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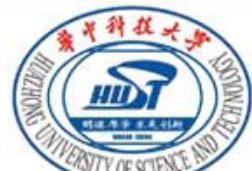
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Prospects for grid-parity of Photovoltaics due to effective promotion schemes in major countries

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Abstract— In recent years the costs of Photovoltaics systems has decreased significantly. A major reason for this effect were efficient and effective promotion schemes in major countries like Germany, Japan and Spain. The core objectives of this paper are: (i) to analyze the historical success criteria for promotion of PV; (ii) to investigate the prospects for looming grid parity — PV generation prices equal to final customers electricity price — and to discuss the design for corresponding effective future promotion schemes.

Keywords- Photovoltaics, grid parity, cost development, PV markets, promotion schemes

I. INTRODUCTION

The high investment costs has been historically a major barrier for harvesting the huge potential of Photovoltaic systems for environmentally benign electricity generation ([1], [2], [3]). In recent years PV systems sold have in several countries like Spain and Germany reached remarkable magnitudes, see Fig. 1. This was mainly due to attractive promotion schemes which has brought down the costs. Especially in Germany significant price reductions have taken place mainly as a response to the national German policy of FIT, see Fig. 1 and Fig. 8. This led to the fact that finally PV systems are on the verge to so-called grid-parity, as already has been argued in Haas (2004) [9].

As can be seen from Fig. 1 over the last decades the countries leading in PV deployment changed over time. From the 1990s to 2003 Japan was the clearly leading country. After that Germany with very ambitious highly subsidized promotion schemes took over. In 2008 Spain was leading followed by a plummeting in 2009. In 2010 (surprisingly) Czech Republic jumped on a major place in the world-wide ranking. Moreover, in the last years Italy has continuously increased its deployment so far with no looming backlashes.

The core objectives of this paper are: (i) to identify the historical success criteria for promotion of PV; (ii) to analyze the effects of promotion schemes on PV markets, mainly prices and (iii) to investigate the prospects for looming grid parity — PV generation prices equal to final customers electricity price — and to discuss the design for corresponding effective future promotion schemes. The idea of grid parity has already been addressed in [9] despite it was not named so. This analysis is focusing on “major countries” which means those with the largest capacities installed recently. Yet, we think that most of

the perceptions and conclusions of this analysis can be used in many countries world-wide.

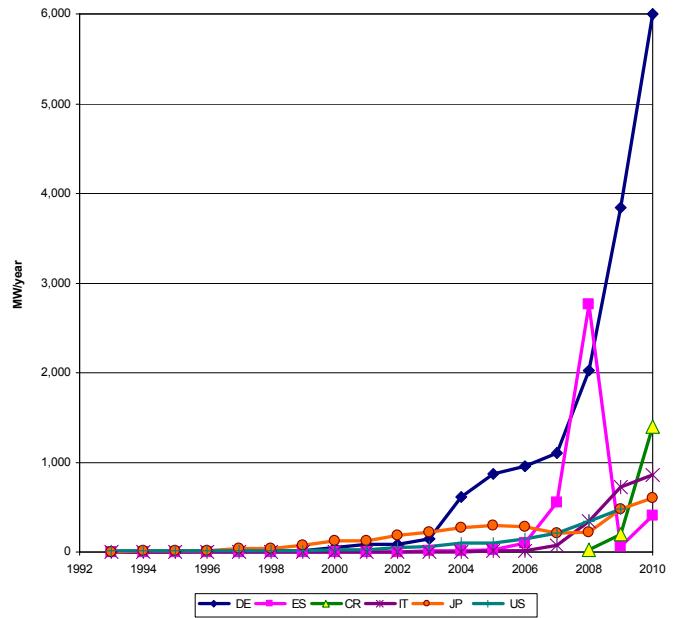


Figure 1. Installed capacities in major European countries in recent years
(Sources: [1], [2], [3], Figures for 2010 preliminary)

II. METHOD OF APPROACH

The method of approach applied in this work is based on a formal framework analyzing the market developments and the economic performance of the promotion programmes from the following points-of-view (see also [4], [5], [6]):

- The concept of Technological learning::How did costs historically follow learning trends?
- identifying investment costs as well as solar yields by country over time and calculating the corresponding electricity generation costs of PV plants ;
- investigating the over-all promotion costs depending on size of system;
- Comparing these costs with household electricity prices.

