DAUPHINE UNIVERSITÉ PARIS

ifri

Chaire Economie du Climat

The cost of Renewable Energy Sources

Paris, FLM December 19, 2014

Foreword

The note "Cost of renewable energy" recently published by IFRI relies on data available in previous studies made by international bodies such as IEA, IRENA, Fraunhofer ISE, etc. Nevertheless, the author is sole responsible for conclusions drawn from this data.

Global investment in renewable energy was $ 254 Billion in 2013. Power attracted by far the largest share, with $ 115 Bn for solar and $ 80 Bn for wind.

Since 2000, solar PV and wind enjoy a two digit global growth rate, with market share expectations as high as 16 % for generation from PV solar by 2050.

Within the EU, the target is 20 % of renewable energy by 2020. However, according to the 27 National Renewable Energy Action Plans, electricity from renewable sources should be 35 % of which 14 % from wind and 3 % from solar.

The note therefore focuses mainly on power, wind and solar.

The cost of Renewable Energy Sources

1 – Overview on costs:

- **Cost for the producer**
- **Cost for the consumer**
- **Cost for the citizen**

2 – Consequences:

- **Cost vs benefit**
- **Redistribution effects**
- **New issues ahead**

3 – Recommendations

4 – Discussion

Cost for the producer

Initial cost

Renewable energy requests large upfront investments, usually higher than fossil fuels. This investment will vary greatly depending on sources and areas.

Typical range of costs for new plants:

	CAPEX		OPEX	
	€/kW		€/MWh	
	Min	Max	Min	Max
On shore wind	696	2 802	7	38
Off shore wind	2 259	4 578	19	39
Photovoltaics	791	4 676	14	44
Hydroelectricity	718	3 125	3	25
Concentrated Solar Power	2 319	9 000	14	29
Solid biomass	602	4 066	47	162
Coal	497	2 786	39	92
Natural gas	423	1 288	35	92
Nuclear	2 688	4 909	37	60

Cost for the producer

From investment to final cost

In well-endowed areas (wind, sunlight, water resources), current techniques now allow renewables to show an estimated cost close to or even lower than conventional sources.

The estimated cost of production is usually expressed by the Levelized Cost Of Energy (LCOE).

For each technology and for each site, three factors determine the LCOE:

- **Life span of the equipment**
- **Load factor of the installation**
- **Cost of financing**

Typical range of LCOE for new plants:

	LCOE €/MWh	
	Min	Max
On shore wind	30	121
Off shore wind	75	276
Photovoltaics	59	467
Hydroelectricity	13	236
Concentrated Solar Power	79	369
Solid biomass	38	151
Coal	26	130
Natural gas	35	111
Nuclear	69	111

Public policies

In some countries experiencing a rapid economic growth, a light public policy is sufficient for renewable energy to develop.

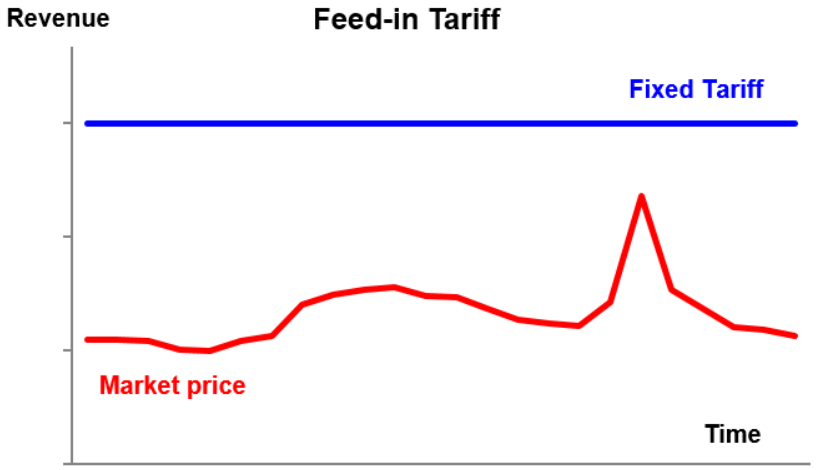
In countries heavily equipped, a comprehensive public policy remains essential for the penetration of renewable energy. This is the case in Western Europe, with policies usually consisting in a blend of:

