The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Price of Solar Power

Posted by Luis de Sousa on February 26, 2013 - 1:05am

All across Europe, feed-in tariffs and subsidies for solar power are being cut or even scrapped. In Portugal and Spain, these actions are justified with the debt crisis, even though they expand these states' trade deficit. This month the Spanish government took a decisive move to scare investors away and expel most renewable energies from the electric grid, particularly solar.

> Reuters
> **Exclusive: Foreign investors set to sue Spain over energy reform**
> 14-02-2013
>
> (Reuters) - Foreign investors in renewable energy projects in Spain have hired lawyers to prepare potential international legal action against the Spanish government over new rules they say break their contracts.
>
> The Spanish Parliament approved a law on Thursday that cuts subsidies for alternative energy technologies, backtracking on its push for green power.
>
> That measure, along with other recent laws including a tax on power generation that hit green energy investments especially hard, will virtually wipe out profits for photovoltaic, solar thermal and wind plants, sector lobbyists say.

Diving into the numbers what one finds behind this policy U-turn is something entirely different.

More expensive, they say

In places like Luxembourg these feed-in tariffs cuts are defended in a different way, as the economy minister, Etienne Schneider, did last August when presenting a new law for renewable energy:

> Le Juedi
> **Le photovoltaïque n'a plus la cote**
> Sébastien Meinbach, 09-08-2012

En se basant sur une analyse de ses services, le ministre de l'Economie, Etienne Schneider fait un constat sans appel. Constat qui touche surtout la filière photovoltaïque, "qui coûte très cher pour un bilan en matière de développement des énergies renouvelables très faible".	Supported by the analysis of his services, the Economy minister, Etienne Schneider, had a rotund remark. An observation that touches above all the photo-voltaic sector, "that is too expensive for a weak result in terms of renewable energies development".
«Par comparaison, 1 megawatt/heure [sic]	«In comparison, 1 megawatt/heure [sic]

(mW/h) [sic] produit grâce à l'éolien coûte 14 fois moins cher qu'1 mW/h [sic] issu du photovoltaïque, précise le ministre.	(mW/h) [sic] produced by wind is 14 times cheaper than 1 mW/h [sic] produced by photo-voltaics, details the minister.
Donc pour la même quantité d'énergie renouvelable, nous payons 14 fois plus pour le solaire. Toutes les autres formes sont aussi moins chères.»	Hence for the same quantity of renewable energy, we pay 14 times over for solar. All the other forms [of energy] are also cheaper."

And thus the Luxembourger economy minister totally erased feed-in tariffs on photo-voltaics (PV) installations above 30 kWp and sharply reduced those on installation under 30 kWp. Apart from the journalistic creativity with the mili-Watts per hour, is solar power really that expensive? This post provides an answer to this question, showing that the real reason behind this detraction of solar energy is pretty much the opposite of what is claimed by minister Schneider.

Investing on Solar Power

The upfront investment on a PV system has three main components:

- panels of solar cells, that harvest the energy;
- an inverter, that tames the raw current coming from the panels into a form digestible by the electrical grid;
- and installation, that includes, labour, paperwork and whatever else needed to get the system up and running.

Panel size or capacity is described with the maximum amount of power they can harvest at optimal sunshine conditions; this is measured in Watts-peak (Wp). Panel prices are quoted in €/Wp and since both the inverter and installation costs scale closely with panel capacity, companies can provide a price for the ensemble on a convenient €/Wp basis.

There is an ecological fair every year in a Luxembourg city by October, better known by the Luxembourgish term: Oekofoire. I was there last year and took my time at the PV companies booths that usually litter the place. Back then the price asked by these companies for a solar system was at 1.6 €/Wp. This price comprised 0.6 €/Wp for the panels, 0.2 €/Wp for the inverter and the remainder 0.8 €/Wp for installation. The fact that the basic hardware is now only half the price of a PV system already indicates that reality may not be exactly matching the political discourse. By December I got the information that in Germany these prices were already down to 1.3 €/Wp, in places with good access and ease of installation. This reflects the relentless price decline of both solar cells and inverters, the former declining by 40% in 2012 alone.

