PV Market & Industry Development

From self-consumption to 100% RES, a paradigm shift for PV

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Content & Strategy, Solar United
Vice-Chairman, EU PV Technology & Innovation Platform
Operating Agent, IEA-PVPS Task 1

BECQUEREL INSTITUTE

- Research oriented Institute and consulting company for Solar Technologies.
- Global PV Market Analysis including competitiveness and economics.
- Industry analysis together with quality & reliability.
- Integration into electricity systems (grids and markets).
- In-house experts / Global network of experts and stakeholders
- **PV Market Alliance** partner

What is IEA PVPS?

- Implementing Agreement from International Energy Agency – Technology Collaboration Program

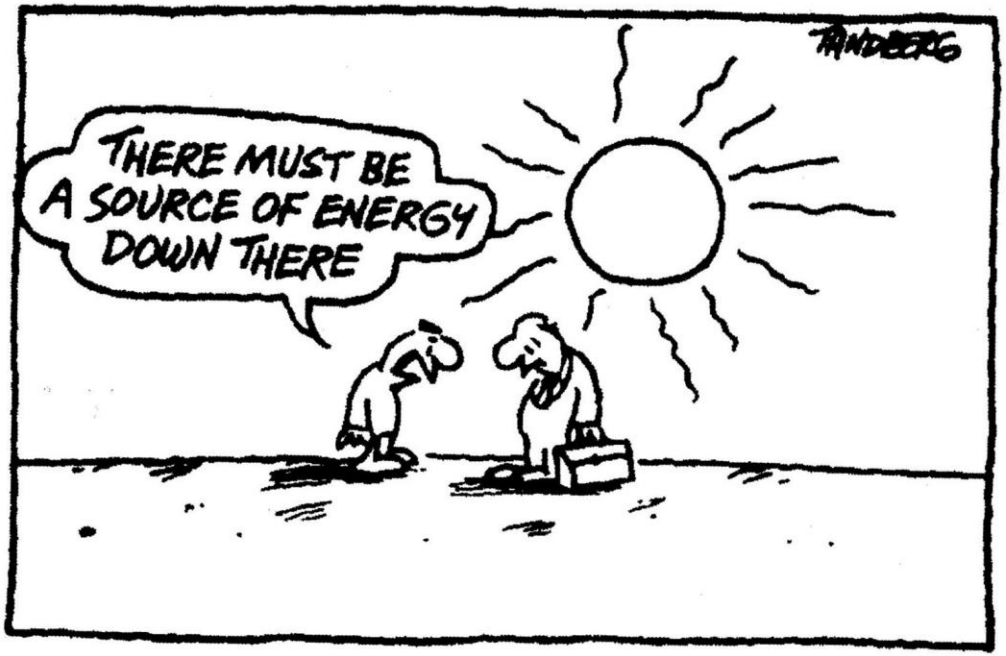
- Established in 1993
- 29 members: 24 countries, European Commission, 4 associations

- Strategy 2013-2017: "*To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems*"

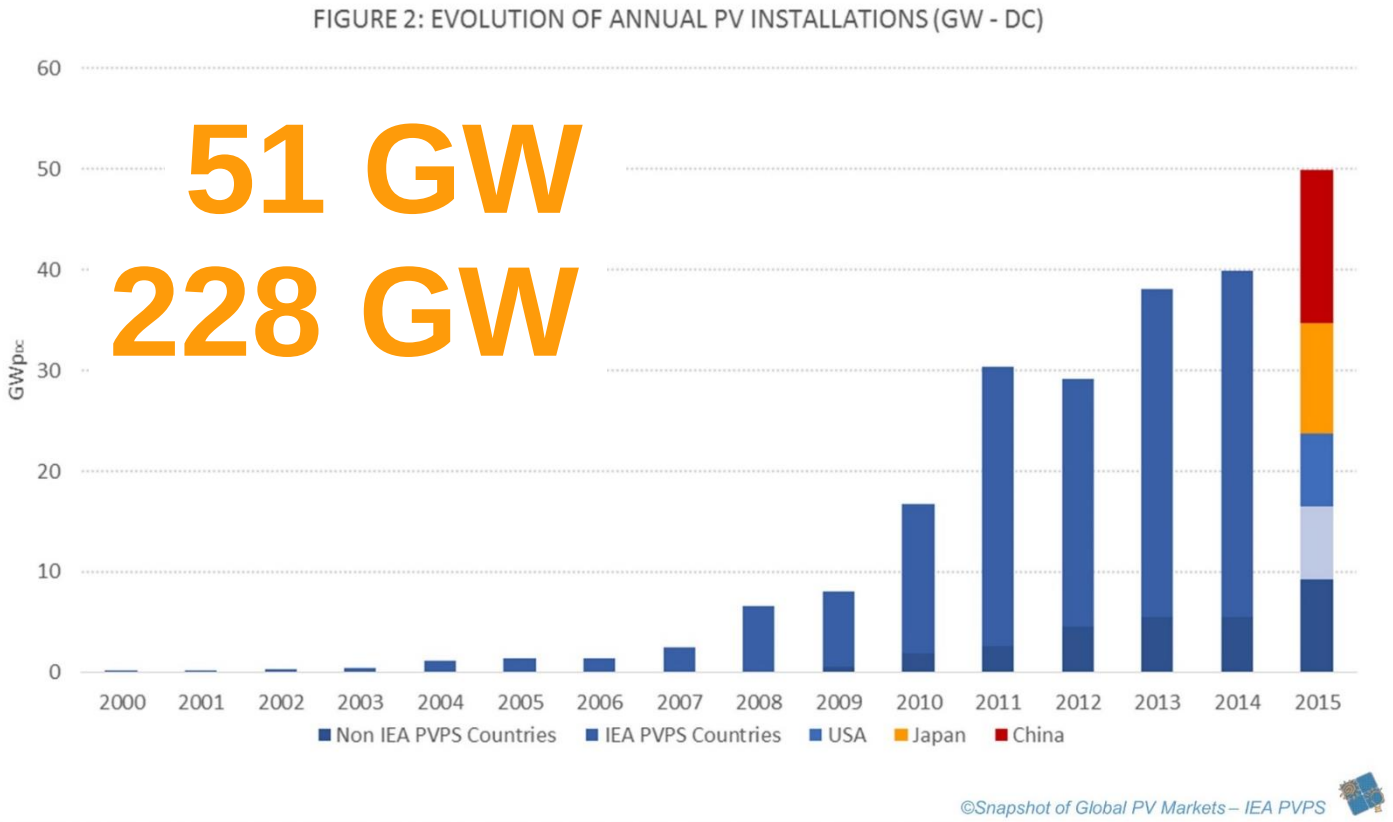
PVPS

- PV market development
- PV prices and technology
- Competitive PV tenders
- PV competitiveness
- 100% RES
- Self-consumption

1. Market Development



FROM 1.1 TO 50 GW IN 11 YEARS



Source: IEA-PVPS 2015

CONFIDENCE IN NUMBERS ?

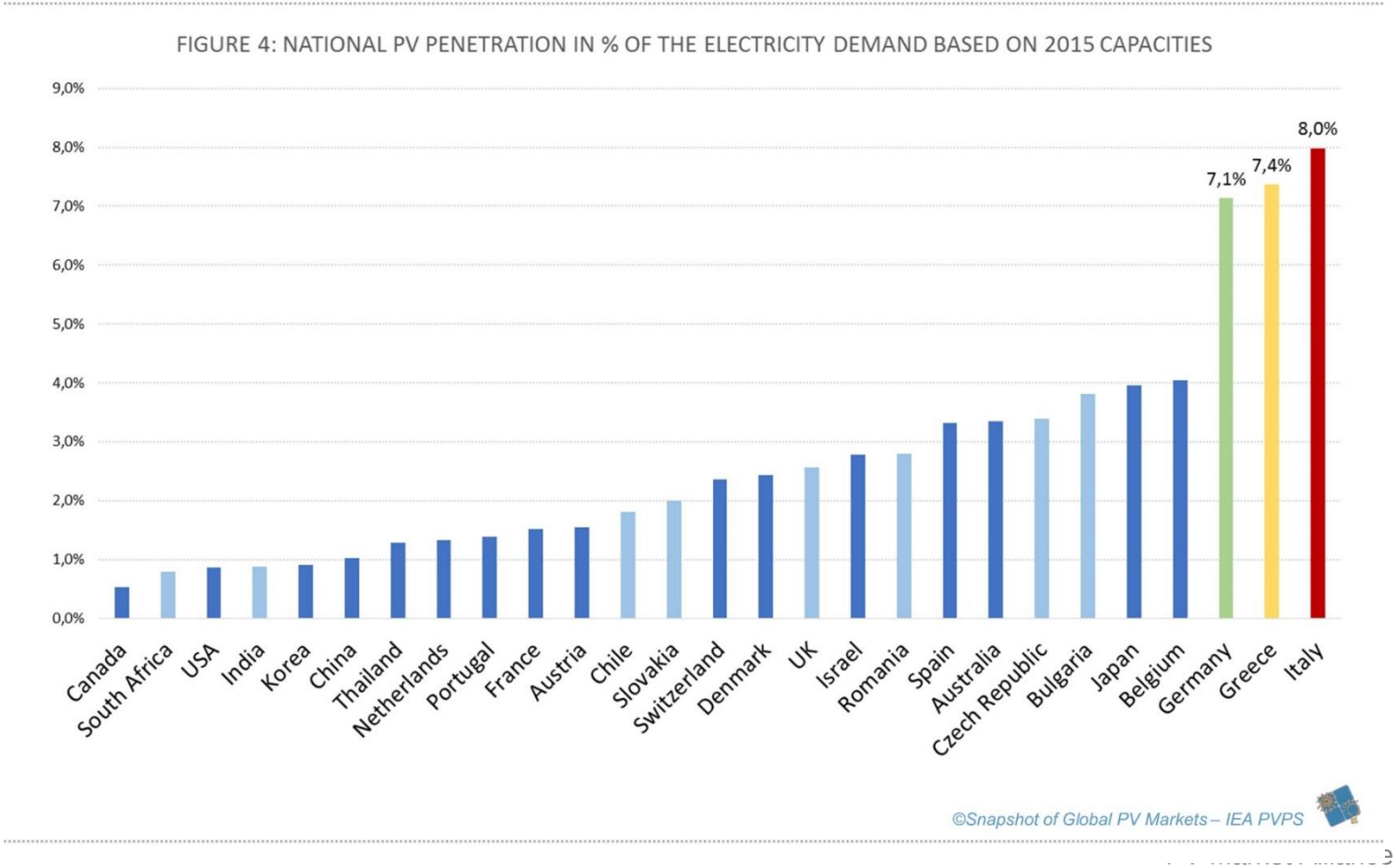
- From 50 to 59 GW installed in 2015
- Who's right, who's wrong ?
- Counting apples, pears… and more ?
- Some rules
  - Counting AC numbers is simply wrong → switch to DC or count both.
  - What does « installed » means? Commissioned?
  - Production > shipments > installations …
  - …

TOP 10 INSTALLATIONS AND TOTALS

TABLE 1: TOP 10 COUNTRIES FOR INSTALLATIONS AND TOTAL INSTALLED CAPACITY IN 2015

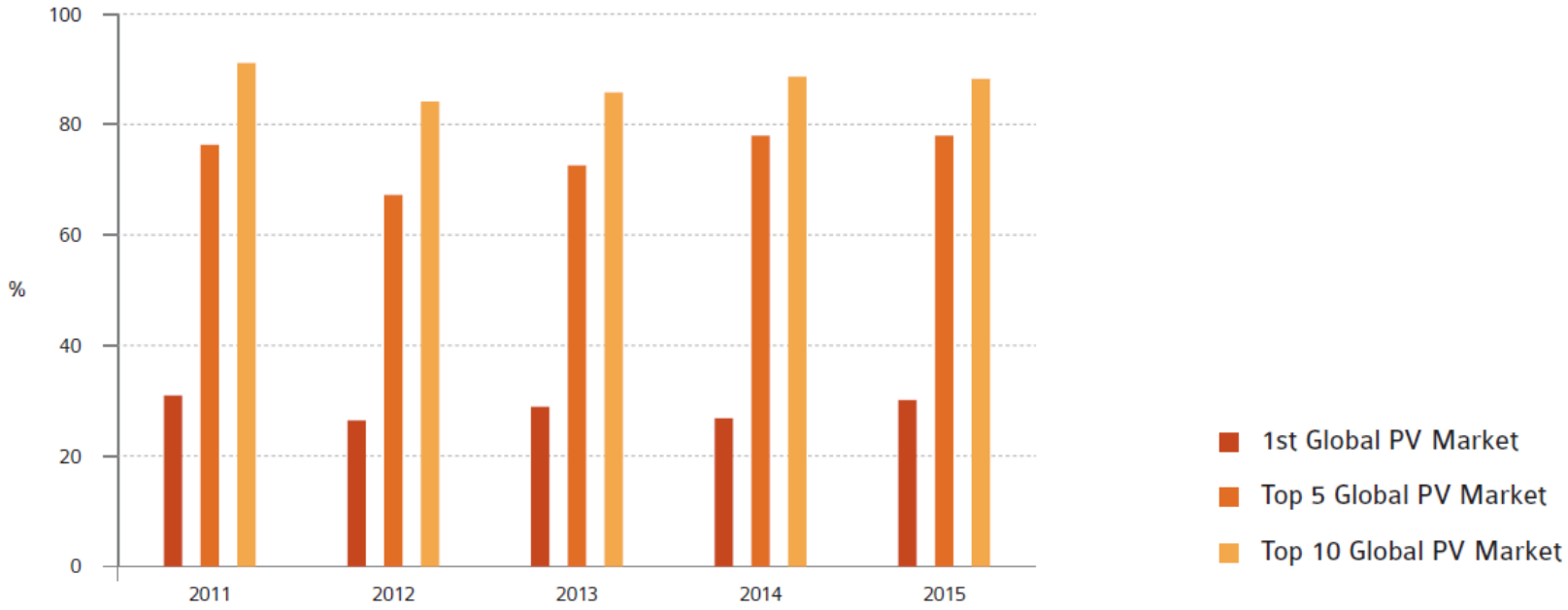
	TOP 10 COUNTRIES IN 2015 FOR ANNUAL INSTALLED CAPACITY			TOP 10 COUNTRIES IN 2015 FOR CUMULATIVE INSTALLED CAPACITY		
1	China	15,2 GW		1	China	43,5 GW
2	Japan	11 GW		2	Germany	39,7 GW
3	USA	7,3 GW		3	Japan	34,4 GW
4	UK	3,5 GW		4	USA	25,6 GW
5	India	2 GW		5	Italy	18,9 GW
6	Germany	1,5 GW		6	UK	8,8 GW
7	Korea	1 GW		7	France	6,6 GW
8	Australia	0,9 GW		8	Spain	5,4 GW
9	France	0,9 GW		9	Australia	5,1 GW
10	Canada	0,6 GW		10	India	5 GW

ENERGY VS POWER



TOP 1 TO 10 MARKETS

FIGURE 6: EVOLUTION OF MARKET SHARE OF TOP COUNTRIES



SOURCE IEA PVPS & OTHERS.

PROSPECTS FOR DEVELOPMENT

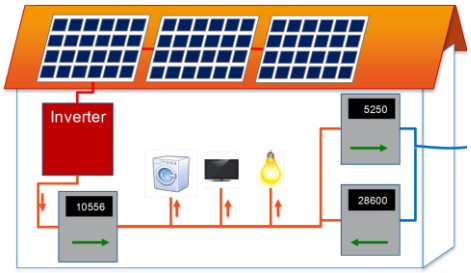
« The Policy Triangle »

Source: PV Market Alliance – Becquerel Institute 2016

5 YEARS FORECASTS ?

- Many countries haven't stepped in the PV market in a sustainable way (see China, Japan or the US)
- Those that have (Europe) are experiencing difficulties.
- Tenders that are popping up are by definition policy-driven: policy stops, the PV market stops
- Self-consumption is difficult to implement (see China, Italy…)
- Uncertainties reflect, not the intrinsic PV potential but the difficulties to realize that potential.