- **Regulatory measures: priority of injection.**
- **Incentives for investment: subsidies, tax reductions, public loans, public guarantees on debts: the cost is passed on to the citizen.**
- **Production supporting schemes, the LCOE of new renewable facilities is always higher than the LCOE of old conventional plants: the additional cost is passed on to the consumer. Support may involve either quantity or revenue.**

In the power sector, feed-in tariffs proved to be the most successful… and also the most expensive supporting scheme: in 2014 the additional cost is roughly € 3,7 Bn in France and € 23 Bn in Germany.

Cost for the consumer

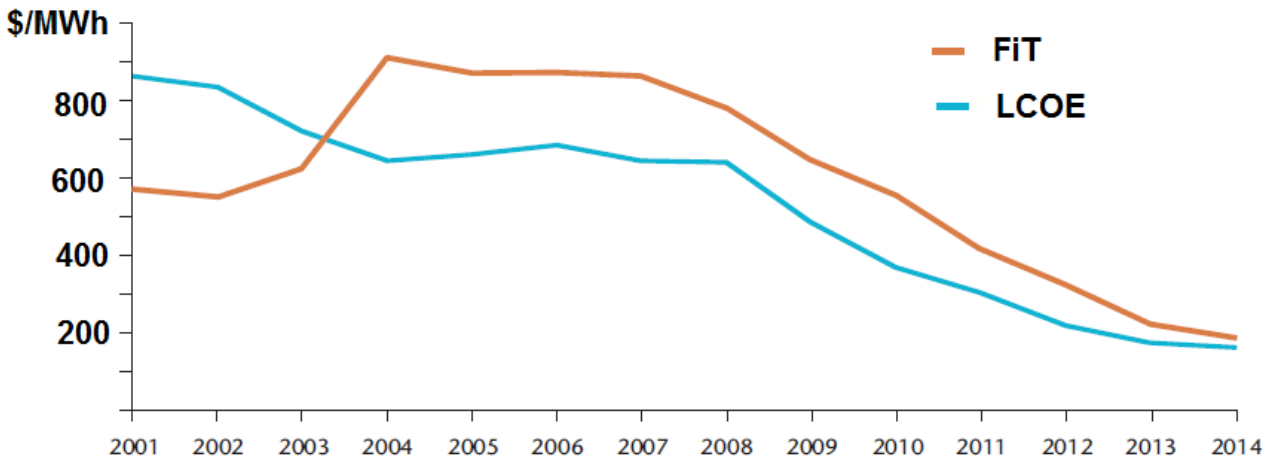
Feed-in Tariffs



Feed-in tariff offers the best visibility to investors. The generation is completely insensitive to the market price.

Until recently, the regulation could hardly catch up with price trends. For utility scale facilities, the tariff level can be set after competitive bidding.

FiT & LCOE for small rooftop PV in Germany:



Cost for the consumer

Impact of Feed-in Tariffs

Soutien aux énergies renouvelables en Allemagne et en France

Surcoût par MWh injecté pour les consommateurs assujettis à la surcharge :

Année 2012	Allemagne		France	
	Soutien en €/MWh	Volumes aidés en TWh	Soutien en €/MWh	Volumes aidés en TWh
Eolien terrestre	49	44,6	34	14,8
Eolien en mer	138	0,7	-	-
Photovoltaïque	246	27,0	343	4,5
Hydroélectricité	30	-	9	7,5
Incinération	126	37,8	37	2,2
Biogaz			-	-
Gaz de décharge	20	5,9	33	1,3
Déchets municipaux			7	2,2

Le surcoût total à répartir entre les consommateurs s'élevait à 3,7 milliards d'euros en France en 2014 et 23 milliards d'euros en Allemagne.

