The Role of EVs in Making the Azores Islands Green

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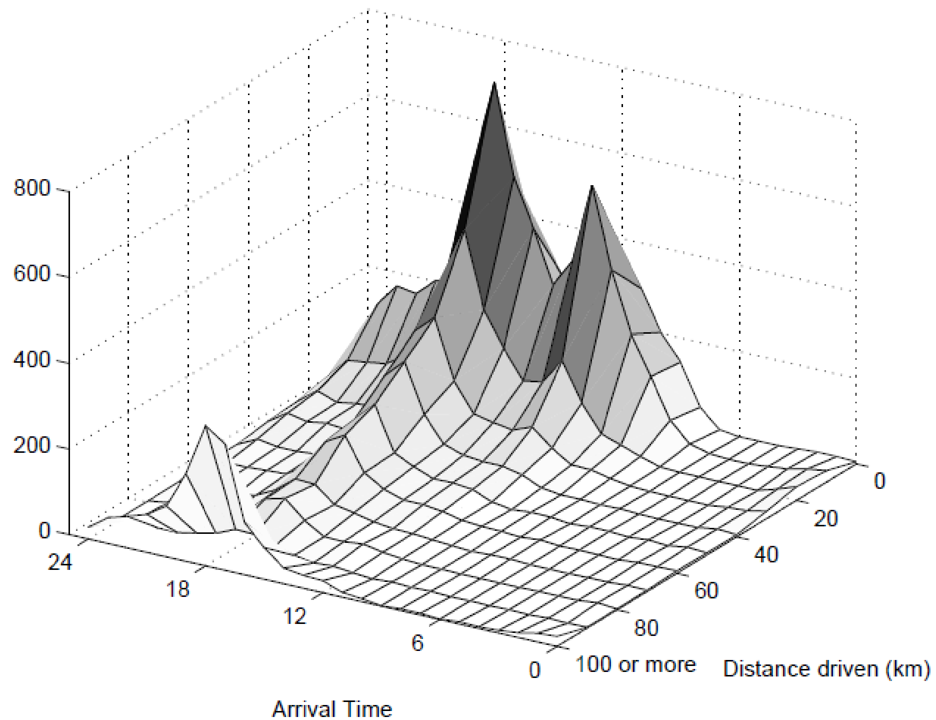
Flexibility of EV charging

Many EVs need not be charged every day.

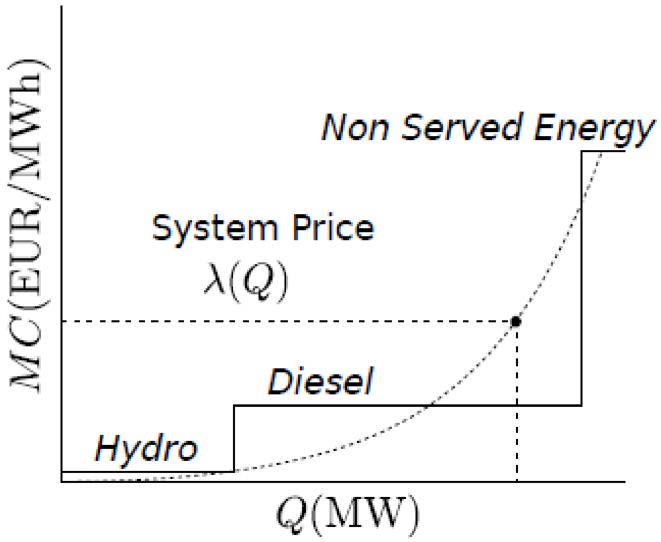
Charging can be scheduled based on availability of wind.



