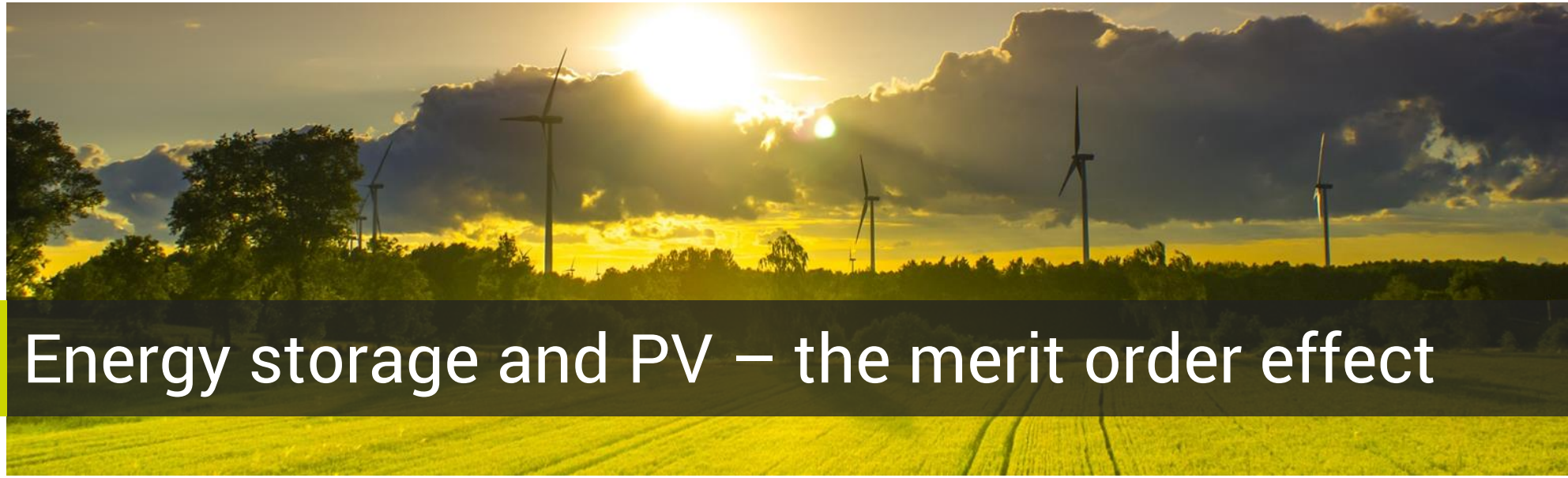
Green Giraffe
The renewable energy financial advisors



Energy storage and PV – the merit order effect

June 2016

Frederico Sanches

Energy storage and PV – the merit order effect

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A specialist advisory boutique focused on renewable energy

We get deals done

Deep roots in renewable energy finance

- Launched in 2010 by experienced finance specialists with a **strong and proven track record** in renewable energy
- 50+ professionals with offices in Hamburg (Germany), London (UK), Paris (France) and Utrecht (the Netherlands)
- Multi-disciplinary skill set including **project & structured finance, contract management, M&A, legal & tax** expertise

High quality, specialised advisory services

- Focus on projects where we can actually add value
- We can provide a holistic approach and are able to include sector-specific tasks in addition to traditional debt or equity advisory (such as contracting, strategic advisory and development services)
- Widening geographical reach with a burgeoning presence in the Americas and Africa in addition to Europe
- Priority given to **getting the deal done!**

More than **EUR 11 billion** funding raised for renewable energy projects in **6 years**

50+ professionals in **4 countries**

Involved in over **75 renewable energy projects** with a capacity of more than **15 GW**

Consistently one of the top financial advisors in project finance

2014 renewable energy – Infranews

	Company	USD bn	Deal count
1	**Green Giraffe**	**5.2**	**8**
2	Santander	3.5	45
3	BNP Paribas	3.1	6
4	Goldman Sachs	2.1	5
5	Citigroup	2.0	2
6	Bank of America Merrill Lynch	1.7	3
7	Lazard	1.3	3
8	Morgan Stanley	1.3	3
9	Rebel Group	1.3	3
10	Linius Capital	1.2	2