Cost for the consumer

Grid & System Costs

Electricity consumers pay not only an additional cost due to generation supporting schemes. They also have to face:

1) Grid additional costs stemming from:

- **Extension and reinforcement of existing grids (transmission & distribution), when new facilities have no constraint on their location**
- **New equipment to insure quality of supply**

2) System costs specifically caused by variability of generation from wind and PV, requiring short term (balancing) and long term (adequacy) back up

Estimated system costs in France and Germany:

€/MWh	On shore wind		Photovoltaics	
Penetration level	10%	30%	10%	30%
Balancing	1,4	4,6	1,4	4,6
Adequacy	5,7	6,4	13,9	14,2

Cost for the consumer

Investments for networks

Transmission: **The Ten Year Network Development Program drafted by ENTSO-E in 2012 considers 52,300 km of new or refurbished Extra High Voltage routes, of which 9 000 km of subsea routes. The vast majority of project (around 39,000 km) use the common HVAC technique. In addition, about 12,600 km of HVDC links are planned.**

Needed investments should be of € 104 Bn.

Distribution: **According to EDSO, total investment needs might be as high as € 400 Bn by 2020. About 200 million smart meters should be in operation by 2020.**

In France:

- **Additional investments for RTE are valued at € 1,2 Bn up to 2020.**
- **ERDF should invest nearly € 4,3 Bn on the grid and € 4,5 Bn for the "Linky" meters.**
- **The network component of the French bill will see at least an increase of 3 %.**

Cost for the citizen

Subsidies & Incentives - Public Aids

Policies usually mix up the following provisions:

- **Subsidies in the R&D phase**
- **Incentives for investment:**

  Subsidies (from local, national and European policies)

  Grants and tax reductions to producers

  Public procurement

  Public loans, public guarantees on debts

- **Incentives for consumption: Subsidies or tax reduction for purchase of equipment and/or energy.**

In France, subsidies from the State amount to approximately € 1.5 Bn per year, mainly from the "Sustainable Development Tax Credit", the reduced VAT and the "Heat Fund" (managed by ADEME). No study has assessed the cumulative amount of aid provided by local authorities, although the latter are involved in the most countries. Finally EU provides financial support through the Cohesion Fund and the European Regional Development Fund (ERDF).

The cost of Renewable Energy Sources

1 – Overview on costs:

- Cost for the producer
- Cost for the consumer
- Cost for the citizen

2 – Consequences:

- Cost vs benefit
- Redistribution effects
- New issues ahead

3 – Recommendations

4 – Discussion

Controversial benefit

The efforts of consumers and taxpayers provide indisputable benefits to the community, as regards dependency on imported energy or damage to the environment, despite some adverse effects, such as needs of rare metals and biomass imports.

The impact on emissions of greenhouse gas appears much less clear:

- **Renewable sources may replace non emitting sources such as nuclear**
- **Renewable energy is still a costly way to mitigate emissions**

The benefit in terms of economic activity and employment also remains at issue:

a) **Additional costs mean higher electricity price, detrimental to some manufacturing sectors**

b) **International competition leaves little benefit to first movers**

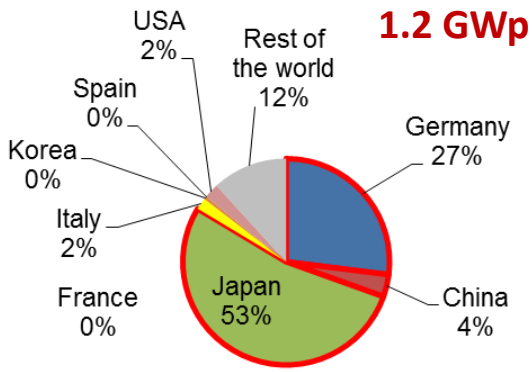
PV: The case for an industrial policy

In contrast to Japan, Germany was not able to retain significant local cell production.