A TALE OF 2 MARKETS



Distributed PV

Self-consumption, energy effiency, grid parity, competition with utilities distribution business

Prosumers

One technology

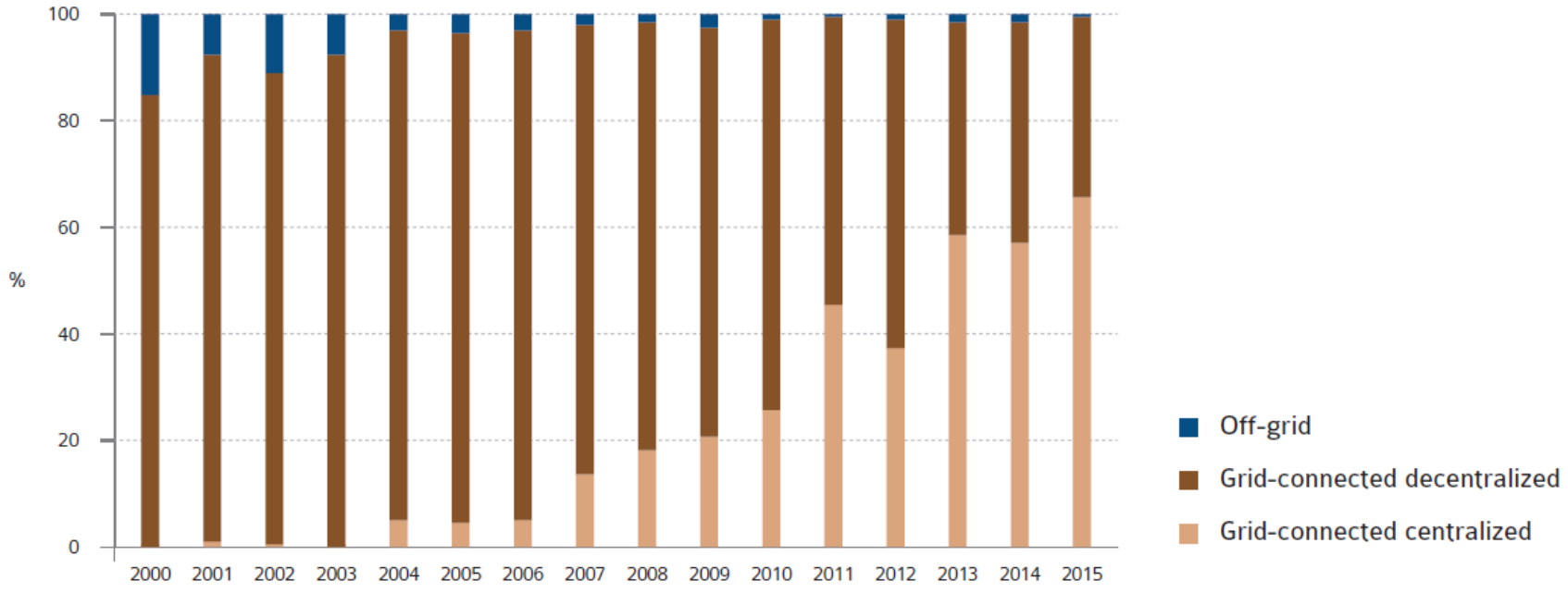
Producers

Grid injection, PPA, competition with utilities generation business

Centralized PV

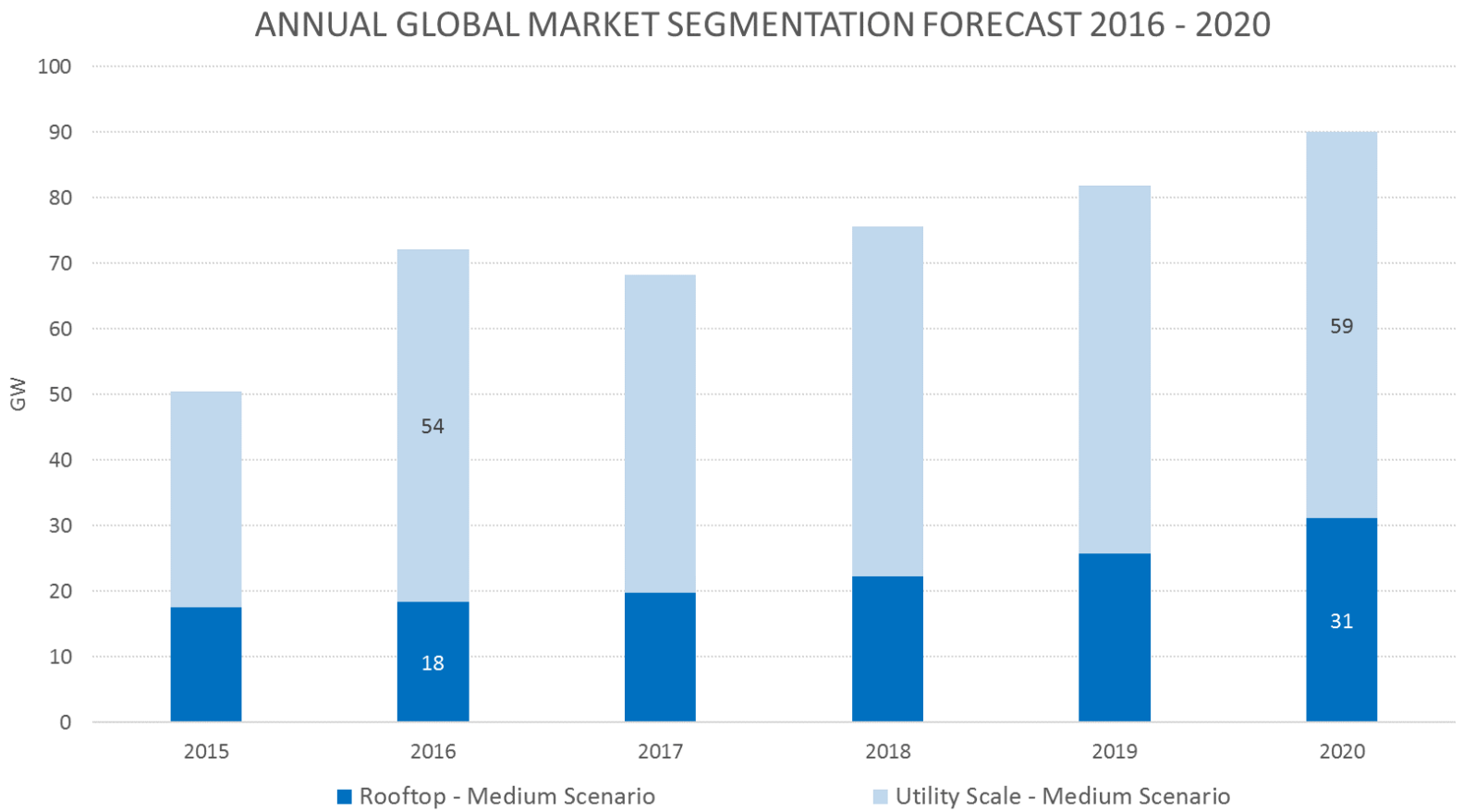
SEGMENTATION OVER TIME

FIGURE 7: SHARE OF GRID-CONNECTED AND OFF-GRID INSTALLATIONS 2000-2015



SOURCE IEA PVPS & OTHERS.

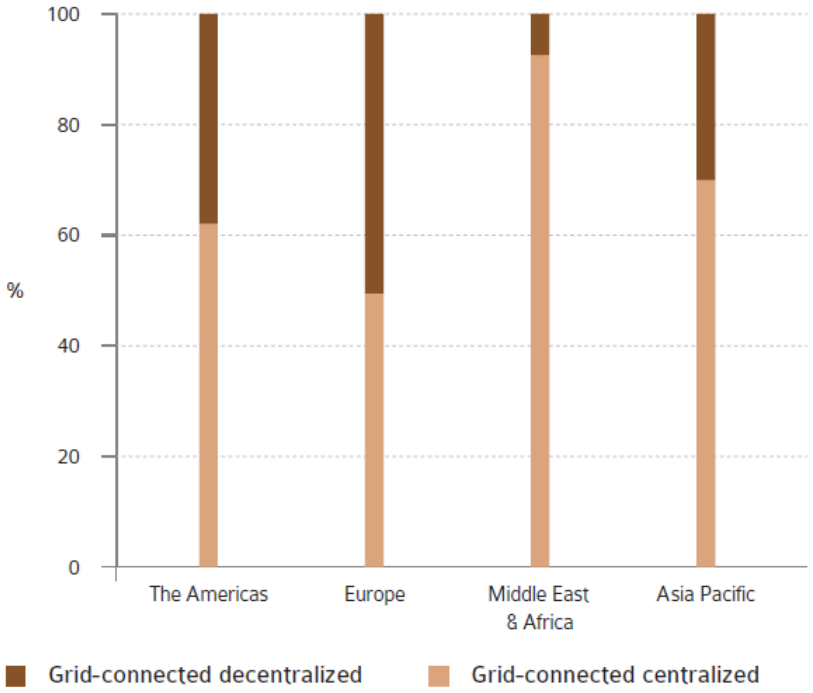
WHAT KIND OF MARKET AHEAD?



Source: PV Market Alliance – Becquerel Institute 2015

SHARE PER REGION

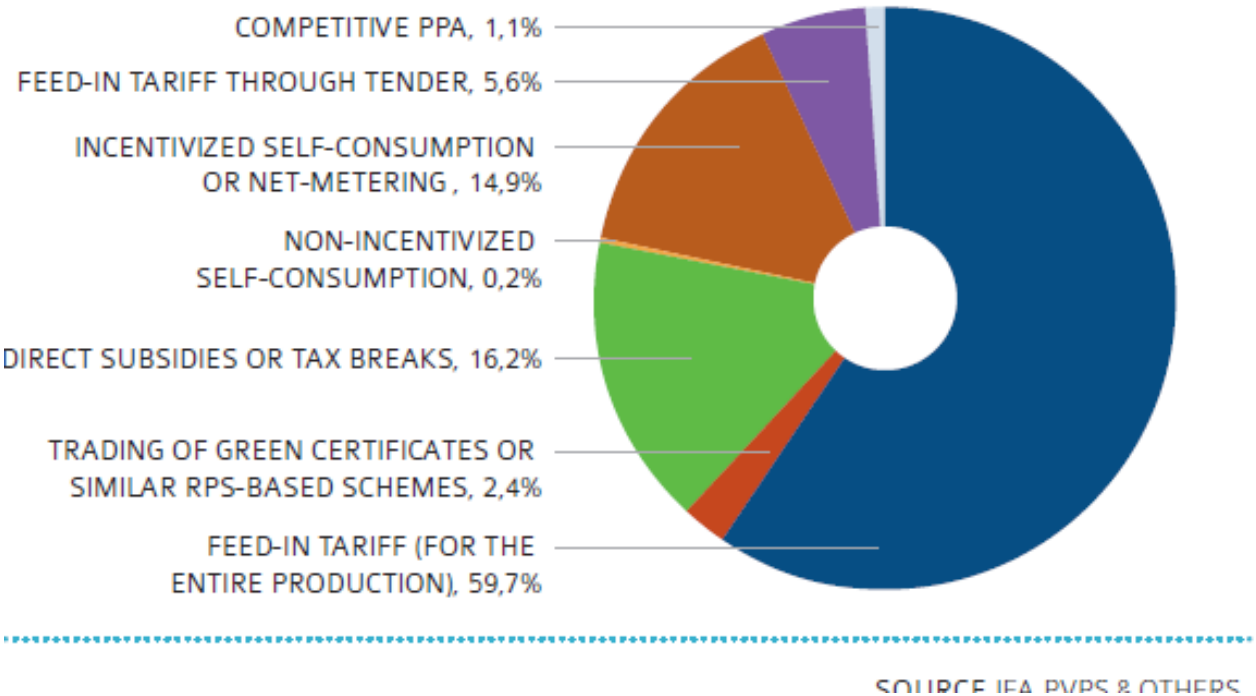
FIGURE 11: SHARE OF GRID-CONNECTED CENTRALIZED & DECENTRALIZED PV INSTALLATIONS BY REGION IN 2015



SOURCE IEA PVPS & OTHERS.

MARKET INCENTIVES

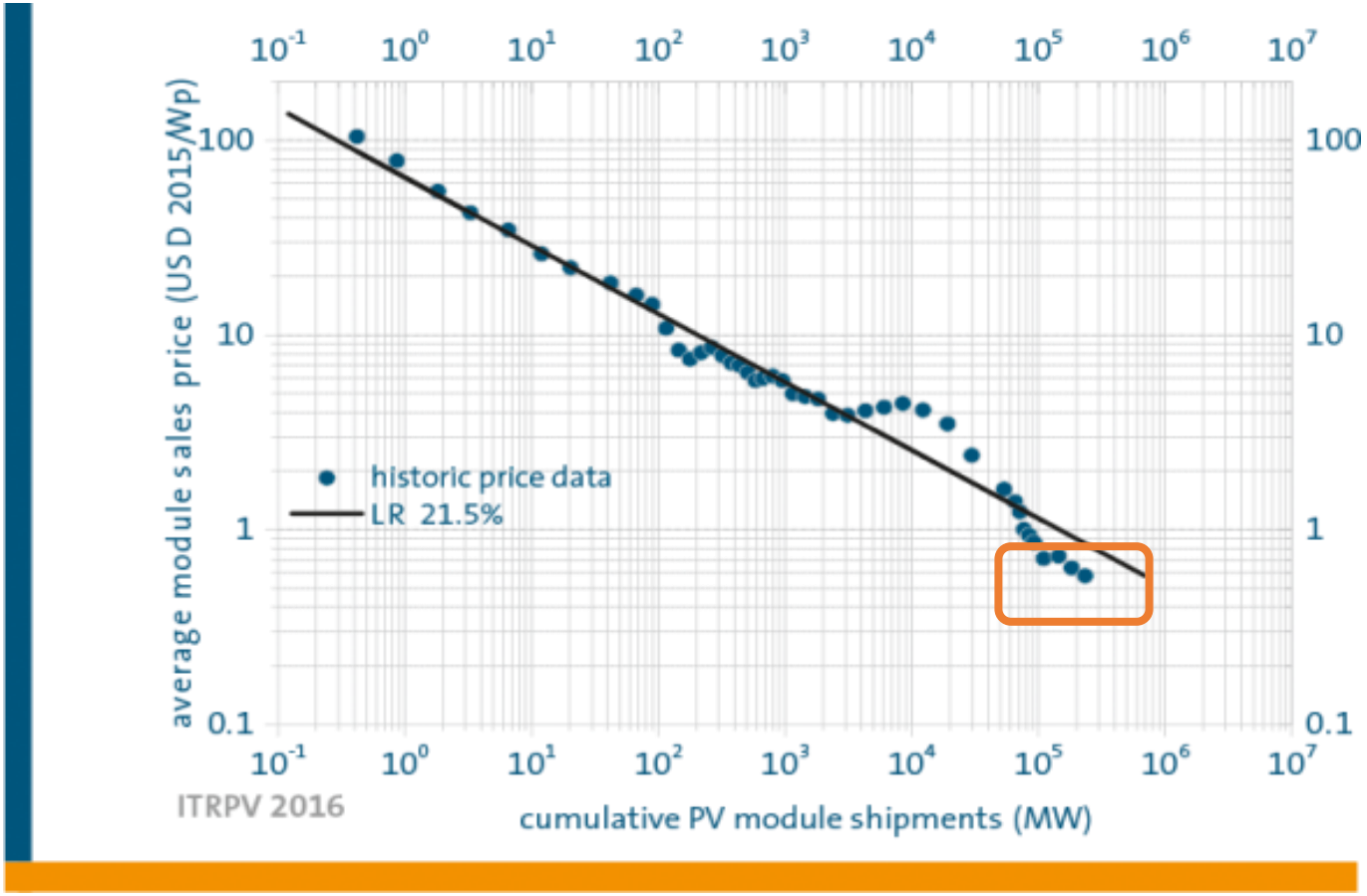
FIGURE 12: 2015 MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS

2. Prices and Technology

THE CSI LEARNING CURVE

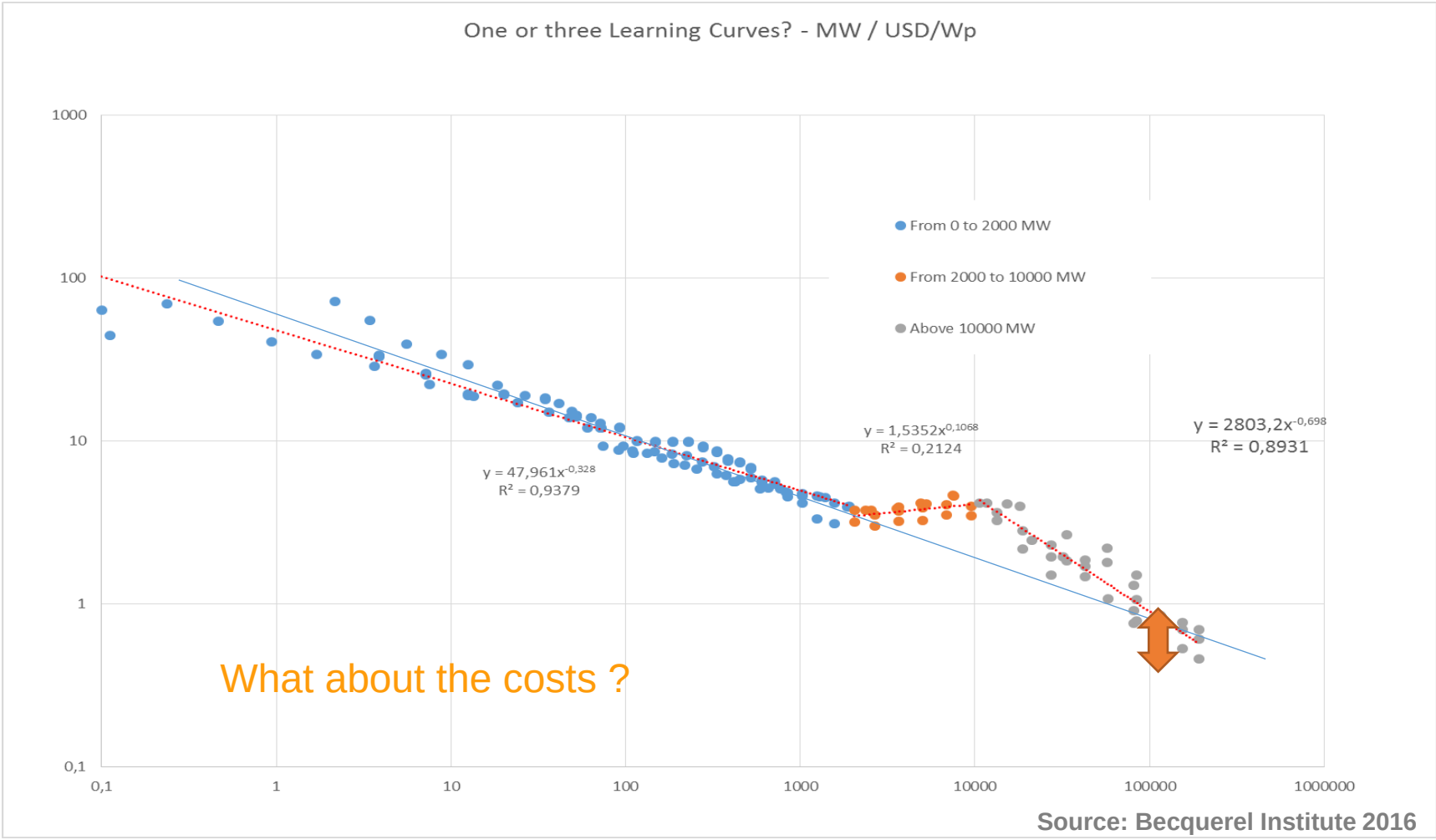


Source: ITRPV 7th Edition - 2016

CRYSTAL BALL ANALYSIS?

- The Learning curve concept is an empirical way of looking at COSTS decrease (due to technology improvements).
- Has been theorized for semi-conductors well before PV (BCG)
- Prices vs Costs
- Automation, industrialisation, different cost paradigm in China (cheaper equipment…)…
- Range of costs and prices: LC is perfect for low prices but what for emerging technologies?
- Modules or cells?