Financial advisor league table derived from InfraNews 2014 website

2015 renewable energy – IJ Global

	Company	USD bn	Deal count
1	**Green Giraffe**	**5.5**	**5**
2	EY	4.4	7
3	BNP Paribas	3.1	2
4	Macquarie	2.9	4
5	Santander	2.4	19
6	Barclays	2.4	1
7	Alderbrook	2.0	2
8	Chatham Financial	1.8	3
9	Fieldstone	1.3	4
10	PwC	1.3	3

IJ Global league tables 2015 (website)

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2. Merit order effect

Purpose of this study

What is the net impact of renewables?

- Challenges
  - Fluctuation in production: priority of dispatch, physical constraint on the system operator
  - Grid reinforcement works
  - High construction costs, usually financed through support schemes that lead to high LCOE (though decreasing recently)
- Benefits
  - Reduction of negative externalities: pollution (non monetary metric), energy dependency (security of gas supply)
  - Reduction of wholesale (market) prices, also called the merit order effect (MOE)

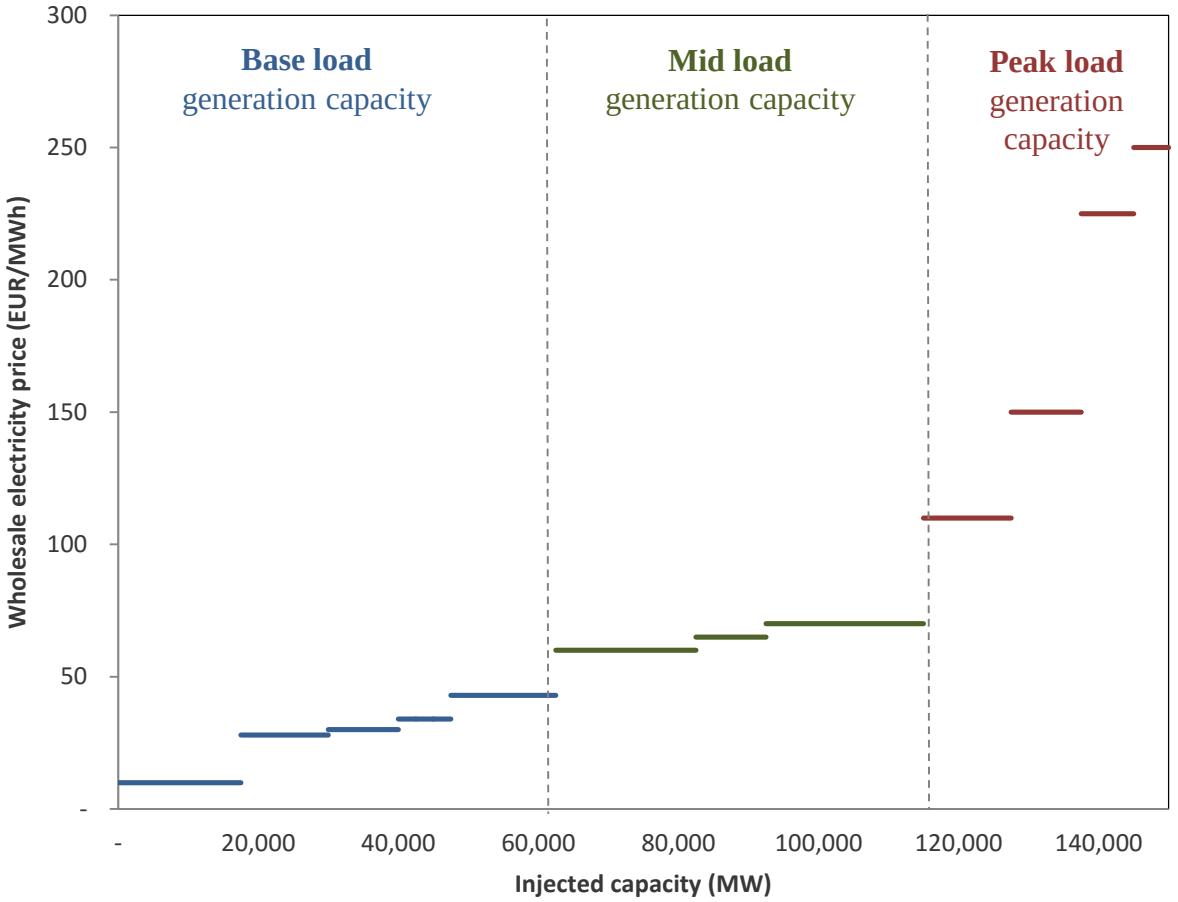
This study focuses on the MOE only

- Focus on Germany, Austria, France, Switzerland and Italy (GAFSI)
- Period of study 2006-2015
- Addition of storage capacity to PV installed capacity

This study builds on a 2014 paper by N. Gourvitch, H. Gouzerh, G. Masson and S. Orlandi on "Quantitative analysis of the merit order effect from photovoltaic production in key European countries and effect on market coupling"

2. Merit order effect

Purpose of this study



Electricity markets

- Electricity demand is inelastic (long term contracts)
- Supply: base, mid & peak load
- Market coupling to improve markets integration

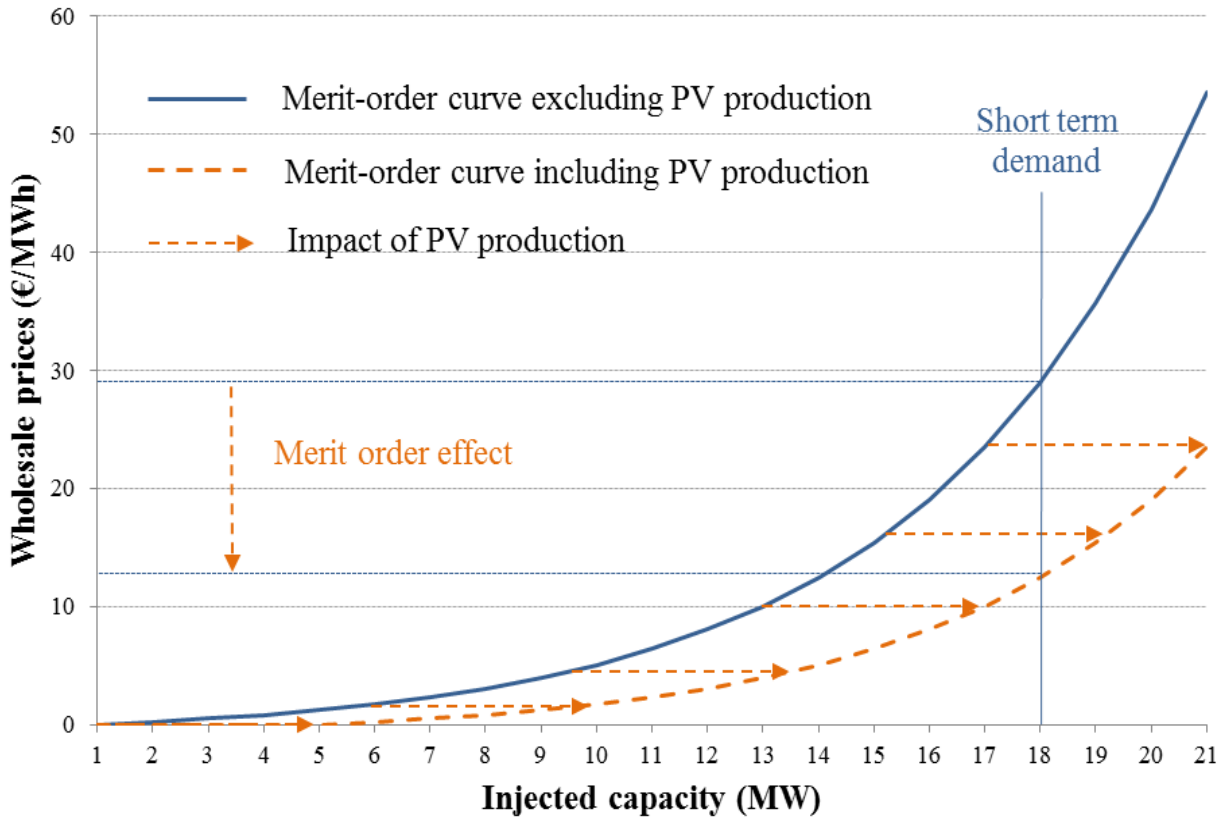
"Uniform pricing": prices are imposed on all power producers and is therefore set by the most expensive producer required to satisfy the demand at any one time