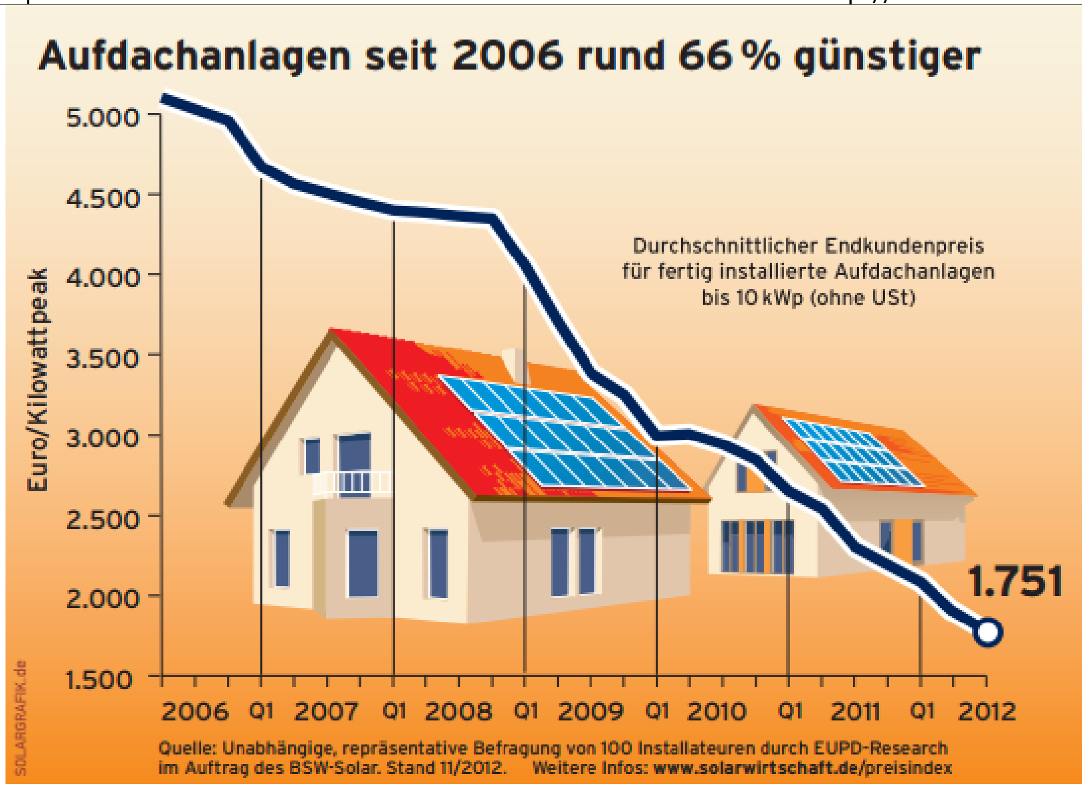

Figure 1 - PV system prices (installation plus hardware) in Germany from January of 2006 to June of 2012, showing a linear decline of 500 €/kWp/year. Source: Solarwirtschaft.de.

In recent years the solar market has undergone the transformation imposed by what is usually termed economies of scale. From small factories in Europe, the production of solar PV cells migrated to huge factories in Asia. And with this transformation came the usual cycles in large markets where product differentiation isn't obvious. By the midst of 2012 some Asian producers were reportedly selling cells about 0.2 €/Wp below cost, in a clear supply destruction cycle. This has created a row in Europe, with local producers calling for taxes on Asian products and investors claiming that this is the way for affordable electricity. Even if this supply destruction cycle is indeed the driver of recent price drops, a return to prices of two, or even one year ago, is not to be expected. In the first place, because the solar market is showing a clear similarity with the computer hardware market, with similar breathtaking price declines. In both cases the final product is pure technology, which can only improve with time, like the number of transistor per unit of area. The efficiency of PV technology keeps increasing, and improvements like auto-cooling are still yet to reach the market. And secondly because production is not going back to Europe, if it's not economical to produce a smartphone or a laptop in Europe, it will be much less so with a simpler technology like a solar cell.

The basic price of PV - Scenario I

So coming to the question: what is the price of solar power in present market conditions? Is it really as high as Mr. Schneider and other politicians claim? Since with this technology the largest share of costs comes upfront, a reasonable approximation can be made. In its simplest form, the price of the electricity generated by a solar system is the ratio between total costs and the total amount of energy produced in its lifetime:

$$P = C / E$$

Costs can be broken down between investment: panels (I_p), inverter (I_i), installation (I_l), and maintenance. The latter can in its turn be broken down into the replacement of the inverter, that usually has a shorter lifetime than the panels, and yearly costs on other tasks such as cleaning or replacing cables (M). Putting it together in a more formal way:

$$C = I_p + I_l + (L_p/L_i) * I_i + L_p * M$$

Where L_p is the system lifetime and L_i the inverter lifetime, both expressed in years.

