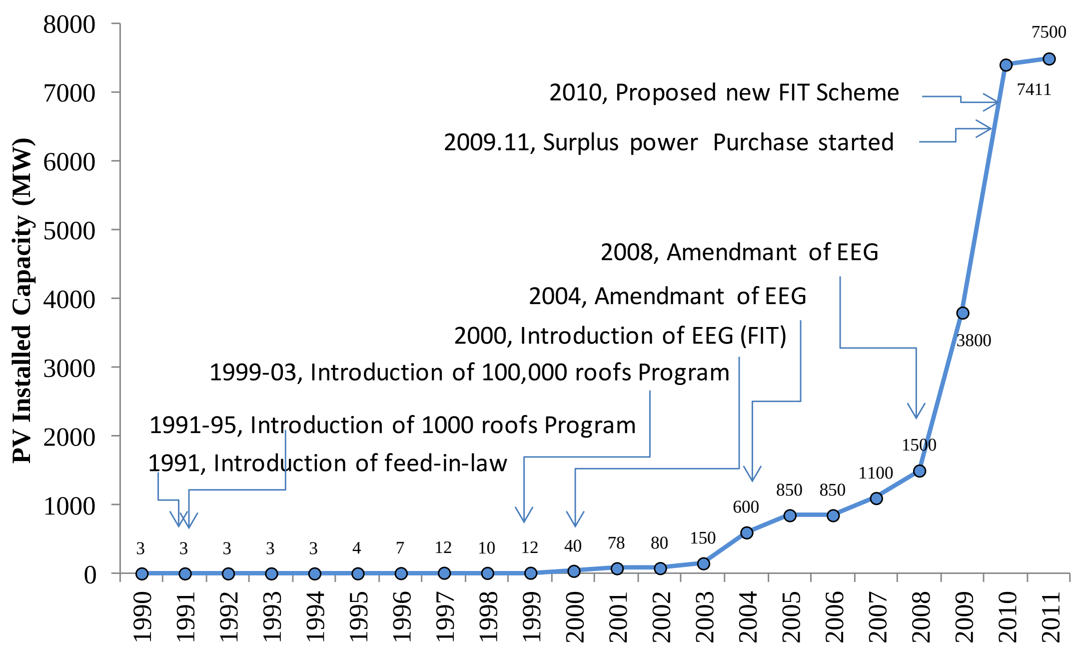

Figure 14. Development of German PV market, 1990-2011

(Created by collecting data from: Chowdhury, S., 2012; BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar, 2011; BSW-Solar, 2012; AGEE-Stat, 2011; AGEE-Stat, 2012; IEA PVPS, 2008; IEA PVPS, 2011; IEA PVPS, 2013; IEA, 2003a; IEA, 2004a; IEA, 2008a; IEA, 2010a; 2011a; 2012a; DBCCA, 2011)

Table 4. Course of Photovoltaic Promotion in Germany

(Created by summarizing the literature and DBCCA, 2011)

Policy	**Operating principle**	**Year of implementation**
1.000 roofs	Investment subsidy of 70% of costs with upper cap	1991-1995
Stromeinspeisungsgesetz (StrEG)	PV receives 90% of retail electricity price (8.45-8.84 Eu cent/kWh) 5% penetration cap for all renewables	1990-
Electricity Feed-in Law (Budget 3.5 M EUR paid by final customer)	Feed-in tariffs (90% of the average price for end consumer)	1991-03.2000
Green tariffs from utilities as voluntary participation for the customers	1) higher feed-in tariffs paid to realize new PV plants	1996-1999
Market stimulation program	Invest. subsidies on schools, churches and congregations	1999-2001 (on schools still ongoing)
100.000 roofs (Subsidy of 695 M EUR)	Soft loan: 10 years duration, 2 years free of redemption PV receives interest-free loans	1999-2003
Erneuerbare-Energien-Gesetz (EEG)	PV receives 52Eucent/kWh 5% annual digression 350 MW program cap 5MW program cap for rooftops 100kW system cap for free-standing	2000
Renewable Energy Act (Budget 83 M EUR paid by final customer)	Feed-in tariff of €0.457 fixed for 20 years (5% decrease annually for later installation from 2002 on)	01.04.2000-ongoing
	PV cap program cap raised to 1000 MW	June 2002
100.000 roofs program	Funds exhausted	July 2003
Promotion of research projects in the field of PV	Financial support for joint projects by research and industry entities	2004-ongoing
EEG Amended	New rates ranging from 46-62 EU cent/kWh go into effect 5%-6.5% digression Program cap removed System size caps removed	August 1, 2004

Table 4. (Continued)

EEG Amended	New rates go into effect in 2009, following 2008 amendment EEG • National Renewable Energy Action Plan (NREAP): The government projects that annual additions for PV will peak in 2010 at 6,000MW and will then contract to 4,500 MW in 2011 and 3,500 MW p/a through 2020. By 2020, a total of 51,753 MW of capacity is projected to be installed in Germany. Rates for façade integration removed Rates for onsite consumption introduced Corridor digression system introduced, with a range of decreases from 5.5%-7.5% National feed-in-tariff registry created	2008-2009
EEG Amended	Building-mounted systems decrease 13% in July, and 3% on October 1,2010 On top of 7.5% digression from 2009 Ground-mounted systems decrease 8-12% in July, and 3% on October 1, 2010 Corridor digression revised with a range of decreases from 6-13%	July 9, 2010
Corridor revision proposal	Joint BMU/BSW proposal to revise corridor digression schedule Rates would decrease by 0%-15% on July 1, 2011, and again by 9% at the end of the year	January 20, 2011

German PV market entrance strategy:

- Create PV demand by 1) granting the right of solar electricity production and grid connection, 2) making solar electricity production financially attractive.
- Building up 1) PV market, 2) PV production, 3) installation capacities, 4) reduction of costs, 5) less energy imports and 6) creation of job.
- PV will become 1) cost-competitive, 2) an important pillar of the sustainable energy system.

German Feed-in-law started first in1991 with a very low tariff. In 1999 the Renewable Energy sources act EEG was introduced and the Feed-in-tariff was renewed. It was affected from the year 2000. This policy was very generous and it helped Germany to rich the world’s top position with in a very short time. In 2004 there was an amendment of EEG (FIT) and until now this policy is helping Germany to have more than half the world's solar-power generating capacity. As shown in Figure 14, from 1990 to1999 German PV market did not grew at all but after 2000 it increased rapidly. During 2000-2011, German PV market increased 170 times from 44MW in 2000 to 7.5GW in 2011. From the above figure we can see that German PV market is developing with the introduction of the government support programs and also growing very fast according to the change or amendments on the incentive programs. One of the benefits of the German FIT is that it provides economic incentives for end-use customers to buy PV systems, reducing the pay-back period to perhaps a few years. In this way, the market is greatly expanded from those who buy PV out of reasons of environmental consciousness to those interested in investment possibilities, thus also increase 'legitimacy' (Schott Solar, 2010).

In Japan, the voluntary program for net-metering and buy-back of excess electricity from PV induces the 'formation of markets', and was very important for the formation of the grid-connected rooftop market. This market has been the most important one for PV in Japan during the last years. The program also influences the 'direction of search', by specifying a main application for PV manufacturers to focus on. However, a difference between the net-metering system and the system in Germany is that it does not provide enough economic incentives to make a PV system economically viable; electricity generated from a typical household PV system is twice as expensive as that bought from the grid. Also, as it is a voluntary program, it may not provide the same financial security as a law. Another available support system, the RPS system, does not seem to function to induce market formation either. The combined power of the Japanese support measures do not provide financial incentives for buying a PV, hence people buy PV for "emotional" reasons.

From the previous data and literature survey about Japanese and German's incentives and government policies we can say that Japanese sunshine project was a very good incentive program, it helped the Japanese PV business to flourish, but after 2003 the market share decreased and at the end Japan lost its position and reputation. On the other side, in Germany the policy Feed-in tariff started from 1991 and is still working on for the PV business in Germany. The incentive program is also helping the consumers to make the system affordable to them.

Chapter 7

7. Environment policy and its effects on PV diffusion

United Nations Framework Convention on Climate Change (UNFCCC, 1992) and its 1997 Kyoto Protocol is a novel global climate governance arrangement to achieve "stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system that has emerged in the last few years (Kyoto protocol, 1998). Under Kyoto, industrialized countries agreed to reduce their collective GHG emissions by 5.2% compared to the year 1990. National limitations range from 8% reductions for the *European* Union and some others to 7% for the United States, 6% for Japan, and 0% for Russia.

Japan is one of the largest greenhouse gas emitters in the world, after the United States and China. Figure 15 shows the greenhouse gas (GHG) emissions of Japan and Germany from the 1990 base year to 2011. Japan's greenhouse gas emissions increased by 8% in 2007 compare to its base year 1990. Additional measures are thus required to achieve the 6% reduction target. Germany is on track to achieve its Kyoto commitment for 2012 as GHG emissions were 26% below the 1990 baseline already in 2009. The share of renewable energy sources, especially solar and wind, increased significantly since 2000, thereby contributing to the reduction of CO_2 emissions in the energy sector. Germany has set itself ambitious targets for GHG emissions, energy efficiency, and renewable energy sources, confirming its leadership role in promoting ambitious climate policy. In the framework of the EU effort-sharing under the Kyoto Protocol, Germany has committed itself to cutting its GHG emissions of 21% in the period 2008 to 2012 compared with 1990, taking a large share of the total 8% target of emission reductions set by the EU.

7.1 Japan policy to meet the Kyoto Protocol objectives

Since 1997, when Japan adopted the Protocol, a raft of climate change mitigation policies has been developed to reduce emissions across different sectors. A set of voluntary mechanisms, strongly advocated by the Japanese Federation of Economic Organizations, have been implemented to reduce emissions in the industry sector. It did not introduce new policy measures. Japanese domestic climate policy has been characterized by difficulties in achieving consensus between three government actors, Ministry of Economy, Trade and Industry (METI), the Ministry of Environment (MOE) and the Ministry of Foreign Affairs (MOFA). Due to the substantive differences in position between the three ministries involved and the lack of effective coordination mechanisms, the government's policy on climate change has been both ambiguous and fragmented. Japanese industry, of which about 80% is united in the Federation of Economic Organizations (FEO or Nippon Keidanren), have historically been a powerful interest group, with strong ties to METI. Keidanren has strongly opposed government interventions, including the use of economic instruments such as carbon taxes and emissions trading (KEIDANREN, 2012; ITPS, 2008). Their main rationale is that the costs imposed would damage the competitiveness of Japanese industry on the international market.

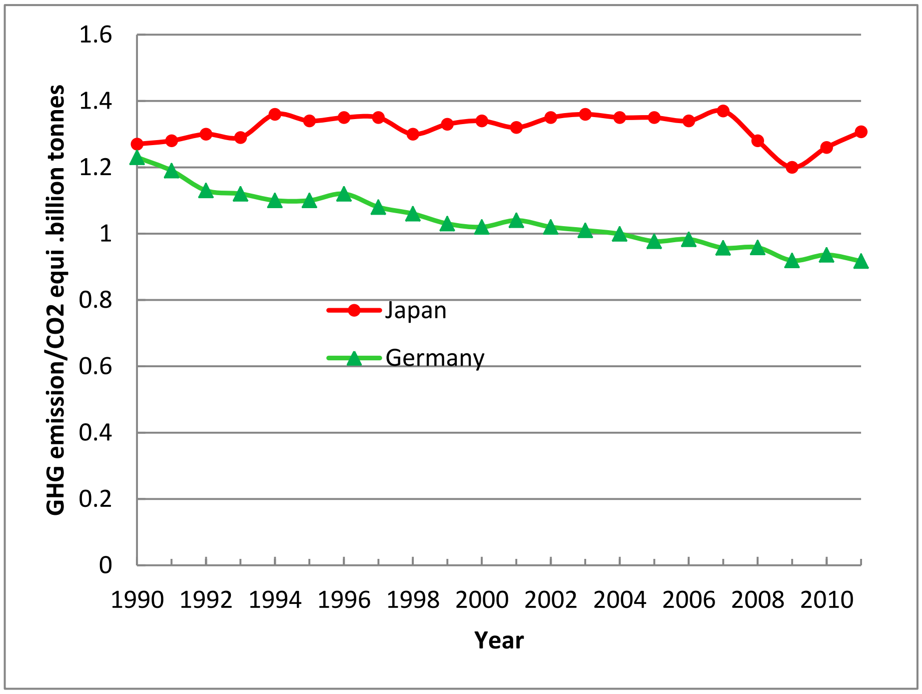

Figure 15: Greenhouse gas emission (GHG) in Japan and Germany, 1990-2011
(Created by collecting data from: PBL NEAA, 2012)

Furthermore, there is a high degree of public awareness of the climate change problem and the Kyoto Protocol. Japan's continuing participation in the UNFCCC is broadly supported by other domestic actors including the public and media, as well as environmental NGOs. Japan's ties in international climate politics are closer with the EU. Both the EU and Japan ratified the Kyoto Protocol, and have been firm supporters of the treaty, although for different reasons. Whereas the EU wants to promote the Protocol in terms of environmental integrity, Japan has above all a symbolic tie with the treaty, given the place of its inception (Asselt, H.V., et al., 2009).

Japan promotes following policies and measure on GHG emissions reduction to meet the Kyoto protocol objectives (ICAP, 2010; Gist of the Kyoto protocol target achievement plan, 2006):

GHG emissions reduction: The "Achievement Plan" is formulated gas specific measures, where developments specific measures for energy related CO_2, CO_2 from non-energy sources, methane, N_2O, HFC and other gases. In order to reduce energy related CO_2 emissions, the Government will promote measures on energy related apparatus as well as on individual facility/stakeholder and take measures to shift socio-economy including urban/regional structure and public transportation infrastructure into low carbon one.

GHG sinks: The Government will ensure the 3.9% removal by sinks and comprehensively and steadily promote to take measures for securing absorption and urban greening.

Kyoto mechanisms: Public and private sectors will further cooperate to promote the effective utilization of Kyoto Mechanisms, by which environment-related technologies are transferred to developing counties in exchange for emission credits. Measures to facilitate credit acquisition have been discussed with a view to implementing them from FY2006. Then, the Ministry of Economy, Trade and Industry (METI) and Ministry of the Environment (MOE) have commissioned NEDO to carry out credit acquisition.

In 2007, Japan announced the "Cool Earth 50". The plan presented a long-term strategy to cope with global warming issues, and upheld the following two purposes: 1) cutting global greenhouse gas emissions to half the current level by 2050, and 2) presenting a long-term vision for developing innovative technologies and building a low-carbon society. In 2008, Japan launched the "*Cool Earth Promotion Program"* to be implemented through the following three parts; post-Kyoto framework, international environment cooperation and innovation. As for the post-Kyoto, Japan agrees to, along with other major emitters, set a quantified national target for the greenhouse gas emissions reductions. In the same year, government announced "Cool Earth-Innovative Energy Technology Program," which identified 21 technologies to be prioritized where Japan is a global leader, boasting the world's top level energy Technologies (MOEJ, 2012).

Table 5. Comparative analysis of environment policies, taken by Japan and Germany

(Created by summarizing the literatures: Kyoto protocol, 1998; PBL NEAA, 2012; KEIDANREN, 2012; ITPS, 2008; Asselt, H.V., et al., 2009; Gist of the Kyoto Protocol Target Achievement Plan, 2006; ICAP, 2010; GED, 2011; OECD, 2012; Jacobsson, S., Lauber, V., 2006; AGEE-Stat 2011; AGEE-Stat 2012; IEE, 2010; Karapin, R., 2012)

	Japan	**Germany**
Environ ment issues	Japan needs to reduce their collective GHG emissions by 6% compared to the year 1990.	European Union needs to reduce their collective GHG emissions by 8% compared to the year 1990.
Policies	1990, PV initiative 1998, Global Warming Act, • Basic policy and responsibilities, • National and local action plans 2002, Amendment of the Act (GWA), • Plan for achievement of Kyoto Target 2006, Amendment of the Global Warming Act • Use of Kyoto Mechanism 2008, Announced “Cool Earth—Innovative Energy Technology Program,” an Amendment of the Global Warming Act, • Policy plans of local governments, • GHG reduction guidelines for companies 2009, Tokyo Metropolitan Government (TMG) set a target of reducing CO2 emissions by 25 % by 2020 from the 2000 levels in its plan called “Tokyo in 10 years”. TMG decided to provide a subsidy of 100 000 JPY/kW in FY 2009 and FY 2010.GHG reduction target • 80 % by 2050 (without any conditions) 2010, Targeted Emission • 1,239～1,252Million t-CO_2; • Total GHG emission -1.8%～-0.8%; • CO_2 removal by sinks -3.8%; • Kyoto Mechanisms -1.6%; 2010 Reviewed Basic Energy Plan, • Increase renewable energy target in 2030 • Increase PV from 9 % to 20 % in 2030. 2012, Targeted CO_2 Emission • 1,254 Mt, -0.6% compared to 1,261 Mt Base Year 1990); • New “Innovative Energy and Environment Strategy”	1990, reducing energy-related CO_2 emissions • by 25% over the 1987-2005 period 1994, objective of cutting CO_2 emissions • by 25-30% by 2005 1999, Germany accepted a target of • 21% reduction from 1990 to the 2008-2012 period 2000, targets for GHG emission and renewable energy; • Set a target of doubling the share of electricity from renewable sources from 6.25 % in 2000 to 12.5 % in 2010. 2001, Phase out nuclear power; For expanding electricity generation from renewable sources, phase out nuclear power between 2003 and 2021 2005, Climate Protection Program, • Set a new goal of reducing CO_2 emissions by 40% from 1990 to 2020, conditional on the EU committing to a 30 % reduction over the same period. 2010, Reduce overall domestic GHG emissions compared with 1990 • 40% by 2020 • 80% by 2050. 2010, Share of renewable energy sources (RES) target Electricity consumption: • 35% by 2020 • 50% by 2030 and • 80% by 2050) Final energy consumption • 18% by 2020 • 30% by 2030 • 60% by 2050. • 2011, early phase out nuclear power; the government resumed the phase-out after the 2011 Fukushima nuclear disaster.

Table 5. (Continued)

Response	1998, Companies' responsibility for GHG reduction • Companies' responsibility to establish and publish action plans. 2005, • Companies requested to estimate and report GHG emission. • Government to make the data publicly available. 2006, Domestic trading and surrendering of overseas emission reduction 2008, Identified 21 technologies to be prioritized where Japan is a global leader, • Boasting the world's top level energy Technologies. 2008, Offset Credits (J-VER) started; • Local government expected to develop energy policies 2009, Environmental tax including; CO_2 tax, • Introduction of a cap-and-trade scheme within a year, • Introduction of a feed-in tariff on all renewable energy 2010, Policies and Measures to Achieve the GHG Target • Promotion of voluntary action plans by industries • Improvement of energy efficiency of houses, equipment, factories and automobiles. • Measures regarding waste and CFC substitutes (HFC, PFC and SF_6) • Measures to promote the use of new energy • Forest management and national campaigns for the development of beautiful forests Issues to be reviewed promptly • Domestic emissions trading • Environment taxes 2011, Establishment of the Energy and Environment Council	1995-1996, Voluntary agreements with industry • Reduce CO_2 emissions by 20 % from 1990 to 2005 1998, promoted renewable energy • Strongly promoted renewable energy to help achieve GHG reduction targets. 2000, targets for GHG emission and renewable energy • With the 2000 act, set a target of doubling the share of electricity from renewable sources from 6.25 % in 2000 to 12.5 % in 2010. • Industrial associations agreed to reduce specific CO_2 emissions by 28 % over 1990-2005 and to cut specific greenhouse gas emissions by 35 % by 2012. • Power industry agreed to further voluntary cuts, totaling an annual reduction of 45 million tons in CO_2 emissions by 2010. 2001, Phase out nuclear power • For expanding electricity generation from renewable sources, phase out nuclear power between 2003 and 2021 2002, Buildings Energy Efficiency Ordinance took effect 2004, EU's emissions trading law. • 2005-2007, very lax, calling for fewer reductions • 2008-2012, The Second National Allocation Plan, cuts of 20.9 megatons per year by the end of the period 2008, By 2020 renewable energies are to cover 14% of heating requirements 2011, early phase out nuclear power Those plans were delayed by the new Merkel government after the 2009 Bundestag elections, but after the 2011 Fukushima nuclear disaster, It was decided in 2011 to terminate the production of nuclear power until 2022.

Since 1997, when Japan adopted the protocol, a raft of climate change mitigation policies has been developed to reduce emissions across different sectors. The instruments that environmental economists have expected to be the most effective emission-reduction tools have not been introduced due to strong opposition from Japanese industry. Hence, the market exerts virtually no pressure on Japanese companies to reduce CO_2 emissions. In addition to this, emissions from electric power stations have been steadily increasing, based on demand increases and increases in the use of coal-burning stations (Table 5).

In 2009, Democratic Party of Japan submitted a bill of Basic Law to mitigate global warming. The bill included a 25% GHG reduction target by 2020 (with the condition that all major GHG-emitting countries, including developing countries, agree to establish an international mitigation framework with ambitious targets), an 80% GHG reduction target by 2050 (without any conditions), and the introduction of a feed-in tariff on all renewable energy. To see real achievements in Japanese climate policy the establishment of market mechanisms, including caps on emissions, and collaboration among stakeholders will be essential. Caps could also lead to the production of innovative technologies and business models (GED, 2011).

7.2 German policy to meet the Kyoto protocol objectives

In 1994 the German federal government confirmed its objective of cutting CO_2 emissions by 25-30% by 2005. As regards the EU (Germany) made an important commitment in the European council of environment ministers in March 1997 when the German government agreed to cut its greenhouse gas emissions (GHG) by 25% between 1990 and 2010, this commitment was part of the proposal of the European Union for the Kyoto conference in December 1997 (FG, 2009).

Germany has reduced gas emissions by 22.4% between 1990 and 2008. Germany's voluntary commitment to reduce CO_2 emissions by 21% compared to 1990 levels has met all intents and purposes. Germany is thus contributing 75% of the 8% reduction promised by the EU. In order to realize European goals, the German government agreed for a coordinated energy and climate policy (GEA, 2007; GEA, 2007a; OECD, 2011). The most important provisions are as follows:

- For fiscal 2008 the government has earmarked some 3.3 billion Euros for climate policy, 1.8 billion Euros more than in the 2005 budget.

- By 2020 renewable energies are to generate between 25% and 30% of the total electricity production.
- By 2020 renewable energies are to cover 14% of heating requirements. To this end the German government will be raising the funding available to up to 350 million Euros a year until 2012.
- There are also plans to better integrate renewable energies in the national electricity grid.
- In future new buildings will have to meet of their energy requirements more from renewable sources than has up till now.

As shown in Figure 16, the share of electricity produced from renewable energy in Germany has increased from 3.1% of the national total in 1990 to about 20.1 % in 2011. Renewable electricity supplied only 3.2% of the total power generation in Japan in 2011, which is only 1% increase since 1990. From 1990-2011, German renewable energy share increase about 17%. In 1990, total renewable electricity generation in Germany was 17.1 TWh which is increased to 121.9 TWh in 2011. In 1990, total renewable electricity generation in Japan was 19.9 TWh which is increased to 38.6 TWh in 2011. From 1990-2011, German renewable electricity generation increased about 7 times but during this time period Japan renewable electricity generation became only double (Figure 16). Germany is the world's first major renewable energy economy. Renewable electricity in 2011 was 121.9 TWh including wind power 46.5 TWh (38.1%), biomass 26.1 TWh (32%), hydropower 19.5 TWh (16.0%) and PV 19.0 TWh (15.6%). The share of electricity produced from PV in Germany has increased from 0.17% of the national renewable energy total in 1990 to about 15.6 % in 2011.

From Table 5 we can see that the environment policy of Germany is more favorable and it had positive impact on PV (AGEE-Stat 2011; AGEE-Stat, 2012, Jacobsson, S., Lauber, V., 2006). From the Table 5 and Figure 16 we can see that in response to the Global warming and Environmental issues to reduce the CO_2 emission Japan considering controlling CO_2 emission through energy saving, waste reduction and low CO_2-energy (non-fossil energy) specially increasing nuclear energy production not the renewable energy like PV energy. Of the Japan’s total electric power generation, roughly 60% came from conventional thermal sources, 29% comes from nuclear sources, 9% from hydroelectric sources, and 2% from other renewable. The Chernobyl nuclear accident occurred in 1986, and brought on changes in energy policy throughout the world, but does not seem to have had a long-term impact on Japanese energy policy. As an example, the Japanese nuclear R&D fell 63% in 1986-1988, but in 1989 it was above the 1986 level (IEA R&D data 1990-2010 PV). As a contrast, Germany decided to phase-out its nuclear power, which was very important for further legitimizing renewable.

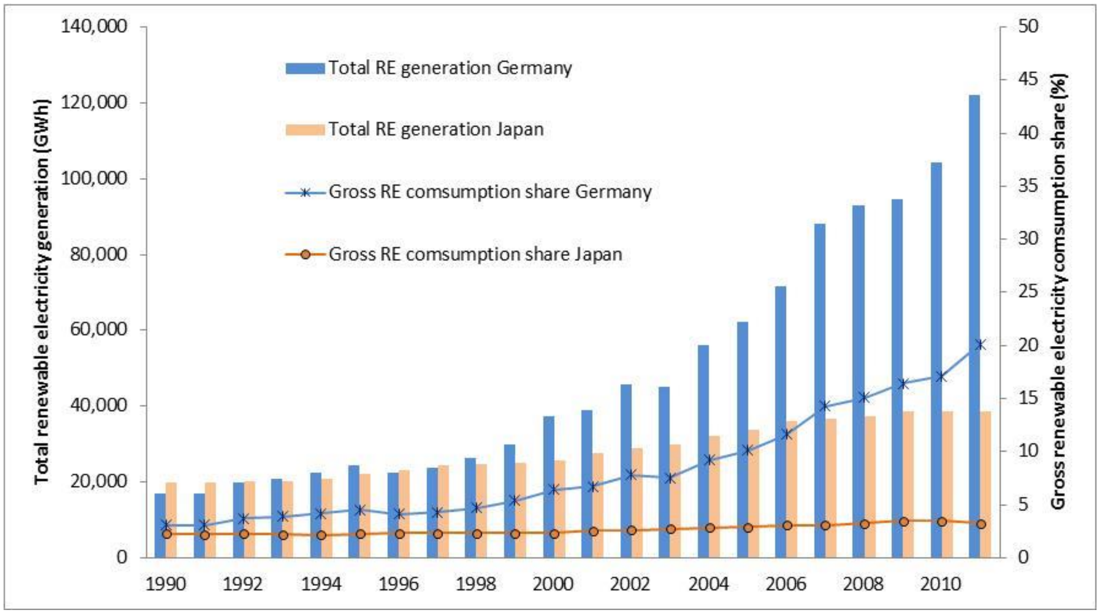

Figure 16. Comparison of total renewable electricity generation and Japan and Germany share, 1990-2011

(Created by collecting data from: EIA 2012; Japan Energy Data, 2011; Wikipedia, 2013, Japan electricity generation; RE-Japan, 2010; AGEE-Stat, 2011; AGEE-Stat, 2012)

Japan currently has 55 operating nuclear reactors with a total installed generating capacity of around 50GW, making it the third-largest nuclear power generator in the world behind the United States and France. Japan has promoted nuclear electricity over the years as a means of diversifying its energy sources and reducing carbon emissions. On the other hand, to satisfy the environmental obligation as reduction of CO_2 emission Germany is promoting renewable energy and continued to support the policy to stay away from nuclear energy. German policy concerning environment promote the renewable energy specially a large growth of solar power sector during last few years (GED, 2011; IEE, 2010; Karapin, R., 2012).

Chapter 8

Major photovoltaic companies: their role and contribution on the diffusion process

8.1 Major Japanese photovoltaic companies: production capacity and market share

In addition to national and local policy measures and utility company backing, PV manufacturers are also supporting PV system development by enhancing industry structure: accelerating the reduction in system costs, as well as expanding production capacity. It is expected that these activities will make a major contribution to the expansion of the domestic PV market. Currently, 11 major companies are manufacturing PV cells/modules in Japan: Sharp, Kyocera, Sanyo Electric, Mitsubishi Electric (MELCO), Kaneka, Mitsubishi Heavy Industries (MHI), Space Energy, Fuji Electric Systems, Honda Motor, Showa Shell Sekiyu and Clean Venture 21. These groups, some of the world's largest PV players, cover a range of technologies (RTS Corporation, 2008; RTS Corporation, 2009, Wikipedia, PV companies).

Major Japanese photovoltaic companies: The best-positioned Japanese companies are Sharp Solar, Kyocera, Sanyo, Mitsubishi, and solar frontier. Figure 17 shows the PV production of major Japanese companies from 1994 to 2011 (JRC, 2011).

Sharp began researching solar cells in 1959 with mass production first beginning in 1963. Since 2000, the Sharp Corporation has been able to feel like the world leader. Sharp was the world's leading manufacturer of PV modules until 2006. In 2001, the yearly production was only 94MW it increased rapidly and become 427MW in 2005. After 2005 its production growth became slow. Though Sharp has increased its production capacity every year but their production did not increase compare to German competitor Q-Cells which became number one PV producer in the world after 2006. After cautious expansion plans over recent years, Sharp increased production to 595MW in 2009. Sharp's solar cell business earned an operating profit of 3.3 billion yen in fiscal 2009, rebounding from a 16.1 billion yen loss in fiscal 2008. Solar sales in Japan jumped 2.3-fold on strong demand from the housing sector, accounting for 43% of Sharp's overall segment sales-compared with 25% a year earlier. For fiscal 2010, Sharp solar sales increased to 250 billion yen, up 19.8% over the previous year, and a production volume of

1170MW, up approximately 50% over the previous fiscal year. Recently, Sharp Corporation has announced a plan to increase its solar cell/module production capacity to 1800MW by 2012 (Figure 18).