MOC: sorting energy sources in growing order of marginal cost

Electricity wholesale prices are determined as the intersection of the instantaneous demand and the MOC, representing the marginal price of production for a given demand level

2. Merit order effect

Purpose of this study



Assumptions

- Acceptable penetration rate (about 3% in GAFSI)
- GAFSI wholesale prices: weighted average price of the market prices by respective electricity consumption
- No negative prices within GAFSI (less than 0.1%)
- Limited interconnection with neighbouring countries (net exports at 1% of GAFSI electricity production in 2013)
- Limited self-consumption
- All electricity is traded on the spot market (internalisation in long term OTC contracts)

PV production shifts the MOC rightward thus decreasing the marginal price of production for a given demand level

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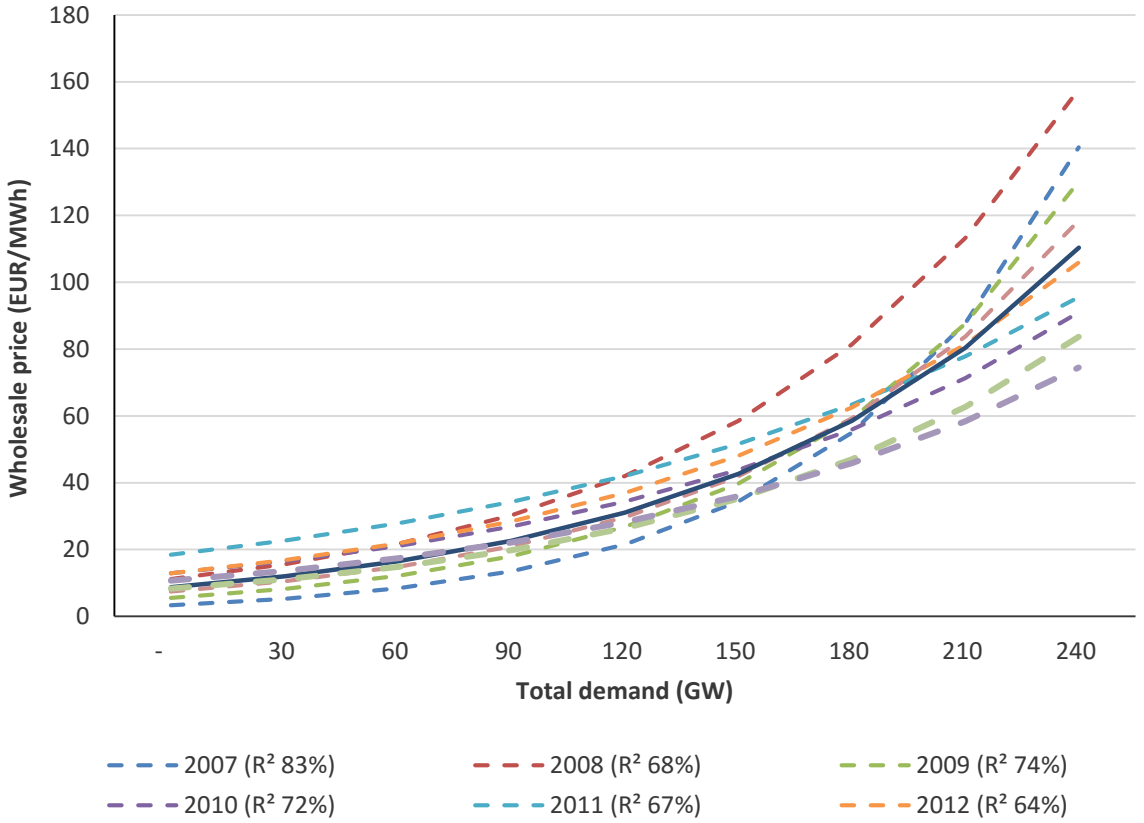
3. Methodology and results