To calculate the total amount of energy produced by the system first must be known the expected energy output per capacity unit at the site of installation. A panel won't produce permanently at maximum capacity, the inclination of solar rays, cloud cover and the amount of diffuse radiance vary throughout the day and the year. Knowing a few climate indicators it is possible to calculate with precision the amount of energy a panel can generate during a year. The Joint Research Centre has created an information system that includes maps and a small web application to provide an accurate estimate of this value (E_c), expressed in Wh/Wp/year (i.e., energy generated per capacity installed per year - here in Luxembourg this figure is around 900 Wh/Wp/a). A second important component to calculate the total amount of energy generated is the decline of cell efficiency with time (d), which is induced by sunlight itself. Back to the formality:

$$E = \mathrm{sum}[t=0,L_p-1][E_c * (1 - t * d)]$$

Substituting all these characters by numbers one can get to a precise price figure in €/kWh, the same units used to measure consumption at the grid and charge consumers. The table below summarises all these parameters and the values used to reach a first PV energy cost scenario:

Table 1 - Parameters and corresponding values used to build Scenario I - basic costs.

Investment cost for panels	I_p	0.6	€/Wp
Investment cost for inverter	I_i	0.2	€/Wp
Investment cost for installation	I_l	0.8	€/Wp
Inverter lifetime	L_i	10	years
Maintenance costs	M	20	€/Wp/year
System efficiency decay	d	0.5	%/year

The only figure here not referred to before is the general maintenance. The PV system I installed in Portugal is now almost 3 years old and so far maintenance costs are 0 €; the thing just sits there and produces electricity. I know I'll have to replace the inverter at some point, since the warranty is only valid for 10 years, apart from that, other maintenance interventions are hard to foresee at this stage.

Finally coming to the price the graph below presents solar power prices as function of system lifetime (L_p) for the figures in Table I in three hypothetical locations: southern Germany (1000 Wh/Wp/a), southern France (1250 Wh/Wp/a) and southern Portugal (1500 Wh/Wp/a).

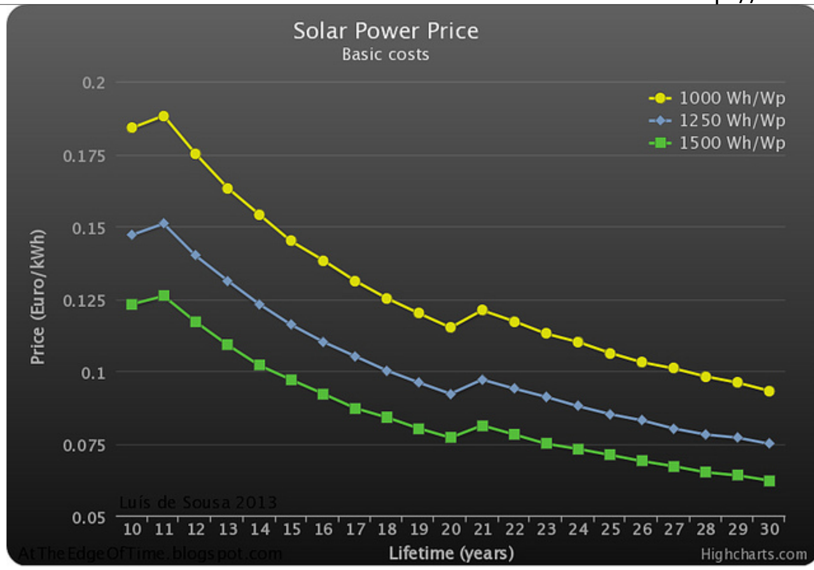

Figure 2 - Prices of solar power as function of system lifetime for three reference locations according to Scenario I.

In southern Germany, for a 20-year project lifetime, the basic cost of solar electricity stands today at 0.10 €/kWh, in stark contrast with grid prices well north of 0.2 €/kWh. It is also interesting to observe the weight of each parcel in total costs:

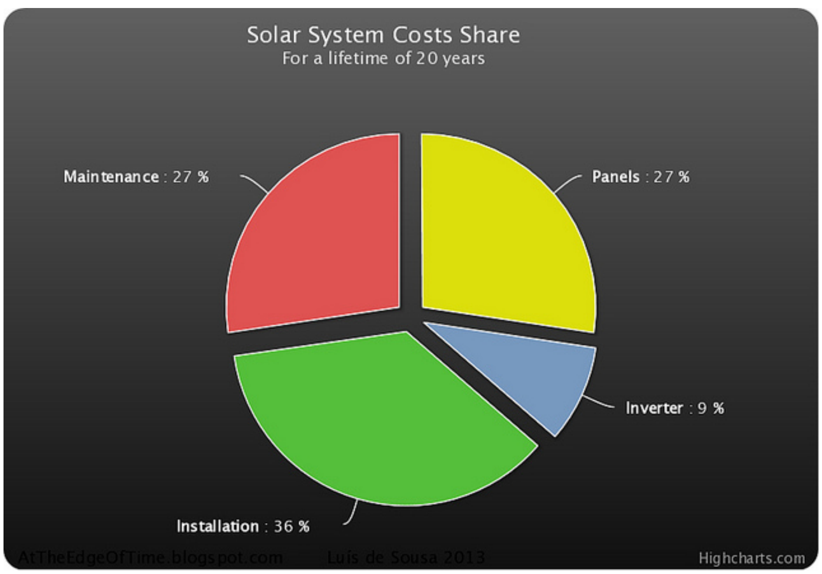

Figure 3 - Share of each cost component in Scenario I.