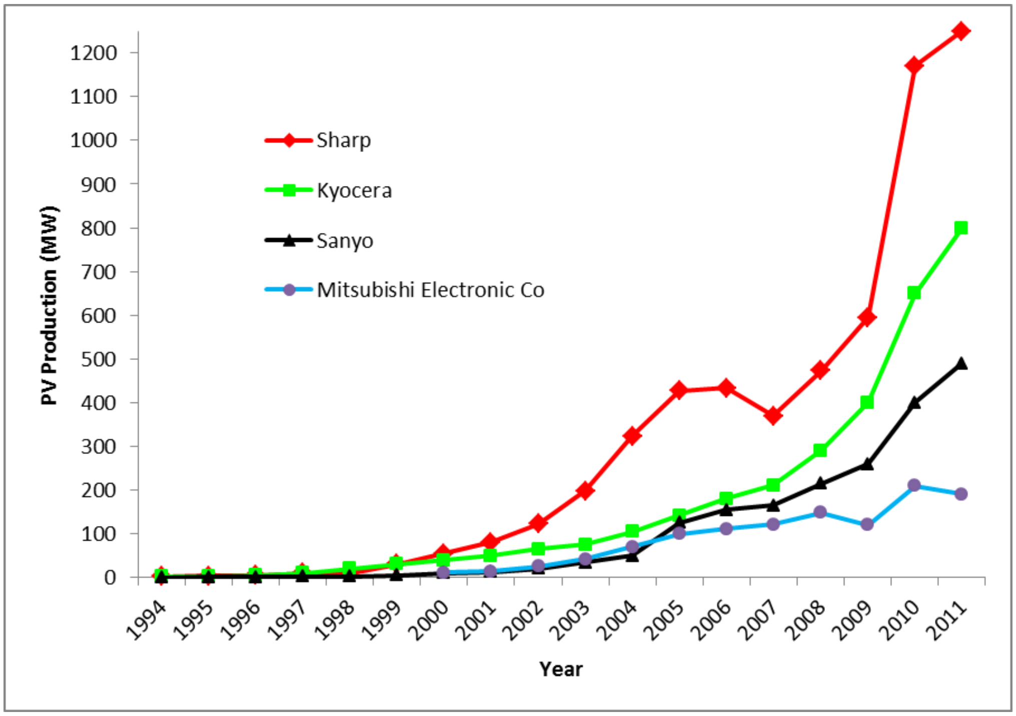

Figure 17. PV production of major Japanese companies: 1994–2011
(Created by collecting data from: IEA, 2003; IEA, 2004; IEA, 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012; JRC, 2011; PV news, 1990-2011; Wikipedia, PV companies, <http://en.wikipedia.org/wiki/List_of_photovoltaics_companies> (Accessed on June 2013))

Kyocera Corporation began researching photovoltaic in 1959 and has installed thousands of systems throughout the world since 1978. Kyocera increased its production capacity rapidly until 2006 when production capacity became 240 MW. After that they did not increase their capacity in 2007. After introducing government subsidy again in 2008, Kyocera increased its production capacity gradually and in 2011 production capacity became 800 MW. The company will reinforce production bases in Japan, the US, Europe and China, investing a total of about ¥30 billion through FY2010. Domestic sales accounted for roughly half of its total solar cell sales for the year, compared with 30% in fiscal 2008. As part of the new plan to increase yearly cell production, Kyocera has now completed the construction of a new cell manufacturing plant in Yasu City. This facility will operate in addition to the company's existing plant. New targets aim for an increase to 1GW annually by March 2013. Through this production enhancement, Kyocera looks to meet increasing demand across the world for solar cells (Figure 18).

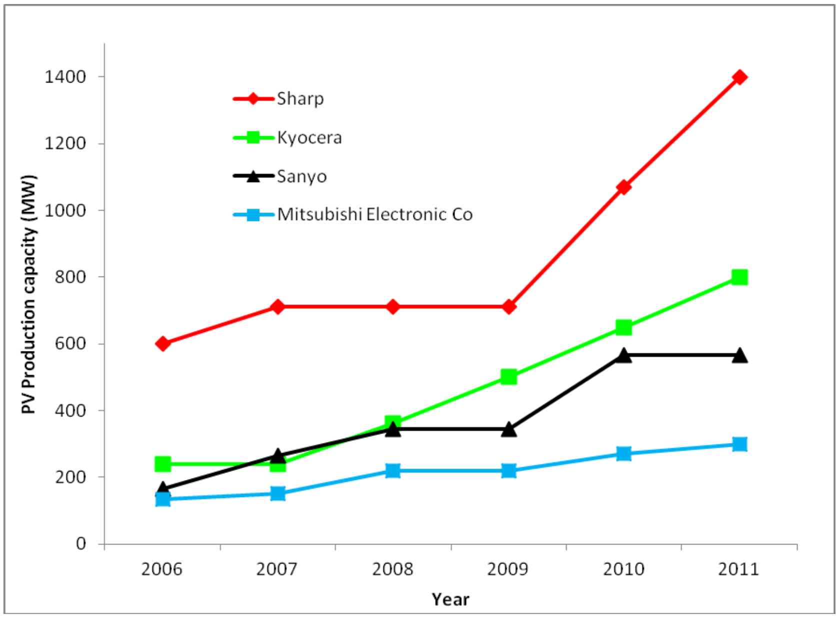

Figure 18. PV production capacity of major Japanese companies: 1994–2011 (Created by collecting data from: Chowdhury, S., 2012; IEA, 2003; IEA, 2004; IEA, 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012; JRC, 2011; PV news, 1990-2011; Wikipedia, PV companies, <http://en.wikipedia.org/wiki/List_of_photovoltaics_companies> (Accessed on June 2013))

Sanyo Electric: Japan's first installation of an on-grid photovoltaic power generating system for residential use was introduced by Sanyo in1992. SANYO Solar Ark was built in 2001, is one of the world's largest photovoltaic power generating systems. In 2003, its production capacity was only 38MW and increased rapidly to 265MW in 2007. In 2007, Sanyo completed a new unit at its solar module plant in Hungary. In late September 2008, Sanyo Electric Company, Ltd. announced its decision to build a manufacturing plant for solar ingots and wafers in Japan. The plant starts operation in 2009 and reaches its full production capacity of 70MW of solar wafers per year by 2010. Sanyo increased its capacity to 565MW by 2011. The company plans to start solar cell production at Panasonic's panel plant by early 2013.

Mitsubishi Electric Corporation has been working on the photovoltaic technology since the 1970s, when they made their first PV modules to provide power to satellites. Mitsubishi manufactures its cells without solder coatings, using environmentally conscious composite materials for crystalline silicon photovoltaic cell surfaces and silver electrodes. Mitsubishi Electric will attempt to meet the diverse demands of various countries and usage patterns. In 2003, its production capacity was only 50MW and increased rapidly to 300MW in 2011. Mitsubishi Electric plans to expand its annual production capacity to 750MW by 2012 (Figure 18).

In 2003, PV cell and module manufacturers were 9, i.e. Sharp, Kyocera, Sanyo Electric, Mitsubishi Electric, Kaneka, Canon, Matsushita Ecology Systems (former Matsushita Seiko), Mitsubishi Heavy Industries (MHI) and Hitachi. Sharps production capacity of sc-Si solar cell was 248MW. Solar cell and PV module manufacturers significantly increased their production capacity to correspond growing demand of solar cells and PV modules 2 years in a row. Estimated labor places were as follows; a) research and development b) manufacturing of PV systems components, c) all other, total about 11,300. In 2006 Japan's global PV production share became 37.5%, 10 companies are listed as PV cell/module manufacturers. Conventional solar cell and PV module manufacturers significantly increased their production capacity to correspond growing demand of solar cells and PV modules for 4 years in a row. Three new companies completed the factory of thin-film PV modules and are preparing for full-scale operation. In 2006, more than 900MW of solar cell was produced in Japan and the total exported shipment of solar cell/module was 629MW. Sharp enhanced production capacity to 600 MW/year, the world No.1 production capacity in October, 2006. In 2009, 11 companies were listed as PV cell/ module manufacturers. In addition to the existing manufacturers specialized in PV modules, namely Suntech Power Japan (former MSK), Fujipream, and YOCASOL, Choshu Industry entered this business in 2009. While several dozen companies manufacture inverters, over ten companies manufacture inverters for PV systems in Japan. Estimated labor places are as follows; a) research and development b) manufacturing of PV systems components, c) all other, about 26,700. In 2010, 12 companies were listed as PV cell/ module manufacturers. Overseas business activities of PV manufacturers: Solar Frontier (former Showa Shell Solar, Honda Soltec, YOCASOL, Itogumi Motech. In 2011, 13 companies were listed as PV cell/ module manufacturers: Sharp, Kyocera, SANYO Electric (current name is Panasonic by M&A), Mitsubishi Electric (MELCO), Kaneka, Mitsubishi Heavy Industries (MHI), Fuji Electric, Honda Soltec (Honda Motor Group), Solar Frontier (Showa Shell Sekiyu group), Clean Venture 21, PVG Solutions, Hi-nergy and Choshu Industry. Estimated labor places are as follows; a) research and development, 1000; b) manufacturing of PV systems components, 9000; c) all other 35,000; total about 45,000.

8.2 Major German photovoltaic companies: production capacity and market share

Integrated solar players of Germany are Q-Cells, SolarWorld, Schott Solar Conargy, Aleo Solar Sunways, Ersol Solar Energy. Among these downstream companies like Conargy, Aleo Solar Sunways, Ersol Solar Energy has very strong growth potential. Figure 19 shows the PV production of major German companies Q-cells, Schott Solar and Solar World from 2002 to 2011 (Wikipedia, PV companies).

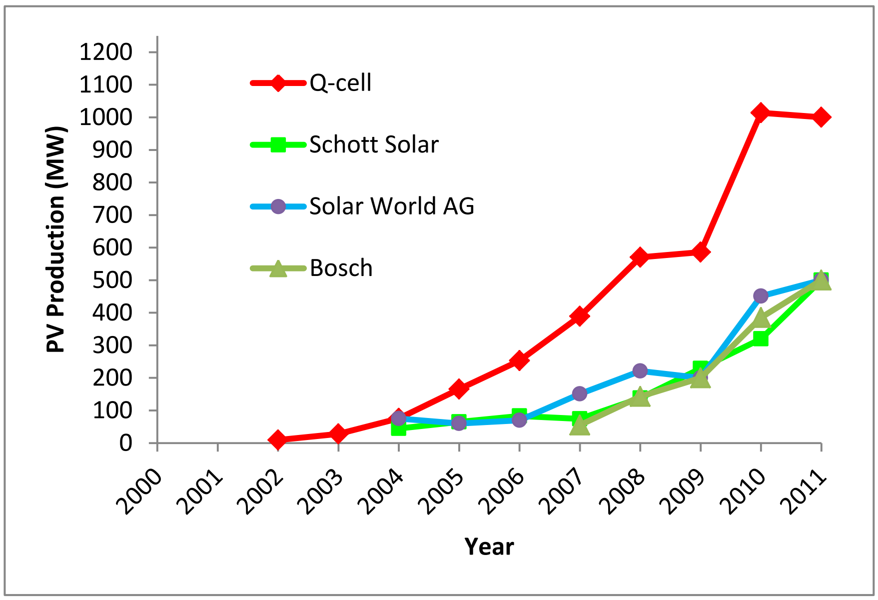

Figure 19. PV production of major German companies: 2002–2011 (Created by collecting data from: JRC, 2011; PV news 1990-2011; Wikipedia, PV companies, <http://en.wikipedia.org/wiki/List_of_photovoltaics_companies> (Accessed on June 2013))

'Q-Cells' is one of the world's largest cell manufacturer established in 1999, based in Germany. Since commencing production in 2001, 'Q-Cells' have grown rapidly and production capacity increased to1265MW in 2011 (Figure 20). In 2008, 'Q-Cells' produced 570MW electricity and its global market share increased to 8.3%. 'Q-Cells' has developed the performance of its cells as well as its technological production processes. 'Q-Cells' is also developing additional important technologies through partnerships for the commercialization of these technologies. Its core business is the development, production and marketing of high-quality (mono- and multi-) crystalline silicon photovoltaic cells. Recently, Germany's Sunfilm AG and Sontor GmbH have merged, becoming one of the world's largest providers of tandem-junction, silicon-based, thin-film modules. The new company will be named Sunfilm AG. Q-Cells increased production to 1000MW in 2011.

Solar World is a fast growing German company dedicated to manufacture and market photovoltaic products worldwide by integrating all components of the solar value chain. The group controls the development of solar power technologies at all levels in-house. Solar World was founded in 1988 as individual company, and engaged in projects to produce renewable energy. In 1998, these activities were transferred to the newly founded Solar World AG. SolarWorld purchased Shell Solar's crystalline silicon activities in 2006. In 2007 their production capacity was 160MW and they produced 151MW. SolarWorld has grown rapidly and production capacity increased to 800MW in 2011 and produced 800MW in 2011 (Figure 20).

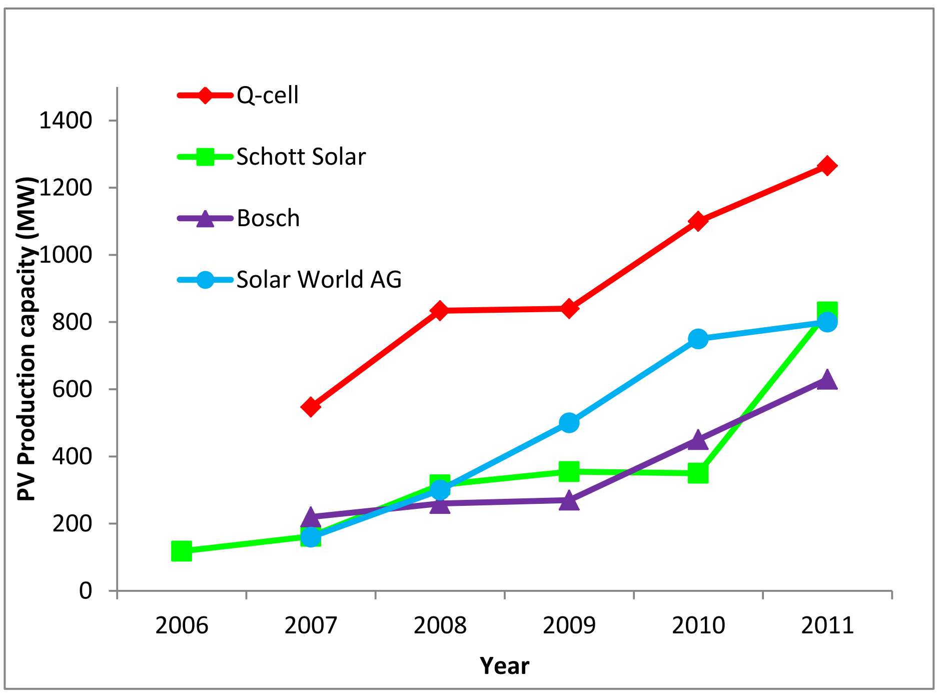

Figure 20: PV production capacity of major German companies: 2003–2011
(Created by collecting data from: Chowdhury, S., 2012; JRC, 2011; PV news 1990-2011; Wikipedia, PV companies, <http://en.wikipedia.org/wiki/List_of_photovoltaics_companies> (Accessed on June 2013))

Schott Solar is one of the world largest producers of solar photovoltaic technologies. In 1978, Schott solar introduced first series production of solar electricity modules in Europe.

1980 they developed the thin-film solar cells. In 1983, concentrated solar power plant (SCHOTT AG) was established. In 2006, its production was only 83MW and increased to 500MW in 2011. SCHOTT had worldwide production capacity of over 800MW in 2011. In 2009 SCHOTT opened the production site for solar receivers and solar modules in Albuquerque in New Mexico. In 2009-2011, Schott increased production capacity of crystalline PV cells and modules with a total of 450 MW. In addition, the company produced thin-film PV wafers with a capacity of 100 MW.

More than 20 companies have started manufacturing PV modules for all kinds of applications in Germany. Most of the German PV cell or module producers (Ersol, Q-Cells, PV Silicon, Sunways and many others) plan to extend their production lines or to increase their output in 2003. In 2002, module prices dropped significantly due to the political and economic situation in Germany and the growing competition by foreign producers. In total a number of about 7000 full time labor places existed at the end of the year 2002: wafer, cell and module industry, 2,200 employees and inverter production, 1,000 employees. In 2005, Calyxo, specializes in cadmium-tellurid technology, was founded. In 2007, Solar cell production (840 MWp) became higher than solar cell import (650 MWp). German foreign trade and inward investment agency lists about 70 companies involved in PV production creating a turnover of 8.6 billion EUR in 2009. In addition 62 PV equipment manufacturers supply tools for every step of the PV value chain. The BSW estimates that meanwhile around 10,000 companies with133,000 employees were active in the PV business. More than 200 companies are producer of cells, modules and components. Major German PV player Q-Cells increased its production capacity to 1100MW in 2010. In 2010, solar cell production in Germany increase to about 2000 MWp. In 2011, Germany is home to around 70 manufacturers of silicon, wafers, cells, and modules. In addition, there are over 200 PV material and equipment suppliers, more than 100 balance-of-system (BOS) component manufacturers, more than 50 PV research institutes and hundreds of project development, system integration and installation companies. The German PV industry currently employs a workforce of more than 130 thousand people.

Germany-passed Japan to lead the world in PV manufacture, producing an estimated 1470 MW of solar cells in 2008. German company Q-Cells out produced Japan's Sharp to become the number one manufacturer worldwide in 2007. Japanese companies markedly increase its production capacities up to 2005 after announcement of elimination of sunshine program they did not increase capacities at all. Sharp corporation continued to increase its production considering global PV market will increase specially the growth of German PV market. On the other hand, German PV companies started PV production later than Japanese PV companies but within very short time between 2005-2010 they increase their production capacity remakably, specially major German PV player Q-Cells increased its production capacity 1100MW in 2010. Though Japanese companies had the advantage of early start of PV business considering the technology and market share advantages compare to German companies, but they failed to keep their leading position. I think lack of future global market planning was the main reason for this decline.

The explosion of photovoltaic production across the globe completely reshuffled the top companies, knocking long established Japanese players out of the top spots. Japan's leading solar companies outline their strategies for this changing market. Fast growing Q-Cells AG became the world's largest solar cell maker in 2007, producing nearly 400MW worth of product. Recently, it increased production about 570MW on 2008. Longtime solar industry leader Sharp found itself in fourth place as production slipped to roughly 470MW (2008), which the company blamed on a constrained supply of silicon. China's Suntech has become second largest solar cell maker in 2008 with 500 MW output, pushing Kyocera with 290MW to a distant sixth.

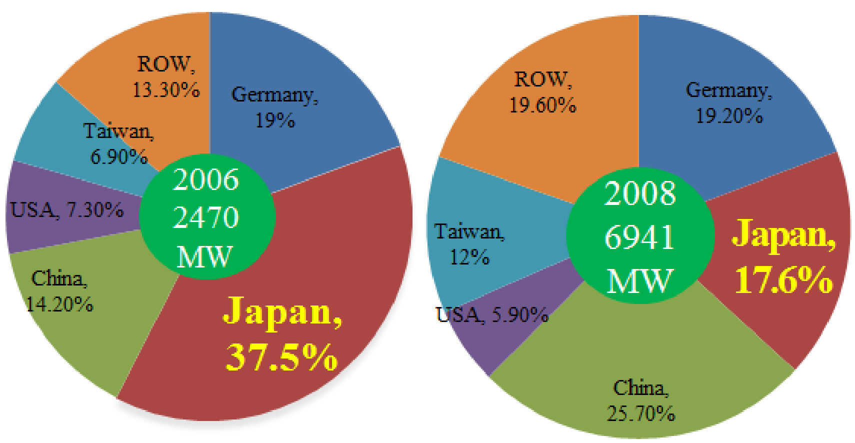

Figure 21. Comparison of different nations PV production share in 2006 and 2008 (Created by collecting data from Wikipedia, PV companies, < http://en.wikipedia.org/wiki/List_of_photovoltaics_companies> (Accessed on June 2013))

Figure 21 shows the total global PV production and its share of major nations of 2006 and 2008. We can see here, the total global PV production of 2008 increased three times than 2006. In 2006 Japan's PV production share was 37.5% and it decreased to only 17.6% in 2008.

This indicates that Japanese companies did not increase their PV production capacity considering the global market growth. The growth rate of Japanese companies' production capacity was unaligned to the growth of global market.

The Japanese solar PV market is in a state of flux; since the market's inception, the 'Big Four' module suppliers-Kyocera, Sharp, Sanyo (owned by Panasonic), and Mitsubishi-shaped PV in Japan while serving their primary suppliers. Foreign entrants like Suntech, Canadian Solar, Yingli, Trina, and JA Solar, as well as Japanese newcomers like Solar Frontier, threaten to dethrone the incumbents. While the country's new feed-in tariff (FIT), intended to develop the large-scale solar market, has positioned Japan as a center of global PV demand, the market's main driver is and will continue to be the residential sector.

In conclusion, German PV companies' production is increasing more rapidly than that of Japanese companies because of their aggressive future plans for increasing production capacity. On the other hand Japanese companies increase their production capacity rapidly from 2000 to 2004 considering Japan's PV market growth. After that Japanese PV market slowed down and Japanese companies did not increase their production capacity by speculating about the European market (Germany and Spain) that were rapidly growing (Figure 21).

Chapter 9

Roles of market-based incentives and research and development (R&D) investment

9.1 Roles of market-based incentive

Both Japan and Germany have implemented a variety of market-based incentive program since the late 1980s to become a key player in the growth of PV market. Table 6 summarize the market-based incentives, like PV installation subsidy/loan and feed-in tariff, and PV installed capacity of Japan and Germany from 1990-2011 to demonstrate gradual progression of PV market. Grants/subsidies and subsidized loans for PV installation programs are commonplace throughout the world, but the terms and conditions associated with them can vary significantly. Designing an effective feed-in tariff depends on a) the way in which the level of remuneration is determined and b) whether and how a tariff may change over time.

Buy-back system for the surplus PV power at the selling price has been implemented (net metering system) in Japan since 1992. During 1991-2005, a feed-in-tariff for the surplus PV power equivalent to the selling price (20-30 JPY/kWh) was offered which was below the supply cost of solar electricity. In 1993, “New Sunshine Project” an effort to create a Japanese solar photovoltaic industry and a domestic market for solar power was initiated. Installations of residential PV systems, in Japan, have been rapidly increasing since 1994 due to the public subsidy from “New Sunshine Project” and the net-metering system provided by electric power companies. This project funded the installations of over 1,100MW from 1992 to 2004. One reason Japan achieved this solar prominence can be attributed to the uninterrupted federal assistance. In 1997 national budgets for photovoltaic were 3,320MJPY for R&D and demonstration/field programs, and 11,110MJPY for market incentives. Subsidy system for industrialists who plan to introduce new energy was established. For the ‘Project for Supporting New Energy Operators’, the total budget from FY 1997 to FY 2009 was 318,103MJPY, included number of 34,480MJPY for FY 2010 would be added. In 2000 national budgets for photovoltaic of the METI totaled 28,210MJPY, of which 9,610MJPY were for R&D, 4,100 MJPY were for

Table 6. Market-based incentives (PV installation subsidy/loan and feed-in tariff), and PV installed capacity of Japan and Germany from 1991-2011

(Created by collecting data from: Chowdhury, S., 2012a, ; IEA, 2003; IEA, 2003a; IEA, 2004; IEA, 2004a; IEA, 2007; IEA, 2008; IEA, 2008a; IEA, 2010; IEA, 2010a; IEA, 2011; IEA, 2011a; IEA, 2012; IEA, 2012a)

	Japan			**Germany**		
Fiscal Year	Subsidy (%) (Subsidy, JPY/kW))	net-metering program [JPY/kWh]	PV Installed Capacity [MW]	PV module Installation subsidy/loan, Euro/kWp	Feed-In Tariff Rates Euro/kWh	PV Installed Capacity [MW]
1991	--	22	4	70%	0.1661	1
1992	--	22	4	70%	0.1653	1
1993	--	30	5	70%	0.1657	1
1994	50% (900,000)	30	7	70%	0.1693	1
1995	50% (850,000)	32.4	12	70%	0.1728	2
1996	50% (500,000)	31.2	16	--	0.1721	3
1997	33% (340,000)	25.2	32	--	0.1715	7
1998	33% (329,000)	23	42	--	0.1679	5
1999	33% (329,000)	25.2	75	3115-6230	0.1652	12
2000	33% (270,000)	25.2	122	3115-6230	0.574	44
2001	13% (120,000)	23	123	3115-6230	0.574	78
2002	13% (100,000)	20.4	184	3115-6230	0.574	118
2003	90,000	23.5	223	3115-6230	0.574	143
2004	7% (45,000)	24	272	3115-6230	0.574	635
2005	20,000	30	290	--	0.5453	906
2006	nil	nil	287	--	0.518	951
2007	nil	nil	210	--	0.4921	1274
2008	nil	nil	225	--	0.4675	1955
2009	70,000	48	483	--	0.4301	3799
2010	70,000	48	991	--	0.3405	7411
2011	48,000	48	1100	--	0.2874	7500

demonstration and field test programs and 14,500MJPY were for market incentives. In 2005, 109 MJPY budget was allocated for field test project on "photovoltaic power generation systems for industrial and other applications (1998 -2006)". Incentive for 'Project for Supporting New Energy Operators, Support for private businesses who introduce new and renewable energy' budget in FY2005 was 34,540MJPY. New Purchase System for Solar Power Generated Electricity started from April 2010 and run for 10 years, purchase excess PV power from households, 48JPY/kWh and schools and hospitals, etc., 24JPY/kWh. Subsidy for Residential PV systems was, 70,000JPY/kWh, started in November 2009, total 4,160MJPY was allocated for R&D related to PV power generation, 2,170MJPY for demonstration, and 43,050MJPY was allocated for market revitalization. In 2009, a new residential subsidy scheme has been announced with a budget of 9BJPY (around 76 million Euros) for 35,000 systems. Subsidies for measures to support introduction of residential PV systems was 40.15BJPY with supplementary budget of 14.53BJPY. Budget for Technology Development of Innovative Photovoltaic Power Generation was 6.38BJPY and for Japan-U.S. Smart Grid Collaborative Demonstration Project was 1.83BJPY. NEDO and the European Commission jointly launch a project (2011-2014) to develop concentrator photovoltaic cells aiming to achieve a cell conversion efficiency of more than 45%, with a budget of about 650MJPY provided by Japan and about 600MJPY provided by the EU. In 2011, the government allocated the budgets for "Subsidy for introducing residential PV systems as restoration measures" (86.99BJPY) and "Projects for establishing a fund for high penetration of residential PV systems as restoration measures" (32.39BJPY) were established as funds (FY 2011-FY 2013) to promote installation of residential PV systems.

As shown in Figure 13 and Table 6, the Japanese PV market decreased after the incentive program and the net metering system was eliminated in 2005. During 2006-2008, PV installation in Japan gradually decreased and became 210MW in 2007 due to end of subsidy program. World cumulative installed PV share of Japan decreased from 30.5% in 2003 to 14.5% in 2008.

Since 2009, PV installation increasing again due to new PV generated electricity purchase system, subsidy for new PV system installation and Feed-in Tariff Law (PV Status Report, 2011). A feed-in-tariff for the surplus PV power equivalent to the supply cost of solar electricity (48JPY/kWh) was offered. In addition, in 2009, the government has provided several hundred million dollars over the past two years to subsidize installation costs for non-residential solar (1/3 of project costs for the commercial sector, 1/2 for the public sector). So far 94% of the PV installed in Japan is grid-connected residential PV systems with governmental subsidies.

Very recently, the government implemented a new feed-in tariff for solar electricity production that is expected to dramatically increase solar energy adoption (PV Status Report, 2011).

During 1990-2000, a fixed feed-in-tariff rate of €0.16/kWh (total budget 3.5M Euro) was offered which was below the supply cost of solar electricity in Germany (BSW-Solar, 2008, 2009; DBCCA, 2011). During the 1990s, a public subsidy of 70% installation cost for a solar roof program (1991-95) resulted in 2,250 installations, representing approximately 5MW of installed capacity were of greater value promoting PV market. 50% of the investment costs under this scheme were funded by federal government, with a further 20% from regional governments. Until 1999, as shown in Table 5 and Figure 14, installations of residential PV systems in Germany were increased slowly. From 1999, PV installations increased rapidly under subsidy program of 100,000 roofs and Erneuerbare-Energien-Gesetz (EEG). Reduced interest loans totaling €695 million were offered by the federal government's banking institutions for a 100,000 PV roof installation program between 1999 and 2003. As recent as 2000, the German PV market had only installed 40MW of solar. However, the catalyst to Germany's rise to prominence within solar power was the replacement of the 1990 FIT by the 'Erneuerbare-Energien-Gesetz' (EEG) in 2000. The 2000 version of the EEG implemented fixed, stepped tariffs, in which the rates were differentiated according to the solar producer's costs, market-responsive incentive levels and increased accessibility, rather than longer tied to the spot price of electricity. Tariffs set based on detailed predictions of project costs to cover solar installation plus a reasonable profit. Total participation and the size of eligible systems were also uncapped, creating opportunities for many types of market participants. The EEG also introduced tariff digression rates, based on theoretical models of technology learning. The biggest benefactor of this new FIT was solar energy, with PV electricity receiving €0.57/kWh fed. Amendments to the EEG FIT in 2004 offered even greater levels of compensation for solar power, including €0.57/kWh for solar electricity from small roof-top systems and an increase in annual digression fees for PV energy to 5%. As a result, development of German PV market increased from 143MW in 2003 to 635MW in 2004 and 950MW in 2006. The EEG has required utilities to purchase PV energy from anyone willing to supply it. Remuneration varies by plant size and energy source, and rates are guaranteed to new system owners for a period of 20 years. Each type of owner is allowed to recoup their up-front costs and make a reasonable return on investment of 4-5% after tax. Tariffs decline annually based upon the market's response, with the cost shared equally among all ratepayers. The remuneration of solar electricity for PV modules installed in 2006 was almost ten times higher than the market price of conventionally produced electricity. In

January 2009, Germany introduced the KfW-"standard" program offers loans for electricity from solar PV (DBCCA, 2011). Stronger support for a potential correlation between the launch and refreshing of FITs and the growth in market share for electricity from solar energy sources can be found in Germany. In Germany, single-digit market share growth throughout the 1990s prompted by a combination of grants, loans, subsidies and a FIT was eclipsed by a higher level of annual growth after the 'Erneuerbare-Energien-Gesetz' (EEG) tariff in and 2004 revision.

In German Feed-in-tariff, solar electricity is exclusively fed into the grid. Whereas in Japan, solar electricity is used for own consumption first, only excess electricity is fed into the grid. A closer comparison of solar PV in Germany and Japan also suggests that market-based FITs were more effective at driving net capacity growth than tax incentives, net metering system and fixed FIT. Figure 14 illustrates that the pivotal year for solar PV in Germany was 2004, when their EEG FIT of 2000 was revised to offer higher levels of compensation, including for solar electricity from small roof-top systems and an increase in annual digression fees for PV energy to 5%. During 2000-2008, development of German PV market increased 42 fold from 126MW in 2000 to 5.3GW in 2008.

German residential PV installation continuously increased under stable and modified EEG program in form of a Feed-in-tariff (FIT). Germany Feed-in-tariff policy was very generous and it helped Germany to reach the world's top position with in a very short time (Figure 14). One of the benefits of the German FIT is that it provides economic incentives for end-use customers to buy PV systems. In this way, the market is greatly expanded from those who buy PV out of reasons of environmental consciousness to those interested in investment possibilities, thus also increase 'legitimacy'.

In Japan, the voluntary program for net-metering and buy-back of excess electricity from PV induces the 'formation of markets', and was very important for the formation of the grid-connected rooftop market. This market has been the most important one for PV in Japan during the last years. However, a difference between the net-metering system in Japan and the FIT system in Germany is that it does not provide enough economic incentives to make a PV system economically viable; electricity generated from a typical household PV system is twice as expensive as that bought from the grid. Another available support system, the RPS system (Renewables Portfolio Standard), does not seem to function to induce market formation either. The combined power of the Japanese support measures do not provide financial incentives for buying a PV, hence people buy PV for "emotional" reasons. 'The residential dissemination program’, though very successful for creating a market, was not connected to goals for actual PV diffusion.

