

Need and opportunities for a strong European Photovoltaic Industry – The xGWp Approach

„Scientific Support to Europe’s Photovoltaic Manufacturing Industry“
Round Table of the European Forum for Science and Industry
Brussels, January 27, 2015

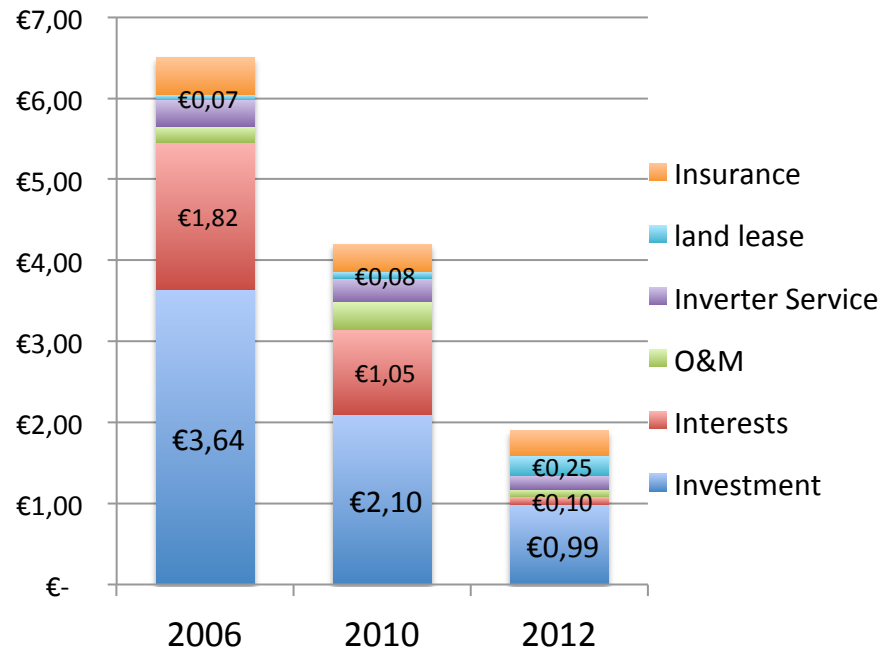
Prof. Eicke R. Weber, director, Fraunhofer Institute for Solar Energy Systems
Ruggero Schleicher-Tappeser, xGWp Coordinator