Considering Financing - Scenario II

Even with the recent price declines, a PV system is a relevant investment. It is reasonable to assume that some investors may have to resort to financing, hence debt servicing should also be included in the cost equation. Financing costs can be calculated using another time horizon (F_l) and an interest rate (F_r), applied to a fraction of upfront costs (F_f). The cost equation now needs this extra element:

$$C = (I_p + I_l + I_i) * (1 + F_f * F_r * F_l) + (L_p/L_i - 1) * I_i + L_p * M$$

The cost as function of lifetime graph is now reproduced with financing costs, assuming that 80% of the upfront investment is financed for a period of 8 years at an interest rate of 2%; all other parameters are kept from Scenario I. In Luxembourg PV financing can fetch interest rates as low as 1.2%, but I prefer a figure perhaps more representative of the wider European market.

Table 2 - Parameters and values for Financing, comprising Scenario II.

Financing horizon	F_l	8	years
Interest rate	F_i	2	%/year
Fraction of upfront investment to finance	F_f	80	%

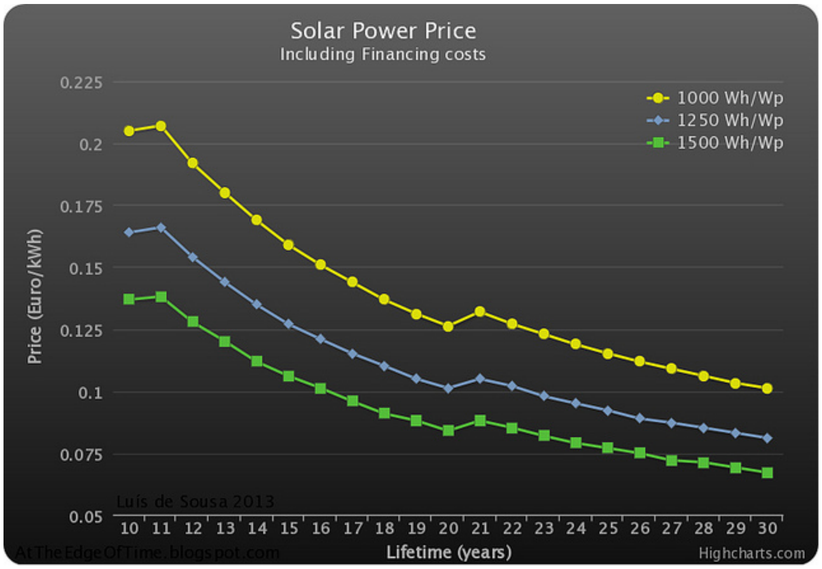

Figure 4 - Prices of solar power as function of system lifetime for three reference locations according to Scenario II.

And the cost components:

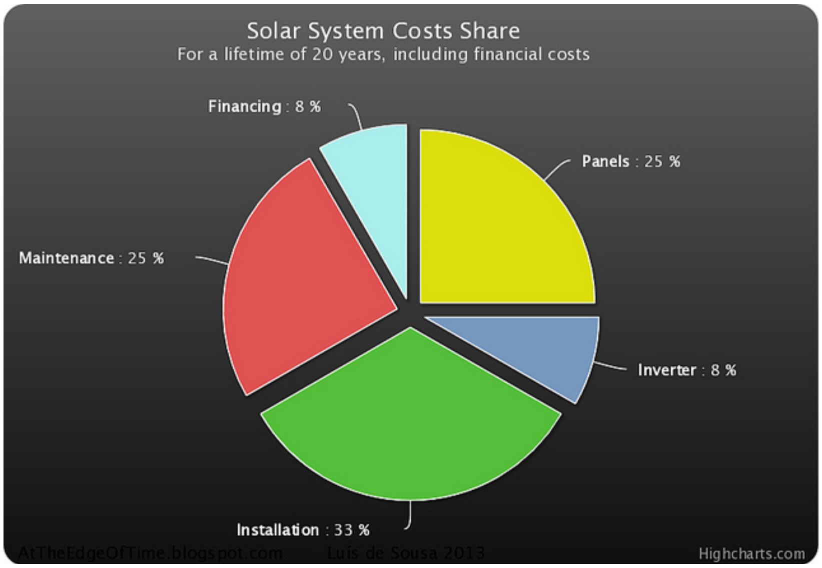

Figure 5 - Share of each cost component in Scenario II.