Cumulative installations

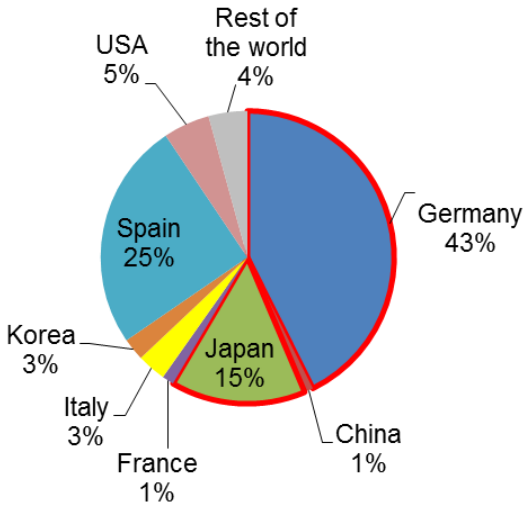
2002

1.2 GWp



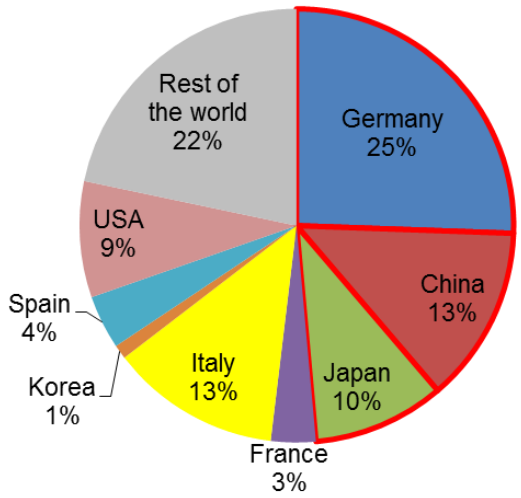
2008

14.4 GWp



2013

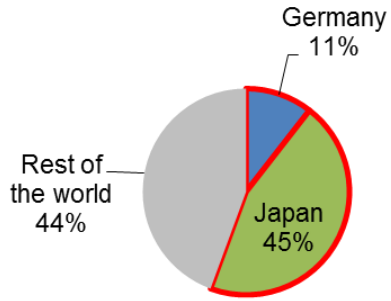
138.8 GWp



Annual cell production

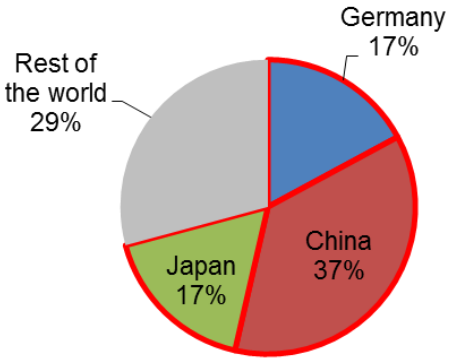
2002

0.5 GWp



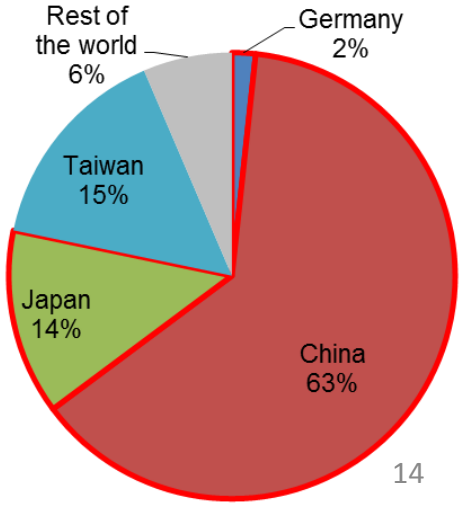
2008

7.1 GWp



2013

43 GWp

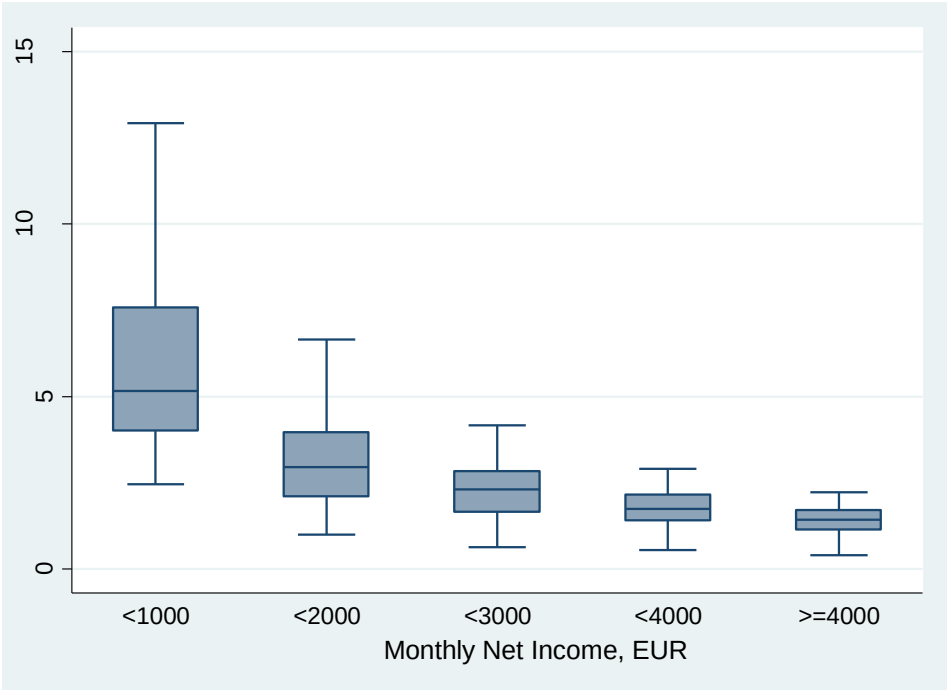


Redistribution effect

The development of renewable electricity also generates a redistribution phenomenon in Europe:

1. **Weakening major historical power generators. The deterioration of their balance sheet will limit their ability to invest in the coming years.**
2. **Affecting the purchasing power of small consumers and the production costs of small businesses, as they bear the bulk of additional costs.**
3. **Deepening differences of situation among States.**
4. **Providing substantial profit to shareholders.**