Price fixing model



Data

- Solar PV production based on the GeoModel and PV GIS irradiation data for 60 cities across GAFSI
- ENTSOE consumption data
- Wholesale prices from EPEX

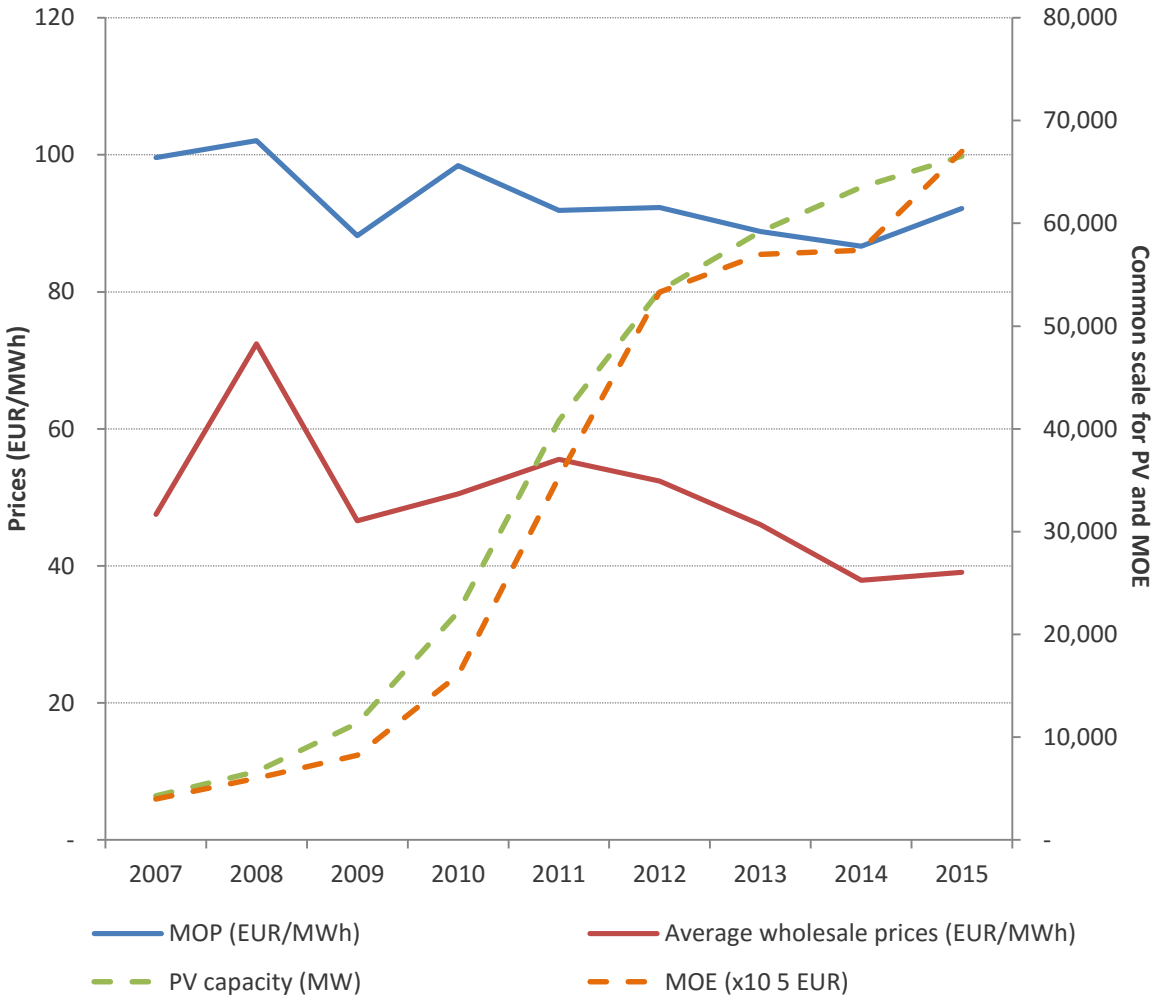
Results

- Constant MOC (2007-2015)
- Exponential shape
- 66% correlation factor for GAFSI (compared to 57% for Germany alone)
- Stable energy mix

The 2007-2015 MOC for GAFSI is a satisfactory price fixing proxy to estimate electricity prices had there not been any PV production

3. Methodology and results

Results – PV



Main findings

- MOE around EUR 31 bn over 2007-2015
- MOP 91 EUR/MWh of PV produced <u>on top of spot price</u>
- Without PV, average spot prices would have been 4% higher (2.0 EUR/MWh)