III. HISTORICAL DEVELOPMENTS OF PV COSTS AND LEARNING

Fig. 2 depicts the basic principle of technological learning applied to PV. Until 2003 it followed clearly the expected Learning path. Then it deviated. Why?

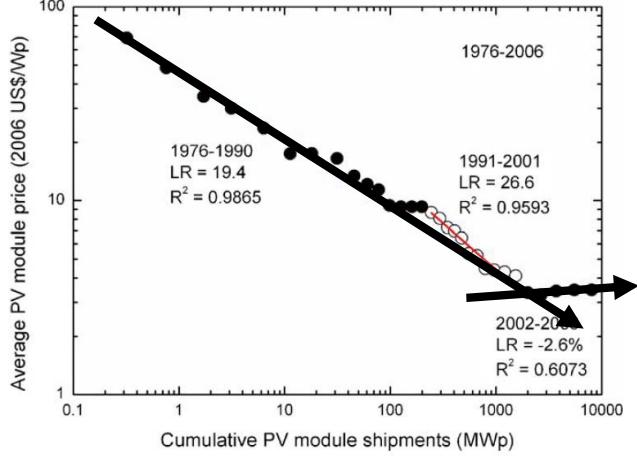


Figure 2. The basic principle of TL applied to world-wide PV (Source: Yu (2011) [11])

To get an explanation for this effect it is necessary to understand how prices come about in markets. Fig. 3 depicts the ideal cost development due to TL (broken line) and temporarily short term mark-ups due to demand increases. However, these demand increases and the observed high profits make it attractive for new companies to enter the market and as a result prices drop again close to the level of the marginal costs. For a continuation of this explanation see chapter 5.

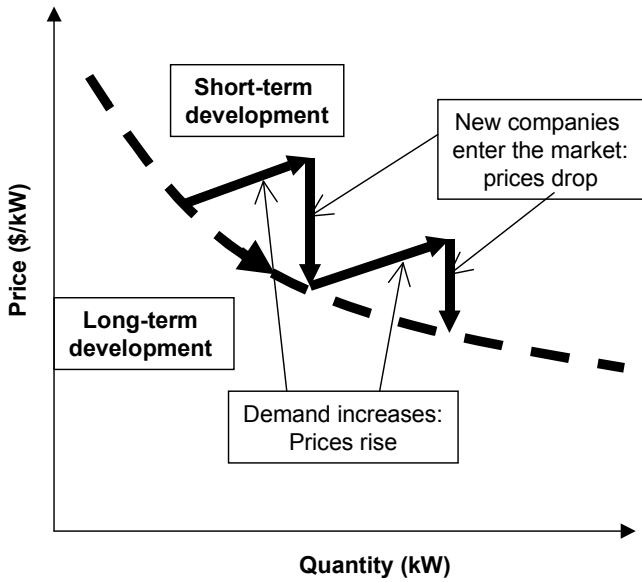


Figure 3. How price and cost developments in markets are linked (Haas (2003), [3])

IV. FIRST LEADER IN PV PROMOTION: JAPAN

Historically, the prices of PV systems were influenced mainly by two countries: By Japan up to about 2005 and then

by Germany afterwards. Fig. 4. depict the development of yearly and cumulative small grid-connected PV systems in Japan 1994-2010. We can see that up to 2004 growth in MW installed per year was virtually exponential and then stagnation took place until about 2008. Fig. 5 shows the corresponding development of system costs and subsidies of small grid-connected PV systems.