From the Japanese and German’s incentives program we can say that Japanese sunshine project was a very good incentive program, it helped the Japanese PV business to flourish, but after 2003 the market share decreased and at the end Japan lost its position and reputation. On the other side, in Germany the policy Feed-in tariff started from 1991 and is still working on for the PV business in Germany. The incentive program is also helping the consumers to make the system affordable to them. As shown in Figure 12, during 2003-2011, Japan global PV market share decrease from 30.5% in 2003 to 11.7% in 2009. On the other side, German PV market share markedly increase from 15% in 2003 to 45% in 2009.

9.2 Research and Development (R&D) Investment

R&D is necessary to reduce the cost and improve the performance of PV technologies in order to make them more competitive with conventional energy sources. Research and development investment will down the price of solar power and performance improvements could help a nation retain its status as a leading global producer of solar technology. To provide insight into the political will to switch to sustainable energy production and use, especially PV energy, we reviewed the government R&D support and also compare R&D expenditures for PV to nuclear power of Japan and German.

R&D activities under Sunshine Project continued from 1974-1994. R&D activities under “Residential PV System Dissemination Program’ 31,475 Residential PV Systems were installed in total from 1994 to 1999 (114.6MW). Budget for 1994 was 2,030MJPY. Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications (1998-2006) started in 2000, with 149 cases (3,680kW) and 4,000MJPY budget. Project for Supporting New Energy Operators Support for private businesses who introduce new and renewable energy continued with more budgets. Total budgets for R&D were 9,610MJPY and for demonstration programs was 4,100MJPY. NEDO started “R&D for Next Generation PV Systems (FY 2006 - FY 2009)”, a new 4-year technological development plan, based on the roadmap for technological development of PV systems, “PV Roadmap 2030 (PV 2030)”. In 2006, total budget was 11,800 MJPY for the “Field Test Projects on Advanced Photovoltaic Power Generation Technology” (662 cases, 22,080kW installed). Project for Promoting the Local Introduction of New Energy (FY 1997 -) total budget from FY 1997 to FY 2009 is 111,749

MJPY. Project for Supporting New Energy Operators (FY 1997 -), the total budget between FY 1997 and FY 2009 was 318,103 MJPY. NEDO and the European Commission jointly launch a project (2011-2014) to develop concentrator photovoltaic cells aiming to achieve a cell conversion efficiency of more than 45%. The City of Yokohama, Toyota City, Keihanna Science City and the City of Kitakyushu are engaged in major demonstration tests of smart grid technologies (test period 2011–2014).

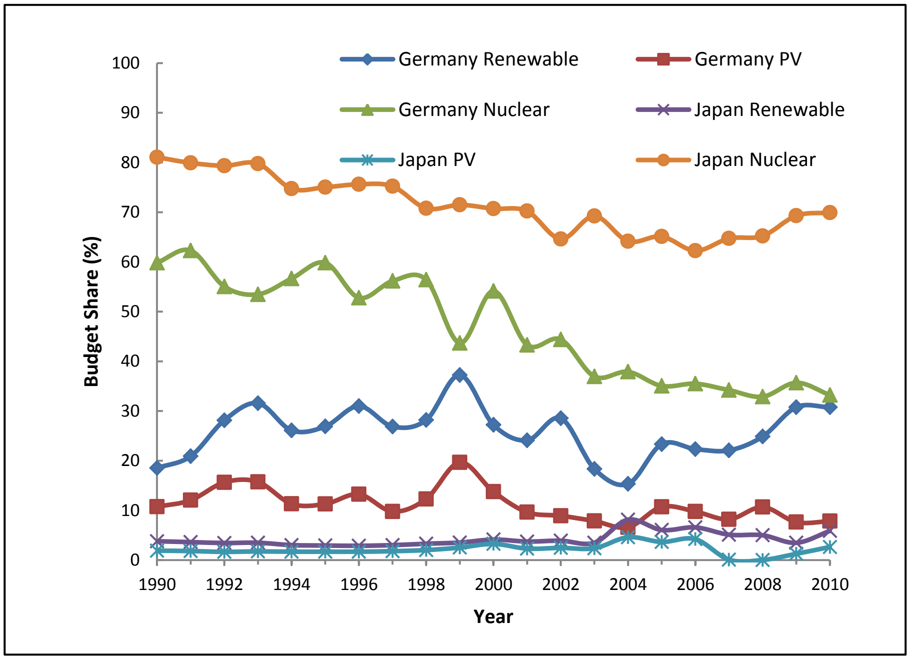

Figure 22. Government R&D expenditures for PV, renewable, and nuclear power (Source: Chowdhury, S., 2012a)

Japan has had an active nuclear power program since nuclear research began in the country in 1954. Nuclear energy contributed prominently into Japan's national electricity mix. Japan currently has 53 nuclear power plants in operation with a total generating capacity of 46 GW (Japan Energy Data, 2011). Nuclear power currently represents 18 percent of the country's total electric capacity and provides 30 percent of the country's electricity generation. Japan's level of renewable energy R&D investment has remained relatively constant over the past ten years (Figure 22) (IEA R&D data 1990-2010 PV). The majority of public funds for energy R&D went to nuclear power, which received about 70% of the total.

On the other side, in Germany, public R&D funds for nuclear energy was 60% in 1990 which was continuously decreased and become 40% in 2010. The review of public R&D budgets shows that Japan's expenditures for PV amount to approximately $1.0 billion in 2000, which was an account for only 3%, the total energy R&D investment. During 2001-2006, Japan's expenditures for PV increased little but again decrease during 2006 to 2010. Alternately, in Germany, renewable energy R&D expenditures continuously increased during 1990-2010, which was 18% in 1990 and increased to 38% in 2010. Germany's expenditure for PV has remained relatively constant over the past ten years which received about 10% of the total. With respect to public R&D budgets on renewable energy as well as PV, Germany stands out Japan. Germany is vigorously developing a domestic as well as an export market for PV. Germany performs high with regard to R&D spending and also host manufacturers of PV cells or panels and enables market growth for PV. Public R&D expenditures are generally a minor fraction of the GDP. The only exception seems to be nuclear R&D in Japan, which accounts for 0.6% of its GDP. This is about seven times higher than the corresponding amount for Germany. It is noteworthy; however, that nuclear R&D in Germany is declining, whereas R&D budgets for, renewable energy as well as PV are increasing. Summarizing, it is concluded that German public R&D programs for renewable energy tend to be linked to the envisioned position of clean energy and -to a lesser extent- in nuclear power generation.

Chapter 10

Comparison between solar electricity and grid electricity cost (solar gap) in Japan and Germany

10.1 PV system price in Japan and Germany

The ‘gap’ between the price of solar electricity and the price of grid-based electricity is needed to evaluate its impact on PV market demand. Solar modules, together with some additional components, such as inverters, balance of system (BOS), form a PV system. The continuing technical development of product components and production processes has paved the way for considerable cost reductions for photovoltaic systems in recent years. In the last 10 years, production costs have decreased by 60%. The energy yield of modern photovoltaic systems has increased significantly. Research and industry are working intensively on the development of even more cost-efficient cell materials, especially for thin-film cells. The industry estimates that the anticipated expansion of the market will result in an average cost reduction of 5% per annum.

Japan PV system price decreased quickly during the period 1992-2005. The decrease in gross system prices resulted from a decrease in module prices and from a decrease in the price of non-module system inputs. Over this period, average PV system prices declined 84% from over 4100yen/Wp in 1992 to under 660yen/Wp in 2005 as shown in Figure 23. From 2005-2008, PV system prices were almost constant and again start decreasing since 2009 and become 520yen/Wp in 2011. German PV installation increased rapidly during last 10 years and a total of 7.5 GW in 2011. As capacity has risen, German PV system cost decreased approximately 76% between the years 1992 to 2011. Over this period, average PV system prices decrease from over 10.23 Euro/Wp in 1992 to less than 2.45 Euro/Wp in 2011. As shown in Figure 24, from 2000-2007, German PV system and module prices were decreased slowly and after 2007 prices start decreasing rapidly and become 2.45 Euro/Wp in 2011. It is note-worthy that non-module price reductions compare to module price reductions were significant in both Japan and German PV markets.

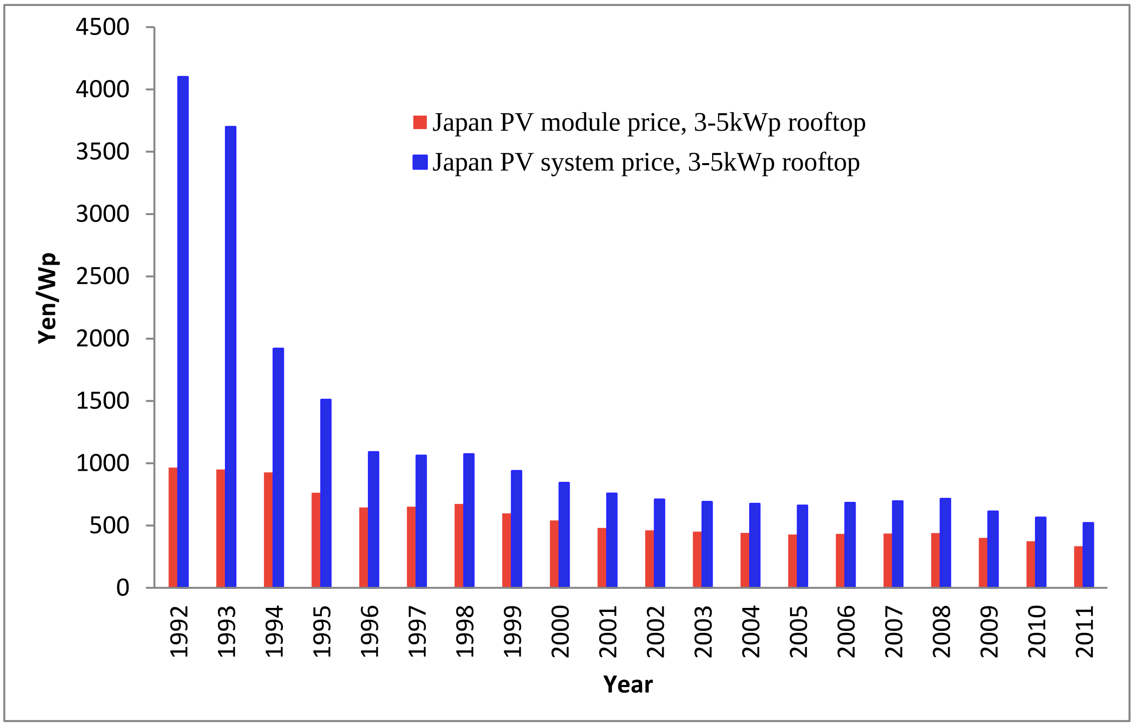

Figure 23. Decreasing Japan PV module and system price from 1992-2011 (Created by collecting data from: IEA, 2003; IEA, 2004; 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012; RTS Corporation, 2012; RTS Corporation, 2011; METI, 2010)

10.2 Grid parity in Japan and Germany

Levelized cost of electricity (LCOE) is the price of electricity (price/kWh) necessary over the life of the solar power system to cover the cost of installing the solar power system, maintaining it over its lifetime, paying for principle and interest on debt and accounting for the time-value of money. The purpose of this modeling effort was to evaluate the price of solar power as perceived by end customers and then to compare it with the price of the grid-based residential electricity price. Levelized cost of electricity (LCOE) depends on performance, system costs, and ongoing operations and maintenance over the lifetime of the system. It takes into account capital costs, ongoing system costs, financial rates (discount rates, taxes, etc.), utilization and fuel costs (if any). All this is taken into account over the lifetime period of the power plant while considering the total amount of energy that is produced over this period. The less a system costs and the more energy it produces, the lower the LCOE. The mathematical definition of LCOE is conceptually simple:

$$\text{LCOE} = \frac{Total\ Lifetime\ Costs}{Total\ Lifetime\ Energy\ Production}$$

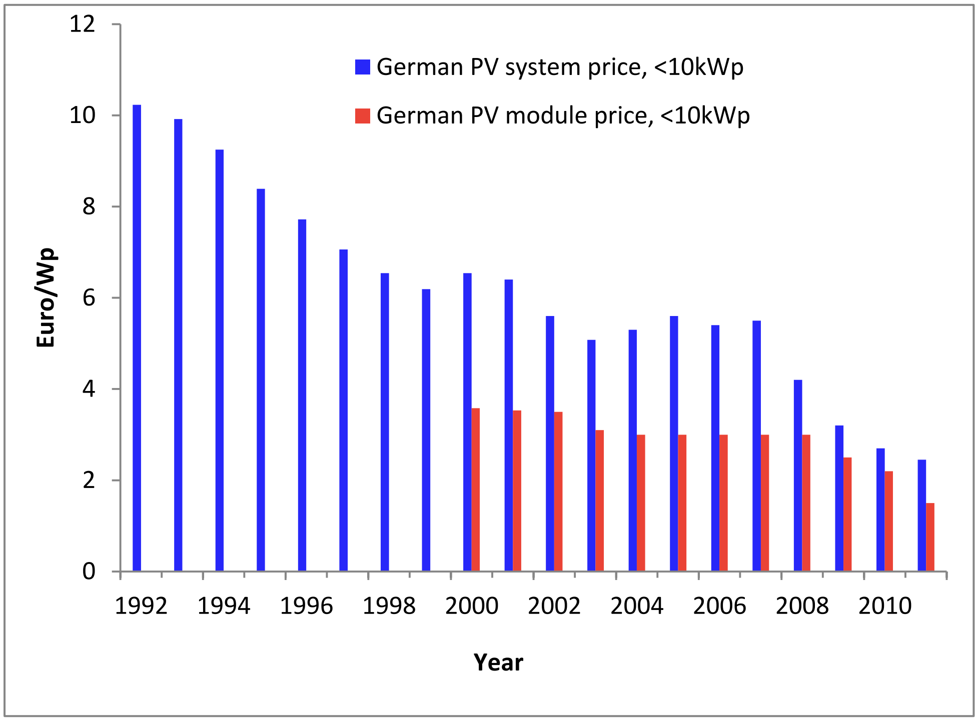

Figure 24. Decreasing German PV module and system price from 1992-2011 (Created by collecting data from: BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar ,2011; BSW-Solar, 2012; IEA, 2003a; IEA, 2004; IEA, 2004a; IEA, 2007; IEA, 2008; IEA, 2008a; IEA, 2010a; IEA, 2011a; IEA, 2012a; ISE, 2012)

Figure 25 shows the levelized cost of electricity (LCOE) and grid electricity price in Japan from 1993 to 2012. The LCOE decreased significantly during this period. Japanese LCOE was 260 yen/kWh in 1993. After that it rapidly decreased to 46 yen/kWh with in 2004 and remained almost constant until 2008. By 2004, the LCOE had decreased 83% compare to 1993. From 2009, LCOE start decreasing again and become 38.3 yen/kWh in 2012. On the other hand, the LCOE in Germany also decreased significantly during the period 1993 to 2008. Figure 26 shows the LCOE and grid electricity price in Germany from 2000 to 2012. The LCOE was roughly 111 €ct/kWh in 1993. By 2004, the LCOE had decreased 49% to 57 €ct/kWh and further decreased to 24.5 €ct/kWh in 2012.

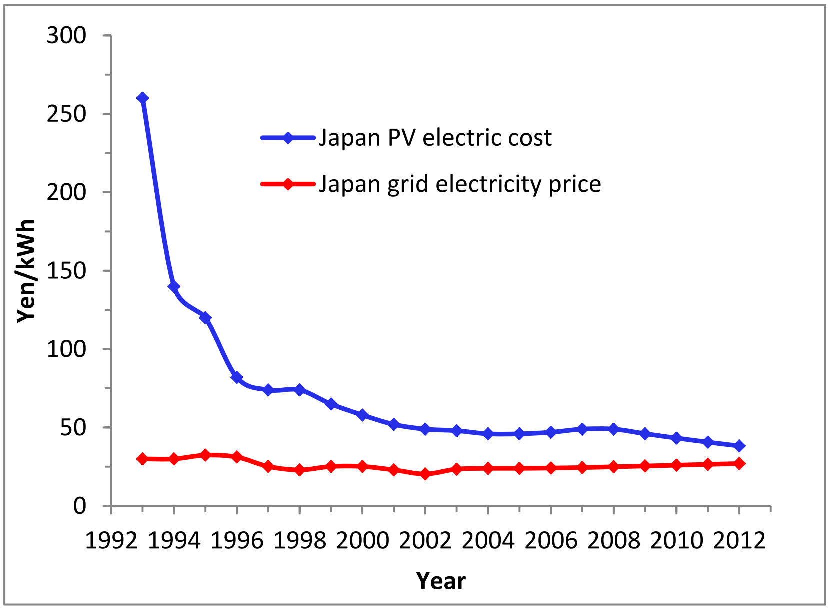

Figure 25. Japan PV electricity price (LCOE) and grid electricity price from 1993-2012 (Created by collecting data from: IEA, 2003; IEA, 2004; 2007; IEA, 2008; IEA, 2010; IEA, 2011; IEA, 2012; RTS Corporation, 2012; RTS Corporation, 2011; METI, 2010)

As we can see from Figure 25 that the grid electricity price in Japan changed from 30 yen/kWh in 1993 to 27 yen/kWh in 2012. We can see here electricity price gap between PV electricity price and grid electricity price in 1993 was 230 yen and it decreased to 22 yen in 2004. From 2005-2008 it was almost constant and again start decreasing from 2009 became 12yen in 2012. During 2000-2012, (Figure 26) German grid electricity price has increased from 15 €ct/kWh in 2000 to 25€ct/kWh in 2012. German electricity price gap was 42.4 €ct in 2000 and it became same as grid electricity price in 2012. In 2004 German energy price gap was 38.4 €ct (>50 yen) whereas Japanese energy price gap was only 22 yen. Between 2004-2008 Japan electricity price gap was lower than that of Germany. Although German PV electric price is higher than Japan, German PV market is growing very fast and demand for PV system is rising. This is because of their government policy to buy back all electricity produced by solar PV. Grid parity is the point at which photovoltaic electricity is equal to or cheaper than grid power. Achieving grid parity is the long term goal of the solar power sector. For estimating the time that it would take solar power to reach parity with (or cross-over) average residential grid price in various markets depends on the volume growth rate of the sector, the cost reduction associated with learning and scale and the annual increase in nominal average residential grid prices.

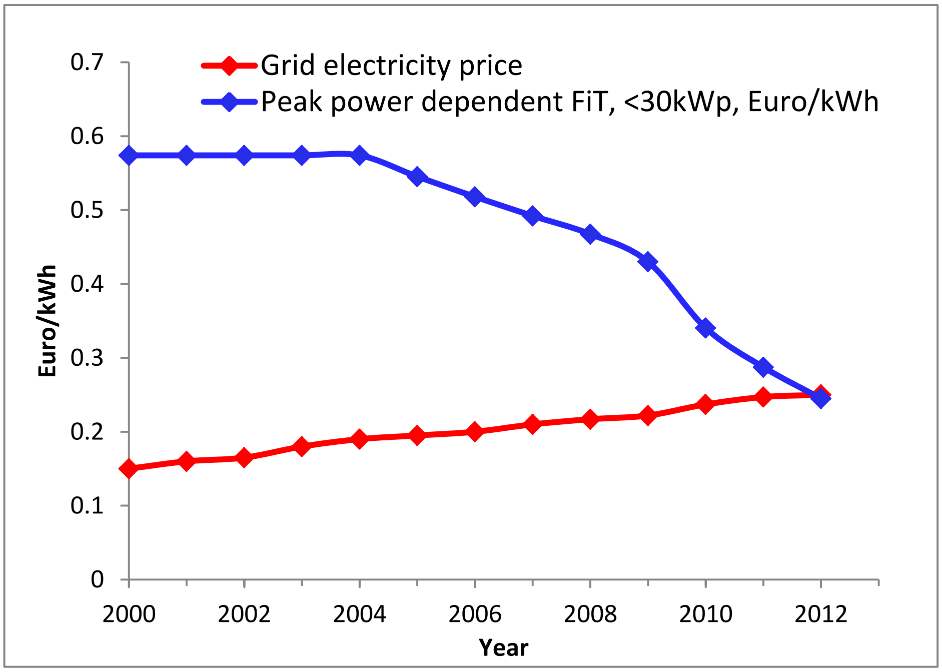

Figure 26. Germany PV electricity price (LCOE) and grid electricity price, 2000-2012 (Created by collecting data from: BSW-Solar, 2007; BSW-Solar, 2008; BSW-Solar, 2009; BSW-Solar, 2010; BSW-Solar, 2011; BSW-Solar, 2012; Industry Overview, 2012; DBCCA, 2011)

Many electricity customer segments in Germany are now able to produce PV electricity cheaper from their roofs than buying electricity from the grid due to sharp fall in PV rooftop system prices in recent years. With a strong digression in recent years, the German feed-in tariff (FIT) has driven this development and the government reduced FITs with a stronger digression rate than expected. Today, the FIT for a rooftop project is already below the level of domestic household electricity prices. This makes it financially more attractive for the PV system owner to directly consume the solar electricity generated than make use of the FIT.

One of the primary inhibitors for the Japanese market has been its high system prices compare to German market. Some of the major factors contributing to these high prices include: Significant subsidy programs in combination with a lack of downstream competition allowing installers to charge high prices, because of domestically produced panels and BOS materials. Preferential use of expensive products such as high-efficiency panels, panels with black or alternative back sheets, or triangular panels. High cost of acquisition of customers, such as expensive marketing schemes including television commercials, door-to-door sales, complicated distribution networks. Sales of products almost exclusively in kits generally include monitoring and other high-cost items such as LCD screens for the monitoring systems. The Japanese yen is valued at a near all-time high compared to the euro or USD at August 2012 foreign exchange rates. This was true throughout 2011, as well. At last the high labor costs compare to other countries.

The sales and distribution channels in Japan are unique and relatively complicated and inefficient compared to European or American markets. Until very recently, there have been very few solar specialists in Japan, and one of the main sales channels has been through home builders. Compare this to the United States or Germany, where the vast majority of residential systems are installed by companies that specialize in solar installations. Many home builders integrate solar systems into the home during construction. In these cases, PV system costs are wrapped into the home mortgage. ‘Eco’ homes are now very popular, especially since the Fukushima disaster and resulting electricity shortages. Sales of home energy management systems (HEMS) and battery storage systems alongside solar systems are becoming popular as well. The percentage of new homes with solar in Japan is rising.

Chapter 11

11. Assessment of PV innovation system of Japan and Germany by using the technological innovation system (TIS) framework

The innovation and diffusion process is both an individual and a collective act (Saxenian, 1994), and that the determinants of technology choice are not only to be found within individual "firms, but also reside in an 'innovation system, which both aids and constrain the individual actors making a choice of technology within it. This "innovation system'' includes a large number of variables apart from prices. The method chosen in this study is to compare and contrast the functional pattern of the primary system of a country (Japan) with that of another countries (Germany) technological innovation system. By a comparison of the functional pattern of the two countries, we may find commonalities and differences, which lead to an assessment of the primary system's performance (Bergek, A. et al. 2008).

11.1 Assessment through system comparison:

Japan and Germany PV innovation system will be assessed with TIS through the evaluation of the seven system functions. All events/activities, from 1990-2011, of the system functions are summarized here. The system functions are rated considering the activities of the year 2011. The function fulfillment of seven system functions of Japan and Germany will be compared using spider diagram. The events linked to the System Functions and its scores are transformed into a narrative on how the TIS developed over time.

Common features and differences between the development of PV in Japan and Germany are designed here and also explained in terms of seven system functions, aiming at assessing how well different functional processes are performing. In the end, blocking and inducement mechanisms for the functional dynamics of the Japan and German PV innovation system will be summarized (Jelse, K., Johnson, H, 2008, Blommerde, J. 2011).

11. 2. Discussion of seven system functions of Japan and Germany from 1990-2011 and rating of the level of fulfillment of each function in the context of the year 2011

11.2.1 Entrepreneurial Activities (F1): To translate knowledge into business opportunities and eventually innovations

F1: Entrepreneurial Activities: Japan

In 1990 PV development under the Sunshine Program was firstly joined by major appliance producers, including Sharp, Matsushita, Hitachi, Toshiba, and NEC (Nippon Electronics Company). It was later joined by Kyocera, Sanyo and more others. Sunshine Program was the biggest stimulus for these firms to expand their activities of PV development (1980's and 90's). Kyocera, Sanyo, and Sharp, played critical roles in the development process of PV technology. These ambitious producers acted as “prime movers”, investing in-house resources in R&D much more than governmental subsidies and lobbying the government for creating market-pull policies. Many companies participated in NEDO projects like “New Sunshine Project-1st Stage” (1990-2001), super high efficiency, (1990-2005), Amorphus Si PV (1985-2000). In 1990, PV production was 16.8 MW. 1992, Sunshine Program promoted a number of demonstration projects, including distributed small applications as well as a large scale solar generation plant (1 MW plant in Saijo City). Until 1995, total PV market share was only JPY 10-15 billion. This lack of market made several participant firms in the Sunshine program, including Hitachi, Toshiba, and NEC, withdraw from PV business. Kyocera, Sanyo, and Sharp, hung on to continue PV development. NTT (Nippon Telegraph and Telephone Corp.) started PV System Introduction Plan to their own facilities. In 1997 Regional new energy introduction projects started. The growing PV market has attracted new entrepreneur, Sanyo (1997) to the development and production of PV. In 1998 PV System Field Test Program for Industrial Use started. PV production increase to 49MW faster than earlier years. In 1999 PV module production was 80MW. In 2000 Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications started, PV production became 5 times compare to the year 1990. Production increased to 129 MW. In 2002, New entrepreneur Mitsubishi Heavy Industries (MHI) participated, (2002) to the development and production of PV. PV production increase faster than earlier years and become 171 MW in 2002. In 2003, total PV cell and module manufacturers were 9, i.e. Sharp, Kyocera, Sanyo Electric, Mitsubishi Electric, Kaneka, Canon, Matsushita Ecology Systems (former Matsushita Seiko), Mitsubishi Heavy Industries (MHI) and Hitachi. In 2003, production increased to 364 MW. Solar cell and PV module manufacturers significantly increased their production capacity to correspond growing demand of solar cells and PV modules. In 2004, there were about 13 major PV module manufacturers in Japan. The world's leading PV companies, such as Sharp, Sanyo, Kyocera, Mitsubishi, and Kaneka are all Japanese. Sharp is the number one PV manufacturer, followed by Sanyo and Kyocera. That year PV module production was 600 MW. In 2004, Fuji Electric Systems entered the PV market with an amorphous silicon PV module designed for rooftop installations. Kyocera becomes second largest PV module producer in the world with 105 MWp of product. Sharp produces mono-crystalline, poly-crystalline, and amorphous PV modules. Annual production of about 315 MWp in 2004 with plans to expand production to 500 MWp by the end of 2005. Sanyo is one of the oldest PV companies in Japan and rapidly growing their PV production capabilities, increased PV production by 50 percent in 2005 compared to 2004. In 2005, Kaneka started production of a-Si see-through PV modules. PV cell/module production was 825 MW in 2005. Mitsubishi announced to increase its production capacity from 100 MW to 255MW by 2006. In 2006 Japan's PV production share became 37.5%, 10 companies are listed as PV cell/module manufacturers. Conventional solar cell and PV module manufacturers significantly increased their production capacity to correspond growing demand of solar cells and PV modules for 4 years in a row. In 2006, more than 900 MW of solar cell was produced in Japan and the total exported shipment of solar cell/module was 629 MW. Sharp increased production capacity to 600 MW/year in 2006. It was the world No.1 production capacity. In 2007, estimated total employees places are about 17, 700 including research and development, manufacturing of PV systems components, and other. In 2007, production volume of solar cells and PV modules in Japan decreased to 845 MW, down from 927 MW in 2006, affected by supply shortage of silicon feedstock. Major Japanese companies markedly increase their production capacities up to 2005 after elimination of sunshine program they did not increase capacities at all, except Sharp. In 2006 Japan's PV production share (global) was 37.5% and it decreased to only 17.6% in 2008. In 2009, 11 companies were listed as PV cell/ module manufacturers. In addition to the existing manufacturers specialized in PV modules, namely Suntech Power Japan (former MSK), Fujipream, and YOCASOL, Choshu Industry entered this business in 2009. While several dozen companies manufacture inverters (power conditioners), over ten companies manufacture inverters for PV systems in Japan. In 2009, PV module production was 1487MW and total PV related employees were estimated to about 26,700. In 2010, 12 companies were listed as PV cell/ module manufacturers. About a dozen (12) companies manufacture inverters for PV systems in Japan. In 2010, estimated total employees places are about 41, 300 including research and development, manufacturing of PV systems components, and other. PV cell/module production increased to 2182MW. PV production increase abruptly last few years and become 2725 MW in 2011. Electric utilities constructed MW-scale PV power plants ahead of schedule and a great number of such PV power plants were completed in 2011 across the nation, from Hokkaido to Okinawa.

In 2011, 13 companies were listed as PV cell/ module manufacturers: Sharp, Kyocera, SANYO Electric (current name is Panasonic by M&A), Mitsubishi Electric (MELCO), Kaneka, Mitsubishi Heavy Industries (MHI), Fuji Electric, Honda Soltec (Honda Motor Group), Solar Frontier (Showa Shell Sekiyu group), Clean Venture 21, PVG Solutions, Hi-nergy and Choshu Industry. Japanese PV manufacturers were facing a tough business environment amid stricter-ever competitions in the global PV market, influenced by progressing yen's appreciation, significant price reduction of PV products globally, full-fledged entries by overseas manufacturers, mainly emerging manufacturers into the Japanese market. The Japanese PV manufacturers sought for a new business development in 2011. Adoption of feed-in tariffs by Japan is a seeming endorsement at the highest international level that rapid development of renewable energy is desirable. The widely expected passage of the new law has unleashed a burst of entrepreneurial activity not seen in Japan for some time. Japanese firms are already lining up projects to take advantage of the new policy, Mitsui and Toshiba's plans to build a 50 MW solar PV power plant in Aichi Prefecture by 2013. Japanese companies are now furiously trying to catch up. The new law will create a dynamic solar market on their home turf, possibly giving Japanese solar companies a new volume edge on the global scene. Meanwhile, with the rapid expansion of domestic PV market mainly driven by the residential PV market as well as non-residential PV market which is expected to expand in 2012, many companies reviewed their PV business and many others entered the PV market. In 2011, estimated labor places are as follows; a) Research and development, 1000; b) Manufacturing of PV systems components, 9000; c) All other 35000; Total about 45000.