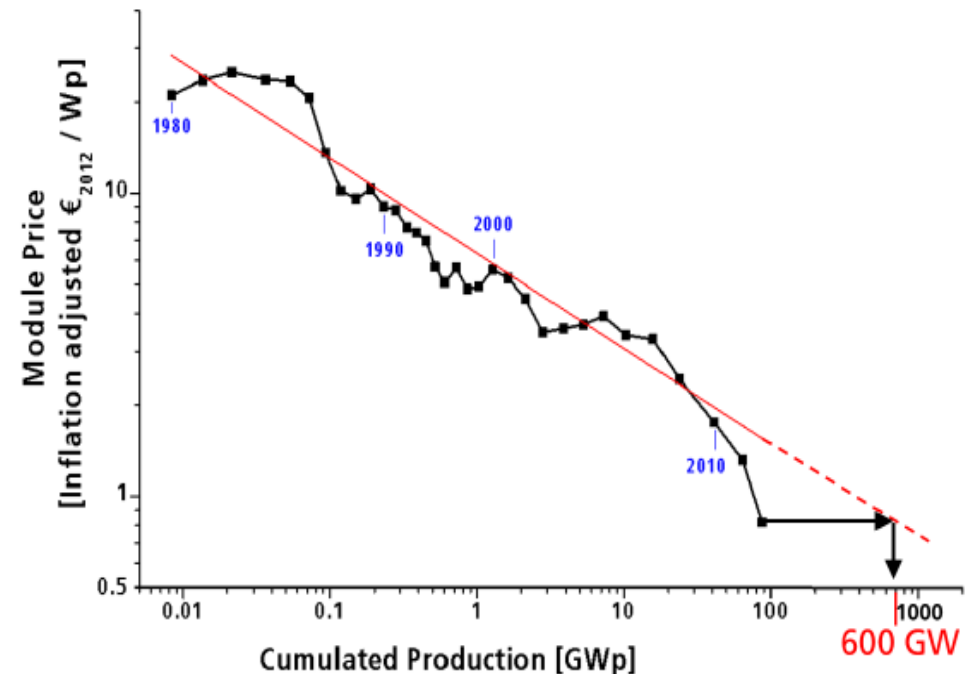
PHOTOVOLTAICS – THE RAPIDLY GROWING KEY PILLAR OF THE FUTURE ENERGY SYSTEM

Dramatically falling costs of PV change the competitive landscape

€/W_{peak}



Data: Bächler (2013),
PV-magazine.de

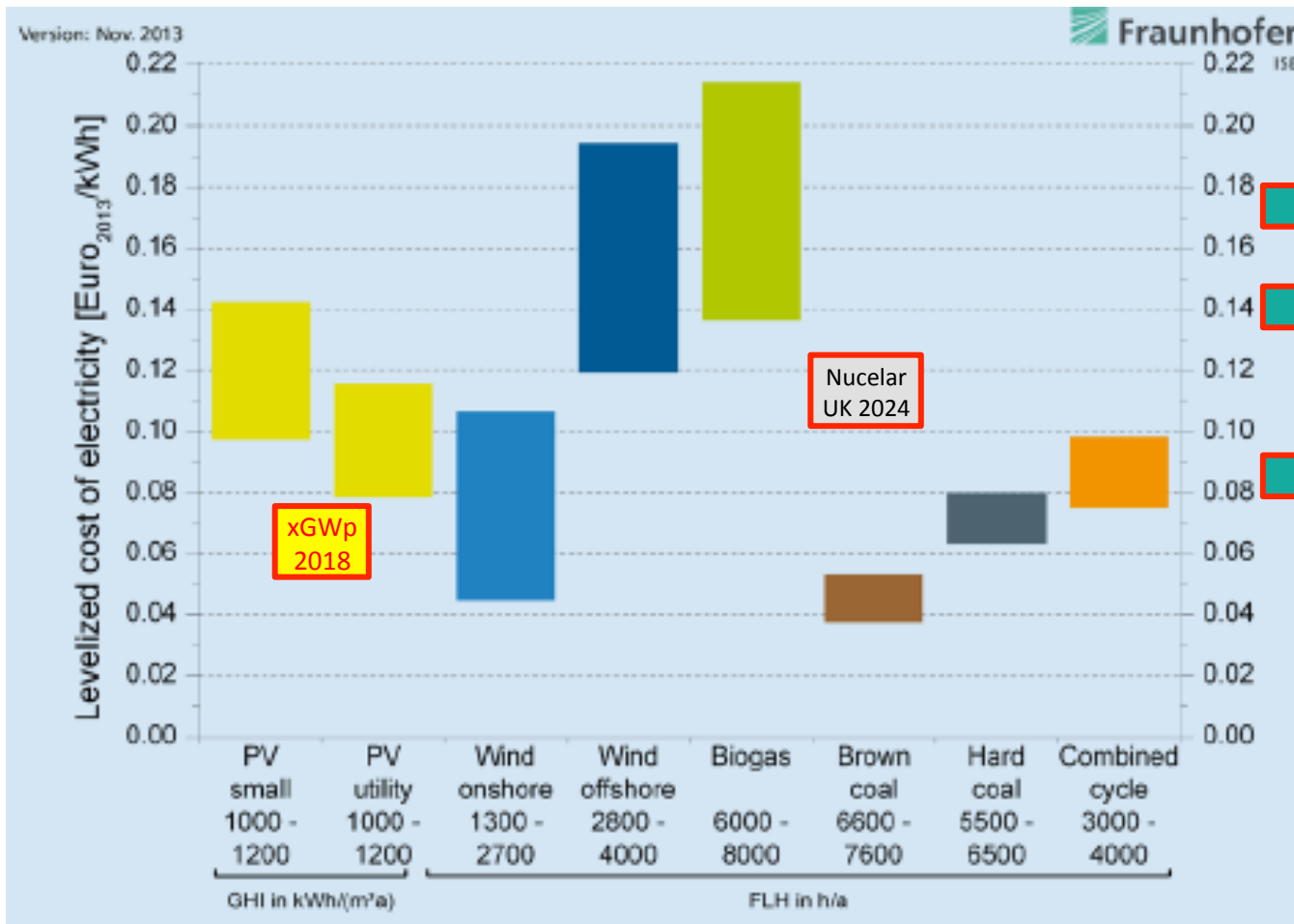


Source: Navigant / PSE 2013

Falling costs of ownership
over 6 years in Germany

The long-term PV experience curve:
Volume +100% → Price -20%
Prices may remain stable for some time...

Levelized Cost Of Electricity (LCOE): PV is rapidly getting very competitive



Worldwide 23% of electricity generation capacities are based on oil and Diesel

- Oil at 100 \$/barrel (only fuel costs)
- Oil at 80 \$/barrel (only fuel costs)
- Oil at 50 \$/barrel (only fuel costs)

LCOE with xGWp modules in 2018 (100kW plant)

Freiburg: ca. 6 ct/kWh

Sevilla: ca. 4,5 ct/kWh

→ Despite additional costs for managing fluctuation, PV power gets very attractive