These figures may seem surprisingly low, but they present an accurate picture of the present PV market, at least at the household scale. On an industrial scale, a few months ago a group of investors appeared in Spain offering electricity to the grid at a fixed price of 0.06 €/kWh, dispensing with any subsidies or feed-in tariffs.

> Finanzas.com
> **Varios inversores interesados en instalar una central fotovoltaica en C.Real**
> 19/09/2012
>
> | El alcalde de Brazatortas, Pablo Toledano, ha valorado el interés que están mostrando varios grupos inversores extranjeros en instalar en ese término municipal una central eléctrica fotovoltaica de 200 o 400 megavatios. [...] | The mayor of Brazatortas, Pablo Toledano, has valued the interest that several foreign investment groups are showing in installing in his municipality a photo-voltaics plant of 200 to 400 mega-Watts. [...] |
> |---|---|
> | Pablo Toledano ha indicado que han sido hasta cuatro grupos inversores, que incluso han llegado a contactar con propietarios de terrenos, los que han proyectado una o varias centrales fotovoltaicas, en las que podrían invertir entre 200 y 300 millones de euros. [...] | Pablo Toledano has pointed that there are four investment groups, that have even contacted property owners, that have projected one or more photo-voltaics plants, into which they could invest between 200 and 300 million euros. [...] |
> | Los grupos inversores son asiáticos y centroeuropeos, y estarían dispuestos a instalar las centrales fotovoltaicas con unos precios energéticos de pull o subasta de mercado de 6 céntimos de euro el kilovatio, sin prima alguna por la energía renovable instalada. | These investment groups are Asian and central-European, and could be ready to install these photo-voltaics plants with energy supply prices of 6 euro cents to the market, without any aid to the installation of renewable energy. |

Already this month, details of the acquisition of a large solar project in New Mexico, where the solar potential is considerably higher than in Spain, point to even lower figures:

> Renewable Energy World
> **New Mexico Solar Deal Details Point to Parity -- and Pain**
> James Montgomery, 01-02-2013
>
> First Solar has acquired a 50-megawatt (MW) solar power project in New Mexico from the solar division of Element Power. The deal is billed as the state's largest solar project; it also, according to some unusually public information revealed in a regulatory filling, raises interesting questions about the purchasing power of solar energy. [...]
>
> In fact, a regulatory filling from the New Mexico Public Regulatory Commission (PRC) is

already loose in the wild, revealing exactly what El Paso Electric is paying: 5.79 cents per killowatt-hour (kWh) [0.043 €/kWh]. That's almost a third of the price that thin-film solar PV projects typically sell for (16.3 cents/kWh [0.12 €/kWh]), says Bloomberg New Energy Finance, and less than half the 12.8 cents/kWh [0.096 €/kWh] average price for new coal plants. [...]

The exceptional nature of renewable energy

If solar power prices are now at these levels, why are governments across Europe apparently thwarting the growth of PV connected to the grid? The answer goes back to the deregulation and privatisation strategies taken about a decade ago. At the same time governments were setting up feed-in tariffs and subsidies to renewable energies in the late 1990s and early 2000s, they were also implementing a new electricity market paradigm, dismantling the monopolistic state owned companies, unbundling energy production from grid management and generally privatising the sector. This created a new market where multiple companies trade electricity in the short (spot market) and long term (futures market), supposedly all in the best interest of consumers. Things went well at first, up to the point renewables reached a critical size and simply killed this venerated electricity market. To understand why one must comprehend two essential concepts of economics about renewable energy.

In first place comes the reality that renewable technologies like wind, solar, tidal or geothermal dispense with any sort of fuel to produce electricity. A gas or diesel fired power plant has a cost every time it produces power, the operator is permanently on the market for the fuel, managing prices that can be rather volatile. Besides this, there are other costs associated with the staff required to run and maintain the plant. In contrast, a solar panel, or a windmill just sit there; they too have maintenance costs, but these are much smaller and can be predicted fairly accurately at project start. The result is that generating an extra kWh of electricity from a solar panel already in place costs close to zero €/kWh. This is what in economics is termed the marginal cost (in this case for electricity generation).

The second important aspect of these renewable technologies is that they generate electricity, and once it is injected into the grid an electron is equal to any other. Moreover, if I have a PV system in my roof and the sun is shining, I can be sure that any other neighbour, or any other investor in the region with a PV system will also be generating electricity. In economics, a market where supply agents are unable to differentiate their products from one another are called Perfect Concurrency Markets; cereals agriculture in Europe is the classical class room example. This sort of market has a very important characteristic: long term the price matches marginal costs and supply agents struggle to make a profit (this is one of the reasons why there are subsidies to agriculture).