Share of household income spent on electricity, 2010

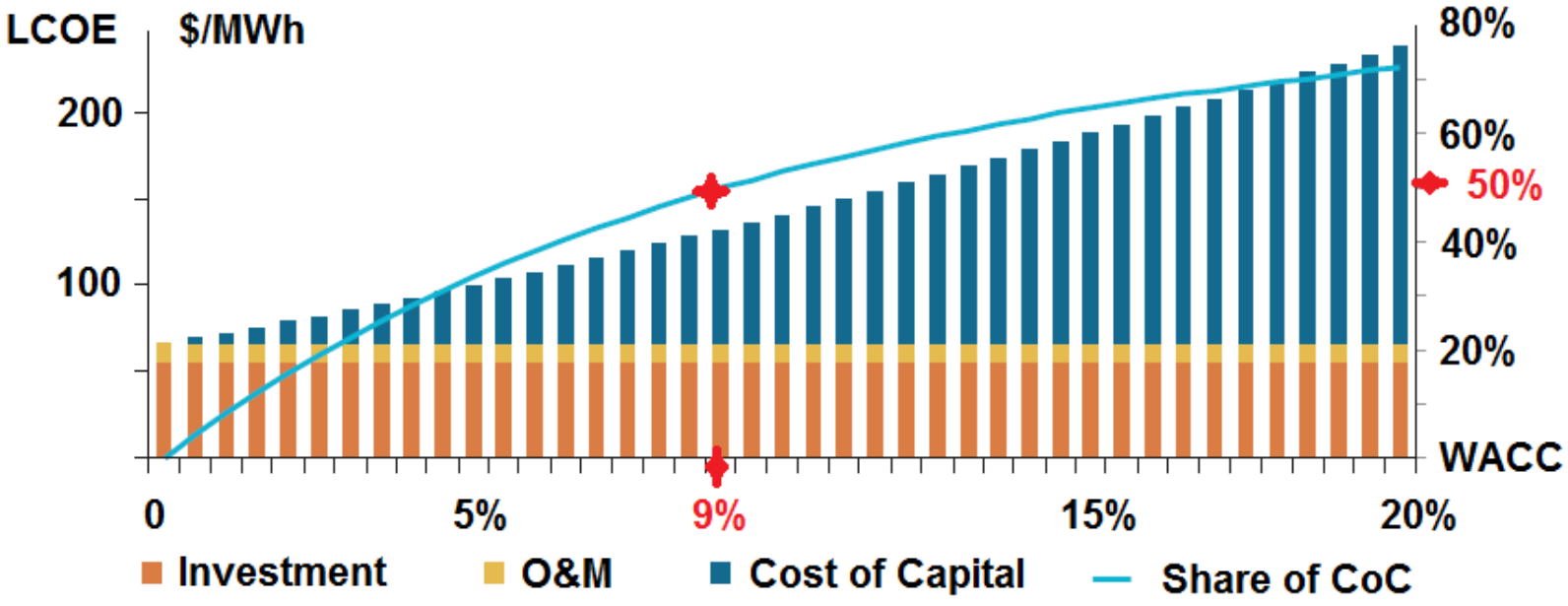


Redistribution effect

Cost of Capital & Profit

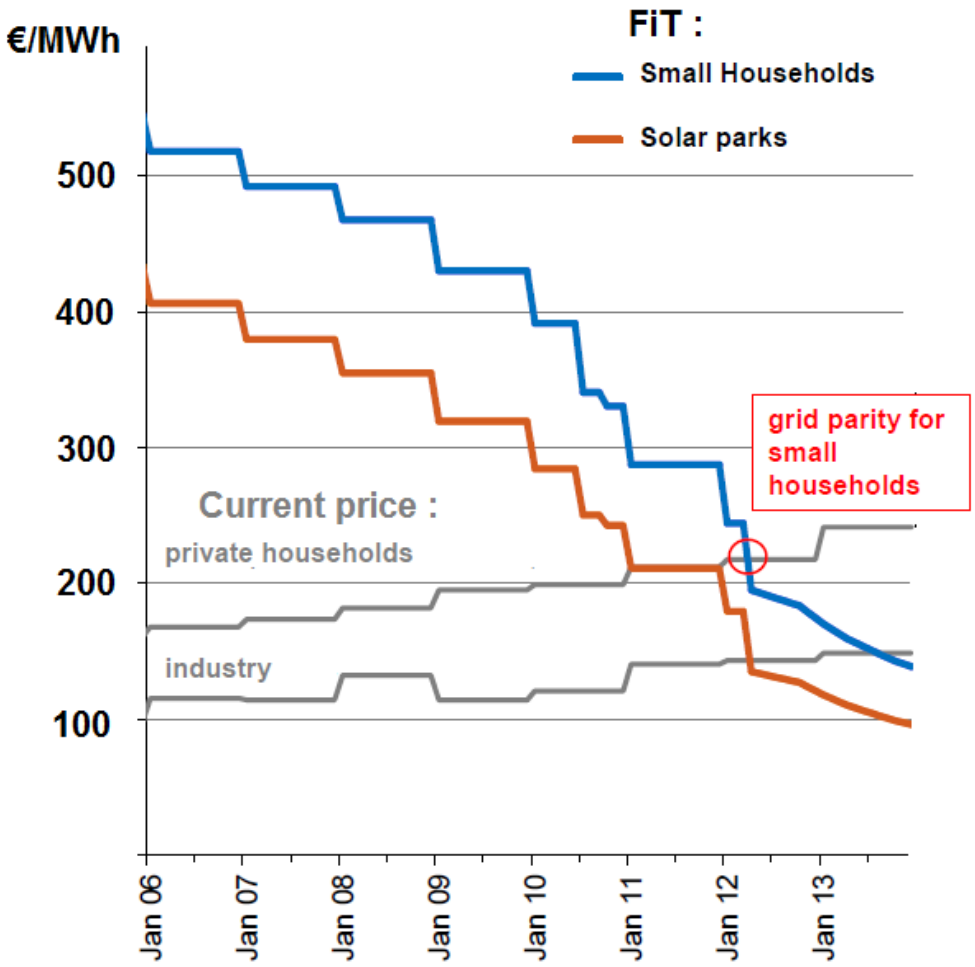
As price of equipment keeps falling, the Cost of Capital becomes the main driver of the LCOE, sometimes providing high profit. In France, on a sample of 91 PV facilities (most of them above 100 kWp), shareholders received on average a return rate on equity of 18 % (2010-2012).