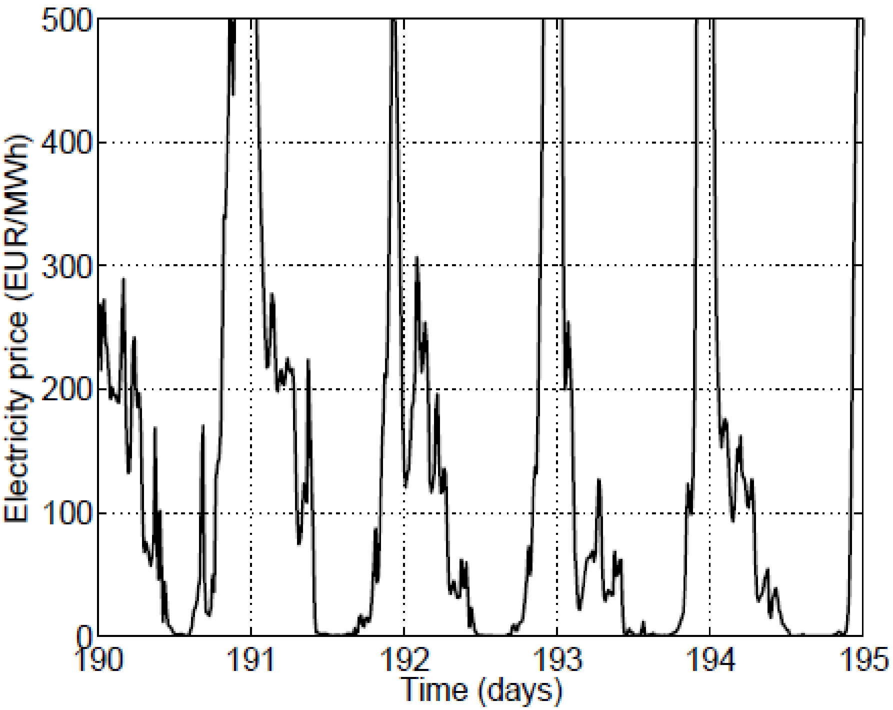
Distribution of home arrival times and daily distance [1]

Charging strategy based on predicted price

Price depends on residual demand (= demand – renewable generation)



Price reflects marginal generation cost and costs of non-served energy.



Modeled price for a period of five days in summer

Optimal charge schedule: dynamic programming

Backward recursive DP equation

$$J_k(x_k) = \min_{u_k \in U_k(x_k)} \{g_k(x_k, u_k, w_k) + J_{k+1}(f_k(x_k, u_k, w_k))\}, \quad k = 0, 1 \ldots, N-1$$

Cost of intermediate steps

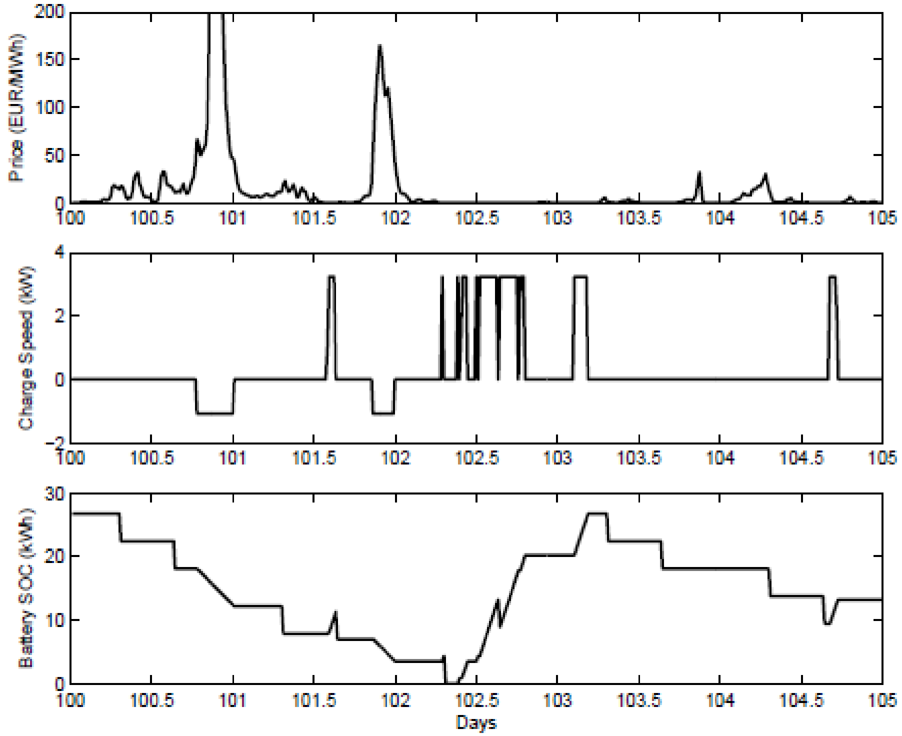
$$g_k(u_k) = \begin{cases} \lambda(k) u_k \Delta t & \text{if } u_k \geq 0 \\ (\lambda(k) - C_{degr}) u_k \Delta t & \text{if } u_k < 0 \end{cases}$$