A perfect concurrency market with a marginal cost of zero is something totally outside the standard study and practice in economics. It is the reason why spot electricity prices collapse during sunny summer days or why during autumn storms there can even be negative prices. These are all symptoms of a market whose price will get closer and closer to zero the larger the number of renewable energy systems connected.

Clean Technica

German Solar Bringing Down Price of Afternoon Electricity, Big Time!

Zachary Shahan, 23-03-2012

While electricity prices rise in the early morning (4am to 8am) as demand rises, from about 8am to 9pm, the price is pretty level.

> Now, fast forward to March 2012:
>
> We again see prices rise from the early morning to about 8 or 9am, but then look at what happens when the sun (and its 25 GW of power capacity from solar panels) kick in — the price drops off a cliff, diving even deeper than the price of electricity in the dead of night!

PV can now lead electricity prices in the spot market down to negative territory on its own, and as early as April. Again showing that reducing electricity prices to the consumer is not exactly what motivates governments:

> Clean Technica
> **Renewables Driving Electricity Prices below $0 Some Afternoons**
> Nicolas Brown, 15-04-2012
>
> Renewable sources of energy such as solar and wind have been outstripping the electricity supply of traditional baseload (coal, nuclear, and some natural gas) power plants during daytime, especially afternoons, in some renewable-leading countries of late. One reason for this is: electricity demand tends to increase during the sunniest (the hottest) hours, and solar power plants generate more electricity when it is sunnier, which is right on cue.
>
> Not perfectly, but solar power production tends to follow electricity demand. This is especially true in the warmer temperatures, since air conditioners (which consume a lot of electricity) are turned up to compensate for the hot afternoon weather.

And this is killing the traditional electricity suppliers with business models around fossil fuel energies. They simply cannot make it in such a market, that on reflection seems clearly ill conceived. Governments have nothing innate against renewable energies, they are simply trying to protect these important companies, and also the philosophical reverence for the market.

Particularly in Germany, far from the sunniest or windiest place in Europe, the mismatch between a fully liberalised market and renewable energy growth is creating all sorts of problems. Grid managers are unable or unwilling to upgrade the grid, voltage goes up during sunny days threatening to bring the grid down and even maintenance is an issue. In some lands it is getting so serious that the government, composed by Conservatives and Liberals, is contemplating the outright nationalisation of the grid.

> Der Spiegel
> **Power Play: Politician Calls for Nationalization of Electricity Grid**
> Frank Dohmen and Gerald Traufetter, 16-01-2013
>
> A member of German Chancellor Angela Merkel's cabinet is calling for a radical solution to the desperately needed expansion of high-voltage power lines across the country, a critical infrastructure project that has stalled in recent months. Ilse Aigner would like to see the partial nationalization of the country's electricity grid in order to ensure that massive power lines required to transport green energy from offshore windfarms and other sources to the industry-heavy regions of southern Germany are finally built.
>
> The consumer protection minister, a member of the Christian Social Union (CSU), the Bavarian sister party to Merkel's conservative Christian Democratic Union (CDU), seems to have struck a chord with the call too. Many experts in business and politics

> believe that Germany would be better off with a national power grid that is partially or even fully owned by the government -- especially at a time when the German electricity market will have to be completely revamped because of the Energiewende, Berlin's policy of phasing out all nuclear power plants by 2022 and ensuring that 80 percent of the country's electricity supply comes from clean energy by 2050.

With these PV prices and in such a market setting, governments can only do so much to hamper the growth of solar power. Without feed-in tariffs investors will simply go off grid.

Going off grid - Scenario III

With solar power prices now at about half the price consumers pay to the grid, investors can easily contemplate an investment scenario where storage infrastructure can be added to the system, allowing for the full consumption of the electricity harvested in place. Calculating prices under these conditions is trickier, but an hypothetical scenario can be attempted. Some assumptions are required: first the amount of storage, here taken as half the energy generated during 24 hours at the summer solstice. At this point in the year my system is generating the equivalent to five hours at pull power, meaning 5 Wh/Wp/day, probably on the high side compared to the rest of Europe. The assumption is that half this electricity must be stored to be used later in the day, this equates to 2.5 Wh/Wp, again probably on the high side. A 12 V 245 Ah battery that costs 450 € can store about 3 kWh; again using a safety buffer, for any extra hardware required, I'll settle with an additional cost for the storage system (I_s) at 0.6 €/Wp. The battery is assumed to have a lifetime (L_s) of 10 years and have an efficiency (E_s) of 90%. Now the tricky part is to estimate the amount of energy that is stored throughout the year (F_s), in winter hardly any and then about half in sunny summer days; I'll use a ballpark figure of 30%. The cost equation must now be expanded to include these storage components:

$$C = (I_p + I_l + I_i + I_s) * (1 + F_f * F_r * F_l) + (L_p/L_i - 1) * I_i + L_p * M + (L_p/L_s - 1) * I_s$$

As so the energy yield equation:

$$E = \mathrm{sum}[t=0,L_p-1][[E_c * (1 - t * d)] * [(1 - F_s) + (F_s * E_s)]]$$

The storage values used to build this third and final scenario are summarised in Table 3, that adds to the values in tables 1 and 2.