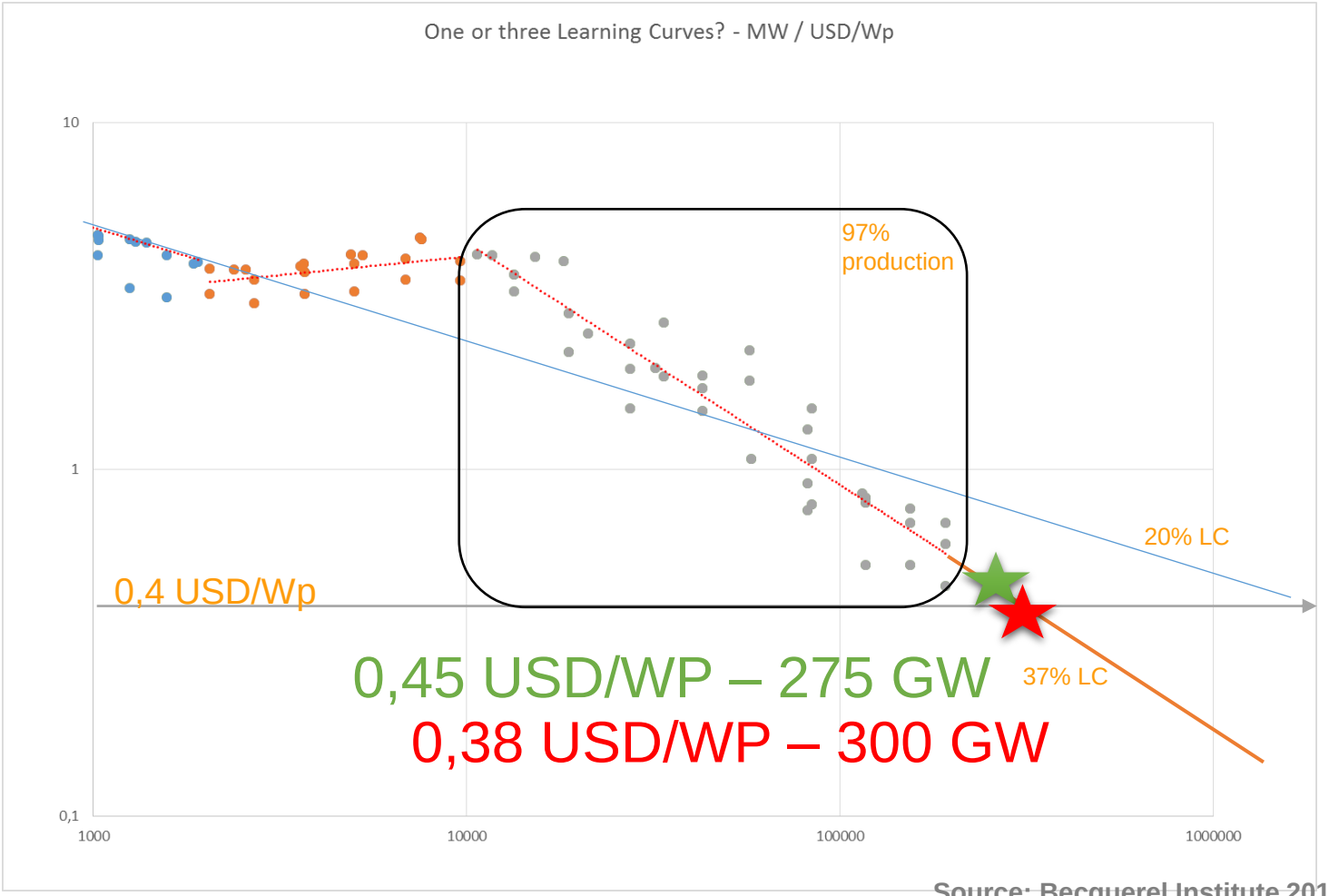
ANOTHER PERSPECTIVE



PUBLIC DATA AND FORECASTS

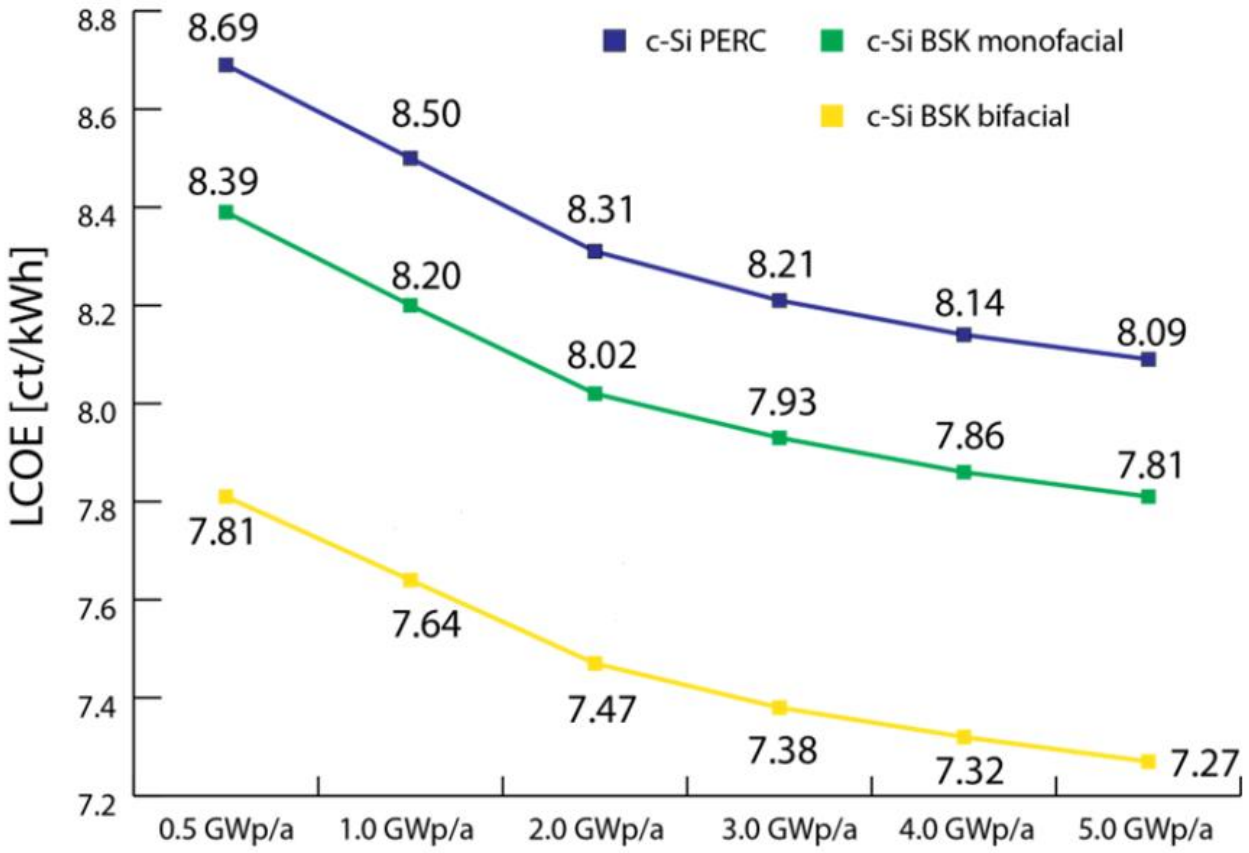
- Jinko announced (Q1-2016):
  - 0,37 USD/Wp production costs (others are close: 0,41-0,43)
  - 0,29 USD/Wp end 2017
  - 0,25 USD/Wp in 2020 (First Solar as well)
  - With GPM at 20%: 0,44 USD/Wp (and 0,35 USD FY 2017)
- Prices and cost decline on a 30%+ learning curve
- Official low market prices (Q3-2016): 0,38 USD/Wp
- Prices for large orders: Down to 0,3x USD/Wp ?
- Super competitive tenders (Dubai, Jordan, Peru, India) are done with multi-Si, CdTe or aSi.
- Large part of the PV market with higher prices !

PV PRICE LEARNING CURVE



Source: Becquerel Institute 2016

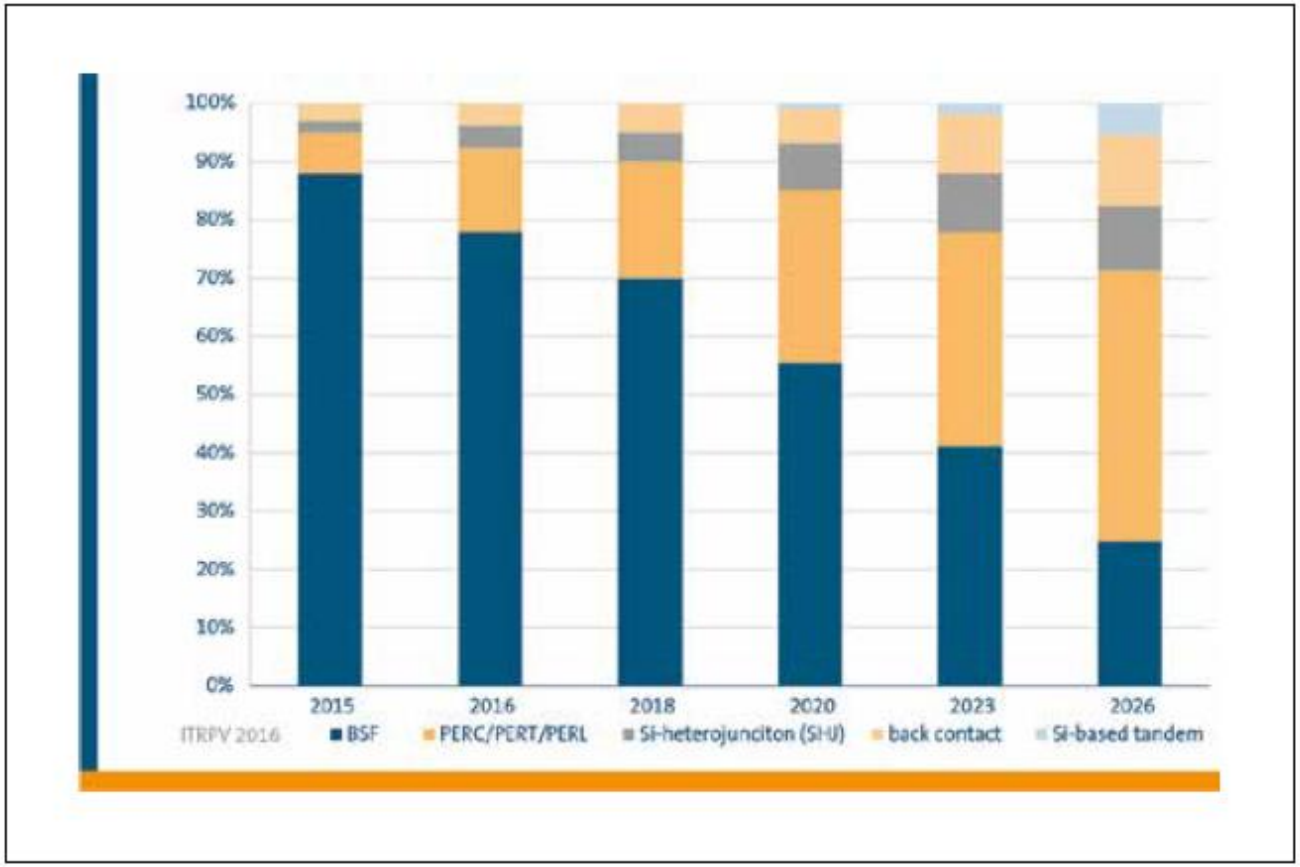
SIZE MATTERS TO LOWER COSTS



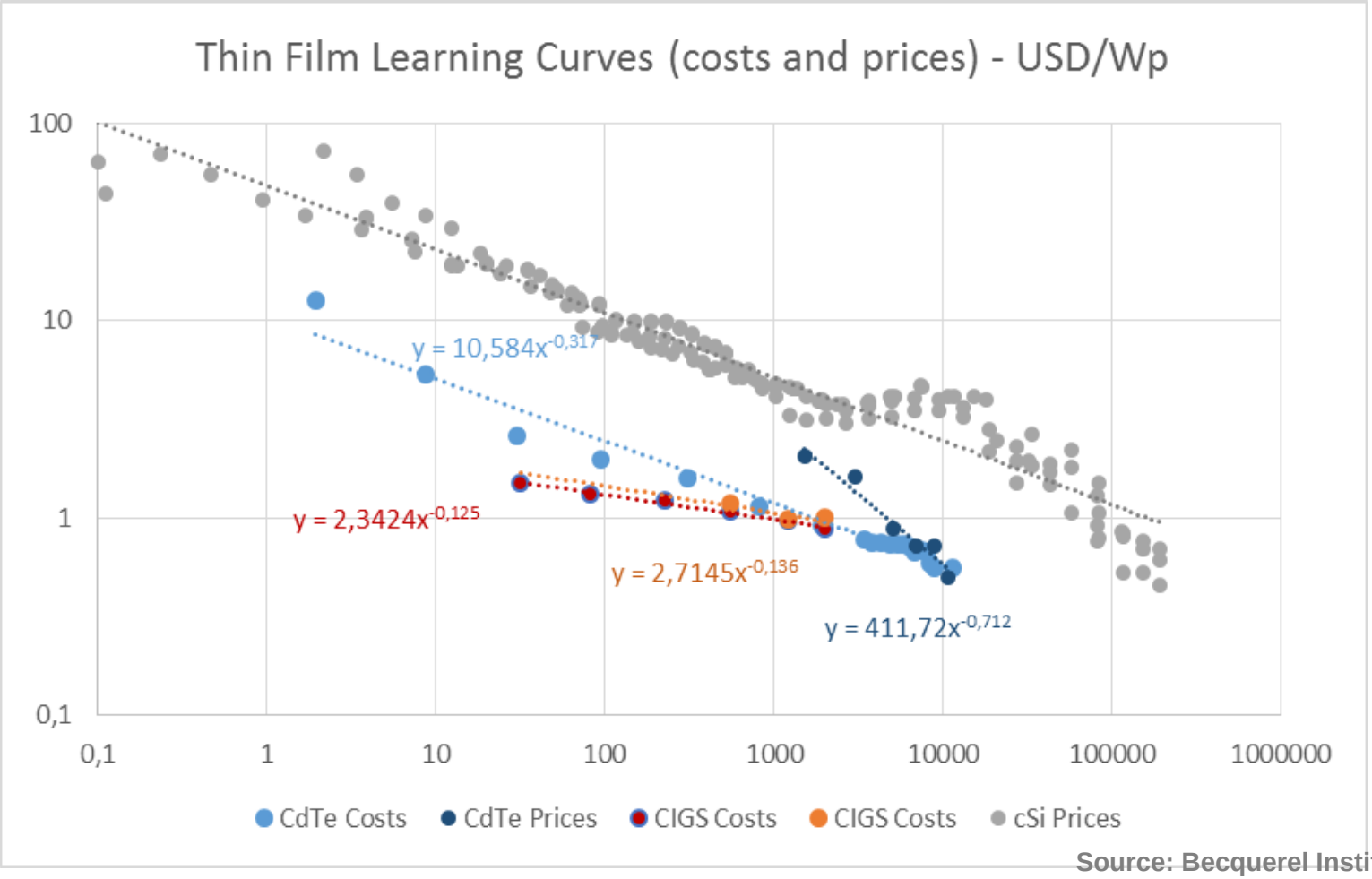
Quest for 10 GW is ongoing

Source: Fraunhofer ISE & IPA, 1 GW Study 2014

WHAT ABOUT TECHNOLOGIES?



THIN FILM LEARNING CURVES

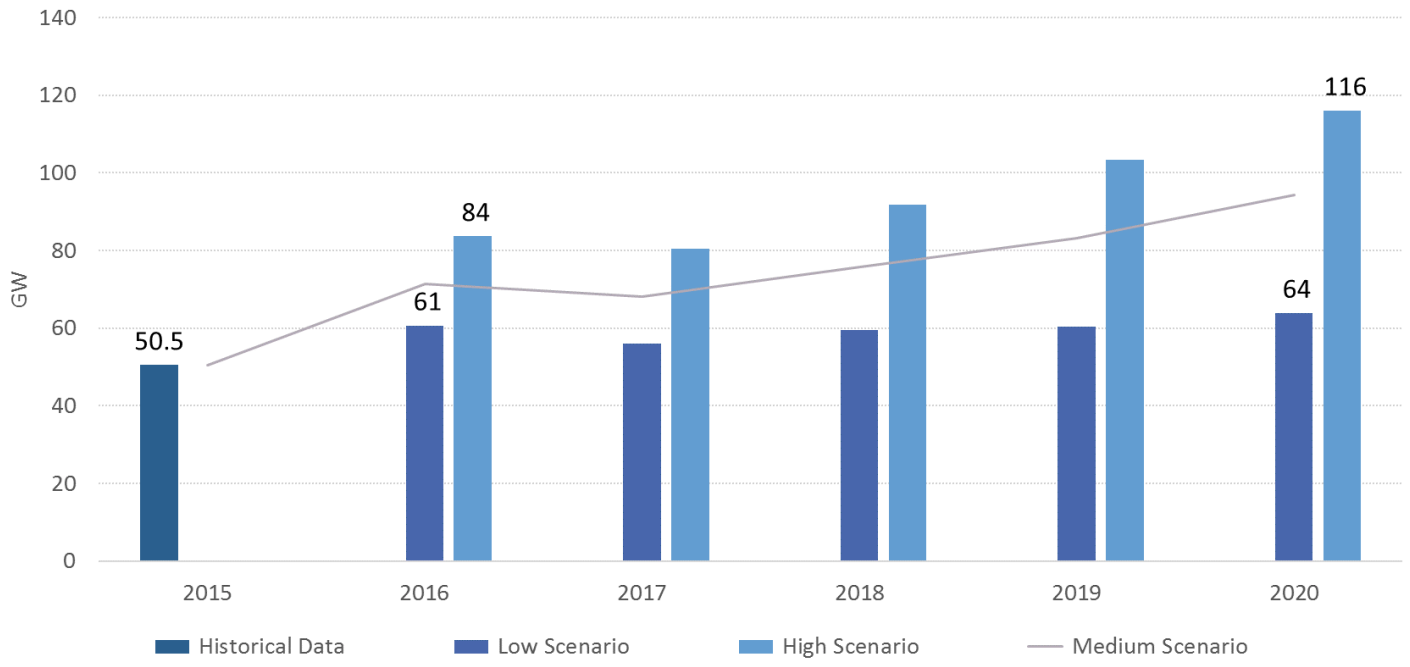


Source: Becquerel Institute 2016

THIN FILM ROADMAP

- CdTe LC – 16-20% (Trina Solar, Becquerel Institute)
  - Costs and prices (annouced) significantly different
- CIGS LC – 8-10% (Trina Solar, Becquerel Institute)
  - But why? One single main producer on a protected market (JP)? Technology intrinsic characteristics?
- Risk that TF might have difficulties to cope with cSi price decline… ?