Charging: electricity price

Discharging: electricity price minus battery degradation cost

Price forecasts are updated by iteration

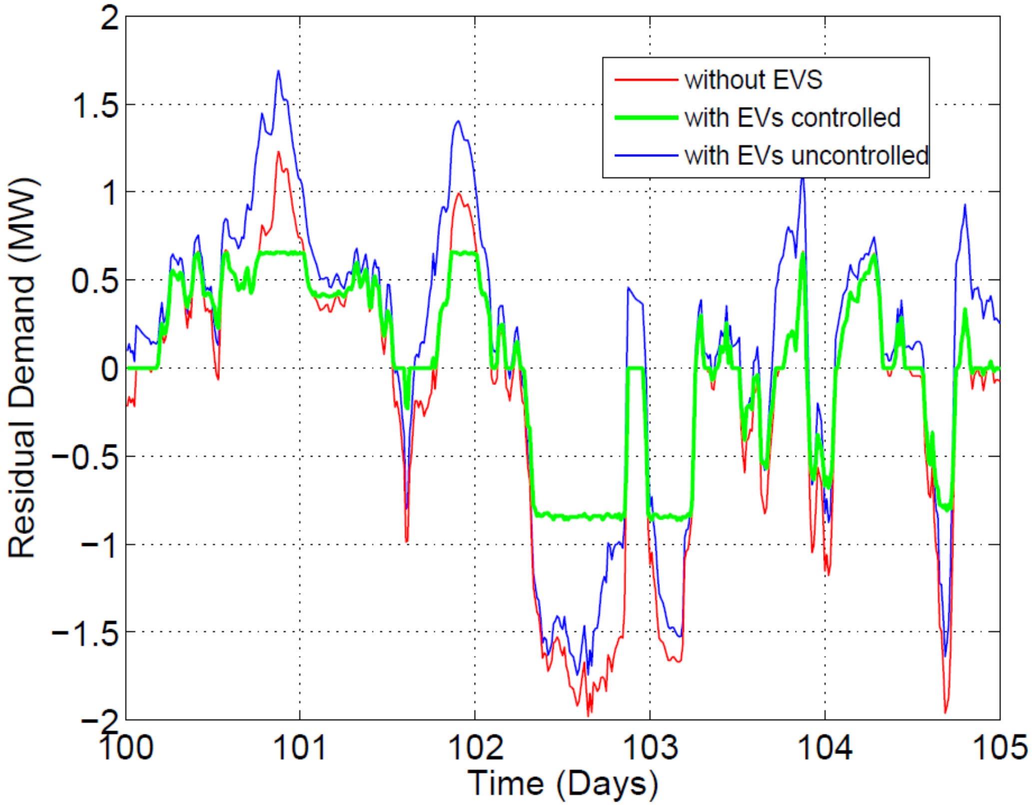
Optimal charge schedule



Results for one vehicle

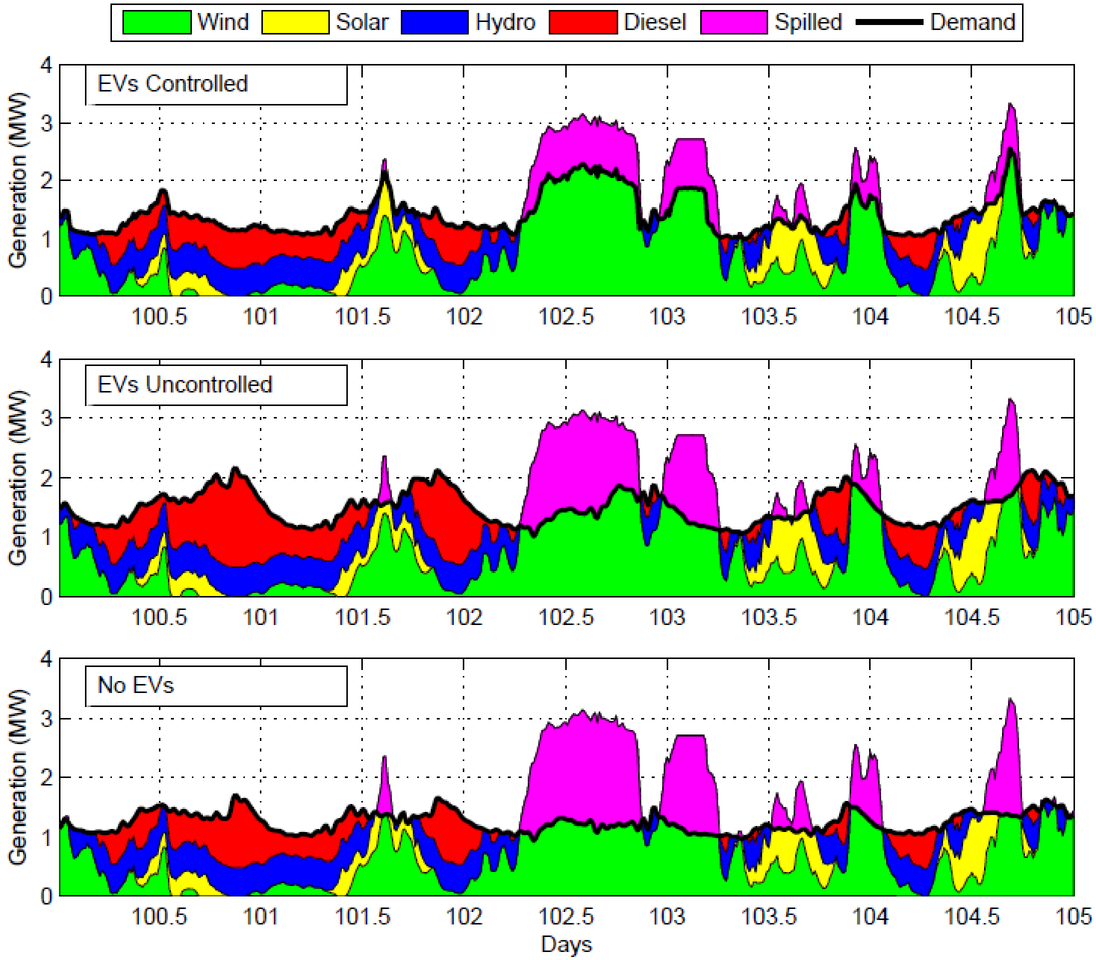
Effect on demand

EVs fill valleys and shave peaks



Residual demand + EV demand (50% EVs)

Effect on dispatch



EVs wait for periods with high wind and solar
Diesel generation displaced by wind and solar

CO_2 emissions

Electricity Scenario	Vehicle Scenario				
	All Diesel ICE	50%EVs Uncont.	50%EVs Cont.	100%EVs Uncont.	100%EVs Cont.
Current generation mix	8.38	8.08	8.06	7.80	7.76
Moderate Wind and Solar	6.18	5.37	4.65	4.26	3.05
Aggressive Wind and Solar	5.52	4.42	3.29	3.13	1.29

Total reduction up to 85% possible

CO_2 reduction due to 'smart'

Economics

Costs of generation:

Diesel ~250 $/MWh (Marginal cost)
Wind ~100 $/MWh (Levelized cost)
Solar ~200 $/MWh (Levelized cost)

How much renewable energy do we need to spill?