F1: Entrepreneurial Activities: Germany

In 1990 Projects on grid-connected as well as on state-alone systems are being supported by German Federal Ministry for Research and Technology (BMFT). Since 1998 different projects started: Crystalline Silicon materials development; crystalline silicon and module development; thin film technologies project. In September 1990, BMFT and Federal States jointly started, "1000 roofs program", an installation of 1500 small (1-5 kWp) PV systems on the roofs. 1000 roofs program started in 1990 and continued until 1995. As the solar industry did not profit from the Energy Feed-in Law (StrEG) of 1991, because compensations did not cover production costs, German solar cell production was almost non-existent by 1994. Solar Fabrik GmbH, started PV module production (75W-115W) in 1997 in co-operation with Astropower. Solarwatt Solar-Systeme GmbH; started production of custom made PV modules in 1997.

Solarnova GmbH developed and erected a special production line for custom made modules (50W-100W) and produces since 1998 in a new building. In 1998, PV module production was 5MW. In 1999, “100,000 roofs program” started to drive further expansion of the industry. The program aimed to drive down the price of solar PV and invited private entities to participate. Solar Fabrik GmbH started module production since 1999. Sunways A.G came with Production of mc-Si solar cells and of semitransparent power cells. As government action opened windows of locational opportunity for the PV industry at the end of the 1990s, the first wave of market entry by PV producers in Germany can be observed. The first market entrants of a specific supply industry emerged from co-operation projects around the year 2000. In 2000, PV production was 15.9MW. Q-Cells AG, A new company came in the market in 2001. Siemens Solar and Shell Solar have merged to a joint venture, the Siemens & Shell Solar GmbH. In 2001 Solarwatt Solar-Systeme GmbH; a new 3 MW production line was installed. Würth Solar GmbH Started a small pilot production line for CIS thin-film cells/modules in 2001. RWE Schott Solar is a joint venture between RWE Solutions AG and Schott Glas AG, founded in October 2002. The extension of the production capacity of cells and modules of most German producers in Germany (Solarworld (Deutsche Solar), RWE Schott Solar, ErSol, Solon) was slower than predicted. Two large companies on the German PV market, Solar World (Deutsche Solar, GPV) and RWE Schott Solar are still following the strategy to a full integrated solar factory containing the most important steps of PV modules production in their company. This guarantees more independence of the fluctuation of the PV market. In 2002, wafers were fabricated by three companies: the Deutsche Solar, former Bayer Solar, in Freiberg, PV Crystalox Solar in Erfurt, and RWE Schott Solar in Alzenau. Five companies have produced solar cells in 2002 applying different technologies such as sc-Si, mc-Si, EFG, a-Si and transparent power cells. PV module production was 57MW in 2002. More than 20 companies are started manufacturing PV modules for all kinds of applications in Germany. Most of the German PV cell or module producers (Ersol, Q-Cells, PV Silicon, Sunways and many others) plan to extend their production lines or to increase their output in 2003. Module prices dropped significantly. Reasons for this were the political and economic situation in Germany and the growing competition by foreign producers.

In total a number of about 7000 full time labor places existed at the end of the year 2002. About 2,200 employees worked in the German wafer, cell and module industry. Another 1,000 jobs existed in the inverter production. The PV module production increased in 2003 with the help of 25 German PV module manufacturers and the total PV module production amounted to 82.4 MW. As a result of the strong market growth and the emergence of new technological solutions, a second wave of market entries by new companies occurred after 2003. CSG Solar, founded in 2004, applies a technology to crystalline silicon on glass. Sovello was founded in 2004; the aim was to produce solar cells and modules using String Ribbon technology. In 2004, 25,000 employees were active in the PV business**.** In 2004, Solar cell production (190 MWp) inside the country was less than the solar cell import (460 MWp). The BSW estimates that meanwhile around 10,000 companies with 42,000 employees were active in the PV business. More than 80 companies are producer of cells, modules and components. In 2005, PV production was 450MW which was more than double compare to 190MW in 2004. In 2006, Sunfilm came in with a technology using amorphous silicon and Solibro in CIGS technology. PV production was 700MW in 2006. Companies in Germany were benefited from a diverse range of regional R&D funding programs which has been made available for the period 2007 through 2013. Two German companies, namely Wacker Chemie AG and Joint Solar Silicon, developed alternative production methods for silicon. In 2007, Solar cell production in Germany (840 MWp) became higher than solar cell import (650 MWp) due to rapid expansion of local PV production capacity considering the future PV market growth. In 2007, Q-Cells International was established and started an active project business developing solar parks. In 2008, 42,000 employees and around 10,000 companies are active in the PV business. More than 130 companies are producer of cells, modules and components. PV production was 1470MW. German foreign trade and inward investment agency "Germany Trade & Invest" lists in total 70 companies involved in PV production creating a turnover of 8.6 billion EUR in 2009. PV production was 1765MW. In addition 62 PV equipment manufacturers supply tools for every step of the PV value chain. In 2009; 64,700 employees are active in the PV business. The BSW estimates that meanwhile around 10,000 companies with 133,000 employees were active in the PV business. More than 200 companies are producer of cells, modules and components. Major German PV player Q-Cells increased its production capacity 1100MW in 2010. PV production increased to 2656MW in 2010. In 2010, Solar cell production in Germany (2656MW) was about 4 times higher than solar cell import (500-800 MWp).

In 2011, Germany is home to around 70 manufacturers of silicon, wafers, cells, and modules. In addition, there are over 200 PV material and equipment suppliers, more than 100 balance-of-system (BOS) component manufacturers, more than 50 PV research institutes and hundreds of project development, system integration and installation companies. The German PV industry currently employs a workforce of more than 130,000 thousand people including 22,000 people in PV production industry, 33,000 people in component supplier, 22,000 people in machine building Industry, and 34,000 in handicraft. In 2011, PV production in Germany increased to 2919MW.

Rating the level of fulfillment of entrepreneurial activities (F1) for Japan and Germany based on the activities in the year 2011:

Government actions brought about very favorable conditions for an expansion in PV production capacity, thus dramatically increasing entrepreneurial opportunities in PV. As the market incentives provided made PV an economic option for electricity generation, the market grew further and the number of companies increased. The reduction of risk gives the PV producers an increased ability to finance their projects with the help of the capital market, and this also enables smaller firms to undertake projects. This situation has had a strong impact on market growth, enabling firms to tackle the construction of large solar parks, which has led to major increases in the demand for PV systems.

German government's action has therefore influenced the number of entrepreneurial opportunities, and possibilities for new entrants have arisen through the creation of uncapped markets and attractive feed-in tariffs in the PV sector. They can sell their products, if they are able to produce at prices below those set by feed-in tariffs, up to their production capacity limit without major entrepreneurial risk. Only five companies have produced solar cells in 2002 which increased to 70 in 2011. About 2,200 employees worked in the German wafer, cell and module industry in 2002 which increased to 22,000 in 2011. In 2011, only 13 companies have produced solar cells and about 9,000 employees worked in the Japan wafer, cell and module industry. Japanese manufacturers markedly increase its production up to 2005 after announcement of elimination of sunshine program they did not increase capacities at all. On the other hand, German manufacturers started PV production later than Japanese manufacturers but within very short time between 2005-2011 they increase their production capacity remakably. In 2011, PV production in Japan and Gernay were 2725 MW and 2919 MW, respectively. Whereas, PV installation in Japan and Gernay were 1,100 MW and 7,500 MW. Japanese manufacturers exported a large percentage of PV wafer/cell to forign market. Where as Germany imported PV wafer/cell specially from China to fufill the local PV market demand. As we are studying here about the diffusion of PV in a country (Japan,Germany) with TIS framework, we have to consider the diffusion inside the country when we rank them (country). The total workforce in Japan and the number of company in Japan will put them (Japan) in level 3 but as the production of PV in Japan is almost similer to the production in Germany I would like to put Japan in between 3~4 level.

In early periods it was mainly large existing firms that extended their business into PV, now more and more companies in Germany focusing solely on PV entered the market, which shows a maturing development of the market. In Germany, a strong domestic market is accompanied by a sizeable production capacity, indicating profits from the early establishment of lead markets. Table 7 shows the rating of Entrepreneurial Activities (F1), of Japan and German PV innovation system considering the entrepreneur activities, specially total PV workforce (PV production, component supplier, building Industry, handicraft and other) and total number of PV manufacturers (silicon, wafers, cells, and modules) for the year 2011.

Table 7: Total workforce, manufactures and rating of the level of entrepreneurial activities (F1) for Japanese and German PV innovation systems in the year of 2011

	Total workforce (PV production, component supplier, building Industry, handicraft and other)	PV production	PV manufacturers (silicon, wafers, cells, and modules) Company	Rating the Level of fulfillment F1
Japan	45,000 people	2725MW	31	3.5
Germany	130,000 people	2700MW	70	4

11.2.2. Knowledge Development (F2): Function involves learning activities

Knowledge Development: Japan

Sunshine Project started with the target of the promotion of research activities aiming at development of technologies from alternative energy; from 1974-1994. The government research program has been tightly coordinated with Japanese industry and academia. R&D activities under Residential PV System Dissemination Program: 31,475 Residential PV Systems were installed in total from 1994 to 1999 (114.6 MW). R&D budget in 1994 was 2,030 MJPY. Government agencies started to study the introduction and application of PV systems. R&D budget for 1996 was increased to 4,056 MJPY compared to 2,030 MJPY in 1994. In 1993, PV system price was 3700yen/kWh and the levelized cost of electricity (LCOE) was 260 yen/kWh which is very high compare to grid electricity price of 30 yen/kWh. Electricity price gap between PV electricity price and grid electricity price in 1993 was very high (230 yen). "Residential PV System Dissemination Program" started on April 1997 as a succeeding program of "Residential PV System Monitor Program" to enlarge the scale of dissemination of PV systems. This program aims to subsidize the PV installation cost for individuals on the condition that they provide the operation data of their PV systems. Project for Promoting the Local Introduction of New Energy started in 1997 with total budget from FY 1997 to FY 2009 was 111,749 MJPY. Project for Supporting New Energy Operators (FY 1997) the total budget from FY 1997 to FY 2009 was 318,103 MJPY. In Eco-school Model Promotion Pilot Project (FY 1997-FY 2011), a total of 818 schools were qualified for PV. PV Field Test Project for Industrial started in 1998. The aim is 1) to install trial PV systems using new technologies effective to introduce to industrial sector, such as industrial facilities, 2) to demonstrate availability for introduction of PV systems by collecting data and analyzing a long-term operation under demonstration test and 3) further standardization and diversified introduction applications toward full scale deployment of PV systems. In 1998 another Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications (1998 -2006) was started. In 2000, the articles and papers published in Japan were 104 in total. In 2001, 5-year plan on technical R&D for photovoltaic power systems was initiated. The R&D activities of the new plan were categorized the following four areas: 1) advanced solar cell technologies, 2) PV system technology for mass deployment, 3) innovative PV technology and 4) development of advanced manufacturing technology of PV systems. Projects for new energies 1) seed identification and 2) advanced PV generation were started in 2001. In 2001, a total budget for R&D was 6,360 MJPY and for demonstration programs was 2,060 MJPY.

In 2002 a demonstrative research project on "Clustered PV system" was started aiming at demonstrating a general power system, where PV systems are intensively grid-connected. Other projects started in the same year are "Residential PV System Dissemination Program" and "PV Field Test Project for Industrial Use". In 2002, total budget for R&D was 7400 MJPY and for demonstration programs was 4500 MJPY. "Field Test Projects on Advanced Photovoltaic Power

Generation Technology started in 2003, aiming at adopting new technologies into PV systems for public and industrial facilities and accelerating further development. The objective of the program is to promote introduction of middle scale PV systems with output capacity of 10 kW and over, improve the performance, and reduce the cost. In 2003, micro grid demonstration projects started and the same year the articles and papers published in Japan were 310 in total. In 2004, PV system price decrease to 675yen/kWh. LCOE was 260 yen/kWh in 1993 and rapidly decreased to 46 yen/kWh in 2004. Electricity price gap between PV electricity price (LCOE) and grid electricity price in 1993 was 230 yen and it decreased to 22 yen in 2004. By 2004, the LCOE had decreased 83% compare to 1993. In 2006, NEDO started “R&D for Next Generation PV Systems (FY 2006 - FY 2009)”, a new 4-year technological development plan, based on the roadmap for technological development of PV systems, “PV Roadmap 2030 (PV 2030)”. In 2006, total 662 cases of 22 080 kW (Field Test Projects), installed with budget 11,800 MJPY. The articles and papers published in Japan in 2007 were 311 in total. The system price per kW dropped over 80% from 1993 to 2006. “R&D project on Innovative Solar Cells (FY 2008-FY 2014)” by NEDO started, 3,700 MJPY was allocated for R&D related to PV power and 12,170 MJPY for demonstration. From 2004-2008, LCOE remained almost constant (about 46 yen/kWh).

In 2010, research project “R&D for High Performance PV Generation System for the Future (FY 2010-FY 2014)” under NEDO was started. Another demonstration project of “Next-Generation Energy and Social Systems” from FY 2010 to FY 2014 was also stated in 2010. In 2011, NEDO and the European Commission jointly launch a project (2011-2014) to develop concentrator photovoltaic cells aiming to achieve a cell conversion efficiency of more than 45%. In that year the number of articles and papers Japan published were 458. The City of Yokohama, Toyota City, Keihanna Science City and the City of Kitakyushu are engaged in major demonstration tests of smart grid technologies (test period 2011–2014). A collaborative project “Verification Test of a Smart Grid System for Remote Islands in Hawaii, USA” from FY 2011 to FY 2014 was started in 2011 and the overall budget scale is approximately 3 BJPY. Two R&D projects for “High Performance PV Generation System for the Future” (budget; 5.98 BJPY) and “Innovative Solar Cells” (International Research center for Innovative Solar Cell Program): (budget; 2.06 BJPY) and a demonstration project on developing forecasting technology of PV power generation started with budget of 0.10 BJPY were started in 2011. From 2009, LCOE start decreasing again and become 40.7 yen/kWh in 2011. From 1993, PV system price decrease to 521yen/kWh in 2011. Japan published 549 articles and papers in 2011. The PV industry strengthened the approach to the domestic market in order to realize the huge expansion of domestic market led by residential field and the development of non-residential market including MW-scale solar power plant which is expected to boost its implementation from 2012.

Knowledge Development: Germany

German PV R&D activities gradually increased under the support from Federal Ministry for Research and Technology (BMFT) and Federal States, since 1974. Government funding aims at improving the economics through R&D of cells and modules and at demonstrating and improving the performance and reliability of complete PV-systems and their components. Four institutions were involved in PV R&D; Research Center Julich (KFA), Hahn-Meitner-Institute (HMI), Deutsche Forschungsanstalt furLuft-und Raumfahrt (DLR) and Fraunhofer Gesellschaft. Since 1990, "1000 roofs program" started. PV system prices was 14€/ kWh in 1990. The governments' 3rd energy research program (running from 1990 to 1995) was focused on lowering the production costs of PV cells, increasing the efficiency, development of thin film cells, optimization of systems, applications engineering and funding pilot installations (Bruns et al., 2011). In the year 2000, total articles and papers published in Germany were 140.

The main goals of 1000 roofs program seemed not be market creation, but rather to learn by using and to facilitate contextual aspects. Four goals of the program can be identified: to gain know-how on installation, to optimize the components of the system, to stimulate users to adapt their electricity use to the pattern of PV energy generation and to harmonize architectural aspects with construction aspects and the use of roofs for power generation (Erge et al., 2001). Thus the program was accompanied by a measurement analysis program. This was done in order to get experience with the operation of PV systems, through identifying weak spots of system design and installation, as well as monitoring the actual output of electricity (Kiefer & Hoffmann, 1994). Furthermore rules and regulation for installation and conditions for the feeding of decentralized power into the grid emerged (Erge et al., 2001). From the 1000 roofs program lessons were learned on more appropriate regulation and condition, which resulted in these new institutional measures. Support program from the Federal Ministries (BMBF, BMWA) for R&D on PV projects. Since 2002 the Federal Ministry of Environment (BMU) conducted Research and Development under the 4th program on energy research and energy technology, which aims to three main goals: cost-reduction for solar cells and PV modules by decreasing production costs and by increasing cell and module efficiencies. Cost reduction, technical optimization and removing of other obstacle preventing the use of PV in different types of buildings. In 2002 the support from the Federal Ministries (BMBF, BMWA) for R&D on PV projects amounted to about 23.6 M. This amount was spent for special research projects, e.g. in the field of cell; the system prices dropped about 14% in 2002.

A sub-program within this 4th energy research program existed for PV: Paving the Way for PV 2005 (Wegbereitungsprogramm Photovoltaik 2005) which was implemented from 1996 to 2005. The aim of the program was to take away obstacles that hindered further diffusion of PV, and three key features formed the strategy of the program were 1) lowering solar cell costs through increasing efficiency and reducing manufacturing costs, 2) using PV to generate network independent and decentralized energy supply, and 3) optimizing the technology and breaking down inhibitions that people might have concerning the integration of PV systems into different kinds of buildings (Bruns et al., 2011).

The system prices dropped about 10% in 2003. Smaller projects with a broad demonstration effect such as the 'Sun at School' or '300 Parish for Solar Energy' were continued by governmental organizations. In 2003 the support from the Federal Ministries (BMBF, BMWA) for R&D on PV projects amounted to about 29.7 M€ after 23.6 M€ in 2002. This amount was spent for special research projects. Total of 282 papers and articles were published in 2003.

The 5th energy research program was launched in 2005. It was launched by the Federal Research Ministry and the Federal Environment Ministry jointly for the first time, and focused on the increasing of efficiency, reduction of material use and the automating and optimization of manufacturing technologies, with regard to both silicon and thin-film solar PV technology (Bruns et al., 2011). Research and Development (R&D) is conducted under the 5th program on energy research and energy technology "Innovation and New Energy Technologies". The program was originally designed to be valid for the period from 2006 to 2008. Within this framework, the BMU (43.4 MEUR in 2006) as well as the BMBF (Federal Ministry of Education and Research) support R&D on different aspects of PV. R&D program (2006-2008) "Innovation and New Energy Technologies" was conducted with support from BMU and BMBF on different aspects of PV.

In 2007 the BMU support for R&D projects on PV amounted to about 32.1 MEUR shared by 140 projects in total. The distribution of the budget shows that one focal point still is on wafer based silicon technologies (57% of the budget). The second center of attention lies on thin-film technologies (32%). BMBF provides funds for the development of PV technologies as well; currently 5 network projects with 29 participants are supported with a total amount of 12.4 MEUR. In accordance with the PV R&D strategy outlined above, 49 new grants were contracted by the BMU in 2007. The funding for these projects amounts to 41.7 MEUR in total. In 2007, total 311 papers and articles were published.

In 2008, the BMBF published its concept paper "Basic Energy Research 2020+" aiming for the support of long-term R&D on renewable energies which is complementary to the BMU funding. In 2008, all the articles and papers published in Germany totaled 311.Since 2008; the costs of electricity from photovoltaic installations become halved. A call for networks aiming for the development of thin-film solar cells was initiated in 2008. Due to the high support of R&D activities by the BMU and other ministries and the engagement by the industry more than 100 R&D projects were continued in 2009. In 2009, public budgets for R&D by BMU and BMBF were 39.0 Mio€ and > 25, 0 Mio€ respectively. In 2010 the BMU support for R&D projects on PV amounted to about 39.1 MEUR shared by 152 projects and that year the articles and papers published in Germany is total 536.

Germany has a strong R&D base with regard to PV. There were 50 state-of-the-art research institutes and university faculties doing research in PV technology and 290 solar patents were registered in Germany in 2010 (GTAI, 2011). On the 26th PV conference, held in Hamburg in early September 2011, quite some papers were presented on silicon wafer based technology (345 papers). Part of these papers originated from solely German organizations, others were of mixed origin (i.e. cooperation between institutes from different countries) and others were of foreign origin.

The 6th energy research program, "Energy Storage Funding Initiative" supported collaborative R&D projects. In 2011, funding was made available for 96 new PV R&D projects by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in September 2011, Germany launched a research and development program for the speedy transformation of Germany's energy supply for research in renewable energies, energy efficiency, energy storage, grid technologies and the integration of renewable energies into the energy supply system. The industry focuses their activities in process optimization to reduce the production cost and to increase the quality of their products. In 2011, R&D budget by BMU was 39.0 Mil Euro and also R&D budget by BMBF was 17.0 Mil Euro. That year the articles and papers published in Germany were 699 in total. The long-term effect of different subsidy schemes in Germany has decreased PV system prices from around 14 €/KWp in 1990 to 2.1 €/KWp by end of 2011. This is a net-price regression of 85 % over a period of 21 years.

Rating the level of fulfillment of knowledge development (F2) for Japan and Germany based on the activities in the year 2011:

During 2000-2011, (Figure 26) German grid electricity price has increased from 15 €ct/kWh in 2000 to 24.7€ct/kWh in 2011. As shown in Table 8 German PV system price was 6.54 €/W in 2000 which was decrease to 2.45 €/W in 2011. Japan PV system price was 844 ¥ /W in 2000 which was decrease to 521 ¥/W in 2011. During 2000-2011, German PV system price decreased about 63% whereas Japan PV system price decreased only 28%. In 2000, German electricity price gap was 42.4 €ct which was only 4 €ct in 2011. Whereas in 2000, Japan electricity price gap was 32.8 yen and decreased to 14 yen in 2011. In 2011, German PV electricity price became almost same as grid electricity price. During 2000-2011, German PV market grew faster because of government policy to buy back all electricity produced by solar PV. Grid parity is the point at which photovoltaic electricity is equal to or cheaper than grid power. Achieving grid parity is the long term goal of the solar power sector. In 2012, Germany achieved grid parity in in PV. Many electricity customer segments in Germany are now able to produce PV electricity cheaper from their roofs than buying electricity from the grid due to sharp fall in PV rooftop system prices in recent years. This makes PV financially attractive for the PV system owner to directly consume the solar electricity generated.

Table 8. PV System price, electricity price gap, number of research papers of Japan and Germany for 2000 and 2011and also rating the level of fulfillment of knowledge development (F2) for Japanese and German PV innovation systems in the year of 2011

	2000			**2011**			Rating the Level of fulfillment F2
	PV System price ¥ (€) / W	Electricity price gap	No. of Research paper	PV System price ¥ (€) / W	Electricity price gap	No. of Research paper	
Japan	¥ 844	¥ 32.8	104	¥ 521	¥ 14	549	4
Germany	€ 6.54 ¥ 850	€ 0.42 ¥ 55.1	140	€ 2.45 ¥ 319	€ 0.04 ¥ 5	699	4.5

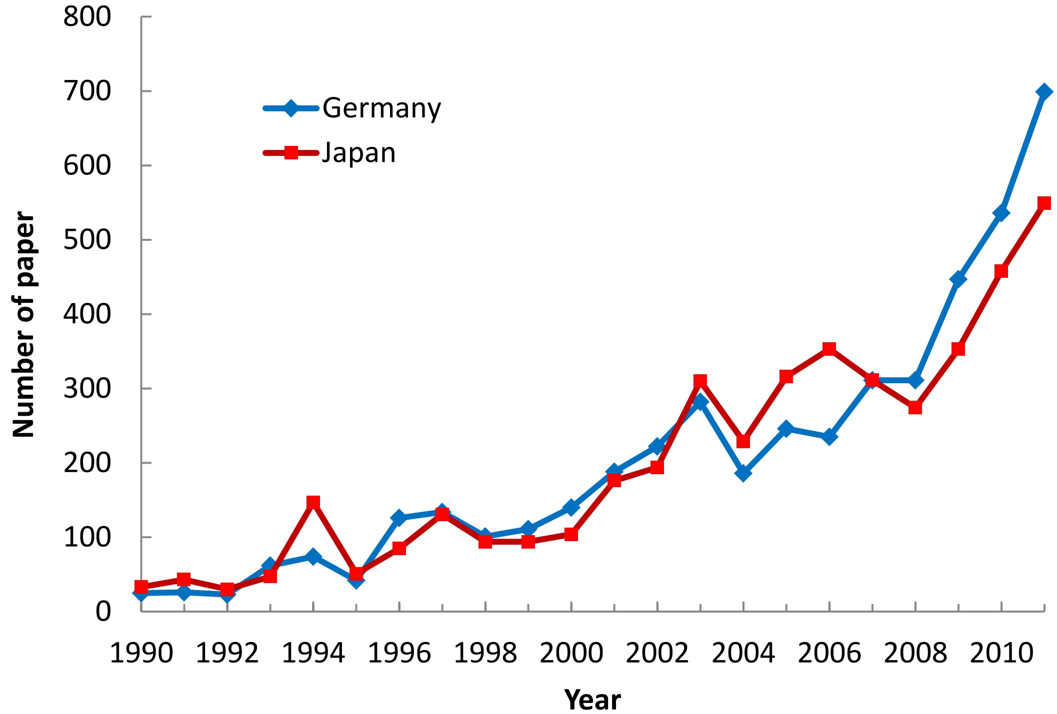

Figure 27. Numbers of papers published by Japan and Germany from 1990- 2011 (Source: Scopus search "solar cells", <http://www.scopus.com/home.url> (Accessed on April 2013))

As shown in Figure 27, the number of research publications of Japan and Germany increased similarly from 1990 to 2007. During 2008-2011, German's number of publications was higher than Japan. In 2011 Germany published about 700 papers and Japan's publications was about 550. Table 8 shows the rating of Knowledge Development (F2) of Japan and German PV innovation system considering the PV System price, electricity price gap, and number of research papers for the year 2011.

11.2.3. Knowledge diffusion through network (F3)

Knowledge diffusion through networks: Japan

Photovoltaic Power Generation Technology Research Association (PVTEC) is an organization, established in 1990, whose members unite to implement studies assigned by NEDO.

A study, when assigned, is split and distributed to individual member companies and associations with a specific goal for R&D each. The union provides the members with a place to collect and exchange information including to what extent other members' R&D have progressed. PVTEC has actually played a role in providing such opportunities to the members.

PVTEC holds a joint research presentation meeting in cooperation with NEDO once a year calling researchers in the fields of government, industry and academia. Meeting to obtain broad information named "Photovoltaic Power Generation Communication Conference". Researchers from universities, member companies, or national institutions who take part in PVTEC projects actively attend international academic societies and other meetings to present their research results and collect and exchange information. In 2000 PVTEC, NEDO research presentation meeting about 61 projects were presented. In 2001, PVTEC members were PVTEC committees (8) include researchers from various corporations (29 companies and 2 associations), universities (16) and national research institution (1). The total number of researchers amounts to 164. They exchange opinions each other about leading-edge technologies including up-to-date information, problems, questions and direction of improvement to the extent that will not interfere with the expertise and patents of private companies. The win and lose game of PV technology R&D is very severe. In 2002, many new members have entered PVTEC. In 2002, Japan filed about 116 patents and published about 85 conference papers with a total public R&D and demonstration project budget of 11.8BJY. "Demonstrative Research on Clustered PV systems" was started. PV systems are to be installed in 400 residences in a selected area under the research. Moreover, the PV industry creates a new industrial structure in corporation with peripheral industries. In 2003, New Energy and Industrial Technology Development Organization (NEDO) started "Demonstrative research on Clustered PV system", a new demonstrative research project of intensively installed PV systems. Under the project, PV systems, 1,800 kW in total were installed in 600 residences and researches to solve technical issues arising from the installation are conducted. Moreover, the PV manufacturers create a new industrial structure in corporation with peripheral industries. In 2006, Japan Photovoltaic Energy Association (JPEA), revised its industrial roadmap and announced "Vision of the Future of the Photovoltaic Industry - Aiming to be the World's leading PV Nation, 2006" considering rapidly growing PV promotion. An international collaboration project "International Cooperative Demonstration Projects for Stabilized and Advanced Grid-connection PV Power Generation System" (budget: 790 MJPY) was started in 2006. The PV industry in Japan establish collaborative and cooperative framework with not only METI but also other ministries and agencies, local governments, related industries as well as users, in conjunction with national energy strategies and enhance the efforts to achieve full-scale dissemination of PV system. In 2007, Japan filed about 194 patents and published about 156 conference papers with a total public R&D and demonstration project budget of 19.18 BJY. In 2007, an international collaboration project "International Cooperative Demonstration Projects for Stabilized and Advanced Grid-connection PV Systems" was initiated with total budget of 300 MJPY. Another international collaboration project " Japan-U.S. Smart Grid Collaborative Demonstration Project in New Mexico, USA" was started in 2009. The term of the project is from FY 2009 to FY 2013 and the budget for FY 2011 was 1 BJPY. During 1992-2009, NEDO supported a total of 21 International projects concerned with Photovoltaic. "International Cooperative Demonstration Project for Stabilized and Advanced Grid-connection PV System (NEDO)" was one of the international cooperative demonstration programs which aims at a stable electricity supply constructing micro-grids using PV power generation. Four projects conducted in Thailand, China, Indonesia, and Malaysia and were completed successfully by FY 2009. "International Cooperative Demonstration Project Utilizing Photovoltaic Power Generation Systems (NEDO)" to verify PV systems under climate conditions which usually not available in Japan was conducted in various Asian countries. From FY 1992 through FY 2010, a total of 19 projects were carried out. Collaborative Projects in the Solar Energy Field with Moroccan government: Governments of Japan and Morocco agreed to jointly promote a comprehensive cooperation in the solar energy sector in December 2010. In 2011, NEDO started Smart Grid Demonstration Projects with USA, France, Spain, India, China and other countries to launch the international operation of Smart Grid projects. Smart Community Demonstration Project in China; Total budget for the project is approximately 3 BJPY for the scheduled project period from FY 2011 to FY 2013. In 2011, a collaborative project in the solar energy field with Moroccan government was signed. Based on this agreement, the two nations planned to promote joint efforts such as large-scale introduction of power generation systems using solar energy and development of technologies to stabilize grids. Under the plan, total 2,000 MW of solar power generation facilities will be installed by 2019. In 2011, NEDO and EU launched first joint technology development project, aiming at developing the world's highest efficiency concentrator photovoltaic cells. This project was jointly conducted by industrial, academic and governmental research organizations from Japan and from six member states of the EU. In 2011, Japan filed about 490 patents and published about 237 conference papers with a total public R&D and demonstration project budget of 9.22 BJY.