HOW MUCH NEW CAPACITIES ARE NEEDED (AND WHEN)?



Source: PV Market Alliance – Becquerel Institute 2016

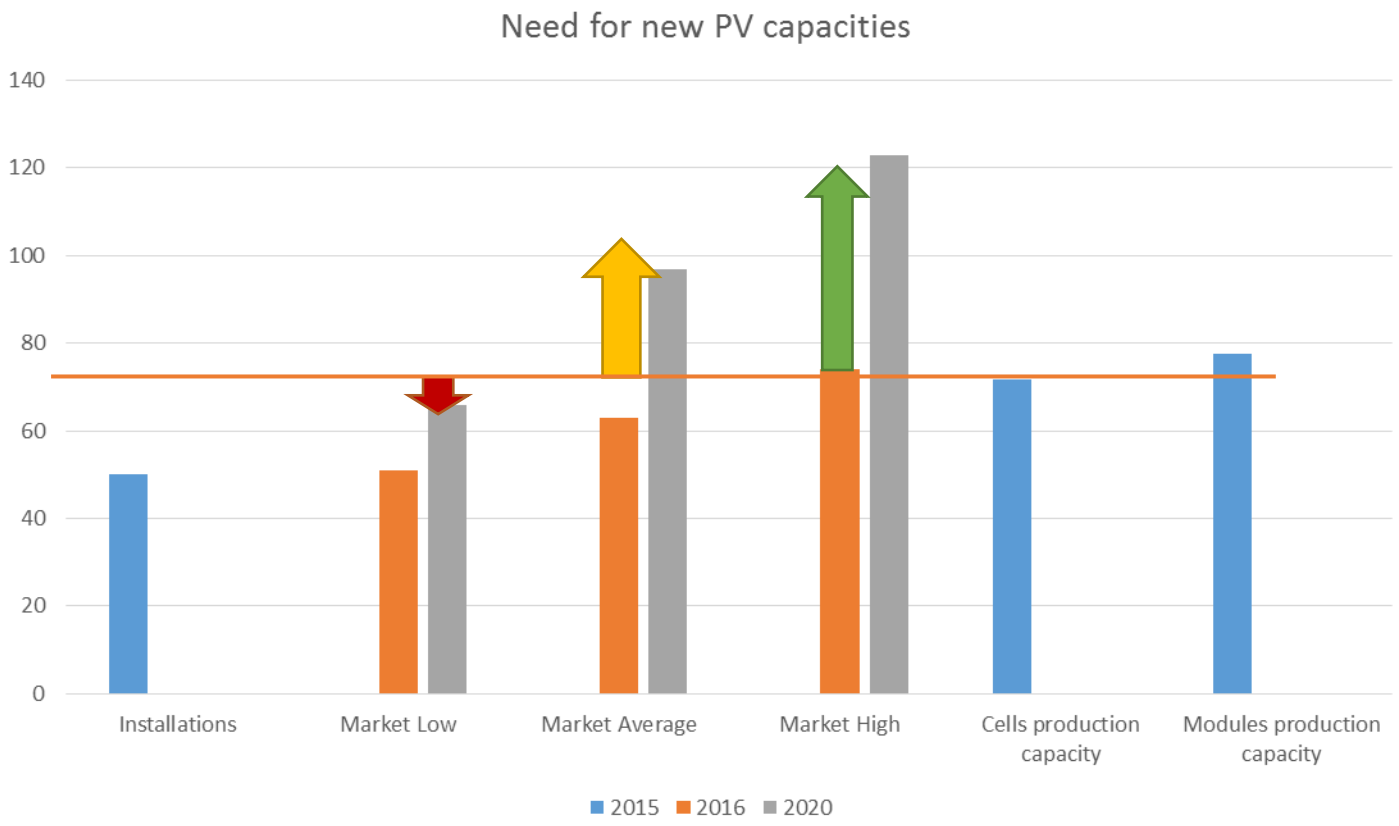
2015 CAPACITIES

Table 1 Global PV cell/ module/ system production volume, production capacity and PV installed capacity in 2015

Solar cell production	**63.0**	GW	35.5 % YOY growth
PV module production	**62.1**	GW	38.2 % YOY growth
PV installed capacity (DC-based)	**50.0**	GW	25.0 % YOY growth
Solar cell production capacity	**71.7**	GW/year	23.6 % YOY growth
PV module production capacity	**77.6**	GW/year	22.0 % YOY growth
PV module production in 2014 (for reference)	**44.9**	GW	22.7 % YOY growth

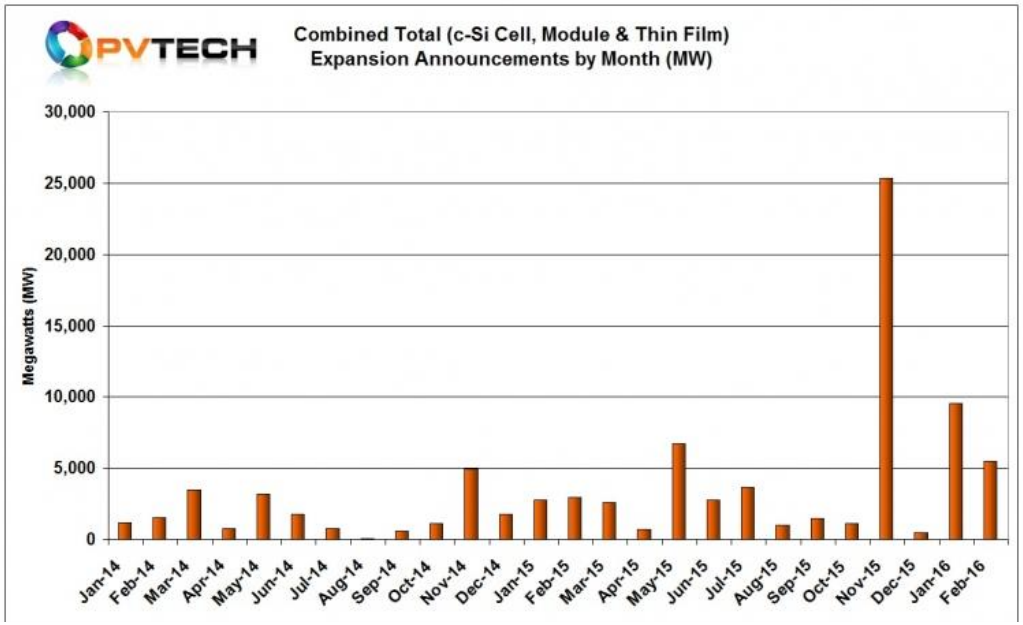
Source: RTS Corporation

HOW MUCH NEW CAPACITIES ARE NEEDED?



Source: Becquerel Institute 2016

A NEW PRICE WAR



Trina Solar warns of overcapacity in 2016. Should the industry panic?

Mar 04, 2016 12:39 PM GMT | 0

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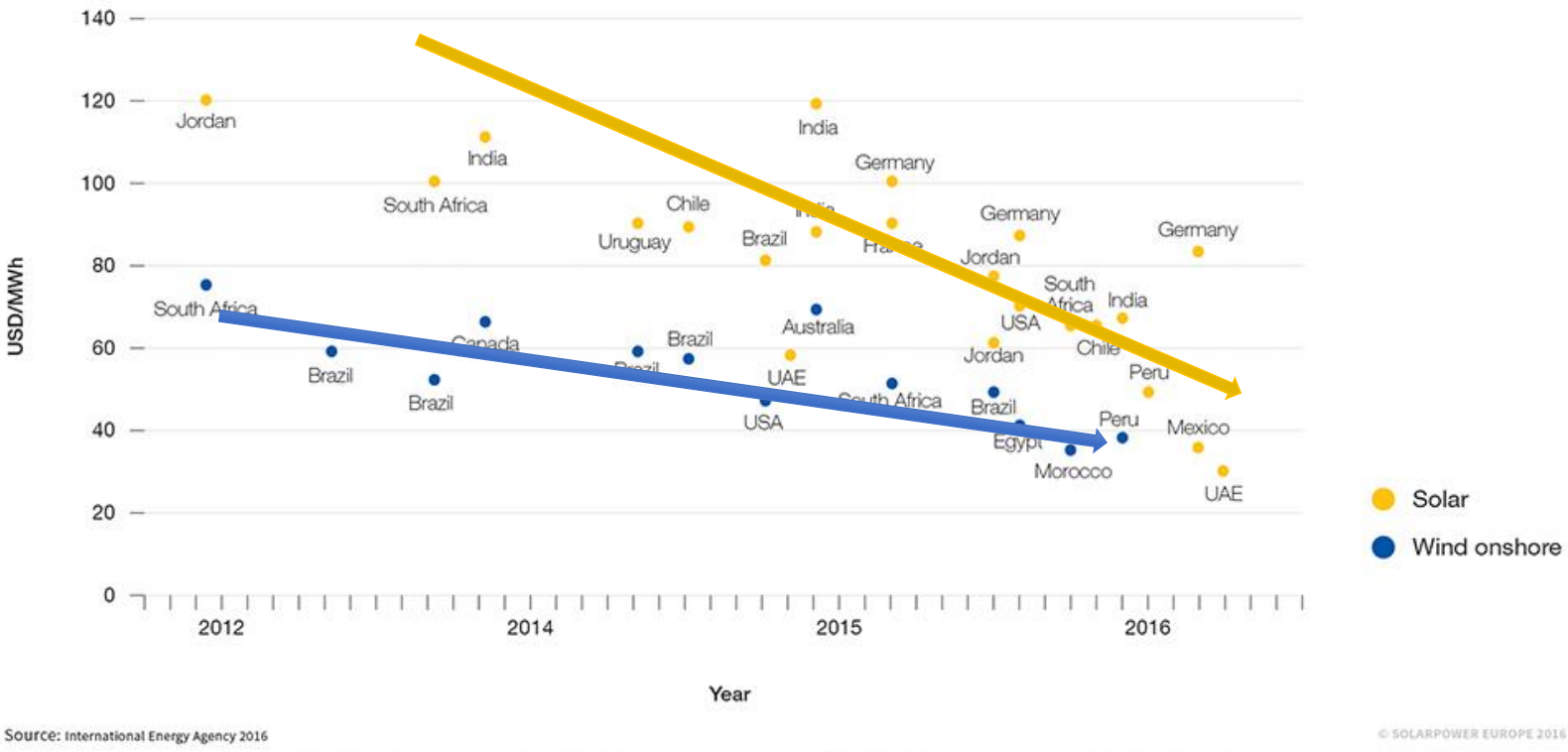
By Mark Osborne, Senior News Editor

3. COMPETITIVE TENDERS

FIGURE 1 PPA PRICE OFFERS FOR SOLAR PV AND WIND ONSHORE POWER PLANTS IN DIFFERENT COUNTRIES



Source: Solar Power Europe – Global Market Outlook 2016 based on International Energy Agency data

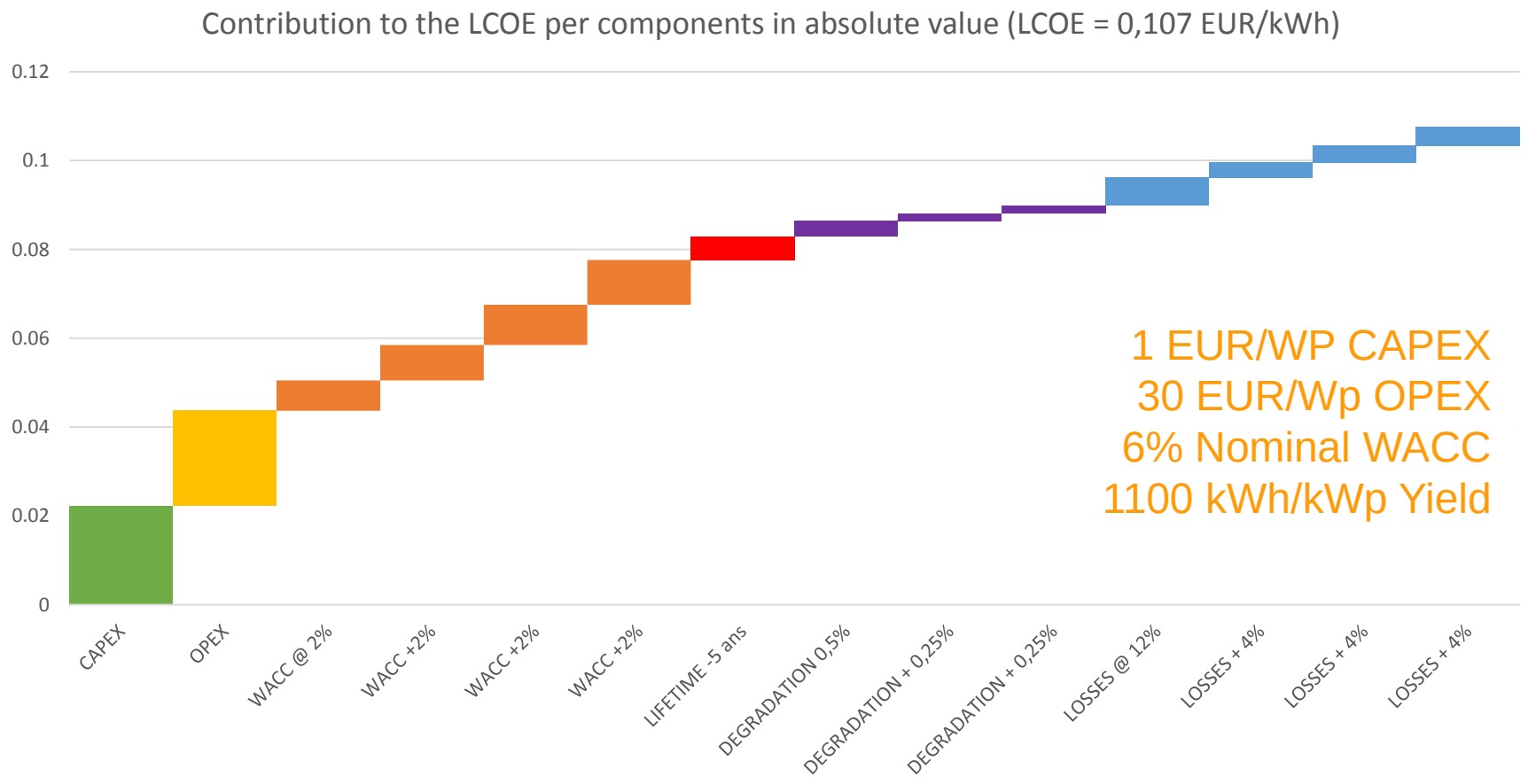
COMPETITIVE TENDERS

Is 0,03 USD/kWh realistic ?

What is needed ?

- Yield: 2000 kWh/kWp
- CAPEX: 0,7 EUR – 0,8 USD/Wp
- OPEX: 15 EUR/kW
- WACC: 4% (nominal)
- Degradation: 0,5%

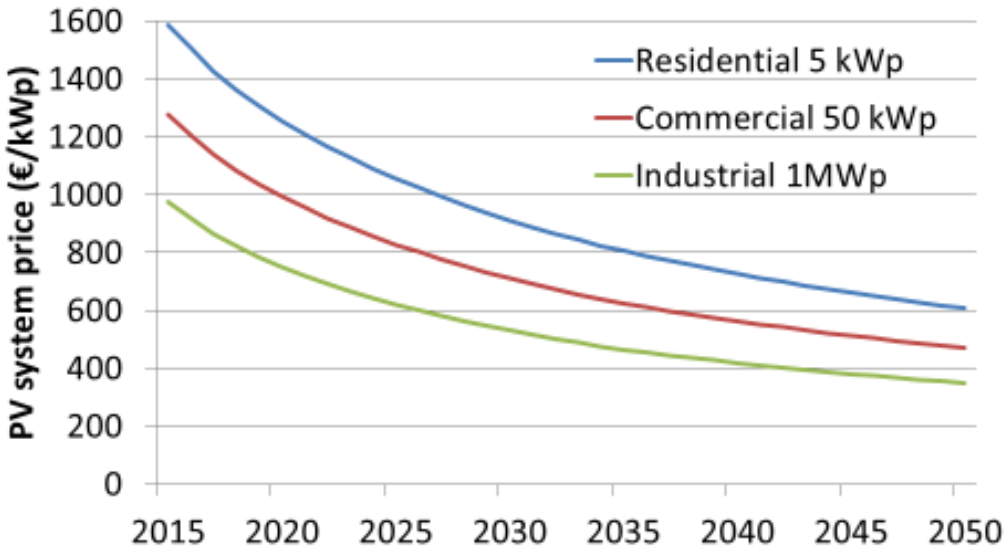
SENSITIVITY OF LCOE



Source: Becquerel Institute 2016

FUTURE CAPEX

Average turn-key PV system CAPEX prices in Europe 2015-50 (w/o taxes)



Source: PV LCOE in Europe 2015-2050 (Vartiainen, Masson & Breyer, 31st EU PVSEC, 2015)
In 2015 real money