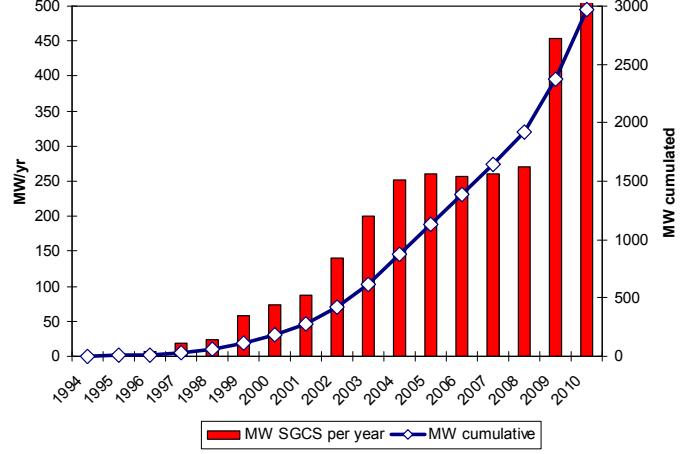


Figure 4. Development of yearly and cumulative small grid-connected PV systems in Japan 1994-2010 (Sources: [1], [2], [3], [9], Figures for 2010 preliminary)

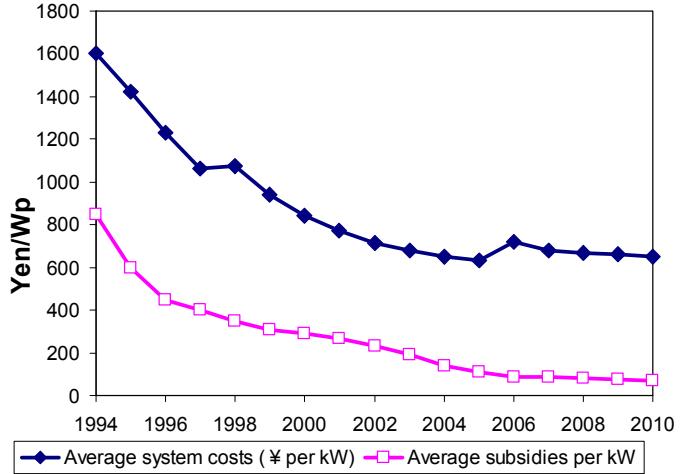


Figure 5. Development of system costs and subsidies of small grid-connected PV systems in Japan (Sources: [1], [2], [3], [9], Figures for 2010 preliminary)

We can finally see that up to 2004 the Japanese system worked perfect. Decreasing subsidies and in lockstep decreasing system prices led to almost exponentially increasing PV capacities. Yet there was a break in 2004/2005. Why?

V. CURRENT LEADER IN PV PROMOTION: GERMANY

Between 2003 and 2005 the German government introduced a new FIT for PV. This tariff led to a considerable uptake of PV systems installed in Germany see Fig. 1. This introduction of higher support led temporarily to price increases which we suspect to be at least partly due to the scarcity in PV systems due to high financial incentives,

especially from 2003 to 2007, see Fig.6. Note, that in this period of time also silicon prices increased and have to some extent contributed to these increases in system costs, see also [11], [12], [13].

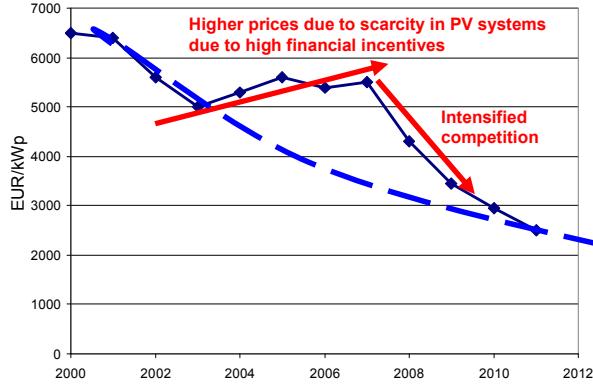


Figure 6. Development of PV system costs in Germany from 2000 to 2011
(Figure for 2011 preliminary)

However intensified competition afterwards led to a rather steep decrease in recent years leading to a skyrocketing in capacities installed in Germany and some other countries. Fig. 7 depicts the development of Feed-in-tariffs (FITs), costs in major European countries 2005 - 2010 (historically) and provides a forecast up to 2012.