Knowledge diffusion through networks: Germany

Four important research institutions Research Center Julich (KFA), Hahn-Meitner-Institute (HMI), Deutsche Forschungsanstalt furLuft-und Raumfahrt (DLR) and Fraunhofer Gesellschaft established a research association (BMFT) for PV. In Germany, the first market entrants of a specific supply industry emerged from co-operation projects around the year 2000. The existence of linked branches, such as the semi-conductor industry, favored the formation of a supplier industry. Since 2002 the Federal Ministry of Environment (BMU) is responsible for the renewable energies. Firms pursuing a strategy of vertical integration established spin-offs or joint ventures with existing PV companies, covering additional parts of the value. Such vertical integration offers the advantage of a comprehensive approach to cost reduction in PV systems and allows the internalization of profit margins throughout the value chain. In 2002, Germany filed about 35 patents and published about 154 conference papers and spends a total public R&D and demonstration project budget of 23.6MEUR in PV. Q-Cells established a number of subsidiaries, each of them working with an alternative technology. Sovello was founded in 2004 under the name EverQ. CSG Solar, founded in 2004, applies a technology to crystalline silicon on glass. Every two years BMU invites renowned experts to a photovoltaic strategy meeting in Glottertal to discuss research priorities and draw up guidelines. Q-Cells pursued different approaches in thin-film technology. Calyxo (founded in 2005) specializes in cadmium-tellurid technology. Both BMU and BMBF support R&D on different aspects of PV under the 5th Program on Energy Research and Energy Technology “Innovation and New Energy Technologies”. In 2006, Sunfilm (founded in 2006 as Sontor) in a technology using amorphous silicon and Solibro (founded in 2006) in CIGS technology formed a Q-Cells based PV cluster. A co-operative research project was conducted, in 2007, between industry and research institutes aims for a minimization of the kerf-loss of the wafer making process. By reducing both the wafer thickness and the sawing gap to 100 µm a cost reduction of 20% to 50% was expected. The German Photovoltaic Cluster boasted more than 10,000 businesses, including over 80 manufacturers of PV components, over 60 PV equipment suppliers, and employed 42,000 people in 2007. The growth of the cluster has been buttressed by a strong focus on innovation and technology, with over 60 research institutes in Germany engaged in the development of PV technology. German investments in PV R&D amounted to approximately EUR 176 million in 2007. Due to an extensive incentive program provided by the German government, the German

PV cluster was concentrated in the former East-German states. Over 90 percent of PV manufacturers in Germany are located in this region. The German PV cluster facilitated to specializing in all or parts of the PV value chain. As a consequence of the clustering stage in Eastern Germany, some leading centers of the photovoltaic industry have developed. In 2007, Germany filed about 53 patents and published about 139 conference papers and spends a total public R&D and demonstration project budget of 86.2 MEUR in PV. Two-thirds of the approximately 14,000 employees working in the PV industry in 2008 were located in Eastern Germany. Two network systems 'SiThin Solar' and the 'INNOCIS' were formed for research co-operation inside the cluster. Inside the cluster many activities like establishment of several endowed professorships, various training programs, and the establishments of specialized public research institutes (for example, the Fraunhofer Center for Silicon Photovoltaic CSP in Halle) were done. Under its High-Tech Cluster Strategy, the German federal government allocated significant resources towards energy and environmental technologies in 2006-2009. The close cooperation and collaboration between research institutes, universities and PV manufacturers and equipment suppliers has helped make the adoption of new PV technologies more cost effective and all-in-one. This has been a vital element in the German PV cluster's success. The Federal Solar Energy Association (BSW) unites over 650 members (producers, wholesalers, consultants, R&D institutes) and serves as a forum between solar businesses and the German government. In 2010, BMU and BMBF initiated the Innovation Alliance PV. Under this scheme R&D projects will be funded which support a significant reduction of PV production costs in order to enhance the competitiveness of German industry. Together, BMU and BMBF supported Innovation Alliance PV with 100 MEUR. The German PV industry agreed to raise additional 500 MEUR to accompany the Innovation Alliance. This R&D projects started at the beginning of 2011. In recent years, German research institutions, universities and corporate research departments have made crucial advances in key areas of the technology. Its ability to develop outstanding technology remains one of Germany's core competencies in PV, and consequently, German speakers continue to lead the international conference scene. Furthermore, a forward-thinking educational policy has helped Germany to retain its leading position in terms of the number of scientists, engineers and technical experts in PV. As part of the so called Photovoltaic Innovation Alliance, the project SONNE was launched, coordinated by SolarWorld Innovations with the involvement of 13 companies and 4 research institutions, aiming at significantly improving module efficiency and achieving further cost reductions with crystalline silicon solar cells. The project will focus on cell and module design, appropriate industrial process sequences, the selection of optimum materials, as well as process steps and the requisite technology, plus demonstrator production. BMU provided 3.4 million euros towards this project. In 2011, another research alliance comprised of 11 companies and 13 research institutions joined forces in the SolarWinS project (Solar Research Cluster to Determine the Maximum Level of Efficiency for Multicrystalline Silicon), coordinated by the Freiburg Materials Research Center (FMF) at Albert-Ludwig University and Konstanz University. Since the physical limitations for mono-crystalline silicon are largely known, the research alliance will focus on the efficiency potential of multi-crystalline material. Thin-film solar cells demonstrate significant differences in efficiency from the laboratory to production. The joint project LIST aims to close this efficiency gap. At the end of November 2011, a strategy meeting was held in Glottertal near Freiburg im Breisgau to discuss the direction of future research funding, to which the BMU invited selected representatives from the worlds of industry and research. The principal outcomes were that: closer collaboration within the German PV industry and the development "from lab-to-fab" needs to be accelerated, for example by means of platform developments in R&D and via the formation of alliances. In 2011, Germany filed about 158 patents and published about 263 conference papers and spends a total public R&D and demonstration project budget of 223.9MEUR in PV.

Rating the level of fulfillment of knowledge diffusion (F3) for Japan and Germany based on the activities in the year 2011:

The number of conference papers of Japan and Germany increased similarly from 1990 to 2011 (Figure 28). During 2004-2007, Japan’s number of publications was higher than German. But from 2008-2011 Germany published more conference papers than Japan. In 2011, Japan published 237 conference papers whereas German publications were 263. Japanese Public R&D and demonstration budget was 11.8 Bill. ¥ (118 MUS$) in 2002, whereas German budget was 23.6 Mill.€ (30.7MUS$). Japanese Public R&D and demonstration budget was higher than Germany up to 2007, after 2007 the budget decreased and in 2011, Public R&D and demonstration budget of Japan was 9.22 Bill. ¥ (92.2MUS$), on the other side German budget was 223.9Mill.€ (291.1MUS$). In 2011 total research project of Germany were 331, but Japanese research project decreased to only 88. Table 9 shows the rating of knowledge diffusion (F3) of Japan and German PV innovation system considering the PV budget for Public R&D and demonstration and number of conference papers for the year 2011. During 2007-2011, German

PV market grows abruptly through cluster project located in the former East-German states. Over 90 percent of PV manufacturers in Germany are located in this region and form a strong network among them. This is a unique example of Knowledge Diffusion (F3).

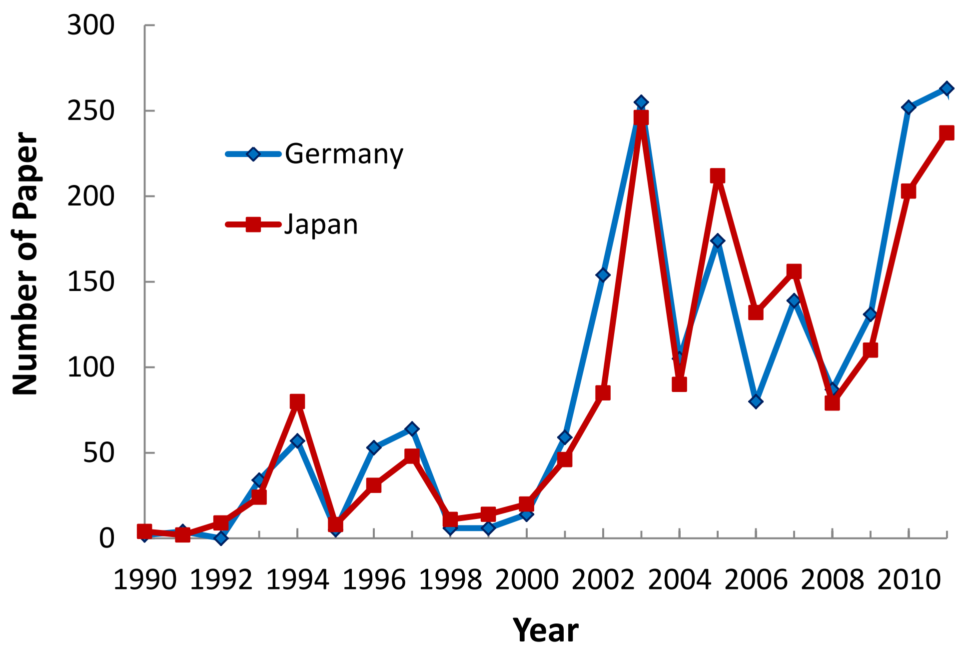

Figure 28. Number of conference paper published by Japan and Germany from 1990- 2011 (Source: Scopus "solar cells" and "conference paper", <http://www.scopus.com/home.url> (Accessed on April 2013))

Table 9: Public R&D and collaboration budget, number of project and number of conference papers of Japan and Germany and rating the level of fulfillment of knowledge diffusion (F3) for Japanese and German PV innovation systems in the year of 2011

	2002	2007	2011		Rating the Level of fulfillment F3
	Public R&D and demonstration budget	Public R&D and demonstration budget	Public R&D and demonstration budget	No. conference papers	
Japan	11.8 Bill. ¥ (118 MUS$)	19.18 Bill. ¥ (191.8 MUS $)	9.22 Bill. ¥ (92.2MUS$)	237	3.5
Germany	23.6 Mill. € (30.7MUS$)	86.2Mill. € (112.1MUS$)	223.9Mill. € (291.1MUS$)	263	4

11.2.4. Guidance of the search (F4): Activities that shape the needs, requirements and expectations of actors; Positive expectations of the technology

Guidance of the search: Japan

In 1990 MITI New Energy Introduction Outlook was an Ambitious target for PV installation was, by the year 2000, 250 MW and by 2010, 4,600 MW. In 1991, PV introduction project; electric utility companies announced to install 2.4MW of PV system by FY 1995.The target of MITI's Economic structure Plan "Program for Reform and Creation of Economic Structure", was the creation of new industry in the field of new energy focused on fostering PV industry. Residential PV System Dissemination Program (former Residential PV System Monitor Program) started to deploy residential PV system on a large scale. Project for Supporting New Energy Operators; This project started from 1997 aims at accelerating new energy introduction by supporting the industrialists who launch introduction of new energy, such as PV, from a viewpoint of energy security and global environmental protection. Eco-school Promotion Pilot Model Project; initiated in 1997. The project aims at implementing pilot model projects to demonstrate and promote environmental-friendly schools, providing students with environmental education and improving school facilities. "Long-term Energy Supply and Demand Outlook" was revised in 1997. The target capacity for PV introduction by 2010 was revised from 4,600MW to 5,000MW. In 1998, Companies' responsibility for GHG reduction; Companies' responsibility to establish and publish action plans. Project for Promotion of Non-profit Activities on New Energy and Energy Conservation; established in 2000. It aims at promoting new energy introduction by supporting projects conducted by NGOs. The amount of the subsidy is half of the eligible cost. Renewable portfolio standard (RPS) legislation aim was at achieving a ratio of 3.2% from the renewable energy in the total energy supply till 2010. It requires each power retailer to set an annual sales target for six types of renewable energy (including PV); 1st April 2003. In 2005, Companies were requested to estimate and report GHG emission; Government to make the data publicly available. In 2006, domestic trading and surrendering of overseas emission reduction project started. JPEA, Japan Photovoltaic Energy Association, revised its industrial roadmap and announced "Vision of the Future of the Photovoltaic Industry - Aiming to be the World's Leading PV Nation, 2006" to correspond rapidly growing PV promotion. Although the national subsidy program for residential PV system, "Residential PV System Dissemination Program" was completed in FY 2005, 319 of local governments provide financial support for dissemination of residential PV system. RPS Law; set a target for usage amount of new and renewable energy in FY 2014 at 16 billion kWh. METI took measures to double count the electricity generated by the PV system under RPS law. METI also formulated “Cool Earth 50”, an energy technology innovation plan towards 2050 and set a long-term strategy for solar cells to achieve 40 % of conversation efficiency.Tokyo Metropolitan Government (TMG) started establishing measures to introduce 1 000 MW of solar energy. R&D for Next Generation PV systems aims at establishing elemental technologies to achieve the target PV power generation cost set for PV 2030, 14 JPY/kWh for 2020, 7JPY/kWh for 2030. In 2008, Action Plan for Dissemination of PV Power Generation; goals to set PV installations amounting to 14 GW by 2020 and 53 GW by 2030. 2008, Identified 21 technologies to be prioritized where Japan is a global leader, boasting the world’s top level energy Technologies. In 2009, GHG reduction target was 25% by 2020 (conditional); 80% by 2050 (without any conditions). Tokyo Metropolitan Government (TMG) set a target of reducing CO2 emissions by 25 % by 2020 from the 2000 levels in its plan called “Tokyo in 10 years”. TMG announced its plan to introduce 1 GW of solar energy and decided to provide a subsidy of 100 000 JPY/kW in FY 2009 and FY 2010. In 2010, Targeted Emission was 1,239～1,252Million t-CO2, and total GHG emission reduction will be 1.8%～0.8%. Reviewed Basic Energy Plan was to Increase renewable energy target in 2030; Increase PV from 9 % to 20 % in 2030. Utilities made plans to construct approximately 30 PV power plants with a total capacity of 140 MW across the nation by 2020 and started introduction of PV systems in their own facilities, which represent their commitment of taking the initiative in introducing PV systems.

In FY 2011, total 11 PV power plants with a total capacity of 56 MW started operation. Adoption of feed-in tariffs by Japan is a seeming endorsement at the highest international level that rapid development of renewable energy is desirable. The new law is also a clear sign that Japan plans to reduce its reliance on nuclear power, after the disaster at Tokyo Electric Power's Fukushima 1 plant. Tokyo Metropolitan Government (TMG) continued this subsidy in FY 2011 with the same grant amount in support of securing electricity after the Great East Japan Earthquake in March 2011, 1300 PV systems totaling 115 MW will be installed from the initiation of the project until FY 2013. Feed-in Tariff Law based on the “Renewable Energy Law”; Target: reported as 30,000 MW within 10 years, though not contained in the law. PV systems with the capacity of 10 kW or larger, FIT was set for 42 JPY/kWh, for the period of 20 years. For PV systems with the capacity of below 10 kW, FIT, 42 JPY/kWh for the period of 10 years; enforced in July 2012.

Guidance of the search: Germany

StrEG or "Electricity Feed-in Law" was Germany's first feed-in-tariff and did not have rates high enough to support PV installations. At that time PV generators were eligible for rebates to 70% of the system cost. In 1990, target for reducing energy-related CO2 emissions; by 25% over the 1987-2005 period time was made public. In September 1990, BMFT and Federal States jointly started , "1000 roofs program" with the target of installation of 1500 small (1-5 kWp) PV systems on the roofs. Feed-in-tariff payment set at 90% of the retail electricity rate, 8.45-8.84 €cent/kWh over the course of the decade. In 1994 the German federal government confirmed its objective of cutting CO_2 emissions by 25-30% by 2005. From 1995-1996, Voluntary agreements with industry was to reduce CO_2 emissions by 20 % from 1990 to 2005.

Green tariffs form utilities as voluntary participation for the customers, where higher feed-in tariffs paid for new PV plants; from 1996-1999. EU Germany made an important commitment in the European Council of Environment Ministers of March 1997 when the German government agreed to cut its greenhouse gas emissions (GHG) by 25% from 1990 to 2010. In the 100.000 roofs (Subsidy of 695 M EUR) program Soft loan for 10 years duration, 2 years free of redemption PV receives interest-free loans; 1999-2003. In 1999, Germany accepted a target of 21% reduction from 1990 to the 2008-2012 period of time. In 2000, with the demonstrated success of the 100,000 roofs program, the new government increased the feed-in tariff rates for solar PV. Part of the updated tariff, providing a clear incentive for the solar industry to develop more cost effective panels; Industrial associations agreed to reduce specific CO2 emissions by 28% over 1990-2005 and to cut specific greenhouse gas emissions by 35 % by 2012. Power industry agreed to further voluntary cuts, totaling an annual reduction of 45 million tons in CO_2 emissions by 2010. Renewable Energy Law (REL) doubles the share of renewables on the electrical power generation in Germany from 5% in 1999 to 10% in 2010. In this law a maximum installed power of 300 MW from 1999 until 2003. Erneuerbare-Energien-Gesetz (EEG) PV receives 52Eucent/kWh; 5% annual digression; 350 MW program cap; 5MW program cap for rooftops. The first EEG established a rate of 0.99DM/KWh (~ 0.51€cent/kWh) for PV starting in 2001. PV cap program continues in combination with the 100,000 roofs program (which offered zero interest loans). The certainty for the industry concerning their investments was set by the German parliament in June 2002 raising the 350 MW limit of REL to 1 000 MW.

While the pay back rate is decreasing annually by 5% from the first rate of 0, 51 € per kWh fed into the grid in 2000 and 2001, the industry is faced with a real challenge to decrease prices by rationalization measures in the production. The EEG law was amended to increase PV capacity, in the cap program, cap raised to 1000 MW. In 2004, EEG Amended; New rates ranging from 46-62 EU cent/kWh go into effect with 5%-6.5% digression, program cap removed, system size caps removed. In 2005, Climate Protection Program set a new goal of reducing CO_2 emissions by 40% from 1990 to 2020, conditional on the EU committing to a 30 % reduction over the same period. In accordance with the PV R&D strategy, the funding for these projects amounts 32.3 MEUR in 2005. In accordance with the PV R&D strategy, the funding for these projects amounts 43.4 MEUR in 2006. For the electricity sector the Federal Government set a national target for renewable energies of 12.5 % by 2010 and 20% by 2020. Green House Reduction Targets: 40% below 1990 levels by 2020. EEG was Amended; New rates go into effect in 2009, the Corridor digression system introduced, with a range of decreases from 5.5%-7.5%. National feed-in-tariff registry created; 2008-2009; Renewable heat target: supply 14% of its thermal energy from renewable sources by 2020. Renewable electricity target: In its 2008 feed-in tariff amendment, Germany established a binding target to supply at least 30% of its electricity from renewable sources by 2020; a revised goal of 35% by 2020.

National Renewable Energy Action Plan (NREAP): The government projects that annual additions for PV will peak in 2010 at 6,000MW and will then contract to 4,500 MW in 2011 and 3,500 MWp/a through 2020. By 2020, a total of 51,753 MW of capacity is projected to be installed in Germany. The transparency of this 10 -years solar PV energy trajectory is instrumental in guiding industry toward making appropriate capital allocation decisions. In 2009, EU Directive was passed; Germany's target was to achieve 18% of final energy consumption from RE sources by 2020. A new tariff for self-consumed power, all rates are guaranteed for an operation period of 20 years. During 2000-2009, Germany's schedule for annual automatic price digressions supported investor security and confidence by enhancing transparency and was one of the key drivers for fostering the growth of the solar market while at the same time driving PV prices toward grid parity.

In 2010 building-mounted systems decrease 13% in July, and 3% on October 1; with 7.5% digression from 2009. Ground-mounted systems decrease 8-12% in July, corridor digression revised with a range of decreases from 6-13% in 2010. Share of renewable energy sources (RES) target was 80% by 2050. Electricity consumption target was 35% by 2020; 50% by 2030; 80% by 2050). Corridor revision proposal; Joint BMU&BSW proposal to revise corridor digression schedule rates would decrease by 0%-15% on July 1, 2011, and again by 9% at the end of the year. During 2010-2011, series of non-scheduled and mid-year price decreases were in response to rapid component cost declines. These interventions appear to have been necessary to account for rapidly changing market conditions and ensure longer term policy durability. Germany intends to utilize price in response to past volume trends to support market volume of about 3,500MWp/year during this decade, in line with its integrated climate and energy projections. The analysis of the EEG cost has taken place in the context of a full cost/benefit frame work.

Rating the level of fulfillment of guidance of the search (F4) for Japan and Germany based on the activities in the year 2011

In 2008, Japan Action Plan for Dissemination of PV Power Generation set a goal for PV installations amounting to 14 GW by 2020 and 53 GW by 2030. Feed-in Tariff Law based on the "Renewable Energy Law" targeted renewable energy increase to 30 GW within 10 years under FIT, though not contained in the law. According to the market growth of 2010 (991MW) and 2011(1100MW) we can see that expectations for the market growth for 2020, 10 GW market growth can be possible to fulfill the target of total installed capacity of 14 GW. According to German National Renewable Energy Action Plan (NREAP), by 2020, a total of 51,753 MW of capacity is projected to be installed in Germany.

As we can see from the market growth of 2010 (7.4GW) and 2011 (7.5GW) we can see that expectations for the market growth for 2020, 52 GW market growth can be possible. The 7.6 GW installed in the year 2012 bring the country up to more than 32 GW, leaving "only" 20 GW to install. At the current growth rate, Germany will reach its target of 52 GW for 2020 by 2015. Table 10 shows the rating of guidance of the search (F4) of Japan and German PV innovation system considering the last 10 years activities on renewable energy target/goal, PV market target/goal and expectations for the market growth in 2020.

Table 10: Cumulative PV Installed capacity of 2002, 2007, 2011 and expectations for the market growth in 2020 and also rating the level of fulfillment of guidance of the search (F4) for Japanese and German PV innovation systems in the year 2011

	Cumulative PV Installed capacity 2002	Cumulative PV Installed capacity 2007	Cumulative PV Installed capacity 2011	Expectations for the market growth 2020	Rating the Level of fulfillment F4
Japan	637 MW	1.92 GW	4.91 GW	10 GW market growth; Total installed capacity of 14 GW	3
Germany	296 MW	4.21 GW	25.04 GW	> 25 GW market growth; Total installed capacity of 52 GW by 2020	4

11.2.5. Market formation (F5): To create artificial (niche) markets

Market formation: Japan

From 1982-1994 the market was very small due to the lack of demand for power applications. In Japan, substantial progress had been made in the Sunshine Program. Many demonstration projects were also implemented. Niche market (4MW) grew under Sunshine Program. Electric power companies adopted net billing system and have been buying back surplus electricity by PV from their customers at the selling price of electricity since 1992 on a voluntary basis. The residential market is by far the largest of the three and has increased under the government's installation subsidy, the 'Residential Dissemination Program', which ran from 1993 up to 2005. The scheme provided home owners with an installation subsidy however the amount decreased as production costs decreased. (1994-2004): Installations of residential PV systems, in Japan, have been rapidly increasing since 1994 due to simplified procedures of PV installation, technical guidelines for grid-connection, the investment subsidy for residential PV systems, and the net-metering system provided by electric power companies. During this period Japan PV market increased 41 fold from 7MW in 1994 to 290MW in 2005. Monitoring program for residential PV systems, aimed at stimulation of the PV market. 50% of PV installation costs were subsidized; from 1994-1996. In “Residential PV System Monitor Program”, 31,475 residential PV systems were installed in total from 1994 to 1999 (114.6 MW). Subsidy program of local governments with funding of up to 40% of the installation costs. There was more increase in Budget In 1996, 4 056 MJPY.

“Residential PV System Dissemination Program” started on April 1997 as a succeeding program of “Residential PV System Monitor Program” to enlarge the scale of dissemination of PV systems. This Program” aims to subsidize the PV installation cost for individuals on the condition that they provide the operation data of their PV systems. Budget in 1997 was 11,110 MJPY. Under the Project for Promoting the Local Introduction of New Energy (FY 1997 -) 261 PV systems totaling 23 678 kW will be installed during 1998 ~ 2009. Budget in 1997 is 2,430 MJPY. Local governments, Non-profit organizations (NPOs), private institutions, are engaged in projects for local production and local consumption of new and renewable energy in collaboration with local authorities. PV Field Test Project for Industrial Use This program started in 1998. The aim were; 1) to install trial PV systems using new technologies effective to introduce to industrial sector, such as industrial facilities, 2) to demonstrate availability for introduction of PV systems by collecting data and analyzing a long-term operation under demonstration test and 3) further standardization and diversified introduction applications toward full scale deployment of PV systems. In 1998, total 73 systems were installed with capacity of 1,940 kW. Under the Project for Promoting the Local Introduction of New Energy (FY 1997 -) 261 PV systems totaling 23,678 kW were installed during 1998 ~ 2009. In “Residential PV System Dissemination Program”, 20,877 PV systems were installed in 2000 (74,4 MW). In 2000, PV installed capacity was 122MW. Under the program “Residential PV System Dissemination Program”, 46,760 PV systems were installed in 2003 (173.7 MW). Field Test Projects on Advanced Photovoltaic Power Generation Technology: 148 cases, 4 480 kW was installed. From FY 1997 to FY 2004, Market grew under “Residential PV System Dissemination Program”. In 2003 production volume of solar cells and PV modules in Japan increased substantially for 7 consecutive years. Japan has been the largest PV production country in the world since 1999, and the share of Japan in the worldwide PV production exceeded 40%. METI reviewed the status of the initial market of PV system and 2003 budget for market incentives decreased by almost half. Thus, total budgets for PV market incentives, R&D and demonstration/ field test programs were significantly decreased compared to 2002 budgets. In 2004 (233, 0 MW) Solar cells have been significantly growing in quantity, with the backing of growth of the PV market for electric power use owing to the Government's "Residential PV System Dissemination Program", "Field Test Projects on Advanced Photovoltaic Power Generation Technology" and "Project for Promoting the Local Introduction of New Energy", introduction of PV systems by electric utilities through "Green Power Fund"

In the final fiscal year of 2004, under the "Residential PV System Dissemination Program", 36 754 systems, totaling 136.3 MW were installed. Project for Promoting the Local Introduction of New Energy (FY 1997 -) 261 PV systems totaling 23,678 kW will be installed during 1998 ~ 2009. Under the "Residential PV System Dissemination Program", 36,754 PV systems were installed (136.3MW), and total installation over 12 years is 253,745 cases, totaling 931,575 kW in 2005. From (2005-2008): Market was developed without subsidy. The overall market growth has leveled-off since 2005. Two reasons are possible; either the stop of the residential dissemination program has a psychological effect on applicants, or the market may be suffering from a temporary dip due to slow market developments, in particular price increases due to material shortages, etc.

During 2006-2008, PV installation in Japan gradually decreased due to end of subsidy program. After 2005 Japan's PV market decreased and became 210 MW in 2007. RPS goal was 0.73% in 2006. Total annual installed capacity of the PV system remained roughly flat in 2006, in reversal to the steady increase observed in the past. The market growth rate decreased to 1.1 % in 2005. Primary factors of the flat growth were termination of the budget for "Residential PV System Dissemination Program" and shortage of silicon feedstock for solar cell. The budget for market incentives (2,600 MJPY in 2005) to create the initial market for residential PV systems was terminated in FY 2005. National support framework for residential PV system was completed in FY 2005 and the market of residential PV system has shifted to a self-supported market driven by the market mechanism. In 2006, installation of PV systems to public facilities, industrial facilities and commercial buildings were advanced through support framework of METI. Although the government backed "Residential PV System Dissemination Program" ended in FY2005, introduction of the residential PV system has been continued without subsidies. There were 35 PV systems (1,130 kW) out of 111qualified systems in 2006. In 2007, 344 local governments continued to implement support programs for dissemination of residential PV system but total annual installed capacity of the PV system drop of 26.6 % from 2006. Factors that largely contributed to the decline are the completion of budget for introduction of residential PV systems and a decrease in production volume of PV modules by Japanese PV manufacturers due to supply shortage of silicon feedstock for solar cells. Main field test and dissemination programs implemented in FY 2007 were “Field Test Project on New Photovoltaic Power Generation Technology”, “Project for Promoting the Local Introduction of New Energy”, and Project for Supporting “New Energy Operators” and “Eco-School Promotion Pilot Model Project”. RPS is now being revised in order to be more beneficial for PV; an especially preferred measure for PV is added where installed PV power is counted double (Ikki & Matsubara, 2008).

Since 2009 PV installation began to increase again due to new PV generated electricity purchase system, subsidy for new PV system installation and Feed-in Tariff Law started. Subsidy for Residential PV systems was 70 thousand JPY/kWh started from November 2009. METI restarted the subsidy program for residential PV systems from January 2009 with the supplementary budget of FY 2008 and continued the program until FY 2011. New Purchase System for Solar Power Generated Electricity; purchase excess PV power: households: 48JPY /kWh; schools and hospitals, etc.: 24JPY /kWh; starting in April 2010 and run for 10 years. 739 kW for off-grid domestic PV systems, 3 422 kW for off-grid non-domestic PV systems and 986 818 kW for grid-connected distributed PV systems was produced mainly from residential houses.

In addition, 12 593 kW was installed for large-scale grid-connected centralized PV power application by utilities and local authorities. Japanese PV market is increasing again from 2009 and exceeds 1GW/year in 2011. 875 local governments and municipalities implemented their own subsidy programs to promote the dissemination of residential PV systems. Recipients can take advantage of these subsidies in addition to the national subsidy program for relevant PV systems by METI. Feed-in Tariff Law based on the “Renewable Energy Law”; PV systems with the capacity of 10 kW or larger, FIT, 42 JPY/kWh, for the period of 20 years; For PV systems with the capacity of below 10 kW, FIT, 42 JPY/kWh for the period of 10 years; enforced in July 2012; “Subsidy for introducing residential PV systems as restoration measures” (86,99 BJPY) and “Projects for establishing a fund for high penetration of residential PV systems as restoration measures” (32,39 BJPY) were established as funds and will be utilized fiscal year (FY 2011) and until FY 2013 to promote installation of residential PV systems. In expectation for the enforcement of the FIT program in July 2012, some local authorities started construction of MW-scale PV power plants.

Market formation: Germany

In September 1990, installations of residential PV systems have started under 1000 roofs and in Feed-in tariffs subsidy program. The target was installation of 1500 small (1-5 kWp) PV systems on the roofs. In 1995, "1000 roofs program" ended. More than 2,000 photovoltaic systems were installed with a cumulative capacity of 4MWp (megawatt peak). From 1996-1999, Green tariffs; higher feed-in tariffs paid to the customers from utilities; Aid from the federal states, many of the dispersed federal, regional and local support programs for PV were available to sustain the market after the end of the 1,000 roof program. The large number of cities adopting local feed-in laws and green pricing schemes revealed that demand for solar power still existed and was still growing. The main market introduction initiative, the 100 000 Roofs Solar Power Program, providing low interest loans of 1.91% since January 1999. Municipal PV FIT existed in over 50 cities and drove modest market growth during 1990-1999. By the end of 1999, about 67 MW of PV were installed due in large part to capital cost subsidies. From 1999, PV installations increased rapidly under subsidy program of 100,000 roofs and Erneuerbare-Energien-Gesetz (EEG). Since 2000, The Renewable Energy Law (REL) in combination with the 100 000 Roofs Solar Power Program has supported the German PV market until the end of 2003. Market stimulation program; Invested subsidies on schools, churches and congregations from 1999-2001 (on schools still ongoing), another market introduction initiative is the Renewable Energy Law (REL), providing buy back rates of 0,481 € for every kWh, which is generated by photovoltaic power plants and fed into the grid (in 2001: 0.51 €/kWh). 100,000 Roofs Solar Power Program accepted 19,882 applications for PV-systems with a total capacity of about 146 MWp. After stagnation in 2002, the PV market in Germany grew again strongly in 2003 with the successful installation of 100,000 grid-connected rooftop solar systems. By its end, Germany's solar PV industry had moved beyond niche markets to become capable of mass manufacture, the program ended after 2004. Since 2004, Germany is the country with the highest annual PV installation world-wide. This remarkable development is based on The “Renewable Energy Sources Act (EEG)” in the area of market introduction: The first PV feed-in tariff was established at a rate of 0.99 DM/kWh (around 0.51 €/kWh), and annual digression rates were set at 5% for all systems. From 2004 onwards, feed-in tariffs were graded according to system capacity and installation types (rooftop, façade, and field installations). In 2005 the market grew up to 889 MW installed grid-connected systems. 2005 around 3 MW were installed as domestic off-grid PV systems with rates between 0.46 and 0.62 €/kWh. Annual digression rates remained constant at 5%, and increased to 6.5% for field installations from 2006 onwards. In 2007 the market grew up to 1100 MW new installed systems (grid-connected systems). The German funding strategy favors the installation of grid-connected PV power systems. Therefore, grid-connected rooftop systems and large PV power plant are further on dominating the market. In 2007 around 3,5 MW were installed as domestic off-grid PV systems. German residential PV installation continuously increased under stable and modified EEG program in form of a Feed-in-tariff (FIT).