4

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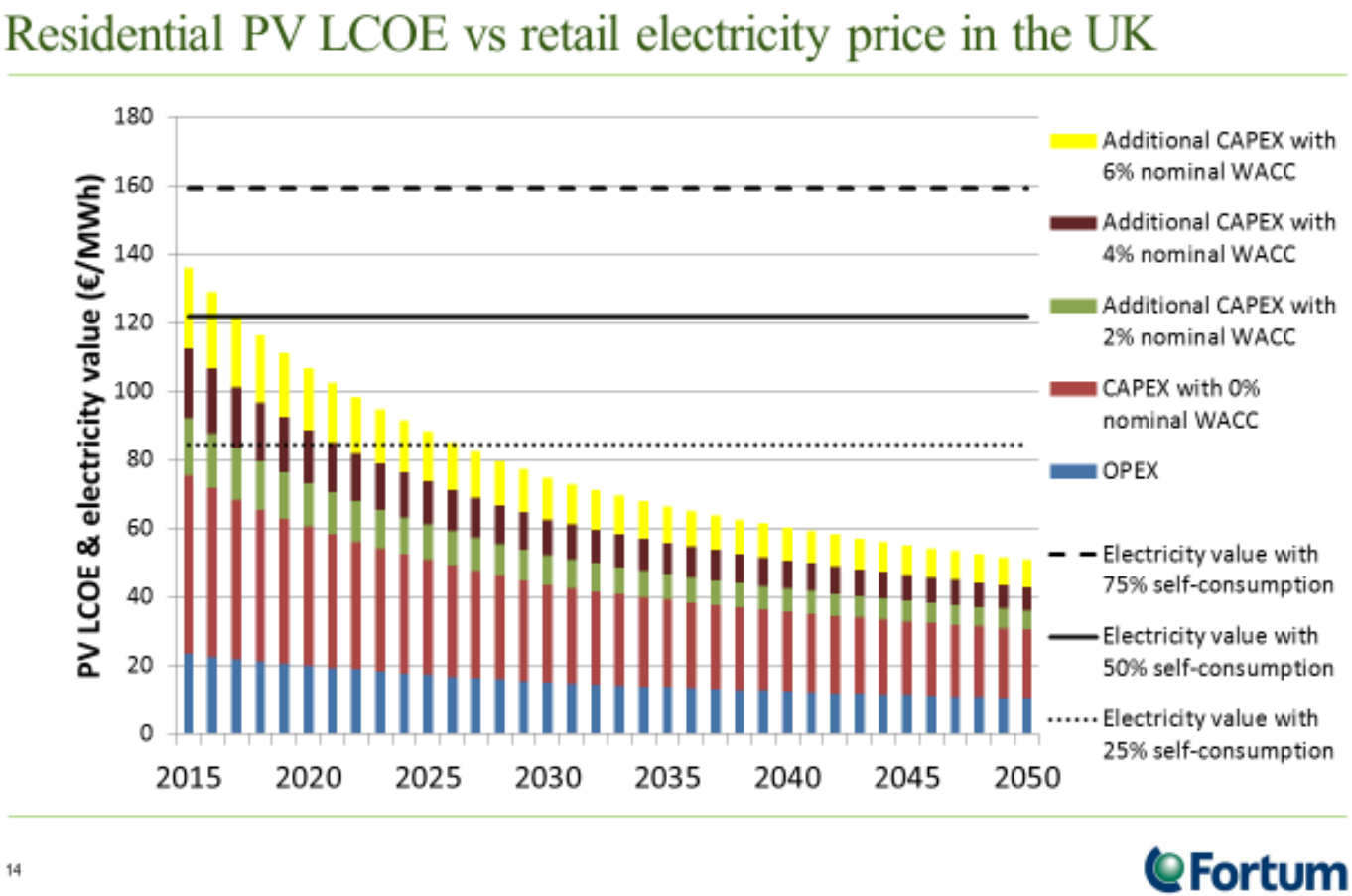
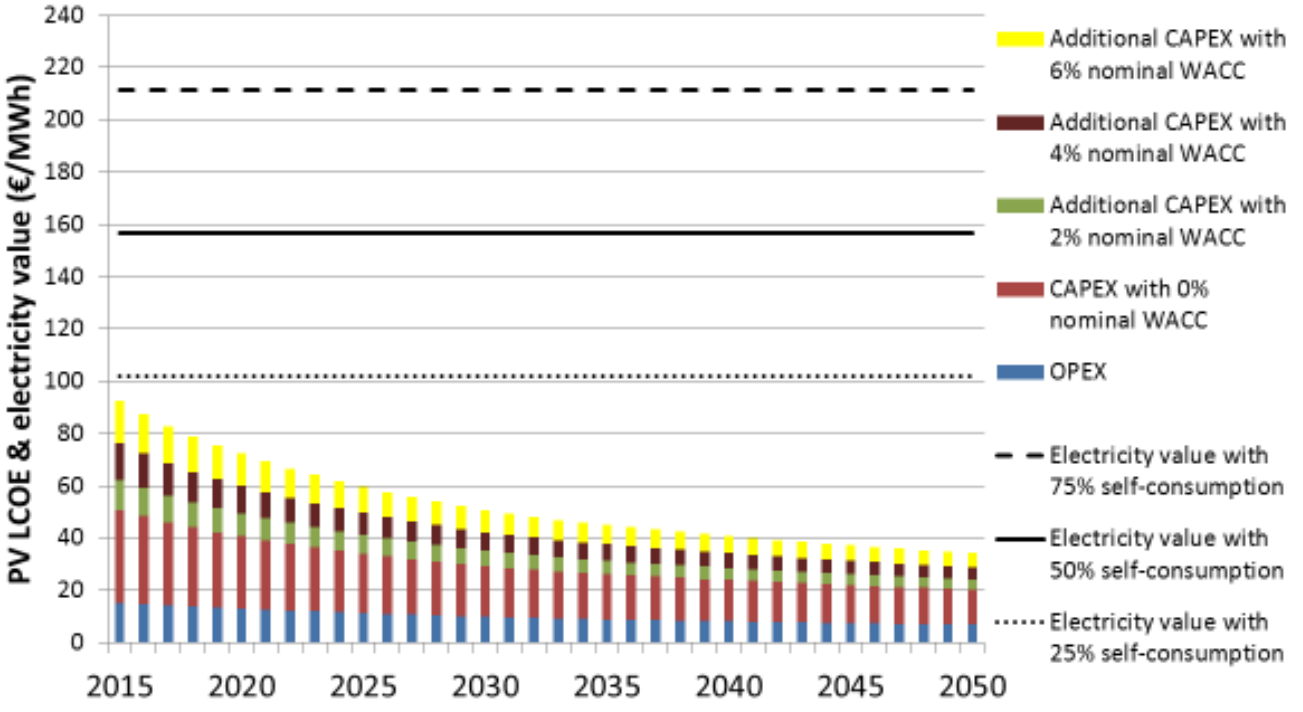
RESIDENTIAL PV LCOE IN UK



RESIDENTIAL PV LCOE IN ITALY

Residential PV LCOE vs electricity value in Italy



Source for retail prices: Eurostat 2015 averages for 5-15 MWh annual consumption, fixed components excluded;
All prices in 2015 real money

15

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COMPETITIVENESS

Summary of when true PV competitiveness is reached with 50% self-consumption in residential segment

Residential	Nominal WACC			
5 kW_p	**0 %**	**2 %**	**4 %**	**6 %**
Stockholm	2020	2025	2032	2040
Helsinki	2019	2024	2030	2038
Amsterdam	Parity	Parity	2019	2023
Paris	Parity	2016	2021	2026
Brussels	Parity	Parity	2018	2022
Istanbul	Parity	Parity	2017	2021
London	Parity	Parity	Parity	2018
Berlin	Parity	Parity	Parity	Parity
Madrid	Parity	Parity	2018	2022
Rome	Parity	Parity	Parity	Parity

20

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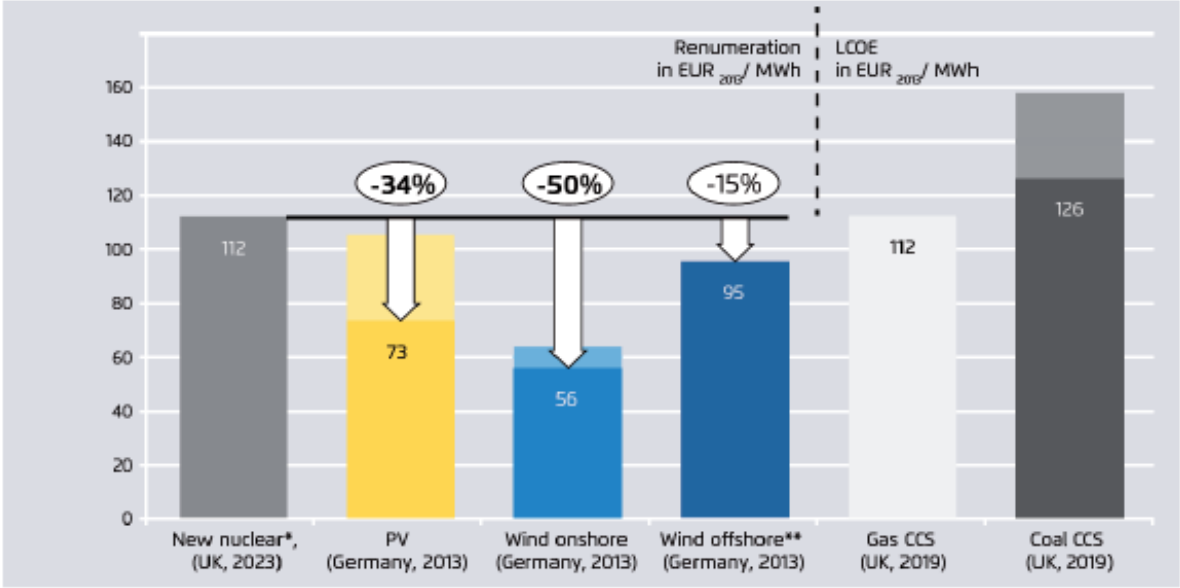
4. 100% RES ?


South-East Asia and the Pacific Rim Super Grid for 100% RE power supply
Christian Breyer, Ashish Gulagi and Dmitrii Bogdanov
Lappeenranta University of Technology, Finland
45th IEA PVPS Task 1 Meeting – GÜNDER Workshop
Istanbul, October 27-30, 2015
NEO CARBON ENERGY

LCOE of alternatives are NO alternative

Comparison of average remuneration for new nuclear power, PV, wind and the levelized cost of electricity for gas/coal CCS



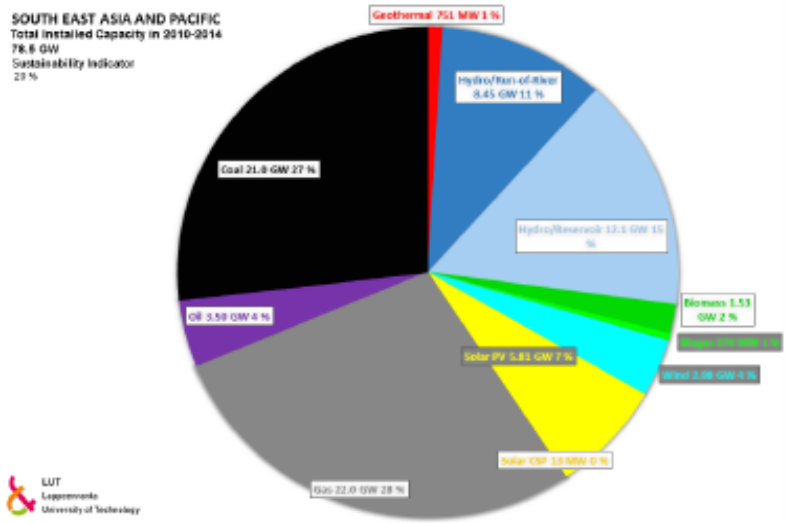
Key insights

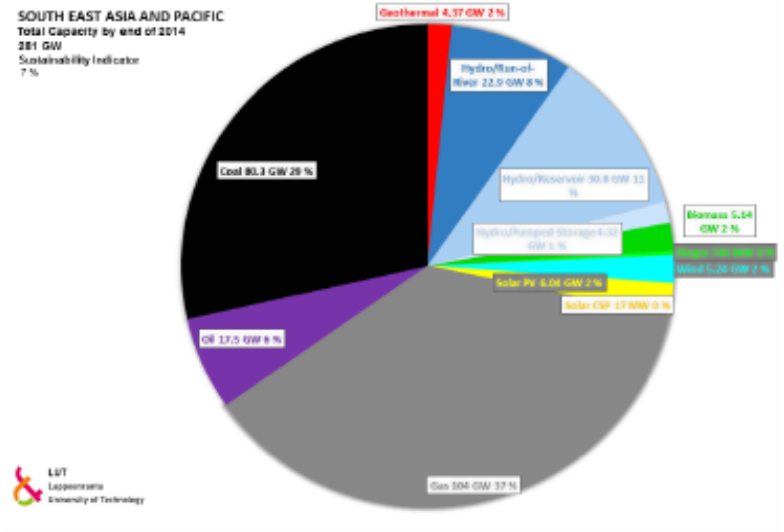
- PV-Wind-Gas is the least cost option (with existing hydro)
- nuclear and coal-CCS is too expensive
- nuclear and coal-CCS are high risk technologies
- high value added for PV-Wind due to higher capacities needed

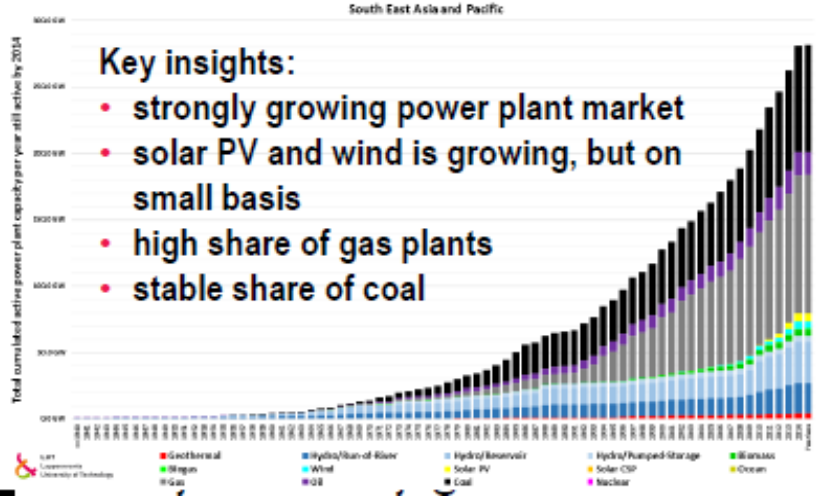
41 South-East Asian Super Grid for 100% RE power supply
Christian Breyer ► christian.breyer @lut.fi

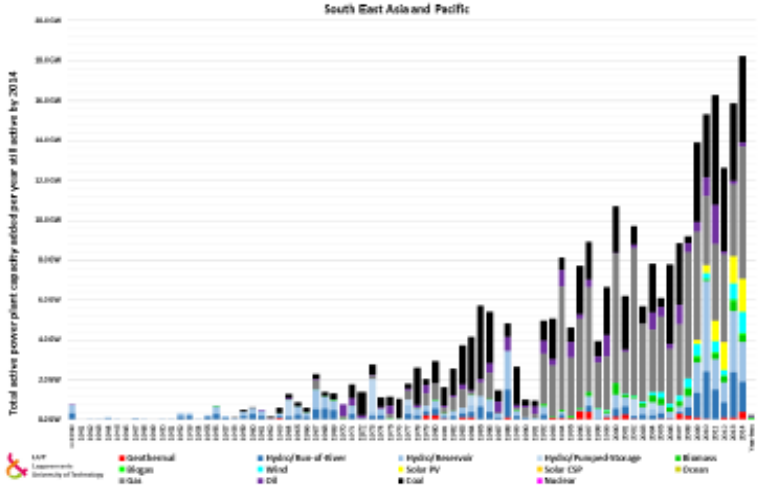
source: Agora Energiewende, 2014. Comparing the Cost of Low-Carbon Technologies: What is the Cheapest option, Berlin

Current status of the power plant mix









4

Scenarios assumptions

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Lappeenranta University of Technology

15 regions

- 2 regions in Australia (East and West)
- 4 regions in Indonesia (according to major islands)
- 2 regions in Malaysia (East and West)
- Mekong countries

Key data

- ~646 mio population
- ~1629 TWh electricity demand (2030)
- ~256 GW peak load (2030)
- ~13 mio km^2 area
- ~10 bil m^3/a water desalination demand (2030)

NEO CARBON ENERGY

Scenarios assumptions

Financial assumptions (year 2030)

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Generation costs

Technology	Capex [€/kW]	Opex fix [€/kW]	Opex var [€/kWh]	Lifetime [a]
PV rooftop	813	12	0	35
PV fixed-tilted	550	8	0	35
PV single-axis	620	9	0	35
Wind onshore	1000	20	0	25
Hydro Run-of-River	2560	115.2	0.005	60
Hydro Dam	1650	66	0.003	60
Geothermal energy	4860	87	0	30
Water electrolysis	380	13	0.001	30
Methanation	234	5	0	30
CO_2 scrubbing	356	14	0.0013	30
CCGT	775	19	0.002	30
OCGT	475	14	0.011	30
Biomass PP	2500	175	0.001	30
Wood gasifier CHP	1500	20	0.001	40
Biogas CHP	370	14.8	0.001	20
MSW incinerator	5240	235.8	0.007	20
Steam Turbine	700	14	0	30

Technology	Capex [€/(m³·a)]	Opex fix [€/(m³·a)]	Opex var [€/(m³·a)]	Lifetime [a]
Water Desalination	2.23	0.096	0	30

Technology	Energy/Power Ratio [h]
Battery	6
PHS	8
A-CAES	100
Gas Storage	80*24

	Efficiency [%]
Battery	90
PHS	92
A-CAES	70
Gas Storage	100
Water Electrolysis	84
CO_2 Scrubbing	78
Methanisation	77
CCGT	58
OCGT	43
Geothermal energy	24
MSW Incinerator	34
Biogas CHP	40
Steam Turbine	42
CSP collector	51

NEO CARBON ENERGY

Scenarios assumptions

PV and Wind LCOE (weather year 2005, cost year 2030)