Table 3 - Parameters and values for Storage, comprising Scenario III.

Storage system cost	I_s	0.6	€/Wp
Storage system lifetime	L_s	10	years
Storage system efficiency	E_s	90	%
Fraction of energy stored	F_s	30	%

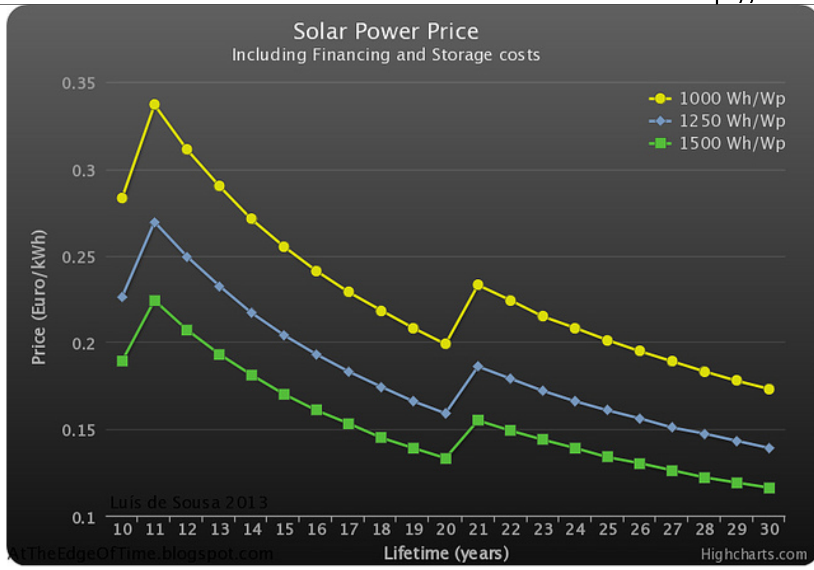

Figure 6 - Prices of solar power as functions of system lifetime for three reference locations according to Scenario III.

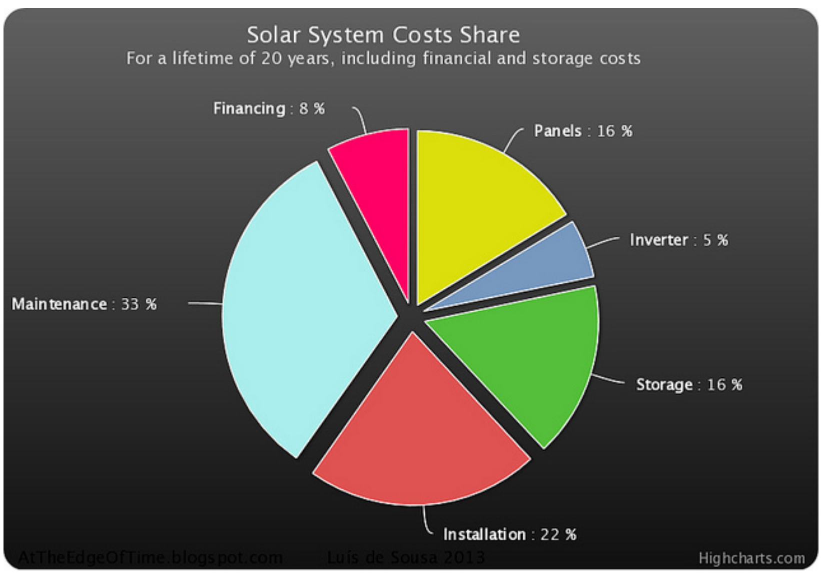

Figure 7 - Share of each cost component in Scenario III.

The impact is inevitable

There are two essential drawbacks with the off-grid option. Firstly the system has to be scaled back to the *in situ* summer demand, potentially leaving rooftop space unused. And secondly there is the efficiency loss imposed by storage, it will always be more efficient to feed this electricity to the grid and reach a broader range of consumers. But in essence, with 0.10 €/kWh or 0.12 €/kWh below the grid price, there is a good deal of room to go off grid with some storage schemes and still save money. There are already today in the market companies that supply such integrated solutions - a few PV panels, batteries and an inverter/controller - claiming prices below the grid benchmark. For households that own an electric vehicle with its own storage pack things get even more straightforward.

In fact, this market is so paradoxical that investors can even think of simply going by without storage, waste the extra electricity generated during summer days and still get a final price below that asked by grid operators. Some analysts are projecting off grid to grow faster than grid connected systems.