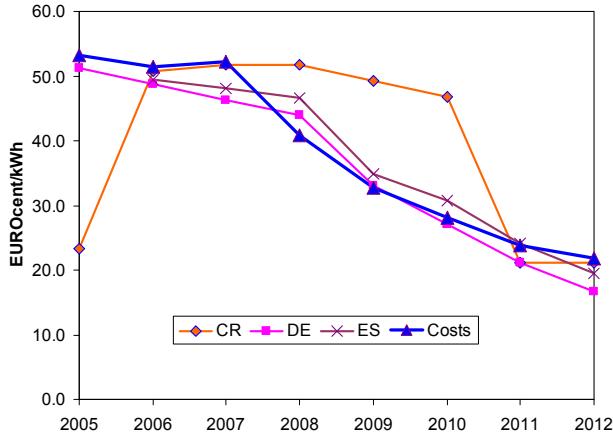


Figure 7. Feed-in-tariffs (FITs) and in major European countries 2005 -2010 (historically) and 2011-2012 (forecast)

VI. PROSPECTS FOR GRID PARITY

Fig. 8 depicts for Germany possible developments up to 2012 for small-scale (top) and large-scale (bottom) systems in an upper and a lower “corridor” depending on the capacity of systems installed. As can be seen from Fig. 9 where also household electricity prices are included for small-scale systems in the lower corridor scenario the so-called grid parity could already be brought about before 2015.

So the situation for Germany can be considered rather promising for PV grid parity. The only reason why there might be some backlash would be if the market – which is still very

sensitive – depending on imports from China and the effective financial support from government – collapses and system prices start to increase again as depicted in Fig. 6 for the past.

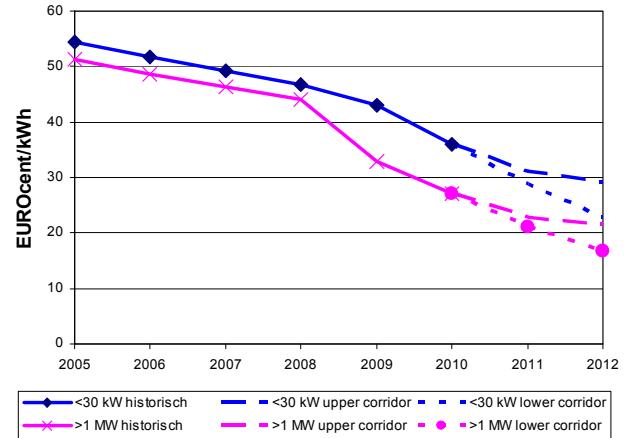


Figure 8. Historical development of PV costs for small and large systems in Germany and expectations up to 2012 in an upper and a lower “corridor”.

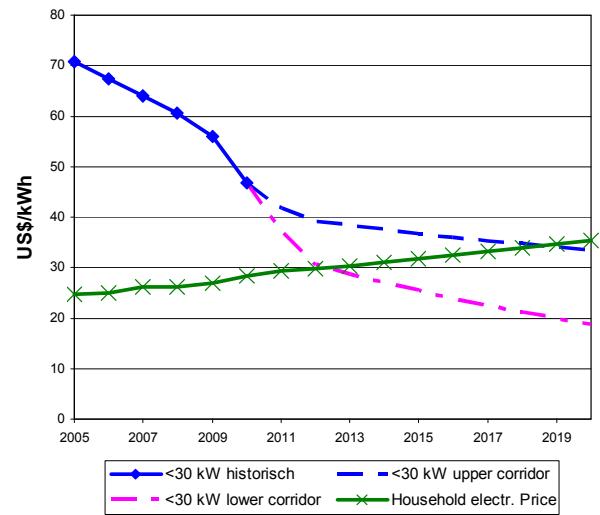


Figure 9. Historical development of PV costs for small systems in Germany and expectations up to 2020 vs household electricity prices leading to “grid parity” between 2012 and 2018