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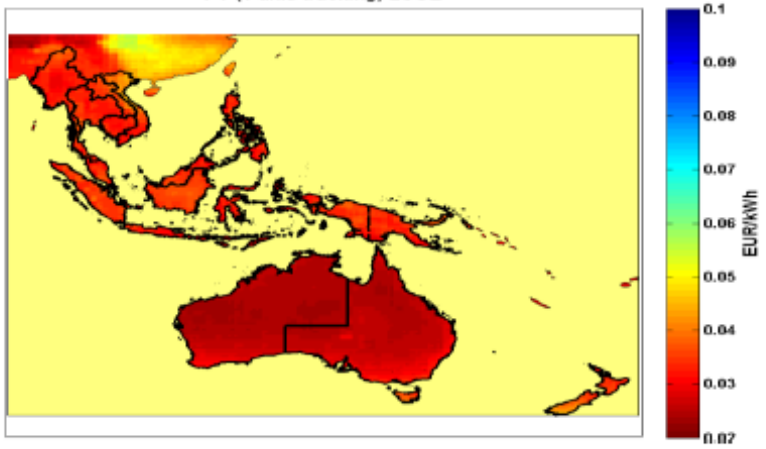
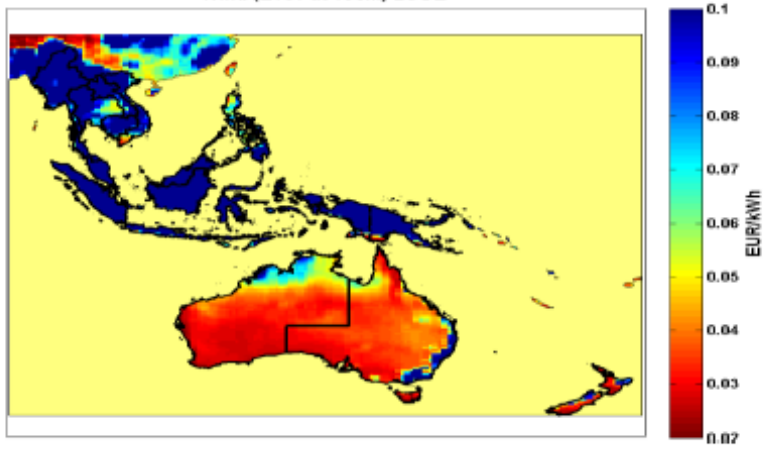
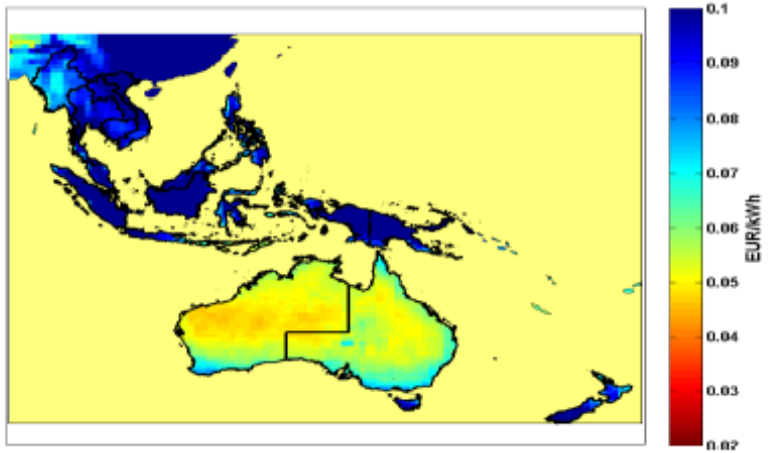
PV (1-axis tracking) LCOE



Wind (E101 at 150m) LCOE



CSP LCOE



NEO CARBON ENERGY

Scenarios assumptions

Generation profile (area aggregated)

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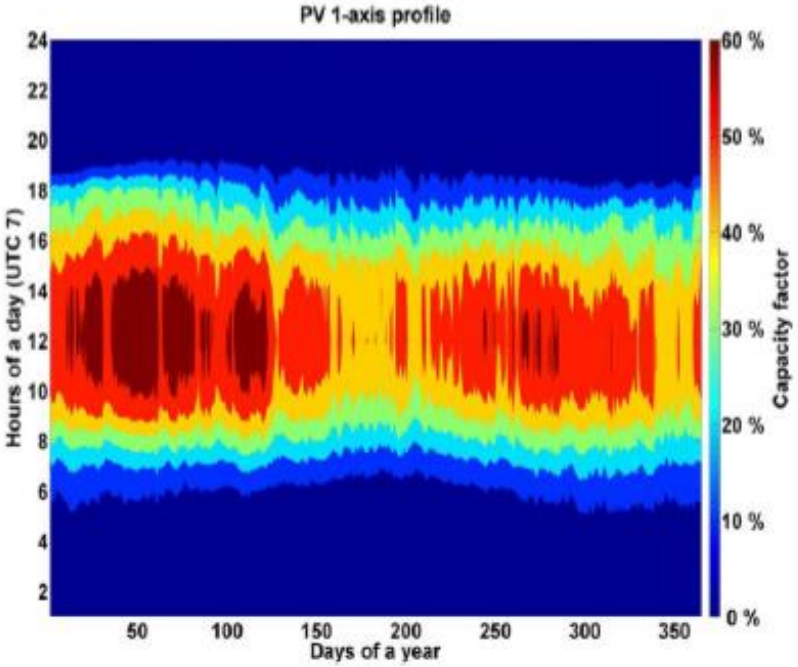
PV generation profile

Aggregated area profile computed using earlier presented weighed average rule.



Wind generation profile

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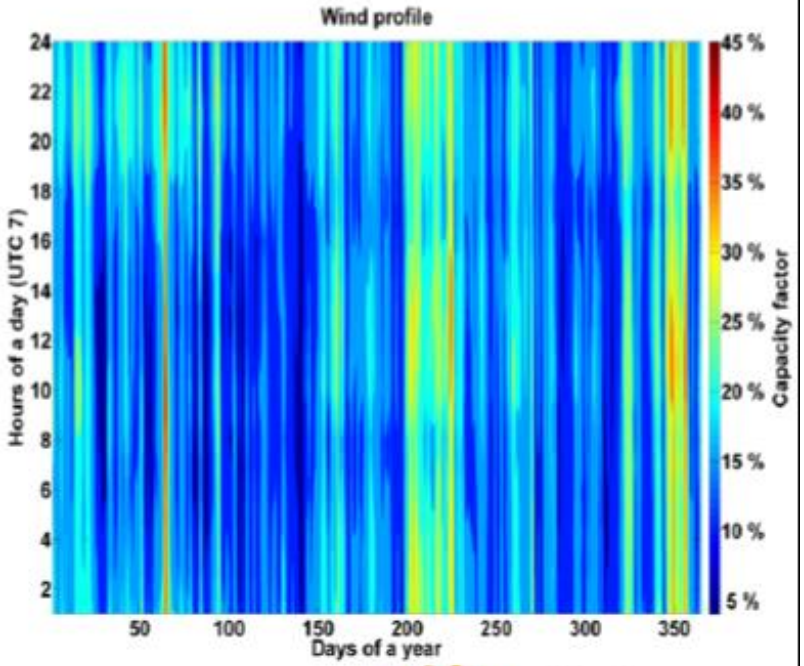

NEO CARBON ENERGY

Scenarios assumptions

Load (area aggregated)

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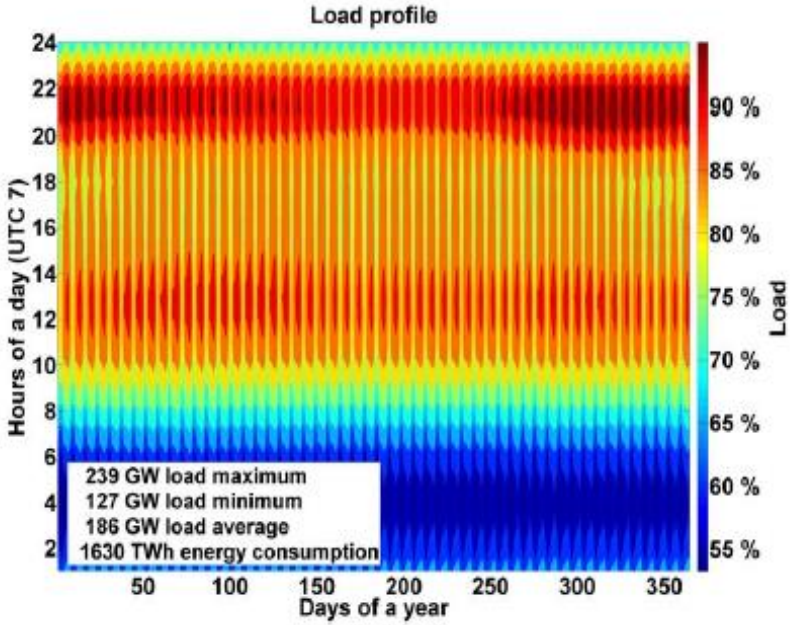
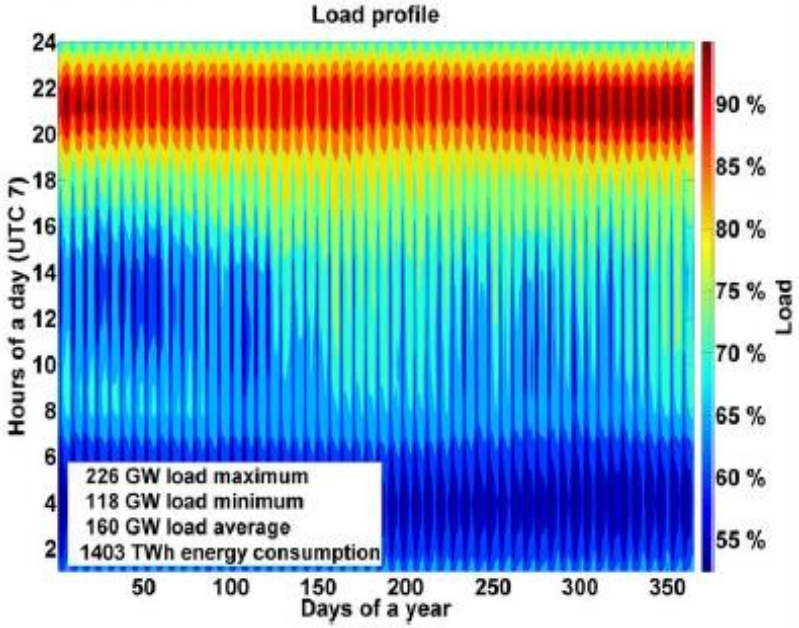
Synthesized load curves for each region

Total load (2030)



Total load (2030)
- excluding PV prosumers



Key insights:

- PV self-consumption reduces peak load by about 5%
- Daytime demand is substantially reduced throughout the year

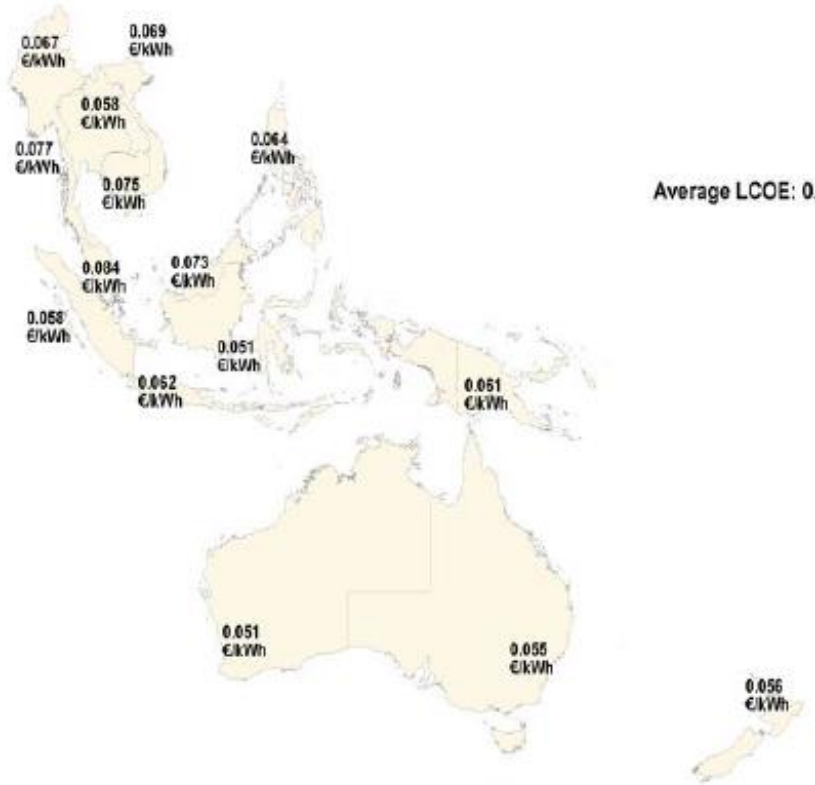
NEO CARBON ENERGY

Results

Total LCOE (year 2030) – region-wide open trade

Open your mind. LUT.
Lappeenranta University of Technology

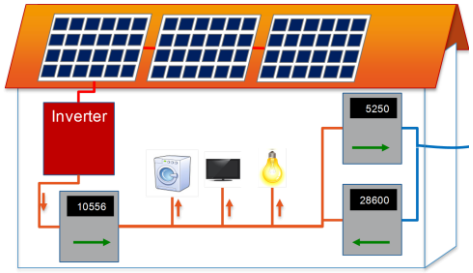
Levelized Cost of Electricity
(generation, curtailment and storage)



Average LCOE: 0.067 €/kWh

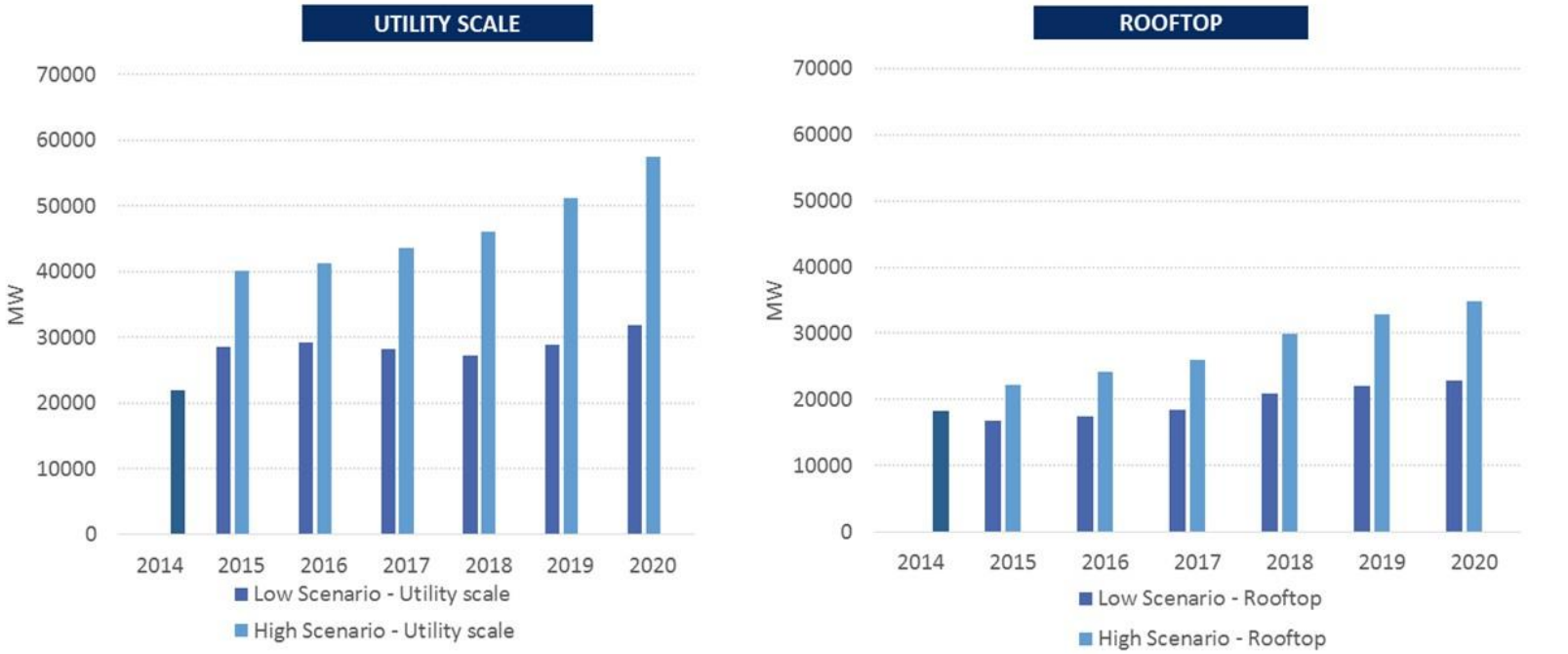
NEO CARBON ENERGY

SELF-CONSUMPTION



ROOFTOP PV DEVELOPMENT

GLOBAL PV MARKET EVOLUTION BY SEGMENT UNTIL 2020

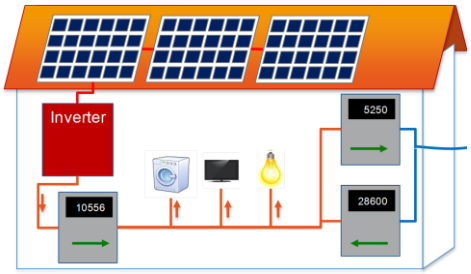


PV Market Alliance – Global PV Market Report 2015 - 2020

PV Market Alliance

BUSINESS MODELS

Savings on the electricity bill
+
Sale of excess PV electricity



Prosumers

Net-metering

Self-consumption + market price + FiT/FiP

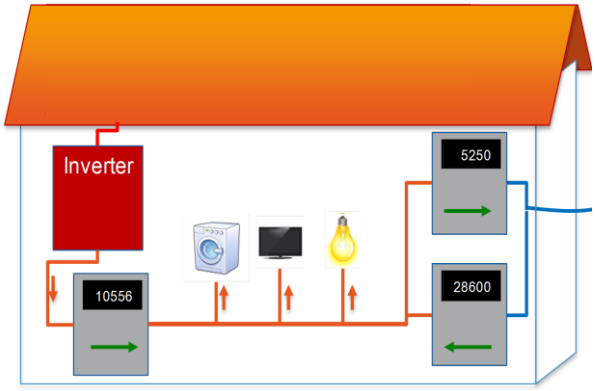
FiT / TGC

Market price (+ premium? FiP)