National Renewable Energy Action Plan (NREAP): By 2020, a total of 51,753 MW of capacity is projected to be installed in Germany. Germany will not implement a hard cap, but will instead continue to utilize price to manage market volume in line-at least-with the trajectory outline in the NREAP. The EEG 2009 envisaged a yearly 8-10% digression rate of these tariffs, which would change according to the amount of newly installed PV capacity each year. However, as PV system prices declined in 2009 much more rapidly than originally expected, deployment increased strongly; in 2009 PV installed capacity was 3799MW. Digression of 8-13% and 3% were implemented on 1 July 2010 and 1 October 2010 respectively. The new corridor system implemented in 2010 projected a baseline of 3.5 GW annual installations. The basic digression rate of 9% would increase by up to 4%, depending on the deployment above this baseline. The installation of PV systems in Germany was boosted again in 2011 driven by the Renewable Energy Sources Act (EEG) on the one hand and on the other hand by the decrease of system prices and modules. In 2011, German installed 7.5 GWp with 238,202 PV systems. The majority (37 percent) of the systems installed were smaller than 50 kWp – making Germany by far the largest residential customer market. Germany is the world's strongest PV market with 24.8 GWp of cumulative installations in 2011. Feed-in tariffs were reduced by 13% in January 2011. On 1 July 2011 the feed-in tariff would be reduced by 3% if between March and May 2011 on a yearly projected basis more than 3.5 GW solar panels had been installed. For each additional GW above this value up to 7.5 GW the tariff would be reduced by another 3%, up to a maximum of 15%. As a result of the dynamic market development grid parity has been reached at the end of 2012.

Rating the level of fulfillment of market formation (F5) for Japan and Germany based on the activities in the year 2011:

Japan was dominating the PV market globally during the decade 1994~2004. During this period Japan PV market increased 41 fold from 7MW in 1994 to 290MW in 2005. After 2005 Japan's PV market decreased and became 210 MW in 2007. On the other side, from 1990 to1999German PV market did not grew at all but after 2000 it increased rapidly. Since 2000, German PV market increased abruptly and it increased from 44MW in 2000 to 7500MW in 2011. During 2000-2011, development of German cumulative installed PV market increased 196 fold from 126MW in 2000 to 24.7GW in 2011. During 2000-2011, Japanese cumulative installed PV market increased only 15 fold from 330MW in 2000 to 4.9GW in 2011. Recently, Japanese PV market is increasing again from 2009 and exceeded 1GW/year in 2011, while the German market is increasing and exceeds 7.5GW/year in 2011. Table 11 shows the market size development of Japan and Germany with the presence of financial market incentive (govt. support program) and Feed-in-tariff (FIT)/ Renewable portfolio standard (RPS) law.

Table 11: Installation capacity of the year 1990, 2000 and 2011 and rating the level of fulfillment of market formation (F5) for Japanese and German PV innovation systems in the year of 2011

	1990	2000	2011	Rating the Level of Fulfillment F5
	Annual installation capacity	Annual installation capacity	Annual installation capacity	
Japan	4MW/year	122MW/year	1100MW/year 1.1GW	4
Germany	0.6MW/year	44MW/year	7500MW/year 7.5GW	5

11.2.6. Resources mobilization (F6): Allocation of resources

Resources mobilization (F6): (Japan)

In the early 1990's, for market-creation policies there was investment for subsidy program for residential PV systems. Budget for the Sunshine Program was 75 MJY. Buy-back system for the surplus PV power at the selling price has been implemented in the early 90's. In 1993 New Sunshine project was introduced; successor of the aforementioned project, integrating the Sunshine and the Moonlight (Energy-saving technology R&D) and the Global Environment Technology Projects started, aiming at acceleration of the market penetration of the technologies.

Monitoring program for residential PV systems; Aimed at stimulation of the PV market. 50% of PV installation costs were subsidized. 1994 national budgets for photovoltaic were 2,030 MJPY for market incentives. Subsidy program initiated by local government; Funding was given up to 40% of the installation costs. In 1995 national budgets for photovoltaic were 3,310 MJPY for market incentives. In 1997, national budgets for photovoltaic were 3,320 MJPY for R&D and demonstration/field programs, and 11,110 MJPY for market incentives. Subsidy system for industrialists who plan to introduce new energy was established. The total budget between FY 1997 to FY 2009 for "Supporting New Energy Operators" was 318,103 MJPY. In 1998, national budget for photovoltaic was 12,200 MJPY for R&D and demonstration/field programs, and 14,700 MJPY for market incentives. In FY 1998, support for private businesses who introduce new and renewable energy was 5,393 MJPY. In 1998, the budget for field test project on photovoltaic power generation systems for industrial and other applications (1998-2006) with subsidy (50%) for private companies, local public organization's for installation of PV systems was 2,400 MJPY. In 1999, national budgets for photovoltaic were 19,530 MJPY for R&D and demonstration/field programs, and 16,040 MJPY for market incentives. Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications (1998 -2006)1n 1999 the budget was 2410 MJP. In 2000, national budgets for photovoltaic of the METI totaled 28210MJPY, of which were 9,610 MJPY for R&D, 4,100 MJPY for demonstration/field programs, and 14,500 MJPY for market incentives. Project for Supporting New Energy Operators and Support for private businesses who introduce new and renewable energy; budget in FY2000 was 11,490 MJPY. 2001 national budgets for photovoltaic of the METI totaled 31, 930 MJPY, of which was 6,360 MJPY for R&D, 2,060 MJPY for demonstration/field programs, and 23,510 MJPY for market incentives. In 2002, budgets were increased in all the areas, PV market incentives, R&D and demonstration/field programs, and especially focused on dissemination. METI reviewed the status of the initial market of PV system and decreased 2003 budget for market incentives by almost half. Thus, total budgets for PV market incentives, R&D and demonstration/ field test programs were significantly decreased compared to 2002 budgets. Field Test Projects on Advanced Photovoltaic Power Generation Technology started in 2003, aiming at adopting new technologies into PV systems for public and industrial facilities and accelerating further development. The budget of these projects was 3,496 MJPY. Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications (1998 - 2006), budget in 2003, 262 MJPY. Public budgets for R&D (6,540MJPY), demonstration/ field test programs (11 110MJPY) and market incentives (5,250MJPY) Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications (1998 -2006), budget in 2004 was 137 MJPY. The 2006 budgets for PV systems are mainly based on the national budgets on R&D, demonstration programs and market incentives. The budget for R&D

was allocated to R&D for Next Generation PV systems", "PV System Technology for Mass Deployment, Phase II" and "PV systems Advanced Practical Technology", etc. In 2006, 3,170 MJPY was allocated for R&D including new and renewable energy other than PV, 13,600 MJPY in 2006 for demonstration/ field test programs. The budget for market revitalization amounted to 4,145 MJPY. Primary factors of the flat growth were termination of the budget for "Residential PV System Dissemination Program" and shortage of silicon feedstock for solar cell. 4,580 MJPY was allocated for R&D including new and renewable energy other than PV, 14,600 MJPY for demonstration/ field test programs. The budget for market revitalization amounted to 4,800 MJPY.

In 2007, 3,700 MJPY was allocated for R&D related to PV power generation, 12,170 MJPY for demonstration and 10,700 MJPY was allocated for market revitalization. New Purchase System for Solar Power Generated Electricity; purchase excess PV power: households: 48JPY /kWh; schools and hospitals, etc.: 24JPY /kWh; There was subsidy program for Residential PV systems; 70 thousand JPY/kWh; November 2009. 4,160 MJPY was allocated for R&D related to PV power generation (3 700 MJPY allocated in FY 2008), 2 170 MJPY for demonstration (12,170 MJPY in FY 2008), and 43,050 MJPY was allocated for market revitalization (10, 700 MJPY in FY 2008). In 2009, a new residential subsidy scheme has been announced with a budget of 9 billion yen (around 76 million Euros) for 35,000 systems (Photon, 2009). Subsidy for measures to support introduction of residential PV systems: 40.15 BJPY + supplementary budget of 14.53 BJPY. Technology Development of Innovative Photovoltaic Power Generation: 6.38 BJPY. Field Test Project on New Photovoltaic Power Generation Technology: 0.14 BJPY. International Cooperative Demonstration Project for Stabilized and Advanced Grid Connected PV systems: 0.208 BJPY. Japan-U.S. Smart Grid Collaborative Demonstration Project: 1.83 BJPY. Utilities completed construction of MW-scale solar power plants across the country and many of them started operation. NEDO and the European Commission jointly launch a project (2011-2014) to develop concentrator photovoltaic cells aiming to achieve a cell conversion efficiency of more than 45%, with a budget of about 650 million yen provided by Japan and about 600 million yen provided by the EU. Subsidy for measures to support introduction of residential PV systems: 34.9 BJPY; Technology Development of Innovative Photovoltaic Power Generation: 8.04 BJPY; Demonstration project on developing forecasting technology of PV power generation: 0.10 BJPY; International collaboration project on efficient use of energy consumption (Japan-U.S. Smart Grid Collaborative Demonstration Project in New Mexico, USA) budget was 1.0 BJPY. In 2011, the government allocated the budgets for "Subsidy for introducing residential PV systems as restoration measures" (86.99 BJPY) and "Projects for establishing a fund for high penetration of residential PV systems as restoration measures" (32.39 BJPY) were established as funds (FY 2011- FY 2013) to promote installation of residential PV systems.

F6: Resources mobilization (Germany)

From 1974-1990, the Federal Ministry for Research and Technology (BMFT) funded about 644.4 M DM to support R&D for PV. In 1990 the support was 95.0 M DM. 1990-1999; StrEG or "Electricity Feed-in Law", was Germany's first feed-in-tariff and did not have rates high enough to support PV installations. Feed-in-tariff payment set at 90% of the retail electricity rate, 8.45-8.84 €cent/kWh over the course of the decade. Electricity Feed-in Law (Budget 3.5 M EUR paid by final customer). In 1991, the Federal Ministry for Research and Technology (BMFT) funded 109 M DM to support R&D for PV. In 1991 "1000 roofs program" (1991-1995) is, in which the government gave subsidies to individuals to cover the cost of installing a PV rooftop system. From 1991-1995, Solar Roof Program offered up to 70% subsidy for installation of PV modules. In 1992, Feed-in-tariff rate was, 8.45-8.84 €cent kWh; 5% penetration cap for all renewables and there was 70% subsidy for installation of PV modules. From 1996-1999, Green tariffs from utilities as voluntary participation for the customers; higher feed-in tariffs paid to realize new PV plants. Feed-in-tariff rate was, 8.45-8.84 €cent kWh. From (1999-2003); 100,000 roofs program was implemented, with an initial goal of installing 300 MW by 2004. Funded with EUR 560 million (~$500 million), the program provided 10-year low interest loans (1.91% in 2001) with no money down and no interest payments for 2 years. This financing package corresponds to a subsidy of roughly 20%. EEG program and project caps to control ratepayer impact started in 2000. Erneuerbare-Energien-Gesetz (EEG) PV receives 52Eucent/kWh; with 5% annual digression, 350 MW program cap, 5MW program cap for rooftops, 100kW system cap for free-standing (2000), Renewable Energy Act (Budget 83 M EUR paid by final customer), Feed-in tariff of €0.457 fixed for 20 years (5% decrease annually for later installation from 2002 on) 01.04.2000-ongoing. R&D expenditures of German PV industry was 6.0M EUR. Support from the Federal Ministries (BMBF, BMWA) for R&D on PV projects was 39.1 M€ in 2000. The first EEG established a rate of 0.99DM/KWh (~ 0.51€cent/kWh) for PV starting in 2001. In2002 the support from the Federal Ministries (BMBF, BMWA) for R&D on PV projects amounted to; 23.6 M€ amount was spent for special research projects for R&D on PV. The EEG law was amended to increase PV capacity, in the cap program, cap raised to 1000 MW. R&D expenditures of German PV industry was 16.1M EUR. In 2003 the support from the Federal Ministries (BMBF, BMWA) for R&D on PV projects amounted to about 29.7 M€. This amount was spent for special research projects. 100,000 roofs program Funds exhausted, the program ran out of fund on July 2003. R&D expenditures of German PV industry was 29.8M EUR In accordance with the PV R&D strategy, the funding for these projects amounted 29.5 MEUR in 2004; Amendment to the EEG tariff resulting in improved payment conditions. EEG Amended, New rates ranging from 46-62 EU cent/kWh go into effect with 5%-6.5% digression Program cap removed, System size caps removed August 1, 2004. In 2006, R&D expenditures of German PV industry were 166.1M EUR. At the EU level, R&D activity grant funding of EUR 53.3 billion has been made available for the period 2007 through 2013. For the fiscal year 2008, the government has earmarked some 3.3 billion Euros for climate policy, 1.8 billion Euros more than in the 2005 budget. To this end the German government raised the funding available to up to 350 million Euros a year until 2012. By 2008, the federal Government had provided about $1.2 billion in subsidies to firms in the East German solar cluster. Government also offered an extensive scheme of operational incentives, training support, wage subsidies, and incentives for R&D. EEG was Amended, following 2008 amendment to law, Rates for façade integration removed, Rates for onsite consumption introduced, Corridor digression system introduced, with a range of decreases from 5.5%-7.5% and National feed-in-tariff registry created. A total R&D funding volume of around 39.8 million Euros was granted. In 2010, BMU approved 45 new projects on photovoltaic, corresponding to a funding volume of 39.8 million Euros. EEG amended; Building-mounted systems decrease 13% in July, and 3% on October 1, 2010. On top of 7.5% digression from 2009; Ground-mounted systems decrease 8-12% in July, and 3% on October 1, 2010. Corridor digression revised with a range of decreases from 6-13% from July 9, 2010.

In 2011, a total R&D funding volume of around 74 million Euros was supported. The federal government started the 6th Energy Research Program, the Forde initiative Energiespeicher ("Energy Storage Funding Initiative") supports collaborative R&D projects with funding of EUR 200 million for the period 2011-2014. Since 2011 the "Innovation sallianz Photovoltaik" ("Innovation Alliance Photovoltaic") has been overseeing a Federal Ministry of Education and Research (BMBF) PV research budget in the region of EUR 100 million, as well as an additional EUR 500 million investment commitment from industry. In 2011, a sum of EUR 74.3 million was made available for 96 new PV R&D projects by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). In September 2011, Germany launched a research and development program for research in renewable energies, energy efficiency, energy storage, grid technologies and the integration of renewable energies into the energy supply system, offering up to $4.77 billion between 2011 and 2014. Corridor revision proposal Joint BMU and BSW proposal to revise corridor digression schedule, by 0%-15% on July 1, 2011, and again by 9% at the end of the year (January 2012).

Rating the Level of fulfillment of Resources mobilization (F6) for Japan and Germany based on the activities in the year 2011:

In 2002, the number of research employees in Japan were 2, 800 and the number of research employees in Germany was 2,200. At the same time in 2002 public investment was 35.1 Bill.¥ (351MUS$) in Japan, whereas in Germany Public investment (FIT) was 23.6 Mill.€ (30.7MUS$), and system expenditure for PV installations 600 Mill.€ (780MUS$). In 2007, the total number of research employees in Japan was 7,000; on the other side Germany had 19,600 research employees. Japan spent 23.98 Bill ¥ (240MUS$) for public investments in 2007, whereas at the same year Germanys Public investments were 86.2 Mill. € (112MUS$) and system expenditure for PV installations 7,000 Mill.€ (9,100MUS$). In 2011, research employees in Japan were 10,000 and the number of research employees in Germany was 22, 000 in 2011. Public investment in Germany was 223.9 Mill.€ (291MUS$); and system expenditure for PV installations of 15,000 Mill.€ (19,500MUS$)(FIT). On the other side in 2011, Public investment in Japan was 46.12 Bill.¥ (461MUS$). Table 12 shows the rating of resources mobilization (F6) of Japan and German PV innovation system considering the number of research employees and public investment (FIT) for the year 2011. During 2002-2011, German Public investment (FIT) and the number of research employees increased but Japanese Public investment (FIT) decreased and the number of research employees did not increase comparatively.

11.2.7. Advocacy Coalitions (F7): Lobby activities for the technology;

Advocacy Coalitions: Japan

The government has always been a main player in the promotion of solar power as an important renewable technology. Since the beginning of the Sunshine Project, solar technologies

Table 12. Availability of research employees[a] and public (FIT) investment[b] of Japan and Germany and rating the level of fulfillment of resources mobilization (F6) for Japanese and German PV innovation systems in the year of 2011

	2002		2007		2011		Rating the Level of fulfillment F6
	Availability of employees[a]	Public (FIT) investment[b]	Availability of employees[a]	Public (FIT) investment[b]	Availability of employees[a]	Public (FIT) investment[b]	
Japan	2,800	35.1 Bill.¥ (351MUS$)	7,000	23.98 Bill.¥ (240MUS$)	10,000	46.12 Bill.¥ (461MUS$)	3
Germany	2,200	23.6 Mill.€ (30.7MUS$)	19,600	86.2 Mill.€ (112MUS$)	22,000	223.9 Mill.€ (291MUS$)	4
		115 Mill.€ (149.7 MUS$)		1,598 Mill.€ (2,077 MUS$)		4,705 Mill.€ (6,116 MUS$)	

[a] Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D; [b] Public investment (R&D, subsidy and manufacturing plants) and total system expenditure for PV installations including FIT (Calculation based on time period of 20 years, 7% discount)

have been part of government's future energy plans. The government has always greatly promoted research on PV, such as the 'New National Energy Strategy' and 'Cool Earth 50'. The practice of interest groups influencing government policy, is known as 'lobbying', differs in Japan from the well-known 'make yourself publicly heard' approach in Europe, and is mostly a process which takes place behind closed doors. There are no large well-known customer organizations or 'green' political parties; however there are no indications that this lack forms a problem. Government regularly receives information from outside actors such as industry and academia through advisory committees. The government's goals and policies in general are not top-down but are made in conjunction with all relevant parties. NEDO is the government's main subsidy provider. NEDO is not staffed with specialists from specific technological fields and does not have the necessary knowledge to judge the highly technical proposals that come in. These evaluations are done by committees of experts which are made up of academic and company researchers. This automatically gives academic and industry researchers a large amount of influence over the future direction of PV in Japan. The main organization which brings

Japanese PV parties together is the Japanese PV branch organization, the JPEA. It consists of a wide range of organizations including: PV manufacturers, equipment manufacturers, engineering companies, research institutes, power companies and raw material suppliers (JPEA, 2009). The JPEA has an important role in the exchange of information and 'lobby' activities of the PV sector. It organizes many seminars and events on a wide variety of topics, it promotes collaboration between actors in the system and provides many opportunities for actors to meet one another and is an important speaking partner for the government (JPEA, 2008). However the JPEA has indicated concerns that the PV industry is too interested in the foreign markets. As a result they might not be working as hard as they could to convince the government to initiate a new scheme. These concerns are shared by the RTS (JPEA, 2006)

Most of all the market-creation policies had been requested by PV producers since the early 1980's. In the late 1980's Japan Photovoltaic Energy Association (JPEA) was established as an industry coalition group. Through JPEA they intensified their lobbying activities against the government around the period of 1990. In1993, guideline of the technical requirements for PV grid-connection with reverse flow was prepared. The New sunshine Project was initiated by MITI. Basic Guidelines for New Energy Introduction came to a decision at the Cabinet meeting in 1994. Local government initiated in drawing up their PV introduction plan under the vision for Regional New Energy in1995. Advisory Committee for Energy made the additional suggestion to energy policy in 1996 for self-sustaining PV market. In 1997, law on special measures for promotion of new energy utilization was enacted. In 1998, Global Warming Act enacted with Basic policy and responsibilities; National and local action plans. "Law on Promotion on Measures against Global Warming" was also enacted in 1998. Policy on "The Law Concerning the Promotion of Development and Introduction of Oil Alternative Energy" was revised. Photovoltaic was placed one of Oil alternative energies. Electric utilities introduced the "Green Power Fund" in October 2000 to promote the dissemination of natural energy. Period between FY 2001 and FY 2010, the fund supported PV installations at 1 568 places nationwide, with a total capacity of 27 593,9 kW. In 2002, the National Diet enacted "the Basic Law on Energy Policy". The Law guides the nation under 3 energy policy principles: stable energy supply, environmental harmony and market mechanism. PV is on the list as a measure to the environmental harmony. The Ministry of Economy, Trade and Industry (METI) enforced the Law. Concerning the Use of New Energy by Electric Utilities (Renewables Portfolio Standard (RPS) Law) as a new policy to promote and deploy new and renewable energy. The target minimum ration of renewable energy usage in 2010 is 12,200 GWh, which accounts for 1.35%

of net sales energy demand. In 2004, Renewables Portfolio Standard (RPS) Law was enacted. 2006, Amendment of the Global Warming Act was the Use of Kyoto Mechanism. In 2008, Announced "Cool Earth—Innovative Energy Technology Program," an Amendment of the Global Warming Act; Policy plans of local governments; GHG reduction guidelines for companies. 2009 was the Start of "New PV Power Purchase Program", As a result, utilities voluntary programs to purchase surplus PV power were replaced by the national program. In 2010 METI approved treatment of PV power generation facilities as "environmental facilities other than green spaces" under the Factory Location Act. In order to ease the regulation, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) perform "the management of building acts regarding PV facilities". MOE) is taking the initiative for studying introduction of the Environmental Tax.

In 2011, the government newly established the Energy and Environment Council to start the revision of the energy strategy with the aim to lower the dependence on the nuclear power and to expand the use of renewable energy. Government also enacted "the Renewable Energy Law" and decided the launch of Feed-in Tariff Scheme for Renewable Energy from July 2012. The Ministry of Economy, Trade and Industry (METI) undertook the development of new Basic Energy Plan in tandem with the newly-established Energy and Environment Council and enhanced the aid budgets in order to disseminate and expand the introduction of residential PV systems. As the Law on Special Measures Concerning Procurement of Renewable Energy Sourced Electricity by Electric Utilities ("the Renewable Energy Law") was enacted in August 2011, the PV market in Japan made a significant step in 2011 toward a full-fledged dissemination of PV systems. Taking program design and pricing away from METI is a major victory for renewable energy advocates in Japan.

Advocacy Coalitions: Germany

PV R&D started in Germany after 1st oil crisis in 1974. 1979 witnessed the foundation of the Association of Solar Energy SMEs, which became German Solar Energy Industries Association in 1986. This association was mainly occupied with lobbying campaigns for the PV industry (Bruns et al., 2011). Also in this period the German Society for Solar Energy (DGS) was founded in 1975. "The groups' objective is to diffuse information to politicians and industry. A presidium undertakes most of the discussions with policy makers and DGS is present on the advisory groups on energy within the different political parties." (Jacobsson et al, 2004). Such associations represent the most important force in lobbying. Since then, R&D activities gradually increased under the support from Federal Ministry for Research and Technology (BMFT) and Federal States. 1990-1999; StrEG or "Electricity Feed-in Law", under this feed-in law, PV and wind shared the same tariff. The first major government action of importance for the PV industry was the 1,000 roof program (1991–1995), it was the world's largest demonstration and market formation program for the PV industry at this time. From 1990-1999; StrEG or "Electricity Feed-in Law" was on act and "1000 roofs program" in 1991-1995. Local support groups for renewable energy were able to request local governments to adopt these models of energy supply in their regions. These smaller contributions were essential in initiating a "public wave of support" for solar energy, and it was key to the survival of the (at that time) small PV industry (Palz, 2010a). Accompanied by intensified lobbying efforts, solar industry and solar development associations began to demand support for a large home market to emerge. Social Democratic–Green federal government in 1998 encouraged renewable energy development. In 1988 the Eurosolar association was founded, on the basis of meeting the need to "create a public climate that would enable it to tear down the walls in people's minds". This non-profit European association lobbies within the political structure, but is not affiliated to any party or interest group. Nonetheless, several members of the German parliament were in the association (Jacobsson & Lauber, 2006), but also scientists, companies, associations and citizens from different occupational sectors (Bruns et al., 2011). This group later on proved to be instrumental in initiating the 100,000 roofs program, a program which in turn had a major impact on the diffusion of PV in Germany. In 1998, Germany strongly promoted renewable energy to help achieve GHG reduction targets. Within the Social Democratic–Green federal government coalition agreement, some arrangements were made that were dedicated to renewable energy. in 1990 several other member of the parliament from other parties (CDU/CSU, the Greens), who were already members of EUROSOLAR, teamed up and this led to the first feed-in tariff law and was adopted by parliament in 1990. Building on proposals from different solar development associations, these included the origination of a "100,000 roof program" for solar market formation and a reform of the Feed-in Law to promote in 1999. A cross-parliamentary group ("solar parliamentarians") alliance was started by Hermann Scheer from the SPD and Joseph Fell from the Greens which had the support of about 50 members from parliament (Bruns et al., 2011). From 1999, four members of the Bundestag (two from SPD, including Herman Scheer, and two from the Greens) were working on a draft bill, and subsequently the famous Renewable Energy Act (EEG) was formed. For this bill, the SPD and Green party parliamentary groups were won over to support it in 1999. The Renewable Energy Sources Act (EEG) foster deployment of renewable energy technologies in Germany and thus support a stable market for manufacturing companies. New Renewable Energy Law (EEG), replacing percentage-based tariffs with fixed-ones over longer periods. Government decided to Phase out nuclear power; for expanding electricity generation from renewable sources, phase out nuclear power within the period of 2003 to 2021. The role of the associations was mainly to support and strengthen the ministries, the parliament and the federal government. In 1998, the Solar Industry Trade Association (UVS) was founded. The German Solar Energy Association (BSE) and the German Solar Industry Association (DFS) merged and became German Solar Sector Association (BSi) in 2003. An important contributor of this time is the German Solar Industry Association. One of their most important activities is political consulting, which basically implies systematically lobbying for investment security and suitable market incentive programs, and creating consensus among politicians for the need for PV energy in the future, In 2004 the Renewable Energy Sources Act (EEG) amended with revised FIT rate, Program cap removed and System size caps removed. In 2008 2nd amendment of EEG following 2008 amended to law, revised FIT rate, rates for onside consumption introduced; corridor digression system introduced; national FIT registry created. Act on the promotion of renewable energies in the heat sector and act on granting priority to renewable energy sources was also enacted. In december 2010 (subsequently amended in July 2011), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety introduced an Energy and Climate Fund (EKFG) dedicated to the promotion of an environmentally-friendly, reliable and affordable energy supply.

Furthermore, there was broad support from the government, as within the government consensus exists on a general level with regard to energy policy. Even the conservative government (the opposition is yet more progressive) supports the energy transition and the phase out for nuclear power (which was related to the nuclear disaster in Japan) It was decided in 2011 to terminate the production of nuclear power until 2022. The Corridor revision proposal; BMU/BSW proposed to revise corridor digression schedule. The decision to exit from nuclear power was not satisfying in itself; therefore they initiated or changed 16 laws in order to also safeguard renewable energies and ensure a reliable energy supply. The EEG amendment prepares the way for a development as it will promote consumers' own consumption to a higher degree: private households that do not feed in solar electricity but consume it themselves will gain up to 8 euro cent per kWh. Therefore a wide range of initiatives, regulations and financial support schemes exists.

Rating the level of fulfillment of Advocacy Coalitions (F7) for Japan and Germany based on the activities in the year 2011:

The 'lobbying' activity in Japan differs from Germany, and is mostly a process which takes place behind closed doors. In 2011, the government established the Energy and Environment Council to make the revision of the energy strategy with the aim to lower the dependence on the nuclear power and to expand the use of renewable energy. Japan Photovoltaic Energy Association (JPEA) was established as an industry coalition group. Through JPEA they intensified their lobbying activities against the government and gradually form networks within society and political parties. Furthermore, Government also enacted "the Renewable Energy Law" and decided to launch the Feed-in Tariff Scheme for Renewable Energy from July 2012. The Ministry of Economy, Trade and Industry (METI) undertook the development of new Basic Energy Plan with the newly-established Energy and Environment Council and enhanced the aid budgets in order to disseminate and expand the introduction of residential PV systems. The PV market in Japan made a significant step in 2011 toward a full-fledged dissemination of PV systems. Taking program design and pricing away from METI is a major victory for renewable energy advocates in Japan. Based on the above activities we can see that Advocacy Coalitions (F7) of Japan is in level 3.

Recently in Germany, there was broad support for the advocacy coalitions from the government, as within the government consensus exists, with regard to energy policy. The government also supports the energy transition and decided to phase out nuclear power (which was related to the nuclear disaster in Japan). In 2011, government decided to terminate the production of nuclear power until 2022. The decision to exit from nuclear power was not satisfying in itself; therefore they initiated or changed 16 laws in order to safeguard renewable energies (PV) and ensure a reliable energy supply. The Corridor revision proposal; BMU/BSW proposed and ensure a reliable energy supply. The EEG amendment prepares the way for a development as it will promote consumers' own consumption to a higher degree. Therefore a wide range of initiatives, regulations and financial support schemes exists. At present the PV technology is strong enough to fight against the conventional electricity. That is PV system price decreased and became the same as grid electricity price in 2012. Many electricity customer segments in Germany are now able to produce PV electricity cheaper from their roofs than buying electricity from the grid due to sharp fall in PV rooftop system prices in recent years. Based on the above fact we can see that Advocacy Coalitions (F7) of Germany is in level 5.