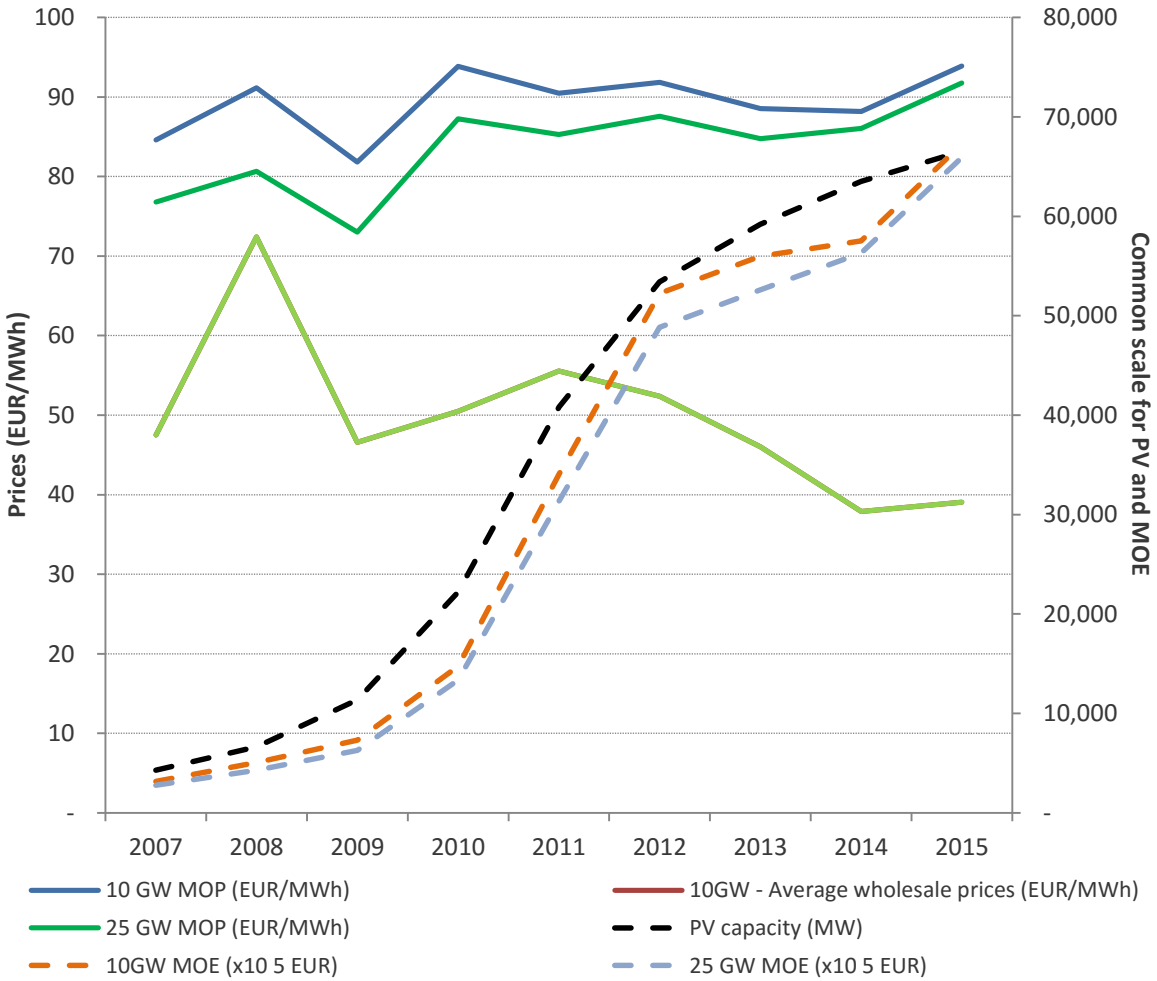
Statistical robustness

- Simulate random irradiation profiles across the 60 cities of GAFSI
- 4 billion random irradiation simulations
- MOE (resp. MOP) increases (resp. decreases) with PV installed capacity
- Predominant metrics: correlation with consumption

PV generation does reduce wholesale prices significantly

3. Methodology and results

Results – PV + de-centralized storage



Main findings

- With 10 GW (25 GW) of storage, MOE around EUR 30 bn (EUR 28 bn) over 2007-2015
- MOP of 90 and 87 EUR/MWh of PV produced (on top of spot price) for 10/25 GW of storage