Producers

Sale of electricity

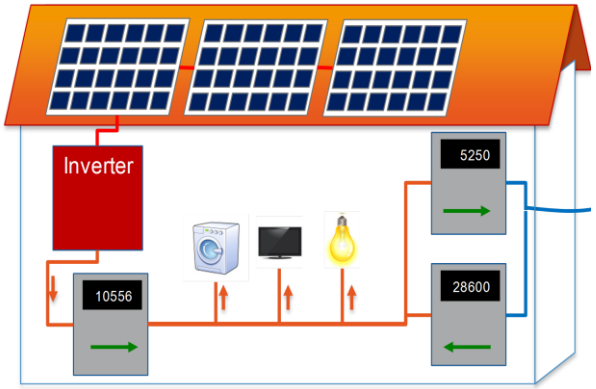
WITH OR WITHOUT PV



Electricity bill

Building without PV

- Electricity comes from the grid



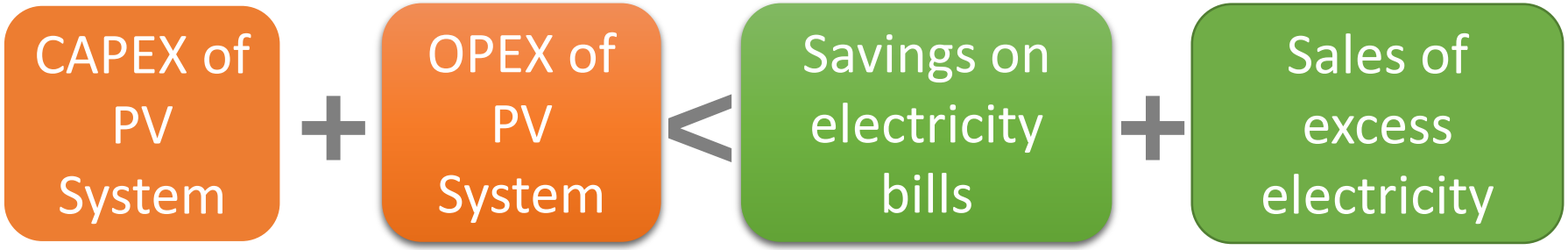
Sales of PV Electricity

Electricity bill

Building with PV

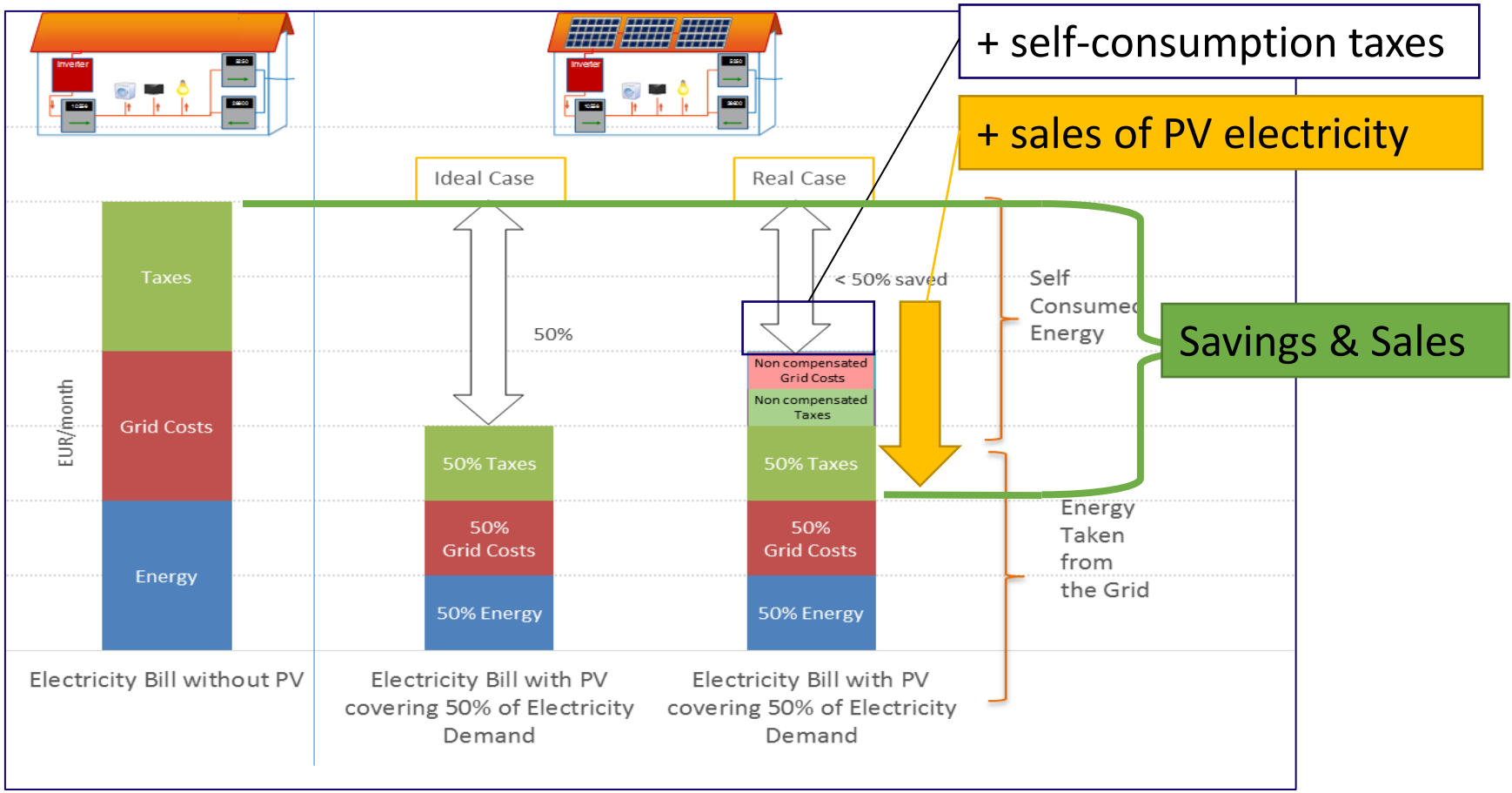
- Part of electricity produced by PV is consumed in the building (reducing the electricity bill)
- Non-consumed electricity goes to the grid and is sold
- When PV is not producing, the electricity comes from the grid

COMPETITIVE PV ?

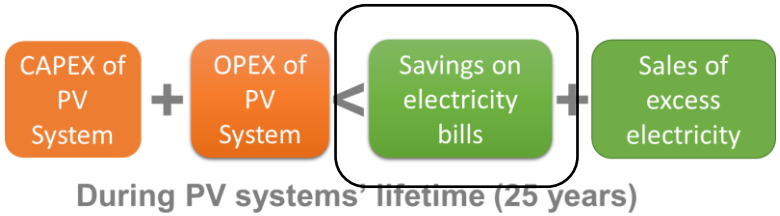


During PV systems' lifetime (20-35 years)

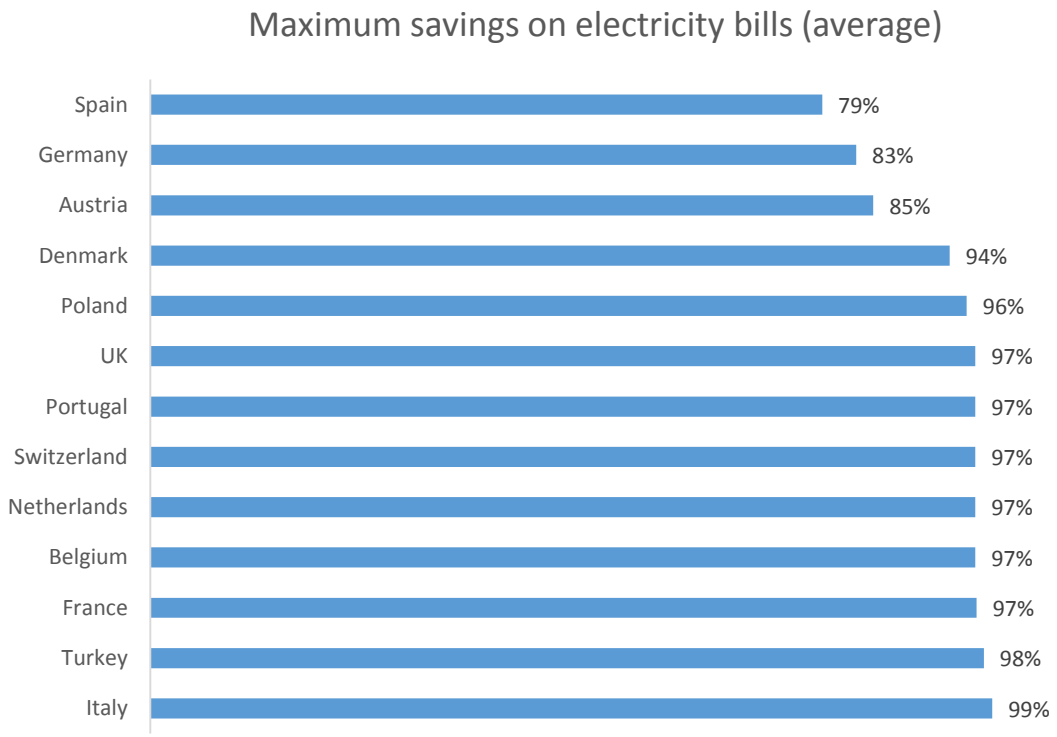
ECONOMICS OF SELF-CONSUMPTION



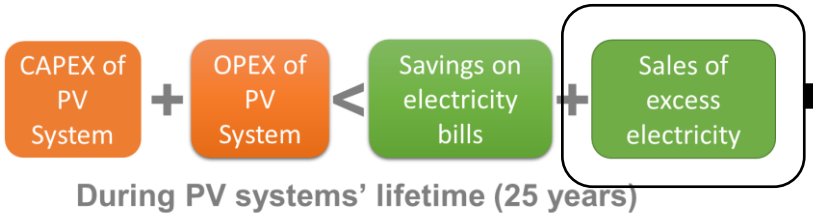
COMPONENTS OF ELECTRICITY



How much can be compensated from the electricity bill ?



SALES OF PV ELECTRICITY

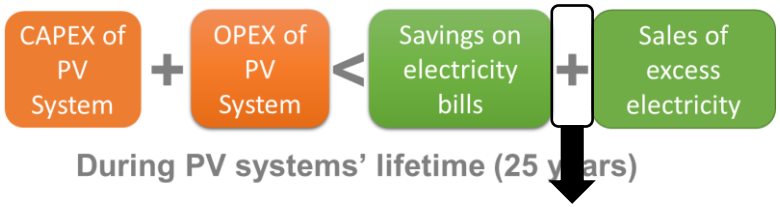


→ Access to wholesale electricity markets

1. Current — Excess PV electricity gets a FiT
2. Current — Excess PV electricity gets a FiP above the market price
3. Future — Excess PV electricity gets the market price though an aggregator
4. Future — Excess PV electrivity gets the market price directly

European Legislation pushed to integrate renewable into wholesale electricity markets

SELF-CONSUMPTION RATIO



SC ratio = PV production locally consumed / total PV production

Hypothesis used: 50% SC - Commercial segment / 75% SC - Industrial segment

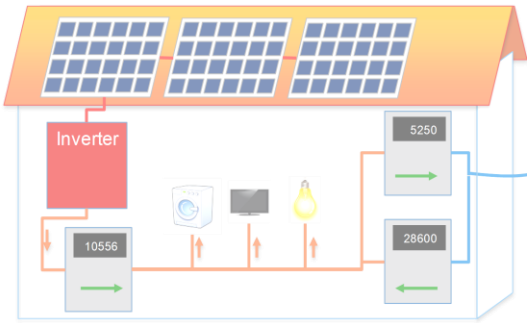
- Example: commercial segment in France 2015
  - Retail electricity price: 0,144 EUR/kWh
  - Wholesale market price: 0,045 EUR/kWh
  - Average value of PV electricity compared to the LCOE of PV electricity (average): 0,10 EUR/kWh

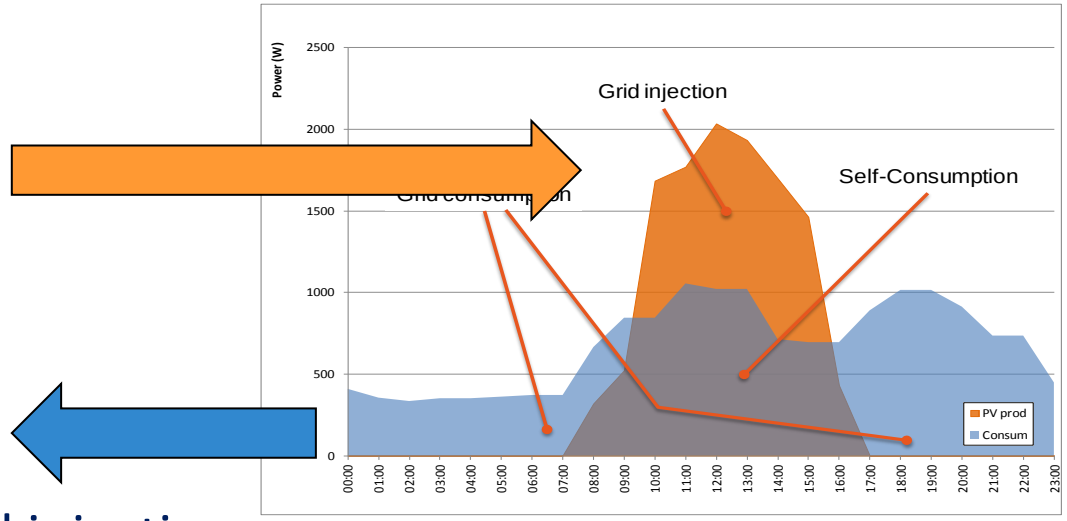
25% SC	50% SC	75% SC	100% SC
0,061 EUR/kWh	0,083 EUR/kWh	0,116 EUR/kWh	0,144 EUR/kWh

THE SC RATIO CHALLENGE

Self-consumption of PV installations

20 to 100%





Challenge: minimizing grid injection

Solutions: decrease PV system size, DSM, Storage

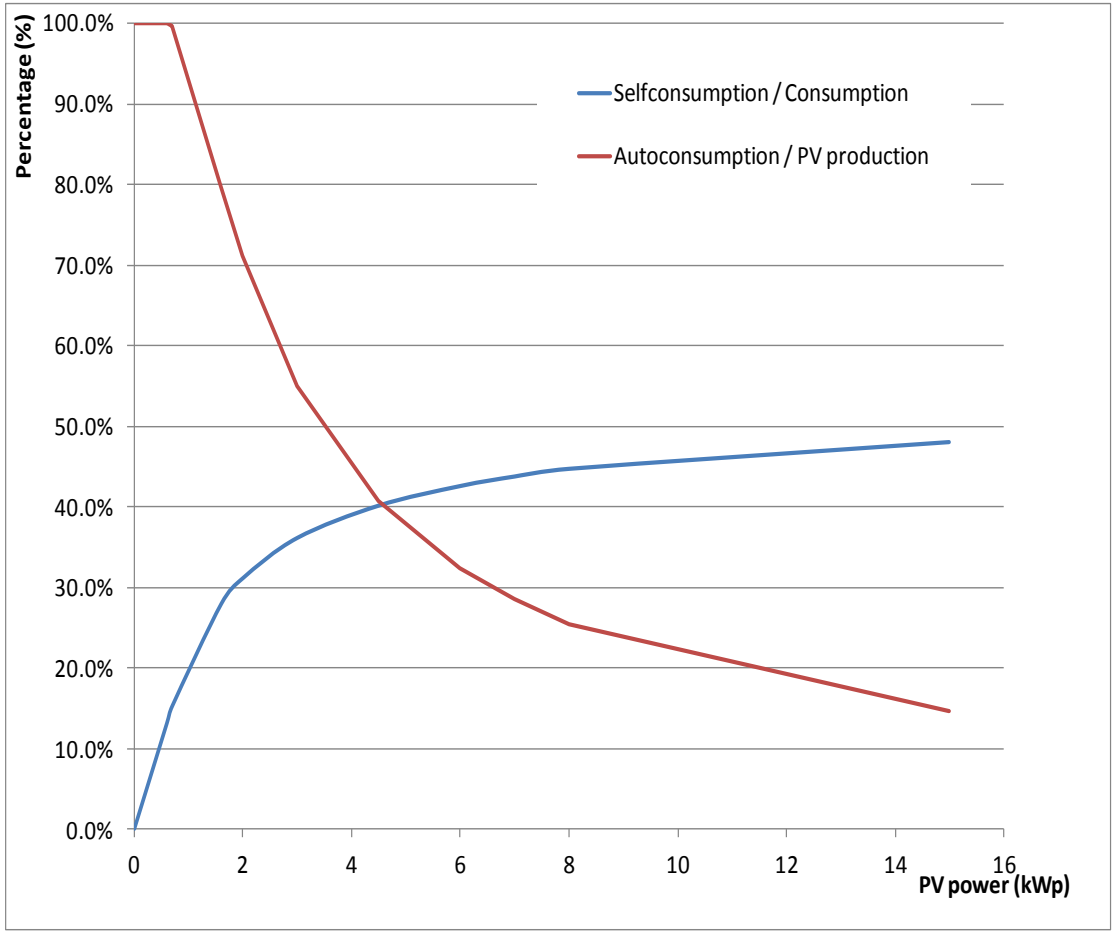
IMPACT OF SC RATIOS

Ratios are smaller in the residential sector (20-30%).

DSM, system size, storage can increased them.

Commercial and industrial applications can reach higher ratios.

But is local optimization of SC optimum from a system point of view ?