> Bloomberg
> **German Power Tumbles to Record Low as Solar Damps Demand**
> Julia Mengewein, 16-01-2013
>
> Power for 2014 delivery in Germany and France dropped to records as rising solar output is expected to cut demand for other electricity sources. [...]
>
> Electricity for Germany next year lost 65 cents to 43.30 euros ($57.93) a megawatt-hour, it's biggest decline since March 6, according to broker data compiled by Bloomberg. The French equivalent lost 15 cents to 46.20 euros.
>
> As much as 18 percent of electricity demand may be replaced by solar panels not connected to Germany's grid, reducing demand for other sources by 6 to 10 percent by 2020, Per Lekander, a Paris-based analyst at UBS AG (UBSN), said in a research note.
>
> "The unsubsidized solar growth should drive wholesale power prices further down," he said.

But these PV prices also bring opportunities, especially for the industry. Companies that are able to shift their operations to concentrate energy intensive processes during the sunnier half of the year can access considerably lower electricity prices, and thus acquire a competitive advantage. This can require a relevant change to the way industrial processes are managed, but with oil at 110 $/b this is a changing world.

And here is the drama traditional suppliers will be facing in the foreseeable future. They will either be dealing with declining prices or with declining demand. Either way base load power plants will be running below capacity or even be mothballed during summer and stormy seasons. Reducing or scrapping feed-in tariffs is the proverbial kick in the can; and without them the impact on the electricity market can in time be even worse. Without fundamental changes to the market, the future for fossil fired and nuclear electricity generation is bleak.

Feed-in Tariffs

Governments should be working towards the complete integration of solar systems into the grid, not to their exclusion. In the first place they must reckon that only by using schemes like feed-in tariffs can they guarantee the long term permanence of solar producers in the grid. With marginal generation costs close to 0 €/kWh, these systems will never be able to yield proper cash flows in the liberalised electricity market. If the investment on grid connected solar technologies is to continue to come from private investors somehow stable revenues must be guaranteed in the long term. Looking at laws in member states like Luxembourg some advantageous changes become obvious: first of all extend the feed-in tariff to the whole lifetime of the technology and then lower their values. Using the example in Spain, with an expected cost of 0.06 €/kWp for industrial systems, the state can set a 0.10 €/kWp tariff for the first ten years and 0.04 €/kWp for the last decade of production, thus also preserving the important role of break-even anticipation in time that feed-in tariffs perform.

With proper feed-in tariffs in place governments can then focus on the monolithic base load electricity suppliers; they won't disappear, but their role will fundamentally change. They must shift their focus from production to storage and load-balancing. Governments can perhaps aid with subsidies on the set up of large and small scale storage infrastructure and most importantly, steering towards the most effective technologies, avoiding pipe dreams like hydrogen.

Finally a note on the concept of smart grids. It might be an indispensable step to absorb renewable energies at a large scale, providing real time information on grid voltage, to which prices can be pegged. But care should be taken on its impact, solar and wind technologies will continue having a zero marginal cost on a perfect concurrency market. Smart grids may avoid dreaded episodes of ramping voltage and negative prices, but there's no guarantee they'll create relevant revenues for renewable technologies.

Summary

The actions recently taken in Europe against solar power are not a sign of failure but rather a consequence of the highly successful progress of PV technologies. Governments are simply trying to defend large electricity suppliers and the electricity markets they created in the last decade. With marginal generation costs close to zero, technologies like solar power wreck havoc on the open market once they reach a critical volume and threaten to steal away revenues from traditional base load suppliers.

The actual prices of electricity generated with PV have fallen relentlessly in recent years and are now on par with the gas fired generation at about 40º North in Europe. Even in more northern member states like Germany the cost of solar electricity is now about half of what consumers pay to the grid. At these prices the installation of solar panels can only grow, either on or off grid, unless installation is outlawed.

Present strategies by governments to keep these technologies away from the electricity market can at most delay the process. A fundamental shift in the way the grid is managed and prices are set is required, otherwise the electricity generation and distribution complex is left subject to major disruptions, both physical and financial.

In great measure the technology required to perform the *Energiewende* is already here. In fact, the scalability and low prices of PV may mean that this transition is now inevitable. But the growth of solar power clashes with the traditional market structures and concepts of our society in such a way that make the end result rather uncertain. The remaining obstacles to the *Energiewende* are now of a social and economic nature, and these may not be exactly the easiest to overcome.

Further reading

Renewables International: The afternoon dip

Crikey: Why power generators are terrified of solar

ICIS: German solar capacity rise pressures electricity prices

Acknowledgement

Special thanks to my colleagues Oli O'Naggy and Daniel Koster for the many insightful discussions on this subject.

Note: You can find the interactive version of the charts at my blog here.