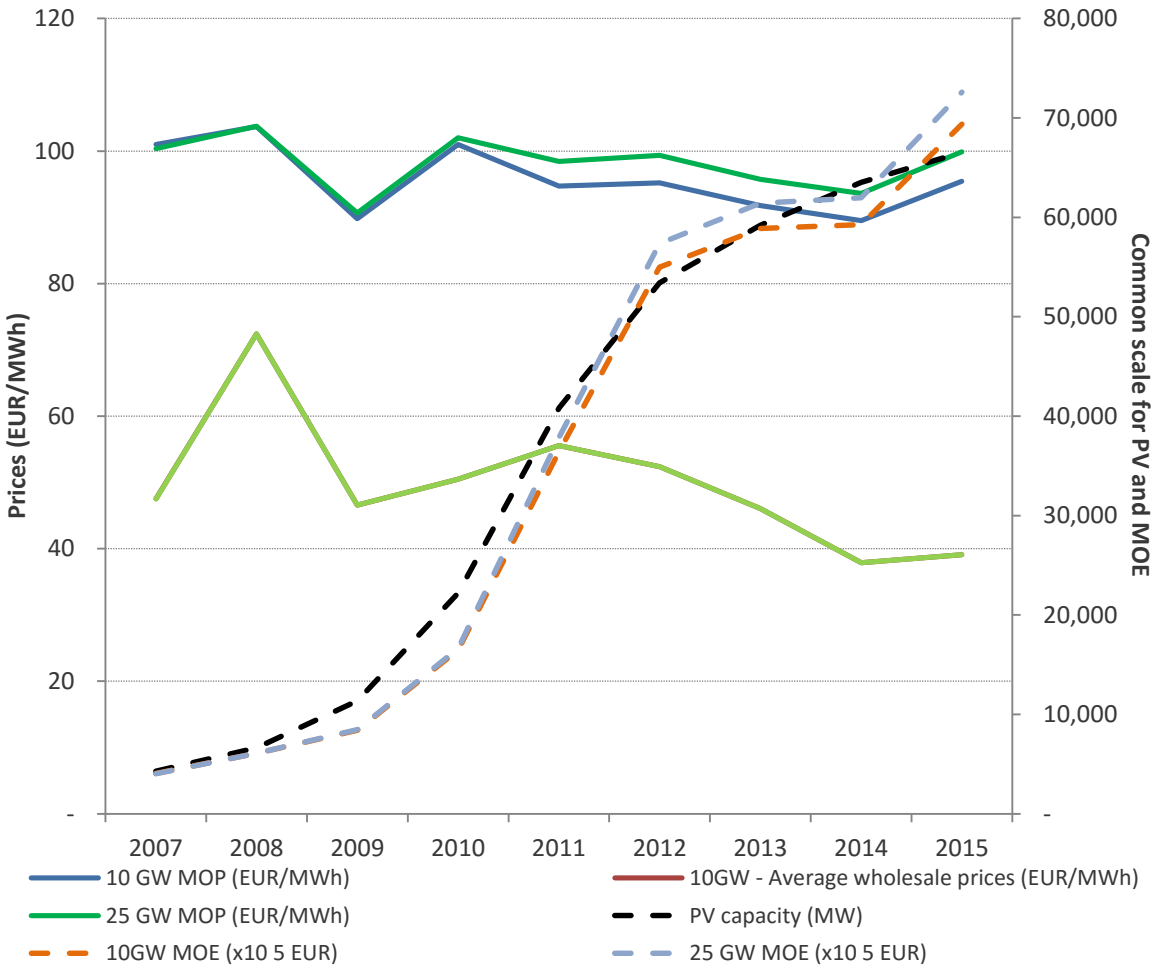
Conclusions

- Results suggest introducing de-localised storage does not improve the MOE of PV capacity installation
- The assumptions used for these calculations most likely under-estimate the benefits (e.g. injection of electricity from storage facility into grid not explicitly linked to demand)

Further optimisation required to de-localized storage to assess full benefit

3. Methodology and results

Results – PV + centralized storage



Main findings

- With 10 GW (25 GW) of storage, MOE around EUR 32 bn (EUR 33 bn) over 2007-2015
- MOP of 94 and 98 EUR/MWh of PV produced (on top of spot price) for 10/25 GW of storage

Conclusions

- Significant improvements compared to the PV – only case (as much as EUR 3 bn increase in MOE).

Centralized storage seems to significantly improve the overall MOE

Energy storage and PV – the merit order effect

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4. Conclusions

Summary - PV

I The MOE is the savings for end consumers linked to the downward pressure on wholesale prices due to PV production

II Focus on Germany, Austria, France, Switzerland, Italy (closed system, market coupling, highly correlated price fixing model)

III MOE has amounted to EUR 31 bn over 2007-2015

IV If the MOE could have been captured between 2007-2015, PV producers could have been remunerated 90 EUR/MWh on top of wholesale spot price at no cost for society

4. Conclusions

Summary – PV + storage

I	Addition of storage could have brought additional MOE savings of around EUR 2 bn
II	With some optimisation this effect could be even more significant
III	The MOE is not a net loss for utilities as they benefit from it through distribution
IV	Potential improvements of the study: (i) include wind, (ii) simulate self consumption, (iii) take account of exports and imports (iv) more sophisticated storage calculations

4. Conclusions

Acknowledgements

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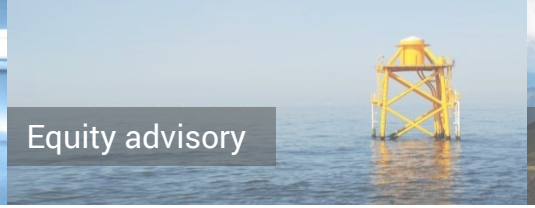

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