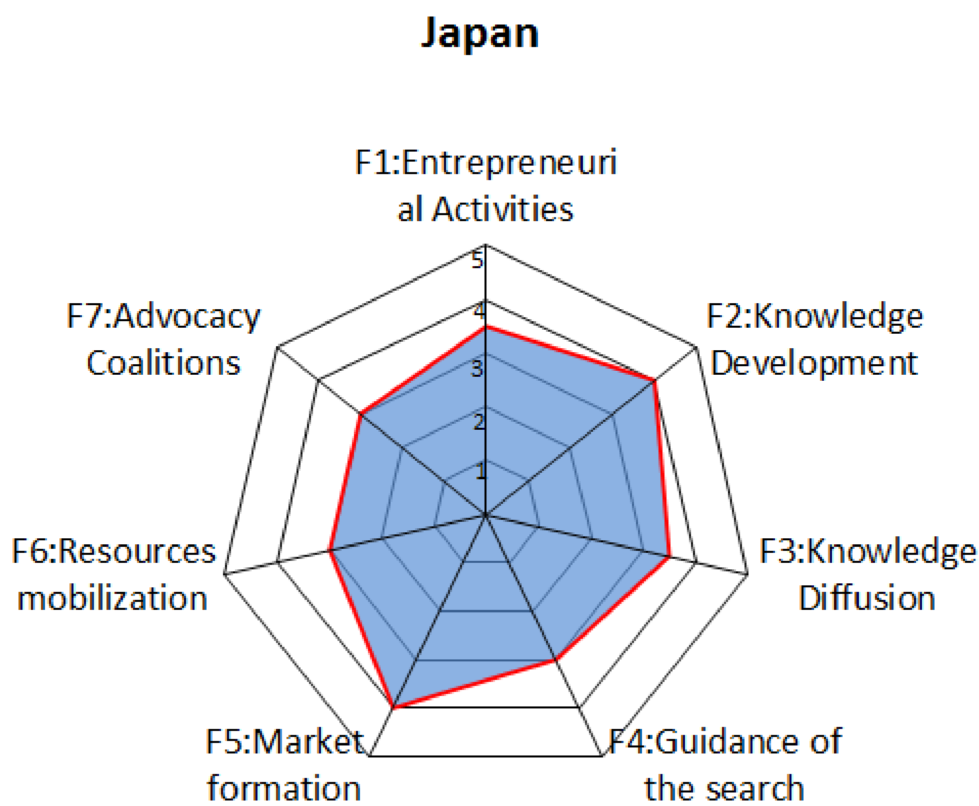

Figure 29: Functioning of the innovation system functions of PV for Japan

Figure 29 shows the functioning of Japan innovation system. Here we can see the rating of the level of fulfillment of the functions are F1 (3.5), F2 (4), F3 (3.5), F4 (3), F5 (4), F6 (3) and F7 (3). Figure 30 shows the functioning of German innovation system. Here we can see the rating of the level of fulfillment of the functions are F1 (4), F2 (4.5), F3 (4), F4 (4), F5 (5), F6 (4) and F7 (5).

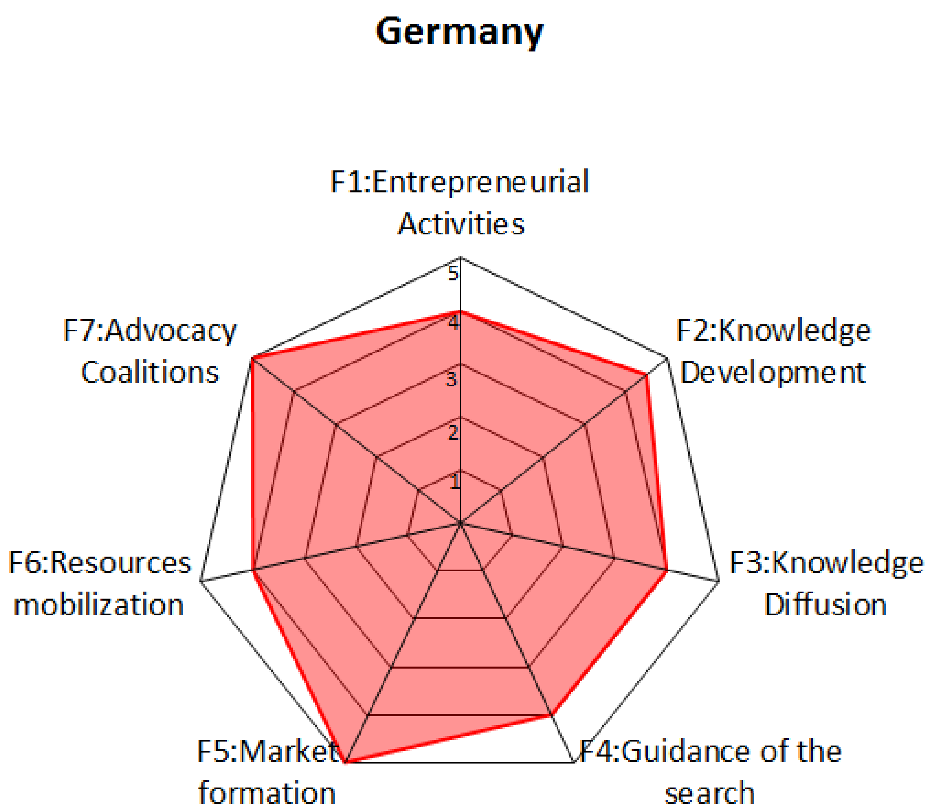

Figure 30: Functioning of the innovation system functions of PV for Germany

Chapter 12

12. Comparative analysis of Japanese and German PV Innovation Systems

12.1. Functional comparison and lessons to be learned

In order for a technology to be successfully developed and implemented a well-functioning innovation system is needed. In the case of the Japanese and German PV innovation system almost all system functions are fulfilled and interact with each other in a positive way, only a few needs extra attention. The positive functions set an inducing mechanism that will support the implementation of PV. The main system functions that trigger the positive build-up of the German PV innovation system are Advocacy Coalitions (F7), guidance of the search (F4) and the large domestic market (F5) as there is a mutual vision on which policies are based and that the policies (FIT) are long-term in order to provide certainty and support to entrepreneurs (F1) and investors in order to set up projects and invest in PV technology and thus the market grew. In addition due to a solid research (F2) base and strong lobby power (F7), realistic expectations are formulated for PV and little technical disappointments occur. Another important aspect is the way of lobby activities in Germany, the government's goals and policies in general are made in conjunction with all relevant parties. This ensures commitment of all parties and allows alignment of the institutional conditions with the needs of the technology. In the case of Japan, not all system functions are strong and perfectly fulfilled, resulting Japanese PV innovation system slower than Germany as soon as institutional conditions are changed. Due to the lack of guidance of the search (F4) and Advocacy Coalitions (F7); market formation (F5), the entrepreneurial activities (F1) and resource mobilization (F6) decline, and the stop of projects; again leads to a loss of knowledge and skills (F2) as there is no feedback from practice, again causing the lack of human capital (F6) for the installation projects. In both countries manufacturers are aiming for export to foreign markets, however as Japan is already one of the largest producer in the world and has an established (domestic) distribution network, it has a much better position for export than Germany. The RPS scheme did not lead to a quantitative increase in renewable energy capacity, instead, it became evident that Japanese renewables, especially photo-voltaic (PV), were losing share in the international markets. Thus in order to facilitate the diffusion of PV technology in Japan and to obtain competitive advantage, a Japanese PV innovation system has to be established, where system functions such as guidance of the search (F4), knowledge diffusion (F3), resource mobilization (F6) and Creation of legitimacy (F7) needs to be more fulfilled and strong enough for the technology to fight with the incumbent technology. Antagonizing advocates can also come from stakeholder of other renewable energy sources and energy saving methods. This creates a competitive situation for the most cost efficient solution. Since PV systems are currently very expensive compare to grid electricity and other technology (nuclear) produced electricity costs, which can lower the technology's legitimacy. A comparison based on long term potential would do the opposite. For that reason we suggest that the weak lobbing activities constitute a blocking mechanism for further 'legitimation' of PV technology. Once again, the lack of political visions for the very long term is hampering PV Technology to grow more in Japan.

12.2 Discussion of Inducement and the Blocking Mechanisms

While analyzing the dynamics in the functional pattern it becomes apparent which mechanisms are blocking the development and which are inducing it. This section is a summary of the analysis with the purpose of creating an overview of the dynamics in the system. Identifying the inducement mechanisms is a way of evaluating the positive effects of the market formation program and identifying the blocking mechanisms is of special importance since they point out crucial targets for the next round of policy interventions. The following are the discussion of inducement mechanisms (Figure 31) and blocking mechanisms (Figure 32) of Japanese and German PV innovation system.

Inducement mechanisms: The subsidy scheme mobilized resources (F6) and opened up a market space (F5). This will influence the guidance of search (F4) of both investors and suppliers in PV system (F1). The subsidy programs sometimes induce market formation (F5) directly. Entry of firms (F1) into the TIS is, thus, stimulated and these have a positive impact on some functions. Among these, we find influence of the direction of search (F4) to more new entrants (F1) which suggests that we may be seeing the beginning of positive feed-backs. A positive "side-effect" of the support is the climate debate campaigns that have positively influenced advocacy coalition or legitimation (F7) and positive externalities like guidance of the search (F4). There are, of course, also other sources than the government support program that have a positive impact on the functional pattern. The government support program influences the knowledge development (F2) and knowledge diffusion (F3) function and also induces the entrepreneurs (F1). There is strong guidance in Japan for PV research activities through the

PV2030 Roadmap, which is incorporated in the governments' energy strategy. The performed research (F2) increases expectations of the technology's capabilities to fulfill the governments' cost reduction targets (F4), which have also been proven (in part) in the large domestic market (F5). The diffusion of PV technology in Japan went very well during the period 2000-2005, due to the New Sunshine program and Residential Dissemination Program (RDP), which triggered several activities to occur, leading to an inducing mechanism. The lobby activities of the PV advocacy organization (F7) reportedly facilitated the initiation of market support mechanisms (incentives) by the government (F6). The growing market (F5) in turn attracted new entrepreneurs, such as Sanyo (1997) and MHI (2002) to the development and production of PV (F1). This increased the lobby power and the RDP program was extended for an additional two years in 2003 (F7). A research based inducing mechanism can be identified in Germany for the period 2000-2008. The country is very active in PV research and has strong international ties (F2). There are many collaborative efforts in the German research community and between German companies and research institutes (F3). This research is supported through national and international research subsidy programs (F6), as the government wants to maintain a leading position with respect to knowledge on PV. As such in Germany PV technology has gained a certain legitimization by the government as a valid option to attain the desired targets of reducing oil dependency and CO2 emissions (F2/F4). The performed research (F2) increases the technology's capabilities to fulfill the cost reduction targets (F4), German PV technology has gained a certain legitimization (F7) by the government which have also been proven in the huge

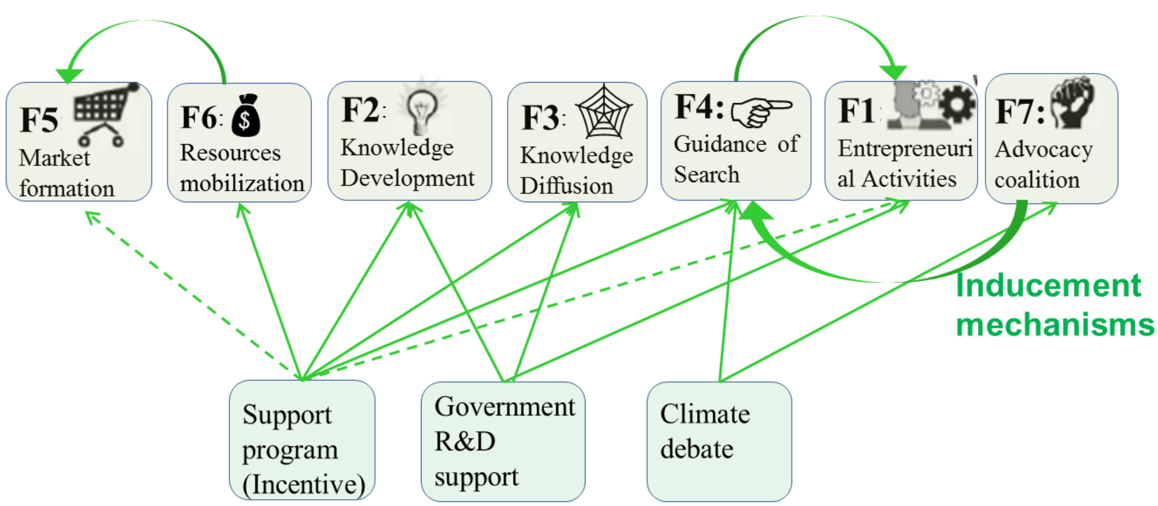

Figure 31: The effects of the inducement mechanisms on the functional pattern

domestic market (F5). One of the benefits of the German FIT is that it provides economic incentives for end-use customers to buy PV systems (F6), reducing the pay-back period to perhaps a few years. In this way, the market is greatly expanded from those who buy PV out of environmental consciousness to those interested in investment possibilities, thus also increasing 'legitimation' (F7).

Blocking mechanisms: This section lists the most prominent blocking mechanisms and describes their effects on the functional pattern; obviously, the main barrier to market formation (-F5) is the high cost of PV systems. This barrier is strengthened by difficulties to include other values than economic ones in pay-back calculations, if the market is not big enough (small niche) it will have blocking effect on knowledge development (-F2) and knowledge diffusion (-F3). Another barrier is the lack of adapted standards regulations and unaligned energy policy, e.g. the current rules for grid- connection of PV systems. Many of the actors in a TIS have very little or no experience of PV technology. So, there is a lack of knowledge among actors in the value chain. Many of the actors that have some experience of PV are only occasionally involved in PV projects which mean that there are no incentives for a systematic knowledge build up. For many companies, especially in the building sector, these incentives are further lowered by the fact that PV projects are an extremely small niche of their regular business. In terms of structural components this not only means that there are 'holes' in the Innovation system but also that the networks between the actors in the Innovation system are not well developed. These features block knowledge development (-F2) and diffusion (in networks) (-F3) as well as further entrepreneurial experimentation (-F1) (in spite of the positive effects of the scheme on that function). As the supply side is affected (e.g. poor supply of eco- houses; impossible to buy solar power in the market) market formation (-F5) is consequently obstructed. The two last blocking mechanisms affect the legitimacy of PV. By obstructing the process of legitimation (-F7), they also, by extension, constitute a blocking mechanism to guidance of search (-F4) and 'entrepreneurial activities' (-F1). However since 2005 the amount of PV that is installed in Japan each year has leveled off (-F5). We have identified two possible causes for this; a psychological effect of the stop of RDP program and outside forces such as the rise in raw material prices combined with unstable market formation (-F) activities, such as inconsistent market subsidy schemes (-F6), leads to a decline of the Japanese PV market (-F5). There is clear interest from some industry and government institutions in new market support measures (-F7). However at the same time, practically all PV manufacturers in Japan are focusing on foreign markets (-F1) and are unwilling to lobby for new measures (-F7). One of these barriers is the absence of a political vision for PV sector in the government (-F7). Many actors in the PV and energy sector in general, feel that there is no long-term agenda for the energy sector and no clear vision for the PV technology in Japan. The second blocking mechanism, the legitimation process (-F7) is powerful advocates of larger scale and centralized technologies (nuclear, fossil fuel) that do not believe that PV has a role to play in the Japanese energy system. These are very large actors that have a great deal of influence on Japanese energy politics and practice. The Japanese government and the country's electric utilities, however, pushed hard for RPS over FIT (F7). Though Japanese interest groups have started to build legitimation on a local level (-F7) which proved successful in Germany – they seem to be less organized. Adding the fact that environmental NGOs seem to be less active, we suggest that their absence constitute an important blocking mechanism for further 'legitimation' of PV. Once again, the lack of political visions for the very long term is hampering PV Technology to grow more in Japan.

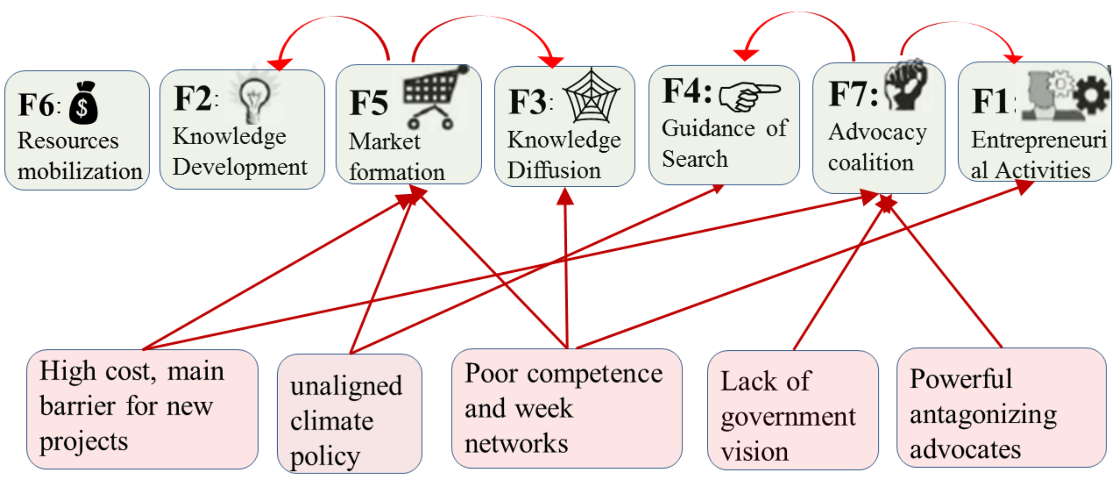

Figure 32: The effects of the major blocking mechanisms on the functional pattern

12.3 Future energy plan (Policy measures) for Japan

To counteract the blocking mechanisms there is a range of conceivable policy measures. The most forthright is, overcoming the high cost barrier, is to introduce some sort of policy instruments that favors PV system. The current support program (FIT) has managed to overcome this barrier, but there is a large uncertainty in the TIS as to what will come after it. For the actors in the TIS, it is crucial to avoid a stop and go policy with its overwhelming risk to lose what has been built up. Short term program (sunshine) creates a lot of uncertainty and impedes investments in knowledge formation and network building. A longer-term market formation program like New Purchase System for Solar Power Generated Electricity to purchase excess PV power from households: 48JPY /kWh; from schools and hospitals, etc.: 24JPY /kWh; starting in April 2010 and will run for 10 years. The Feed-in Tariff Law based on the "Renewable Energy Law"; for PV systems with the capacity of 10 kW or larger, FIT is 42 JPY/kWh, for the period of 20 years, would overcome that blocking mechanism as well as the high cost barrier. It would also deal with the lack of government vision barrier and it can also overcome the poor competence and weak networks barrier, especially if the support program is combined with clear political targets for the PV technology (Figure 33).

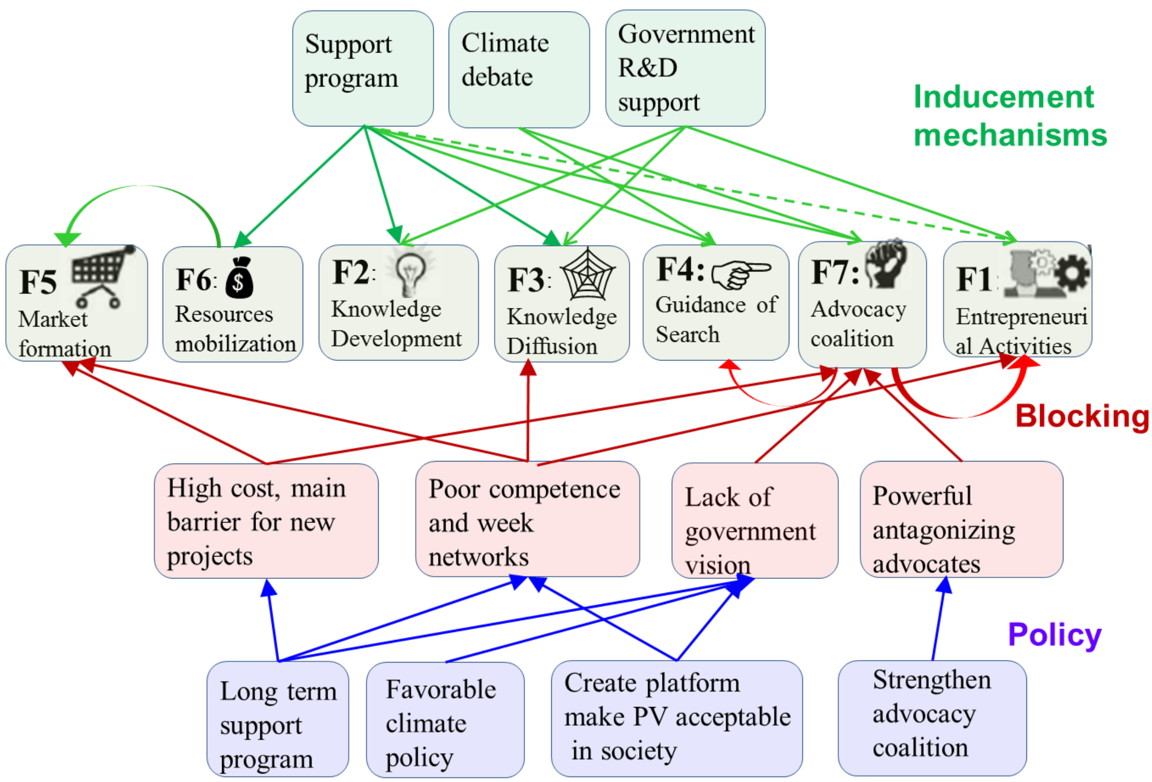

Figure 33: Blocking mechanisms and the effects of policy measures

The problem with standards and regulations that does not fit the PV technology can be solved by 'simply' changing these so they are adapted to the PV technology as well. However, this often becomes a question of legitimacy and market power (network companies have regional monopolies) and there are many problems connected to making changes in the regulatory framework. To manage the strong forces from the antagonizing advocates (nuclear, fossil fuel), it is necessary to find and strengthen some sort of counterforce. The TIS (PV) specific advocacy coalition is a central part of this counterforce and a policy option is to strengthen it. To avoid the blocking effect of the powerful nuclear innovation system in Japan, include numerical targets for both nuclear energy and renewable energy in the same policy documents or law. The most important way of doing this is to induce more actors (Technology developer, adopter, regulator, and financer, entrepreneurs) to enter the TIS. It would be particularly important to induce large, and influential, actors that can bring momentum to the legitimation process. As described earlier new entrants play a key role for the development of positive externalities. Furthermore, Japan needs to create a strong platform for PV in the society. Renewable energy NGOs should expand their efforts to express the value of PV energy in low-carbon economic development and make PV more popular in the society, that way create a strong platform for PV in the society. By doing this government vision will change and the PV technologies week network and poor competence will improve.

Considering the multiple obstacles facing the renewable energy (PV) technology in Japan, it is clear that it would be nearly impossible for the country to abandon nuclear power. Japan Coal Energy Center suggested that abandoning nuclear energy is probably not possible. Rather, most likely the existing nuclear plants will continue to operate and no new ones will be built. Japan should have high hopes for renewable energy, but it still need a base, steady energy supply. Recent opinion polls conducted by Tokyo Shim bun in June 2011 shows that, while an overwhelming 82% supported Japan's move away from nuclear energy, most respondents recognize the need for it and favor a gradual phasing-out of nuclear power instead. Some may wonder why, unlike Germany, Switzerland and Italy, Japan has not decided to discontinue its nuclear program. But it is important to consider society, manufacturing and lifestyle as factors in Japan. Renewable energy's unsteady supply is probably fine for an agrarian society, but as a manufacturing society, Japan need to ensure a stable electricity supply. Japanese Prime Minister Yoshihiko Noda declared that japan will decommission reactors at the end of their life spans but it is impossible to immediately reduce their dependence on nuclear into zero. Going forward, Japan will need to reconcile its industry needs with popular sentiment. Japan needs to think about the "best mix" of energy resources to diversify their energy sources to mitigate the impact of crises and issues in other countries, while keeping CO_2 emissions in mind. The natural and nuclear disasters of March 2011 have compelled Japan to reexamine its energy matrix. This new debate could pave the way for a greater adoption of renewable energy. It is time for alternative energy to be more than just an alternative.

12.4. The transformation process

Transforming the energy system involves replacing or supplementing, established technologies with new one. A necessary condition for the development and diffusion of a new technology is that variety in the knowledge base is increased by means of experimentation. Thus, understanding how variety in the knowledge base is created and sustained is the first step for the transformation of the energy system. Here research leads to new technological variations and possible societal applications. In the competition between an emerging new technological system and an incumbent one, the latter is supported by a whole set of institutions, for instance in the form of legislation favoring the incumbent technology. Thus the second step is therefore, the process of institutional change where the new technology starts to influence the existing system. Competition starts and the new technology acquire a niche market. Since the construction of a new system often involves the destruction of an alternative system, actors within the existing system can be expected to try to obstruct the development of the new one. In this phase the existing system is adjusted to fit the new technological system. In the final stage the system is totally adjusted to the new technology and a new balance is formed. That is the new technology is ready to transform into the existing system.

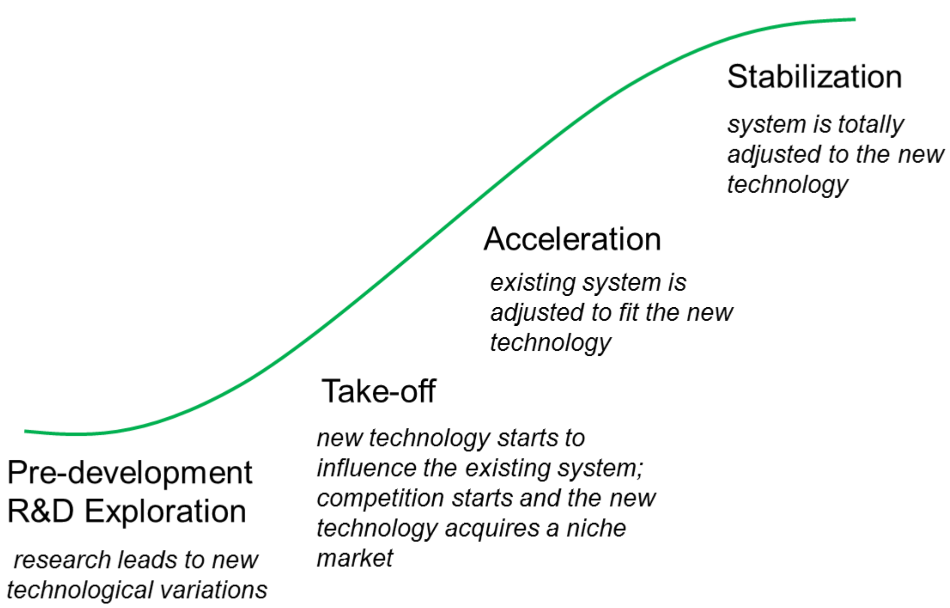

Figure 34: The diffusion curve of innovation

(Source: Van Lente, Hekkert, Smits & Waveren, 2003)

Technological Transition

The goal of transforming the current energy system to a more efficient renewable energy system Like PV needs a long-term process. This can be seen as a technological transition where new innovations diffuse in the existing energy system (Figure 34). This process can be divided in the following phases (Van Lente, Hekkert, Smits & Waveren, 2003): ‘Exploration’ in which research leads to new technological variations and possible societal applications. ‘Take off’ in which the new technology starts to influence the existing system, competition starts and the new technology acquires a niche market. In the embedding or the ‘Acceleration’ phase the existing system is adjusted to fit the new technology. ‘Stabilization’ finally occurs when the system is totally adjusted to the new technology and a new balance is formed. That is when the new technology is ready to transform into the existing system.

Stage of development

In the first stage the general position of the transition is determined on the diffusion curve. The first phase is the exploratory or pre-development phase. This extends to the presence of a prototype. In the takeoff phase the demand for the technology starts and there is a limited amount of commercial available products. The acceleration phase is characterized by the maturing of the market and a wider demand of the technology. In the last phase of stabilization of the technology becomes part of the established structure. By comparing the position of each system function of Japan and Germany in the spider diagram, we can assume their position on the diffusion curve of innovation. Previously we have discussed about the diffusion of Japan and Germany with quantitative data in chapter 5. Studying the Japanese and German PV industry from 1990-2011 we can see that Japan was dominating the PV market globally during the decade 1994~2004. During this period Japan PV market increased 41 fold from 7MW in 1994 to 290MW in 2005. After 2005 Japan’s PV market decreased and became 210 MW in 2007 and world cumulative installed PV share decreased from 30.5% in 2003 to 7.3% in 2011. On the other side, from 1990 to1999 German PV market did not grew at all but after 2000 it increased rapidly. Since 2000, German PV market increased abruptly and it increased from 40MW in 2000 to 7500MW in 2011. During 2000-2011, development of German cumulative installed PV market increased 196 fold from 126MW in 2000 to 24.7GW in 2011. During 2000-2011, Japanese cumulative installed PV market increased only 15 fold from 330MW in 2000 to 4.9GW in 2011. The Japanese market has stabilized at around 290 MW/year in 2005, while the German market is increasing and exceeded

7.5GW/year in 2011. Recently, Japanese PV market is increasing again from 2009 and exceeded 1GW/year in 2011.

Current State

Stage of development of Japan PV innovation system is in the acceleration phase. Considering recent rapid market growth in Japan, due to new FIT, we can assume that current Japan's position will have shifted towards acceleration (Figure 35). Japanese PV market is increasing again from 2009 and exceeded 1GW/year in 2011.The PV products are well developed for specific market segments, the market is well matured and there is wide demand of the product (PV system). For individual consumers, 'systems' can be bought and installed very easily. The electricity produced by PV goes to the grid directly. Companies install PV that can be rolled out over the roof. Many products are readily available. But the policy, incentives and lobbing activities are still weak. New policies (FIT) are finding its way to the PV market but still in development.