Share of the Cost of Capital in the LCOE of PV systems:



New issues

Situation in Germany:



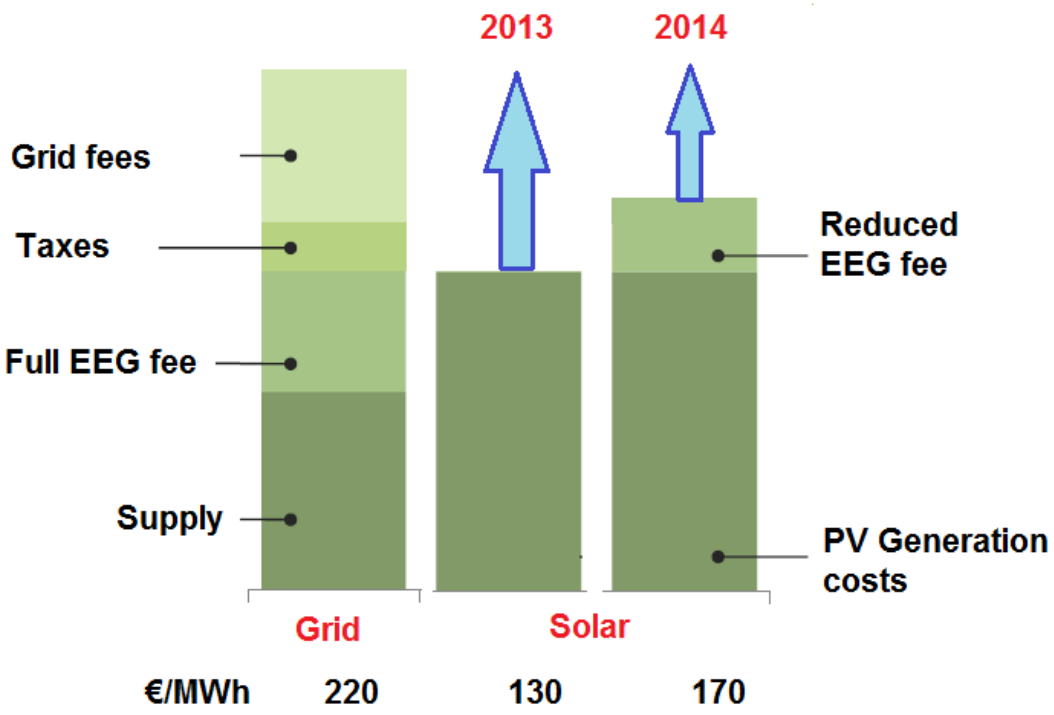
The gradual reduction in guaranteed purchase price is an incentive to self-consumption.

The relevant criterion is now the socket parity.

New issues

Consequences of self-consumption

New regulatory framework in Germany:



Self-consumption leads to new issues:

- **Sharing the effort to support renewable energy**
- **Taxation on electricity**
- **Grid fees, whose fixed component is usually low.**

Self-consumption could grow if storage technologies were to develop.

New regulation regarding networks

Transformer 20 kV/220 V

Power < 100 kW

At the level of the whole of Europe, the needs of the distribution network may be close to € 200 Bn for strengthening and modernization. The German experience shows that we can reduce this cost with a better regulation:

- **Through a locational signal, foster the introduction of new sources on sites where the network is already dense (in France outside rural areas).**
- **Allow network operators to limit the power injected certain days of the year. With dynamic network management, a reduction of 5% of the accepted annual production can sometimes double the grid capacity.**
- **Introduce standards on electronic equipment so that it contributes to the quality of the current (stability, frequency and voltage).**

Main recommendations

Reduce the cost:

1. **Spread out the development of renewable energy in order to reap all innovations**
2. **Allow generation and network to progress at the same pace**
3. **Improve access to capital, allowing scope to small savings**
4. **Introduce specific constraints either through regulation (e.g. locational signal), standardisation (e.g. smart inverters), incentives (e.g. balance of the system) or market tools (e.g. trading blocks)**