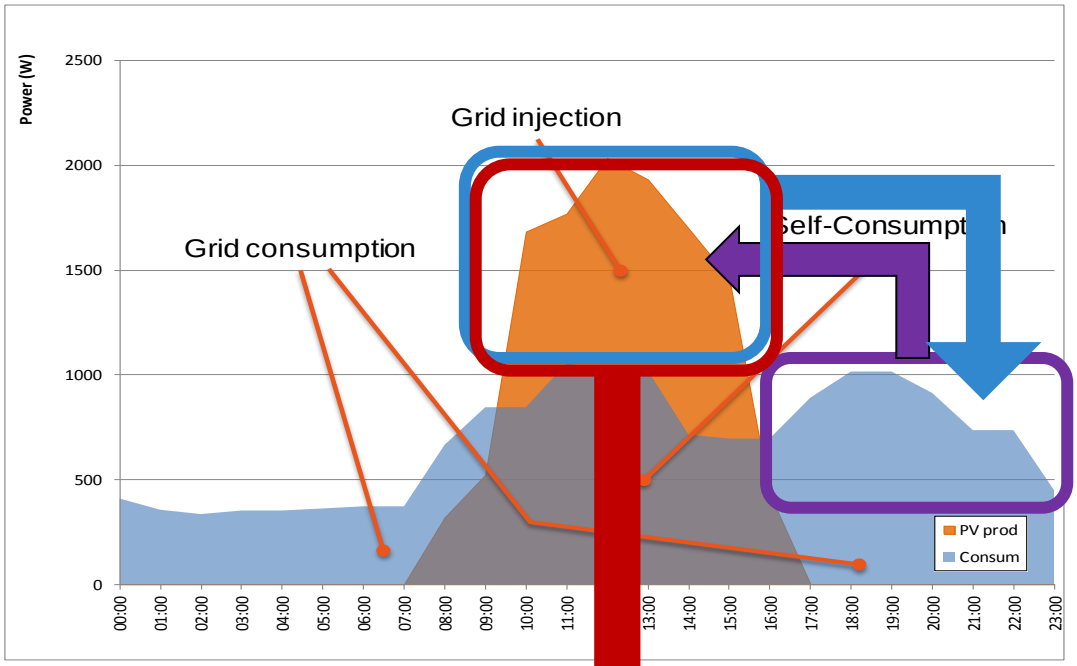


DSM & STORAGE SOLUTIONS

DSM

Electricity Storage

Other uses(out of the load)



H&C, Transport

SELF-CONSUMPTION BUSINESS CASE

- A simple (residential) business model in Belgium

  PV electricity production cost: 0,12 EUR/kWh (950 kWh/kWp + 1,5 EUR/WP + WACC @ 4%)

  Residential electricity prices 0,2 EUR/kWh (assuming 100% savings on electricity bill)

  Value of injected electricity = 0,04 EUR/kWh

  (Net-metering with grid tax: +0,13 – 0,12 = +0,01 EUR/kWh)

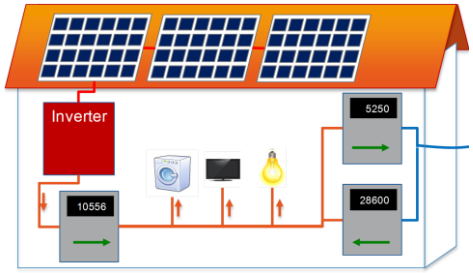
  With 30% SC: +0,09 – 0,12 = -0,03 EUR/kWh

  With 70% SC: +0,15 – 0,12 = +0,03 EUR/kWh

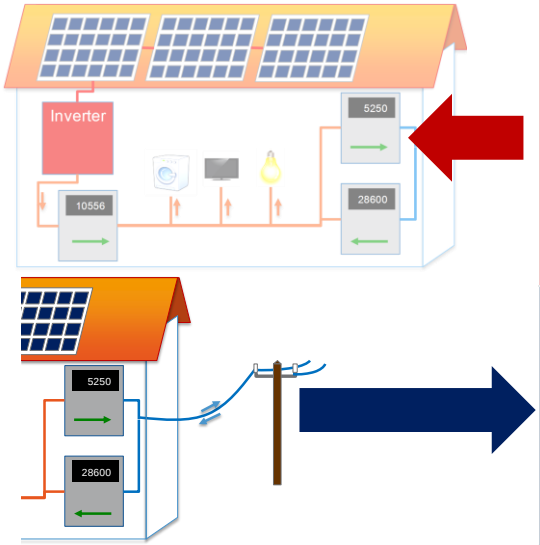
  Margin for investment in Smart tools, storage or H&C

  NPV_20years (i=2%) for a 5kWp PV system = 2400 EUR

REGULATIONS & PARAMETERS



A NEED FOR REGULATIONS



Onsite Self-Consumption	Right to self-consume	• Self-consumption is legally permitted
	Revenues for self-consumed PV electricity	• Savings on the variable price of electricity from the grid
	Charges to finance T&D costs	• Additional costs associated to self-consumption such as fees or taxes may exist
Excess PV Electricity	Value of excess electricity	• Net metering: energetic compensation (credit in kWh) • Net billing: monetary compensation (credit in monetary unit)
	Maximum timeframe for compensation	• Self-consumption: real time (e.g 15 minutes) • Net metering and net billing: time frame is typically one year although there are some exceptions (from credits that can be rolled over to the following billing cycle to quarterly compensation)

Key:
- Same between shemes
- Main differences

CATEGORIES OF SELF-CONSUMPTION

On-site PV self-consumption	1	Right to self-consume
	2	Revenues from self-consumed PV
	3	Charges to finance T&D costs
Excess PV electricity	4	Revenues from excess electricity
	5	Maximum timeframe for credit compensation
	6	Geographical compensation
Other characteristics of the system	7	Regulatory scheme duration
	8	Third-party ownership
	9	Grid codes and additional taxes/fees
	10	Other enablers of self-consumption
	11	System capacity limit
	12	Aggregate capacity limit

Clarify existing and future schemes,

Allow comparison from one scheme to another

Consider some emerging questions such as:

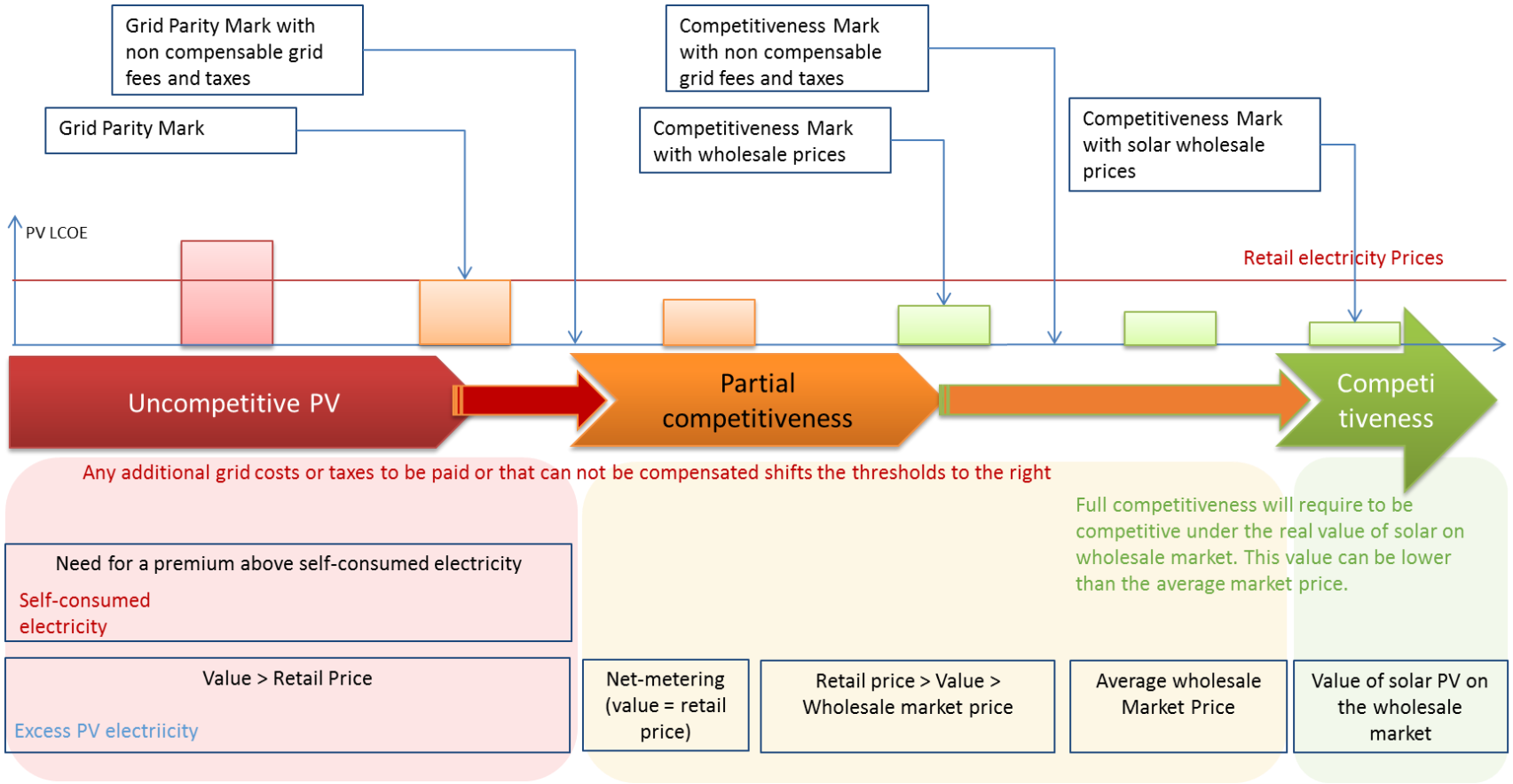
- How to finance the grid?
- How to keep government revenues stable?
- How to save utilities ?

WHICH POLICIES ?

		Production based: classical "FiT" - style. No self-consumption	Self-consumption with constrains	Self-consumption + FiT GC, FiP	Net-billing	Net-metering	Self-consumption + Premium
1	Right to self-consume	Not Allowed	Yes	Yes	Yes	Yes	Yes
2	Revenues from self-consumed PV	N/A	Savings on the electricity bill	Savings on the electricity bill	Netting of production revenues and consumption costs	Savings on the electricity bill	Savings on the electricity bill
	Additional revenues on self-consumed PV	N/A	No	No	No	No	Premium
3	Charges to finance T&D cost	N/A	Yes	No	No	No	No
4	Revenues from excess electricity	N/A	Zero	< retail price	<= retail price	= retail price	> retail price
5	Maximum timeframe for compensation	N/A	Real-time	Real-time	Long period	Long period	Real time

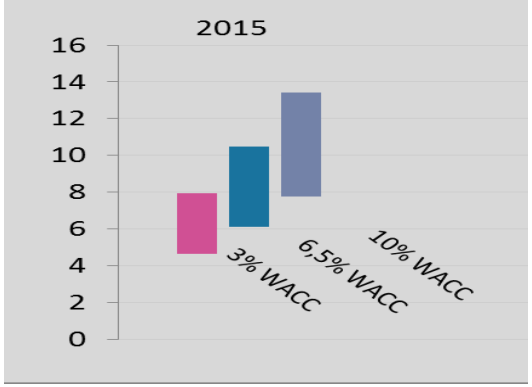
THE DEBATE ON SELF-CONSUMPTION

Self-consumption will be constrained due to limited savings on the electricity bill

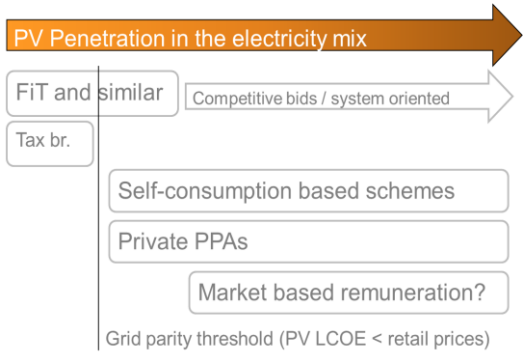


IN SUMMARY…

Competitiveness ?

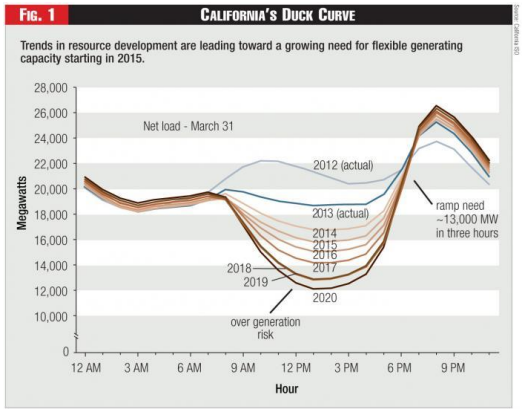


Which Incentives ?



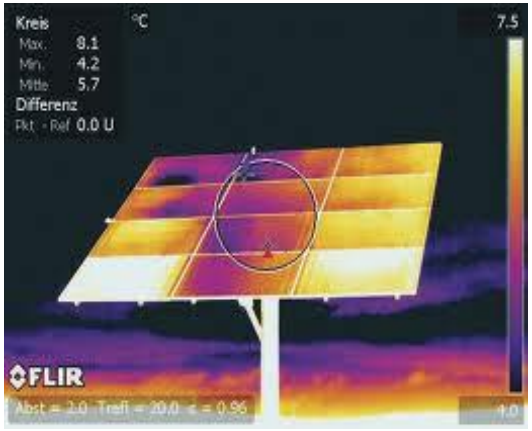
Local industry vs low prices?

Market Integration ?

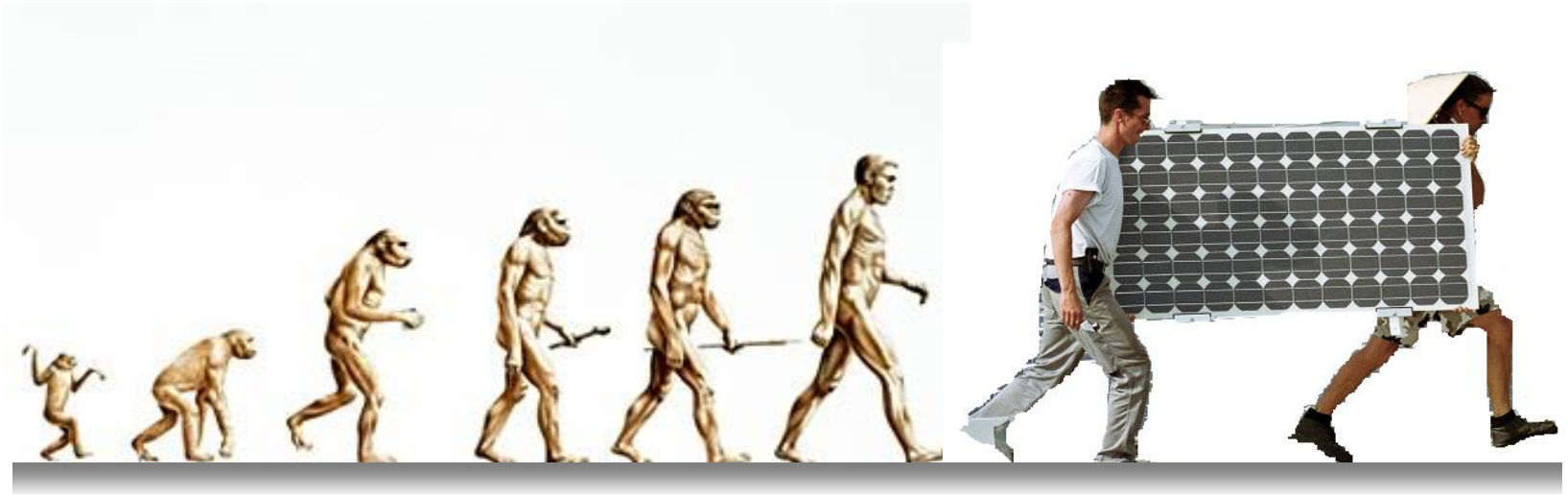


Cost of financing

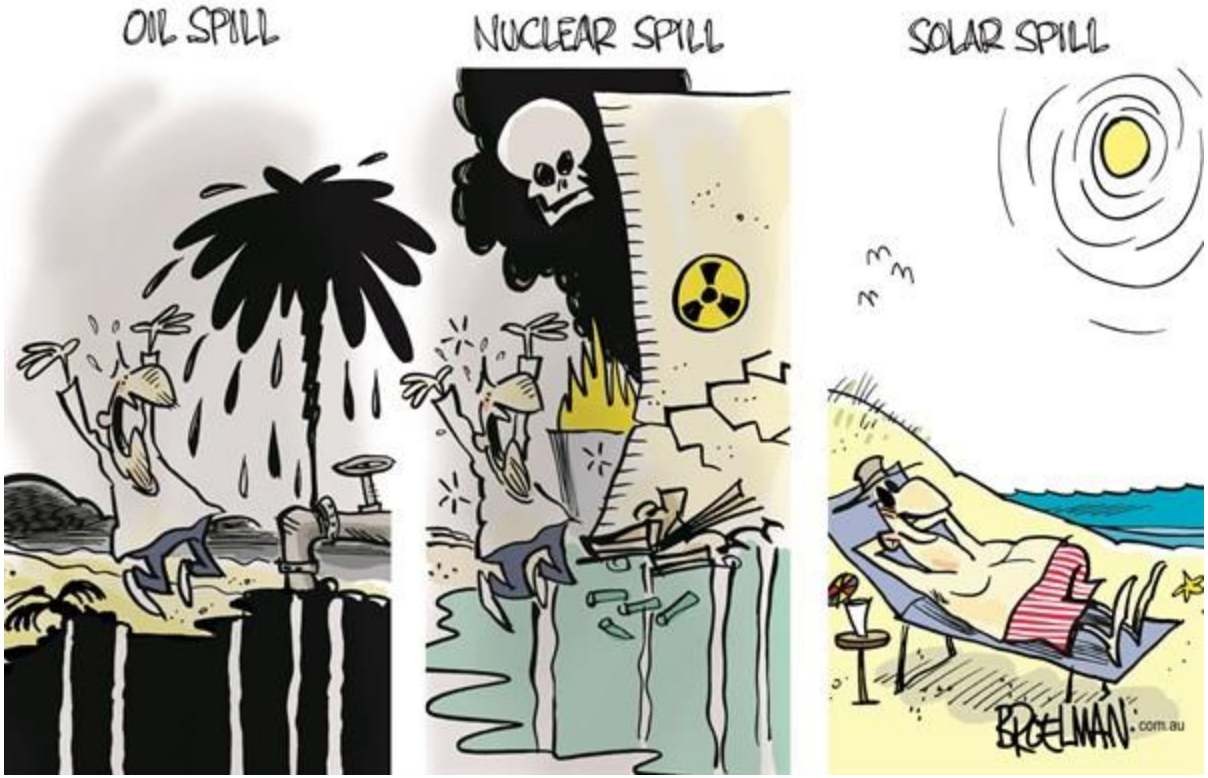
Quality & Reliability



NEXT STEP IN EVOLUTION



TIME TO SPILL ;-)



Thanks for your attention

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