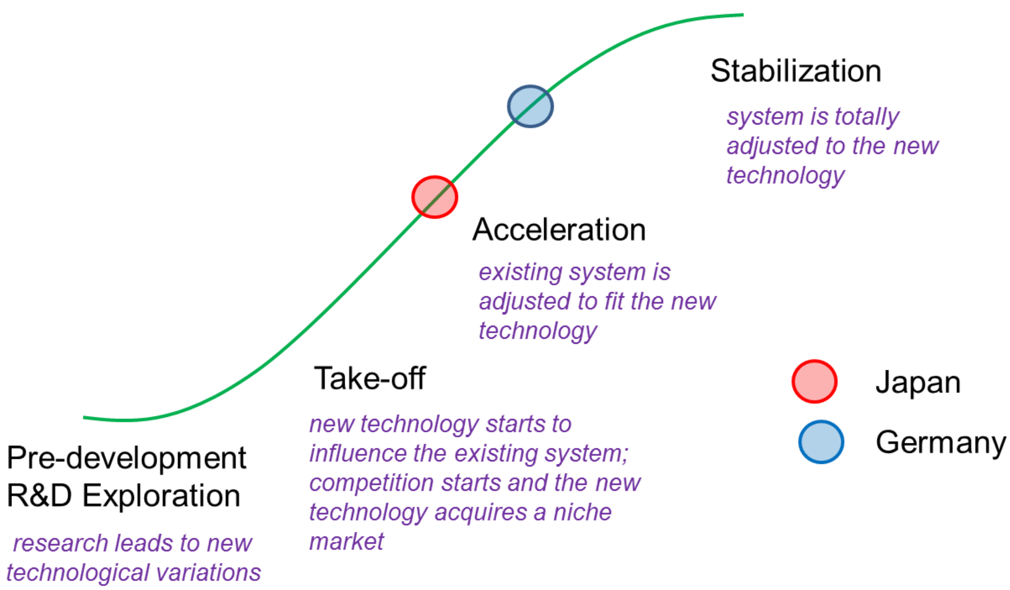

Figure 35: The position of Japan and Germany on the diffusion curve of innovation (Source: Van Lente, Hekkert, Smits & Waveren, 2003)

In 2011, Germany installed 7.5 GWp with 238,202 PV systems – making Germany the largest residential customer market. Germany is the world's strongest PV market with 24.8 GWp of cumulative installations in 2011. Recently Germany achieved grid parity and now people are able to produce PV electricity cheaper from their roofs than buying electricity from the grid. Therefore Germany’s position in the diffusion curve will probably shift further along towards stabilization. German policy EEG (FIT) is well developed and established policy. One of the benefits of the German FIT is that it provides economic incentives for end-use customers to buy PV systems (F6), reducing the pay-back period to perhaps a few years. In this way, the market is greatly expanded (F5) from those who buy PV out of environmental consciousness to those interested in investment possibilities, thus also increasing ‘legitimation’ (F7). In Germany PV technology has gained a certain legitimization by the government as a valid option to attain the desired targets of reducing oil dependency and CO_2 emissions (F7). So we can assume the current German position in the diffusion curve will probably have shifted towards stabilization.

Chapter 13

Conclusion

In conclusion, this study gives us an overall idea of the PV industry. The comparative study between Japan and Germany shows the key points of, how Japan stayed on the top position for a long time, the declining factors of Japan and also the success story of Germany in the PV industry. This study also shows that the causes behind the declining factor of the PV market in Japan is the unaligned energy policy, Japan's concentration on nuclear power more than renewable energy, the termination of incentive program, no specific targets for the growth of renewable energy and the companies lack of future plan to expand production capacity.
Germany is now able to produce PV electricity cheaper from their roofs than buying electricity from the grid due to sharp fall in PV rooftop system prices in recent years. With a strong digression in recent years, the German feed-in tariff (FIT) has driven this development and the government reduced FITs with a stronger digression rate than expected. Today, the FIT for a rooftop project is already below the level of domestic household electricity prices. This makes it financially more attractive for the PV system owner to directly consume the solar electricity generated than make use of the FIT.

Today, the diffusion of photovoltaic cells in japan is mainly hindered by high cost, and the demand is primarily driven by government procurement projects. Japan stimulated solar panel uptake by subsidizing the cost of home installations until 2005, when the government program was discontinued. Japan reintroduced the subsidies for solar panel installations program in 2009, that year Japan was third in solar power generation with 483 megawatts (MW) generated; after Germany (3,845 MW) and Italy (723 MW). That same year, Japan began a FIT program for power companies, which entailed purchasing surplus electricity generated by households at a higher-than-market price (JPY42 per kWh) (US$0.55). Solar energy has been popular in Japan, especially with the government subsidy. Applications for solar panel subsidies in May and June 2011 were 30% up, at the same period the previous year. Despite the advantages, many issues remain. The growth of solar energy is highly dependent on government support to reduce costs. Even with the government subsidy for installation and the FIT, it still takes the average household 10 years to recoup its installation expenses. In addition, solar energy's greatest shortcoming is its uneven output. Fluctuating output from PV cells can disrupt the power grid’s supply and cause problems with its quality. Currently, there is no affordable storage battery large enough to store surplus energy on the grid for later release. Thus, some kind of intervention (subsidies and or procurement projects) will continue to be needed for some time for the transformation process to be a success.

The purpose of this study was to analyze the influence of the market support program for PV. We developed an analytical framework that allows us to evaluate the effects of the scheme on the dynamics of the technology innovation system centered on PV. A preliminary impression is that the analytical framework seems to be well suited for this kind of evaluations where the dynamics of a system is in focus. . First we studied the Structures or the System components of PV innovation system. It is clear that the support scheme already has had significant effects on the dynamics of the Japanese and German PV innovation system. In terms of its effect on the system’s structural components, the most notable changes are the entry of a number of new firms. The second point of analysis was the effects on the functional pattern, what is being achieved in the system function. This framework proposes seven System Functions that need to be fulfilled for TIS to function well. Both the fulfillment of each System Function and the interaction dynamics between them are important. By observing the interactions of Japanese and German PV innovation system with the presence of self-reinforcing the inducement and blocking mechanism can be determined which respectively support or hinder the functioning of the TIS. In this study we have seen that different functional patterns occur for the PV Innovation Systems. And finally this study leads us to an assessment of the functionality of the Japanese and German PV system today. From the comparative analysis of Japan and German PV innovation system, we can see that the main system functions that trigger the positive build-up of the German PV innovation system are Advocacy Coalitions (F7), Market formation (F5), knowledge development (F2), and entrepreneurial activities (F1). The guidance of the search (F4), resource mobilization (F6) and knowledge diffusion (F3) is also in a very good position.

On the other side we can see that In the case of Japan, not all system functions are strong and perfectly fulfilled, resulting Japanese PV innovation system slower than Germany. Due to the lack in the guidance in search (F4), advocacy Coalitions (F7), resource mobilization (F6) and knowledge diffusion (F3), Japan is a step behind of Germany in the diffusion curve. But In knowledge development (F2), market formation (F5) and in the entrepreneurial activities (F1) Japan is in a very good position.

For both countries a market space has been created and together with exogenous factors, the scheme has some influence on the search for new business opportunities in PV and for a number of entrepreneurial activities. As a consequence, knowledge development of a more applied nature has been initiated, supplementing the previous relative strength in academic research and module manufacturing. The legitimation process has also started to gain momentum, for the formation of the TIS specific advocacy coalition. The effects on the dynamics of the system and the occurrence of positive feed-back loops, helps the TIS to diffuse well. The positive “side-effect” of the support is the information campaigns that have positively influenced knowledge diffusion (F3), legitimation (F7) and positive externalities which resulted the large domestic market (F5) as there is a mutual vision on which policies are based and that the policies (FIT) are long-term in order to provide certainty and support to entrepreneurs (F1) and investors in order to set up projects and invest in PV technology and thus the market grew. In addition due to a solid research (F2) base and strong lobby power (F7), realistic expectations are formulated for PV and little technical disappointments occur.

The evaluation point has revealed the most notable blocking mechanisms. Market formation (-F5) is blocked by the high cost of PV systems and lack of adapted standards and regulations (-F7). Poor competence and weak networks on the supply side obstructs entrepreneurial activities (F1) which hinders market formation (F5). Weak networks also block ‘knowledge development and knowledge diffusion (-F2, -F3). Powerful antagonizing advocates (nuclear) and the lack of a clear political vision for the PV technology hinders the ‘legitimation’ process. The second blocking mechanism, the legitimation process (-F7) is powerful advocates of larger scale and centralized technologies (nuclear, fossil fuel) that do not believe that PV has a role to play in the Japanese energy system. These are very large actors that have a great deal of influence on Japanese energy politics and practice.

This study has identified a few policy measures and future plan for Japan that may be useful for PV diffusion. The most direct way is a new support program that continues. A longer term program, combined with clear political targets for the PV technology, would be expected to deal with several blocking mechanisms (lack of a national vision for PV, poor competence on both supply and user side and – to some extent, high costs). Standards and regulations need to be adapted to the PV technology. Building platforms would facilitate network creation and platforms are also an ideal place for creation of positive externalities. Finally, to deal with the powerful advocates that are skeptical to the PV technology it is important to support an advocacy coalition that can become a counterforce for the technology.

This study may be of use as inspiration for a continued research on the diffusion of solar PV. Increasing the amount of renewables and transforming energy system is an urgent matter. Achieving this goal in solar PV technology will require an effective, long-term and balanced policy effort in the next decade to allow for optimal technology progress, cost reduction and ramp-up of industrial manufacturing for mass deployment. Governments will need to provide long-term targets and supporting policies to build confidence for investments in manufacturing capacity and deployment of PV systems. Governments and industry must increase R&D efforts to reduce costs and ensure PV readiness for rapid deployment, while also supporting longer-term technology innovations. Aid organizations should expand their efforts to express the value of PV energy in low-carbon economic development. Provide long-term targets and supporting policies to build confidence for investments in manufacturing capacity and deployment of PV systems. Implement effective and cost-efficient PV incentive schemes that are transitional and decrease over time to foster innovation and technological improvement. Develop and implement appropriate financing schemes, in particular for rural electrification and other applications in developing countries. Increase R&D efforts to reduce costs and ensure PV readiness for rapid deployment, while also supporting longer-term innovations.

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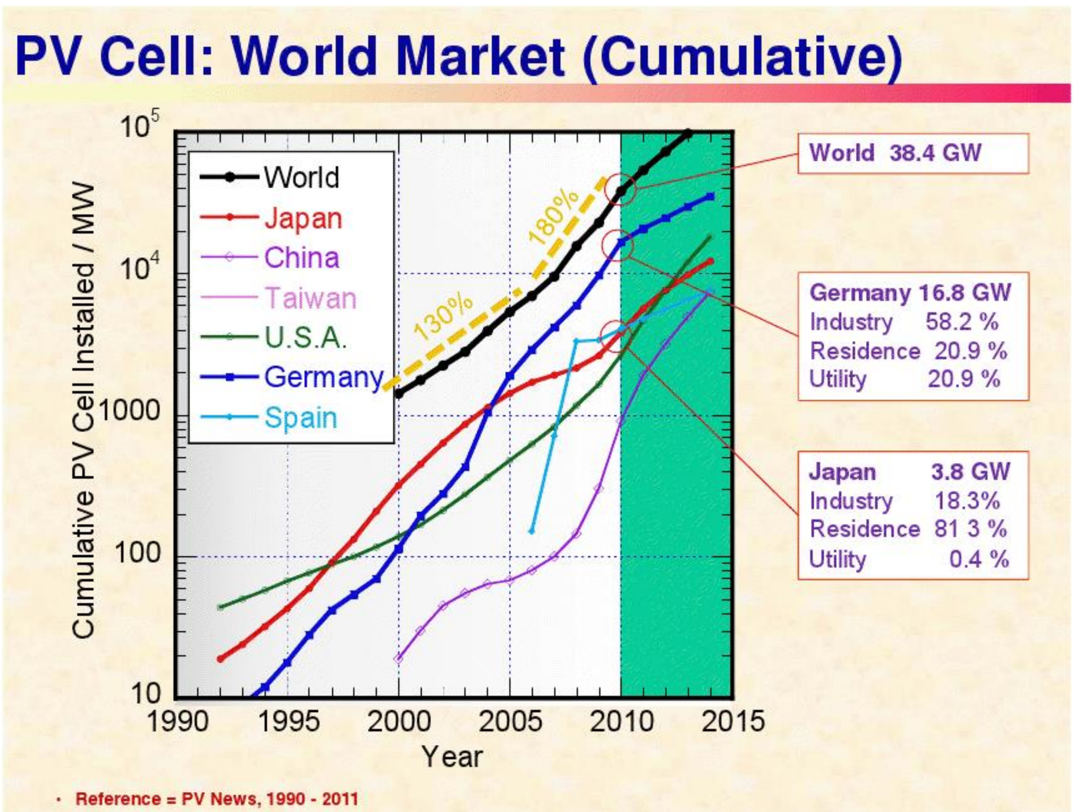
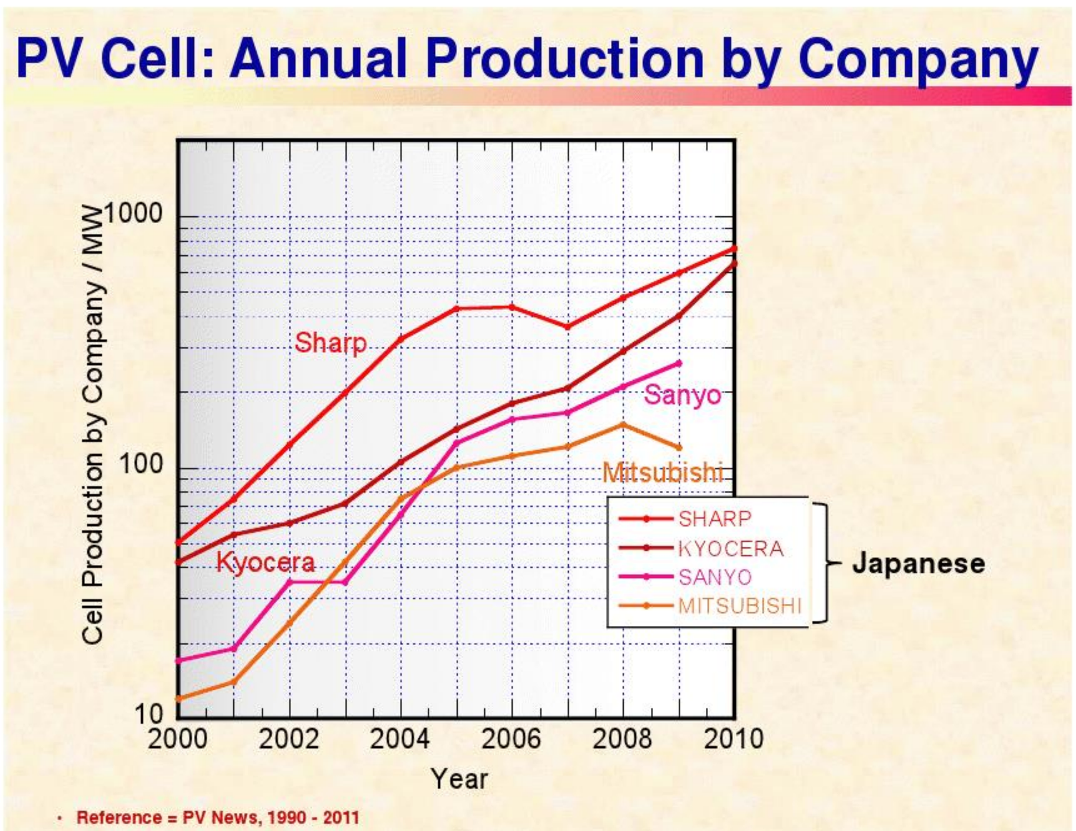
Appendix

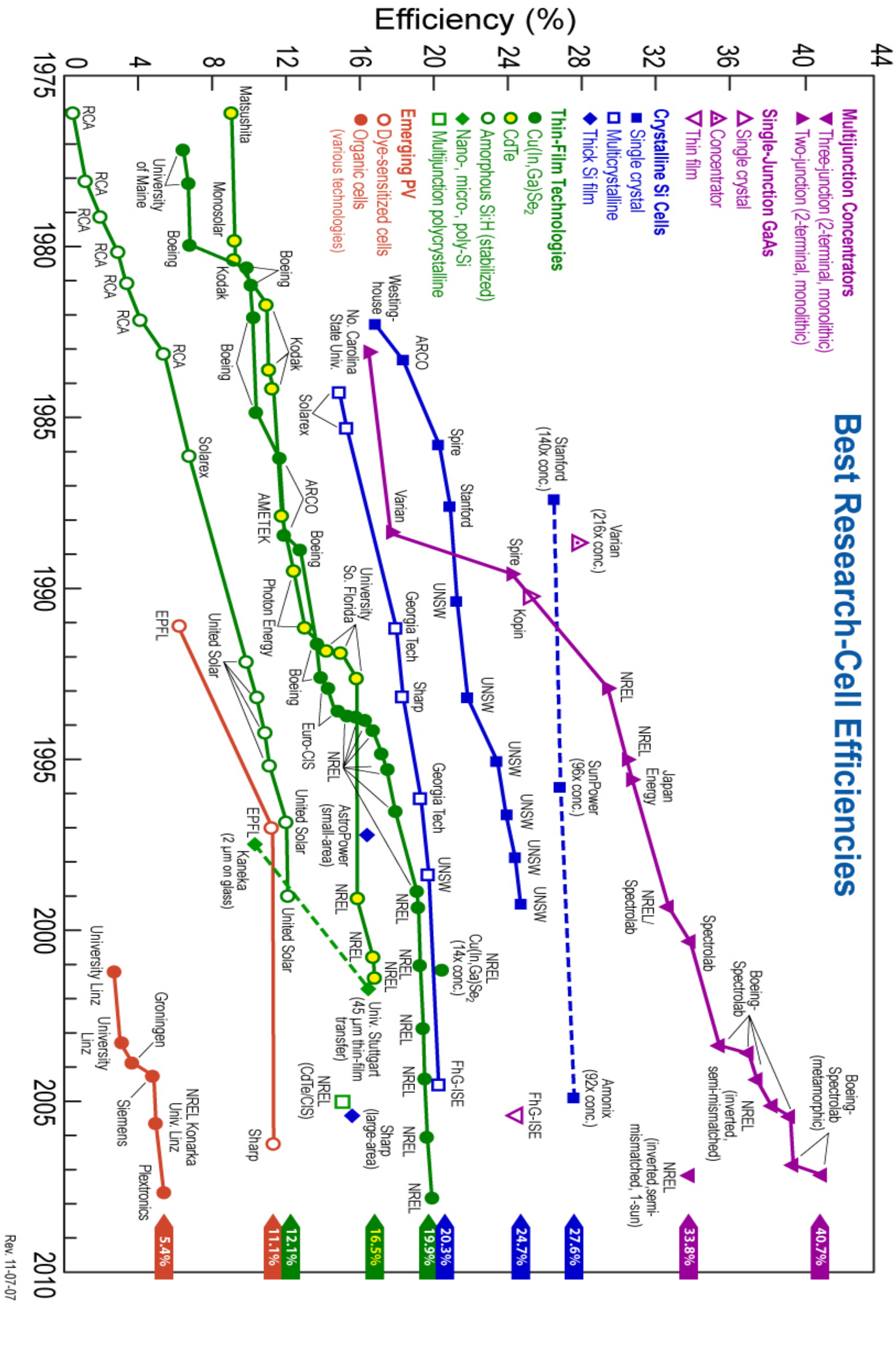
Appendix 1



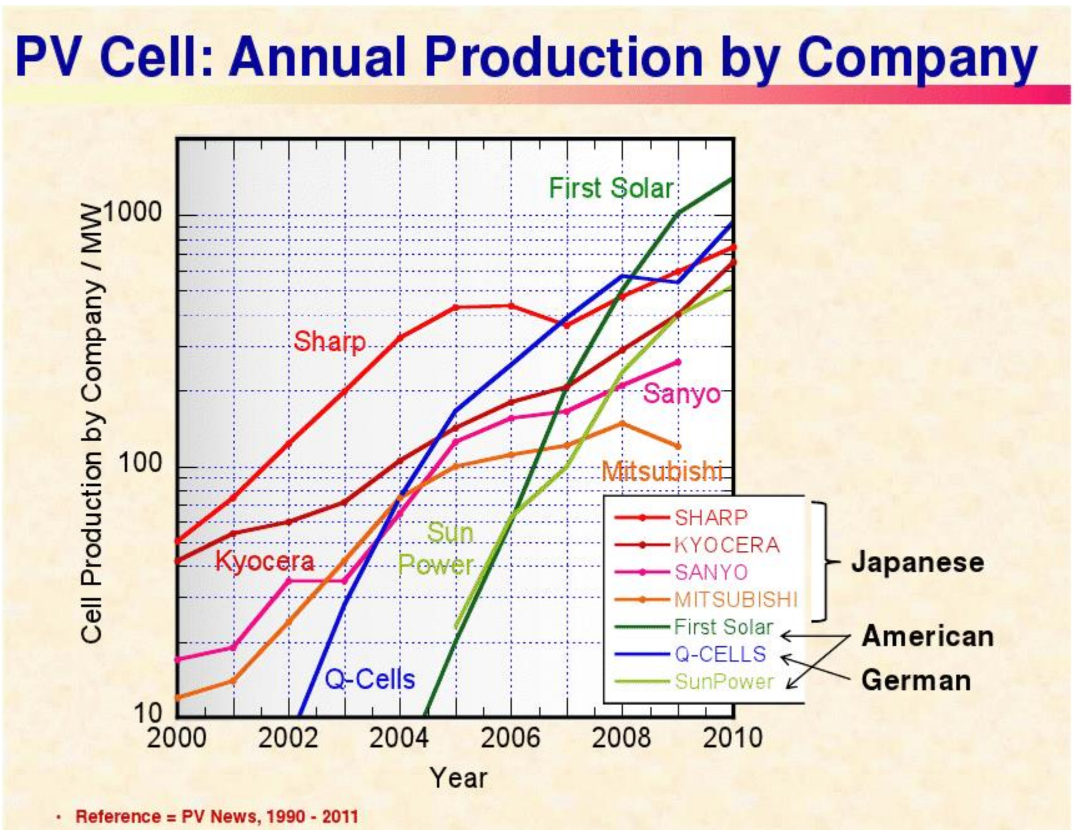
Appendix 2


PV Cell: Annual Production by Company
Cell Production by Company / MW
1000
100
10
2000
2002
2004
2006
2008
2010
Year
Sharp
Sanyo
Mitsubishi
Kyocera
SHARP
KYOCERA
SANYO
MITSUBISHI
Japanese
Reference = PV News, 1990 - 2011

Appendix 3: Best research –Cell Efficiencies; Source: Review 2011.07.07



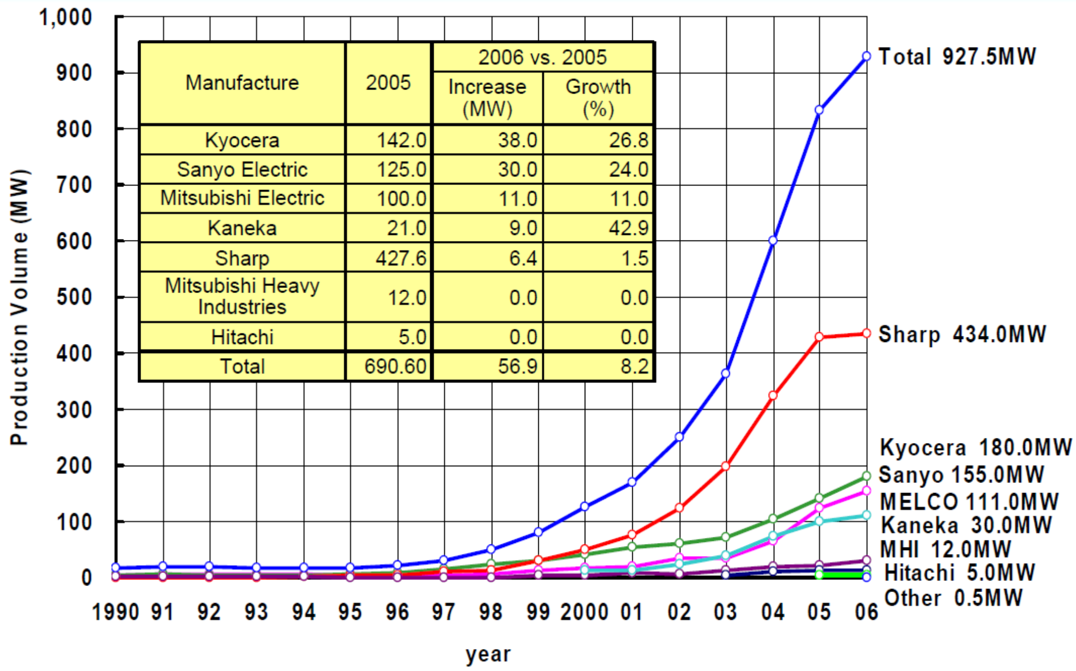
Appendix 4



PV Cell: Annual Production by Company
Cell Production by Company / MW
1000
100
10
2000
2002
2004
2006
2008
2010
Year
First Solar
Sharp
Sanyo
Mitsubishi
Kyocera
Sun
Power
Q-Cells
SHARP
KYOCERA
SANYO
MITSUBISHI
First Solar
Q-CELLS
SunPower
Japanese
American
German
• Reference = PV News, 1990 - 2011

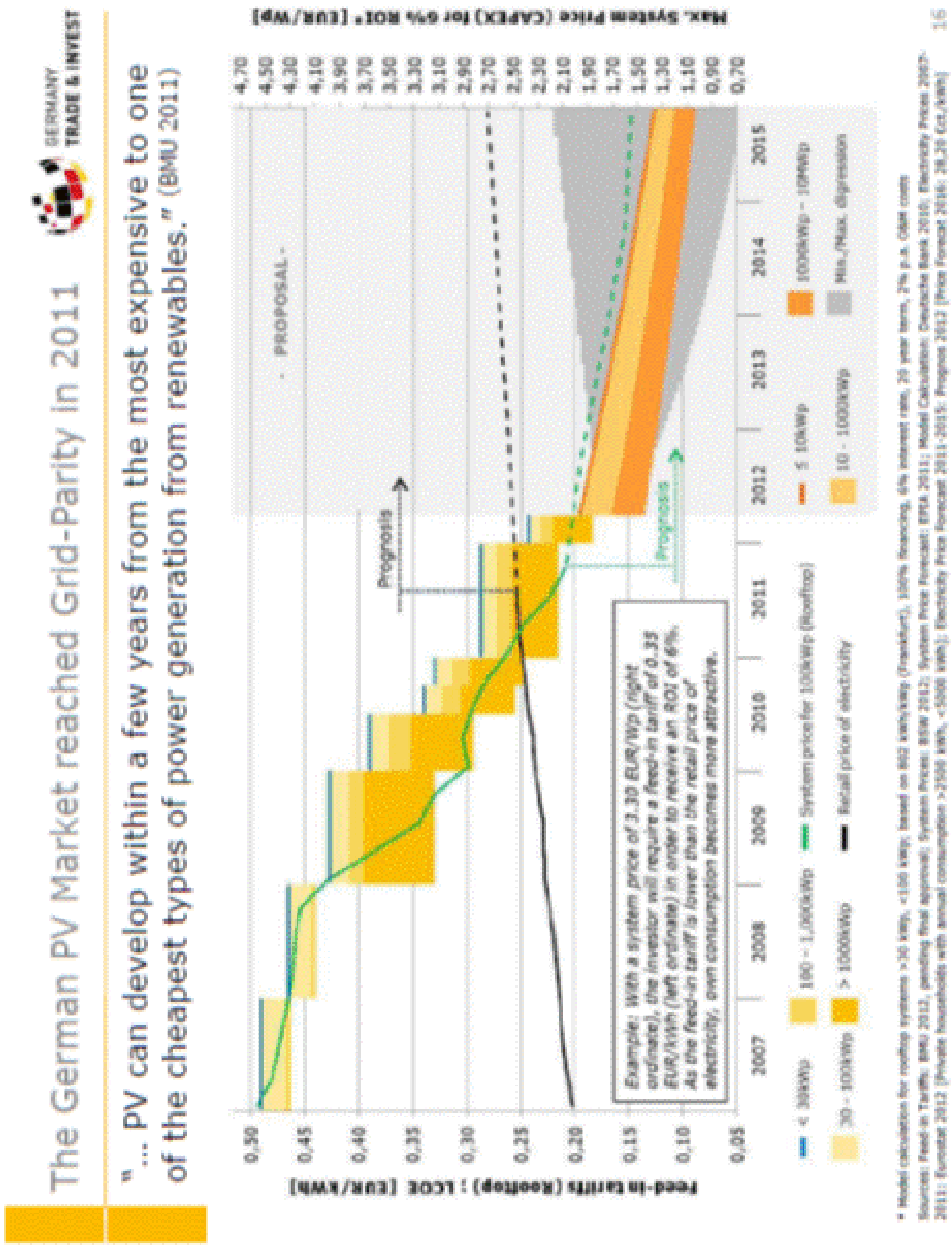
Appendix 5

Production Volume by Manufacturer in Japan



Manufacture	2005	2006 vs. 2005 Increase (MW)	Growth (%)
Kyocera	142.0	38.0	26.8
Sanyo Electric	125.0	30.0	24.0
Mitsubishi Electric	100.0	11.0	11.0
Kaneka	21.0	9.0	42.9
Sharp	427.6	6.4	1.5
Mitsubishi Heavy Industries	12.0	0.0	0.0
Hitachi	5.0	0.0	0.0
Total	690.60	56.9	8.2

Appendix 6


The German PV Market reached Grid-Parity in 2011
"... PV can develop within a few years from the most expensive to one of the cheapest types of power generation from renewables." (BMU 2011)
GERMANY TRADE & INVEST

Appendix 7

Plan of production capacity enhancement of Japanese companies

RTS Corporation

Company	2006	2007	2008	2009	2010	2011 onwards	Technology
Kyocera	240	240	240	240	500	650 (2012)	mc-Si
Sharp	600	695	695	695	695	planning	mc-Si, sc-Si
	15	15	160	160	640	6,000	a-Si/ μc-Si
SANYO Electric	5	5	5			50 (2011)	a-Si, μc-Si
	165	260	350	500	650	650 (2011)	a-Si/ sc-Si (HIT)
Kaneka		25	40	40		planning	a-Si, a-Si/ TF Si
Mitsubishi Electric	135	150	220	220	250	600 (2012)	TF Si, mc-Si
Mitsubishi Heavy	14	54	128	128	600	planning	a-Si, a-Si/ TF
Hitachi	10	10	–	–	–	–	sc-Si (bifacial)
Space Energy			3.5	7	7	planning	sc-Si (bifacial)
Honda Soltec	2.8	27.5	27.5	27.5	27.5	planning	CIGS
Fuji Electric	12	12	30	40	40	150	flexible a-Si
Showa Shell Sekiyu		20	20	80	80	1,000 (2011)	CIGS
Clean Venture 21	3	12	12	40	65	100 (2012)	Spherical Si
MSK	180	180	100	100	100	?	PV module
YOKASOL			60	70	90	120 (2011), 150 (2012)	PV module
Fujipream		12	24	planning	planning	planning	PV module

List of publications

Refereed Journal Papers

1. Sanjeeda Chowdhury , Ushio Sumita, “Diffusion of PV in Japan and Germany- role of market-based incentive and research and development (R&D) investment”, Journal of Technology Innovations on Renewable Energy (JTIRE) 2012, pp.80-86
2. Sanjeeda Chowdhury, Ushio Sumita, “Importance of policy for energy system transformation: diffusion of PV technology in Japan and Germany”, **(Submitted in Energy Policy).**
3. Sanjeeda Chowdhury, Ushio Sumita, Ashraful Islam, “Exploratory Study of PV Industry, 1990-2008: Lesson from Japan and Germany”, Proceedings of the 2012 IEEE 2nd International conference on the Developments in Renewable Energy Technology (ICDRET 2012) January, 2012, pp.1-4
4. Sanjeeda Chowdhury, Ushio Sumita, “Photovoltaic (PV) technology development in japan (1990-2012): PV diffusion, public policies, and market formation”, abstract submitted to the 2nd International conference on Solar Energy Materials, Solar cells & Solar Energy application, Solar Asia 2013**. (Abstract accepted)**