Electricity Scenario	Vehicle Scenario				
	No EVs	50%EVs Uncont.	50%EVs Cont.	100%EVs Uncont.	100%EVs Cont.
Current generation mix	0	0	0	0	0
Moderate Wind and Solar	28 %	21%	10%	23%	8%
Aggressive Wind and Solar	49 %	42%	30%	45%	29%

With control even most aggressive scenario still feasible

Conclusions

-EV have large potential for emissions and cost reduction

-Right signal to react on wind/solar is key

-Solar complementary to wind makes sense

Future research

-Uncertainty in forecasts

-Network, stability, reliability, dynamics etc.

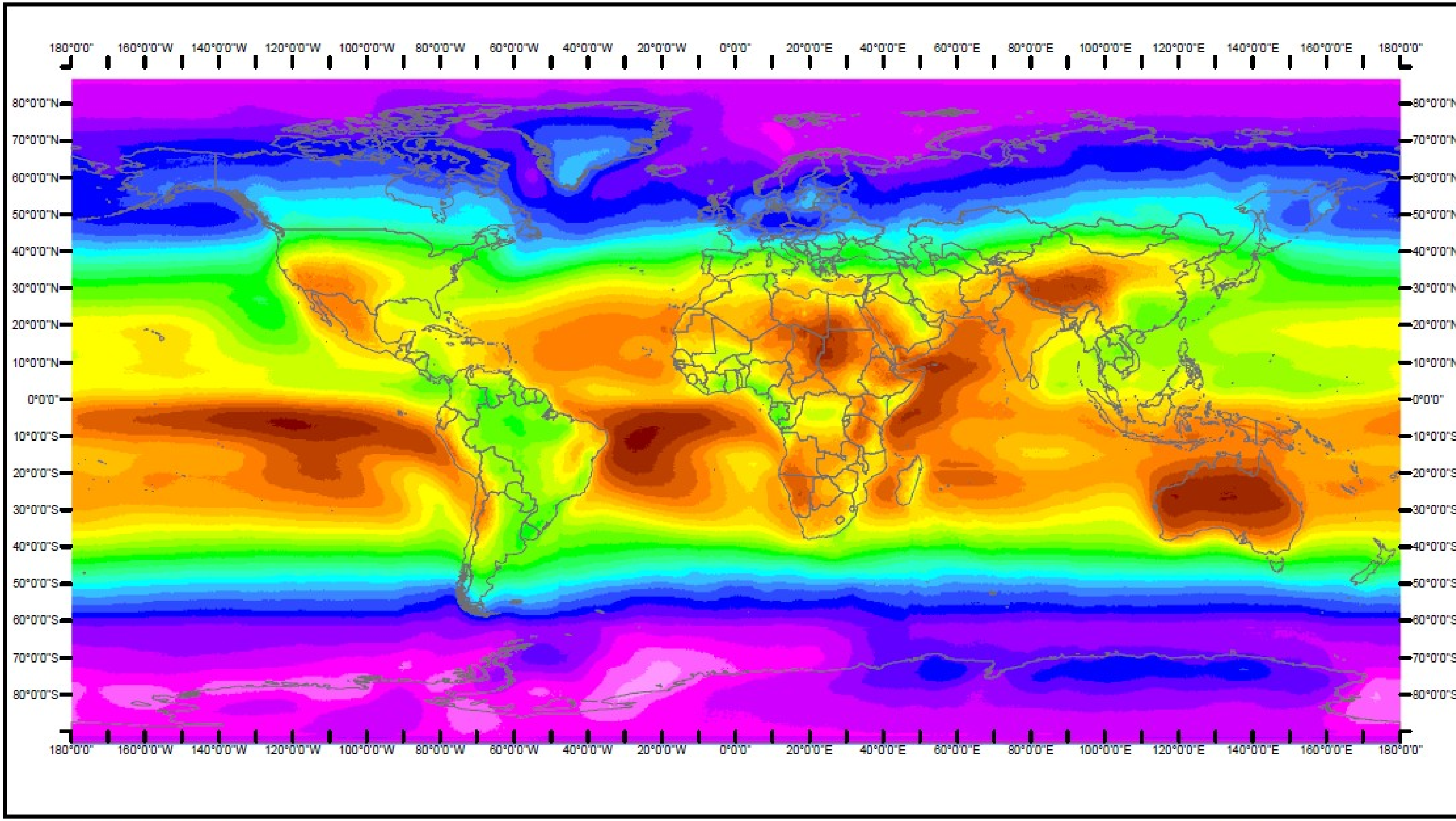
References

[1] R. A. Verzijlbergh, Z. Lukszo, E. Veldman, J. G. Slootweg, and M. Ilic, "Deriving electric vehicle charge profiles from driving statistics," in Power and Energy Society General Meeting, 2011 IEEE, July 2011, pp. 1–6.

[2] R. A. Verzijlbergh, M. D. Ilic, and Z. Lukszo, "The role of electric vehicles on a green island," in North American Power Symposium (NAPS), 2011, aug. 2011, pp. 1 –7.

[3] R. Verzijlbergh, M. Ilic, and Z. Lukszo, "The role of electric vehicles in making azores islands green," in Engineering IT-Enabled Electricity Services. The Case of Low-Cost Green Azores Islands, M. Ilic and L. Xie, Eds. Springer, 2012,

Averaged Solar Radiation 1990-2004



Yearly Mean of Irradiance in W/m²

0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 50, 50 - 60, 60 - 70, 70 - 80, 80 - 90, 90 - 100, 100 - 110, 110 - 120, 120 - 130, 130 - 140, 140 - 150, 150 - 160, 160 - 170, 170 - 180, 180 - 190, 190 - 200, 200 - 210, 210 - 220, 220 - 230, 230 - 240, 240 - 250, 250 - 260, 260 - 270, 270 - 280, 280 - 290