However, grid parity is looming also for other major countries. The prospects for grid parity of PV systems in these countries are shown from 2010 to 2020 in Fig. 10. We can see that except Australia with very low household electricity prices in all the other countries analyzed – Japan, Spain and California in addition to Germany up to 2020 grid parity can be expected. For further more country-specific studies on this issue see [14].

VII. HOW TO PROMOTE PV FURTHER?

Now the core crucial question is how to design future promotion schemes for PV. This is relevant for the remaining time till grid parity is reached. We think the following reflection is important this system might be improved by

conversion into an investment subsidy to stimulate an own use share of PV as high as possible; This might lead to a lower burden for the distribution grid and, hence, cause less costs for society;

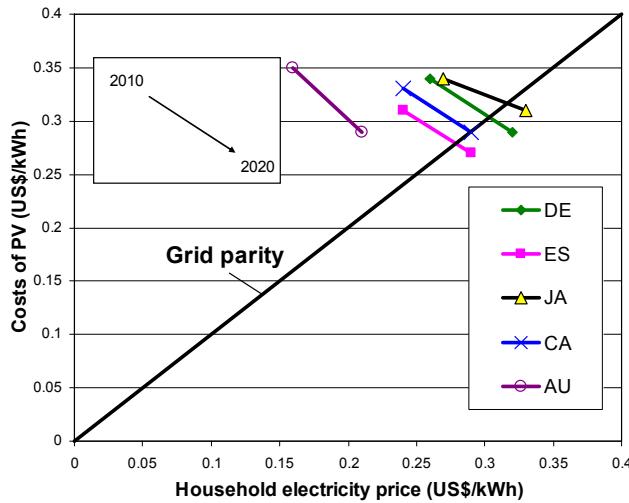


Figure 10. Prospects for grid parity of PV systems in major countries from 2010 to 2020 (reference for Electricity price: [15], reference for costs of PV: Own calculations based on [2] [3] [9])

VIII. CONCLUSIONS

The major conclusions regarding country-specific lessons learned are: (i) The Japanese promotion system starting in 1994 can so far be considered as the world-wide most successful one: It led – with decreasing financial incentives – to up to 2003 continuously increasing capacities and decreasing costs; (ii) The Japanese system came in troubles after Germany introduced higher financial incentives which led temporarily also to higher costs. Since then Germany was – with the exception of the year 2008 – world-wide leading country in yearly PV installations; (iii) in 2008 Spain became champion in new PV-capacities installed per year. However, the Spanish system was not really sustainable and the peak in 2008 was followed by a crash in the years after. Moreover, already today (in 2011) major shortcomings like low-quality problems in installations of the 2008 boom in Spain emerge; (iv) The most recent country with skyrocketing PV installations was Czech Republic in 2009/2010. Yet, due to this deployment increase the FIT were already radically cut down.

The most important conclusions with respect to an efficient and effective deployment of PV systems are: (i) A well-designed (dynamic) Feed-in tariff system provides a certain deployment of photovoltaic electricity fastest and at low costs for society; However, the correct dynamic design is the crucial point; (ii) In addition this system might be improved by conversion into an investment subsidy to ensure an own use share of PV as high as possible; (iii) radical changes in the system can lead to an immediate breakdown as observed in Spain and recently in Czech Republic; (iv) If the proper dynamic adaptation to cost decreases due to Learning is missing – like in Czech Republic – it can lead to an extreme overheating of the market; (v) However, all in all these

European developments led to a significant cost decrease which bring PV systems on the verge to cost-competitiveness with household electricity prices , the so-called “grid parity” in most cases before 2020..

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