Enlarge the scope:

a. **Pay close attention to hardly hit customers & sectors under pressure**
b. **Protect nascent industry from international competition**
c. **Pursue R&D efforts, notably on power storage**

Chaire Economie du Climat

Paris, FLM December 19, 2014

Comments & Questions are welcome

michel.cruciani@dauphine.fr

Sources (1/2)

Slide 2 : Bloomberg New Energy Finance, Press Release, 15 January 2014
ECN - Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States – 20 November 2011 – Summary report, page 115

Slides 4 & 5 : Author's table based on:
IEA (International Energy Agency), Renewable Energy - Markets and prospects by technology, November 2011
Survey ordered by IEA: PRYSMA, Study on Cost and Business Comparisons of Renewable vs. Non-renewable Technologies ("RE Cost"), July 2013
Fraunhofer ISE - Levelized cost of electricity - Renewable Energies - May 2012
IRENA (International Renewable Energy Agency) - Renewable Power Generation Costs in 2012
WEC (World Energy Council) - World Energy Perspectives - Cost of energy technologies – 2013
REN 21 - Global Status Report – June 2014

Slides 6 : Author's table based on:
Germany : BDEW, *Erneuerbare Energien und das EEG: Zahlen, Fakten, Grafiken* (31 Janvier 2013)
France : Rapport de la Cour des Comptes, "*La politique de développement des énergies renouvelables*", Juillet 2013, page 90

Slide 7 : Top: Author's graphic
Bottom: IEA - Technology Roadmap - Solar Photovoltaic Energy – 2014 Edition, page 44

Slide 8 : Author's table based on:
Germany : BDEW, *Erneuerbare Energien und das EEG: Zahlen, Fakten, Grafiken* (31 Janvier 2013)
France : Soutien : Rapport de la Cour des Comptes de l'Etat, "*La politique de développement des énergies renouvelables*", Juillet 2013, page 90
Volumes aidés : Observ'ER : Baromètre 2013 des énergies électriques renouvelables en France
CSPE : Délibérations de la Commission de Régulation de l'Energie des 9 Octobre 2012 (et 9 Octobre 2013) portant proposition relative aux charges de service public de l'électricité et à la contribution unitaire pour 2014 (et 2013).
CRE : La contribution au service public de l'électricité (CSPE) : mécanisme, historique et prospective, Octobre 2014

Sources (2/2)

Slide 9 : NEA, Nuclear energy and renewables, System effects in low-carbon electricity systems, 2012, page 127

Slide 10 :
Transmission: ENTSO-E : European Network of Transmission System Operators for Electricity, Ten Year Network Development Plan 2012, page 62
Distribution: EDSO, Declaration 22 May 2014
France : Rapport de la Cour des Comptes, "*La politique de développement des énergies renouvelables*", Juillet 2013, page 90

Slide 14 : Julie Hyun Jin Yu, Solar photovoltaic (PV) energy policy and globalization: a multi-perspective approach with case studies of Germany, Japan, and China - 29th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2014), Amsterdam, The Netherlands, 26 September 2014

Slide 15 : Pr. Dr. Colin Vance, CGEMP Conference, May 31, 2013, University Paris-Dauphine, "*Germany's Renewable Energy Promotion*", slide 11

Slide 16 : Top: Commission de Régulation de l'Energie, "*Coûts et rentabilité des énergies renouvelables en France métropolitaine*", Avril 2014
Bottom: IEA - Technology Roadmap - Solar Photovoltaic Energy – 2014 Edition, page 44

Slide 17 : Office Franco-Allemand pour les Energies Renouvelables - Conference on Avril 10, 2014, Paris Presentation of Dr. Karin Freier, Head of Division III B 5 „Renewable Energy Technologies (Wind, Hydro, Solar, Biomass, Geothermal Energy)“, Federal Ministry for Economic Affairs and Energy, slide 11

Slide 18 : Office Franco-Allemand pour les Energies Renouvelables - Conference on Avril 10, 2014, Paris Presentation of M. Felix Benjamin Schaeffer, Heidelberg Energie Genossenschat e.G., remix of slides 4 & 6

Slide 19 : Photo prise par l’auteur