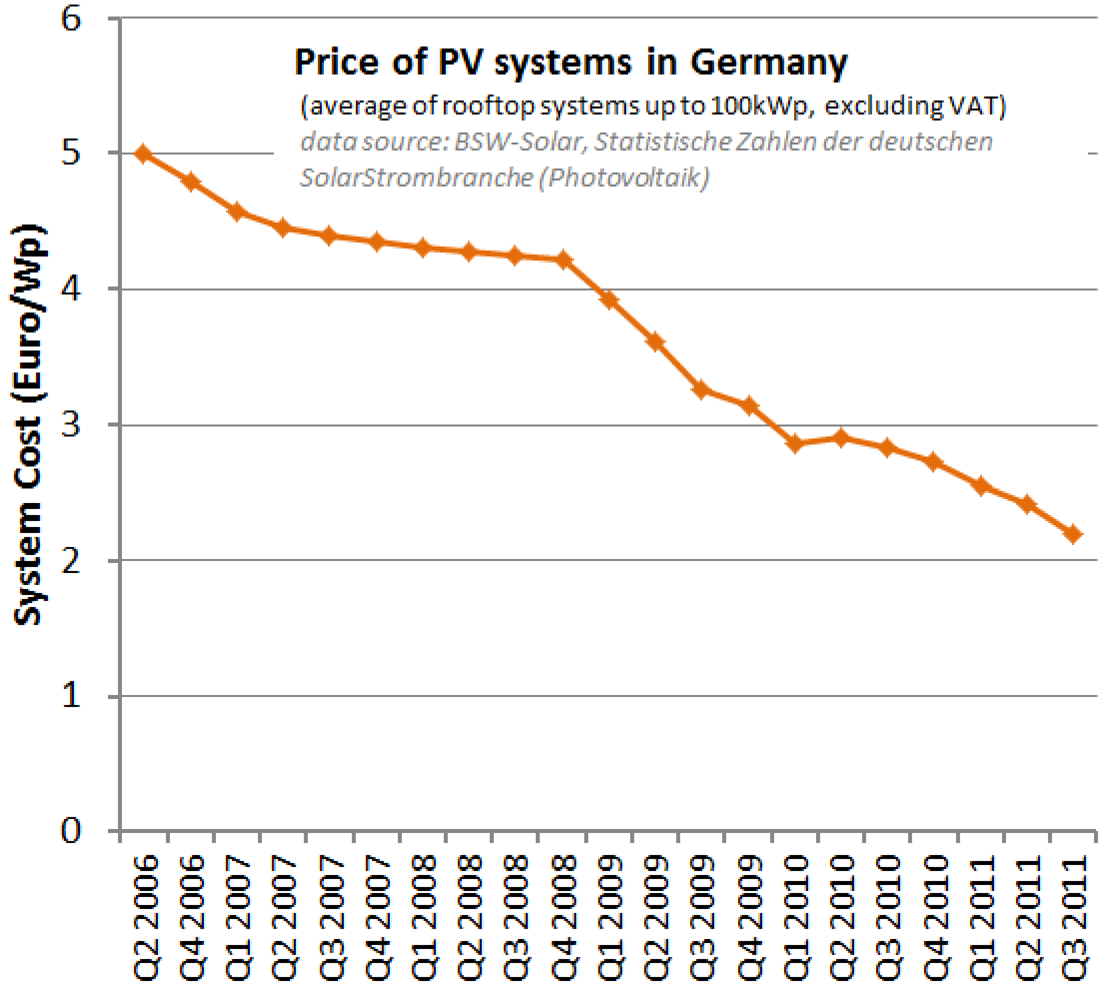
MINES PARIS

Realized by Michel Albuisson, Mireille Lefèvre, Lucien Wald.
Edited and produced by Thierry Ranchin. Date of production: 23 November 2006.
Centre for Energy and Processes, Ecole des Mines de Paris / Armines / CNRS.

Table 2. Regional Variation in Levelized Cost of New Generation Resources, 2016.

Plant Type	Range for Total System Levelized Costs (2009 $/megawatthour)		
	Minimum	Average	Maximum
Conventional Coal	85.5	94.8	110.8
Advanced Coal	100.7	109.4	122.1
Advanced Coal with CCS	126.3	136.2	154.5
Natural Gas-fired			
Conventional Combined Cycle	60.0	66.1	74.1
Advanced Combined Cycle	56.9	63.1	70.5
Advanced CC with CCS	80.8	89.3	104.0
Conventional Combustion Turbine	99.2	124.5	144.2
Advanced Combustion Turbine	87.1	103.5	118.2
Advanced Nuclear	109.7	113.9	121.4
Wind	81.9	97.0	115.0
Wind – Offshore	186.7	243.2	349.4
Solar PV[1]	158.7	210.7	323.9
Solar Thermal	191.7	311.8	641.6
Geothermal	91.8	101.7	115.7
Biomass	99.5	112.5	133.4
Hydro	58.5	86.4	121.4

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)



Price of PV systems in Germany
(average of rooftop systems up to 100kWp, excluding VAT)
data source: BSW-Solar, Statistische Zahlen der deutschen SolarStrombranche (Photovoltaik)
System Cost (Euro/Wp)
0
1
2
3
4
5
6
Q2 2006
Q4 2006
Q1 2007
Q2 2007
Q3 2007
Q4 2007
Q1 2008
Q2 2008
Q3 2008
Q4 2008
Q1 2009
Q2 2009
Q3 2009
Q4 2009
Q1 2010
Q2 2010
Q3 2010
Q4 2010
Q1 2011
Q2 2011
Q3 2011