However, markets need time to adapt.

Levelized Cost of Electricity (LCOE), Germany, 2013

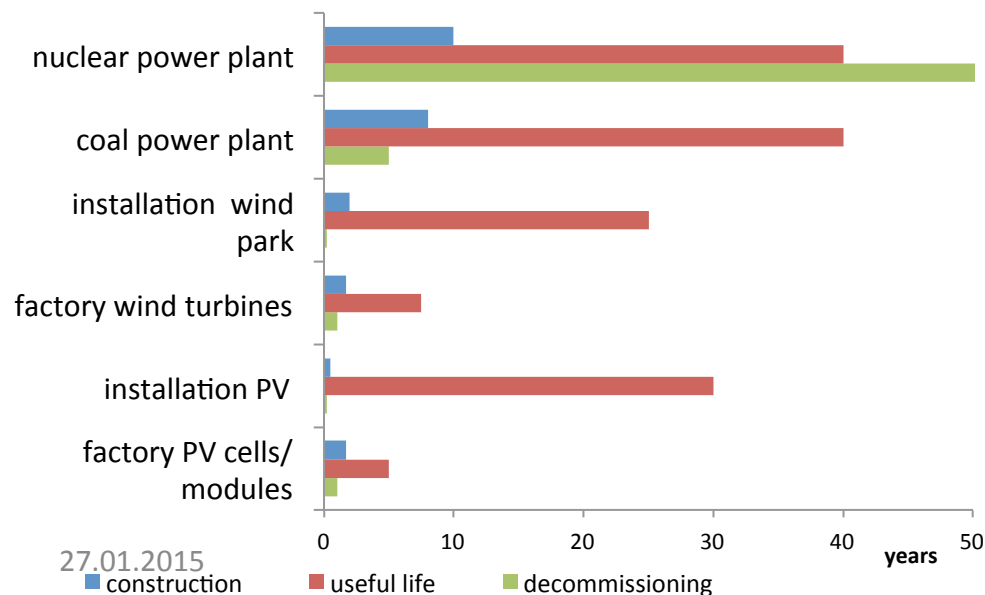
Source: Fraunhofer ISE, November 2013

Disruptive speed of change

A global market of over 100 GW in 2020 ?

Photovoltaics and power electronics show a disruptive speed of change

- Innovation cycles are 5-10 times faster than in conventional energy technologies
- Decision makers in industry and politics are struggling to adapt: diverging time horizons / decisive changes of price relations within months
- That's semiconductors, as we know them from IT
- Battery technologies are emerging at similar speed



- Increasingly Analysts and investors are discovering the new opportunities
- New manufacturing capacities are being built...
- Global market growth rates are estimated to be above 20% over the next years

Deutsche Bank Research, Jan 2014

Let the Second Gold Rush Begin

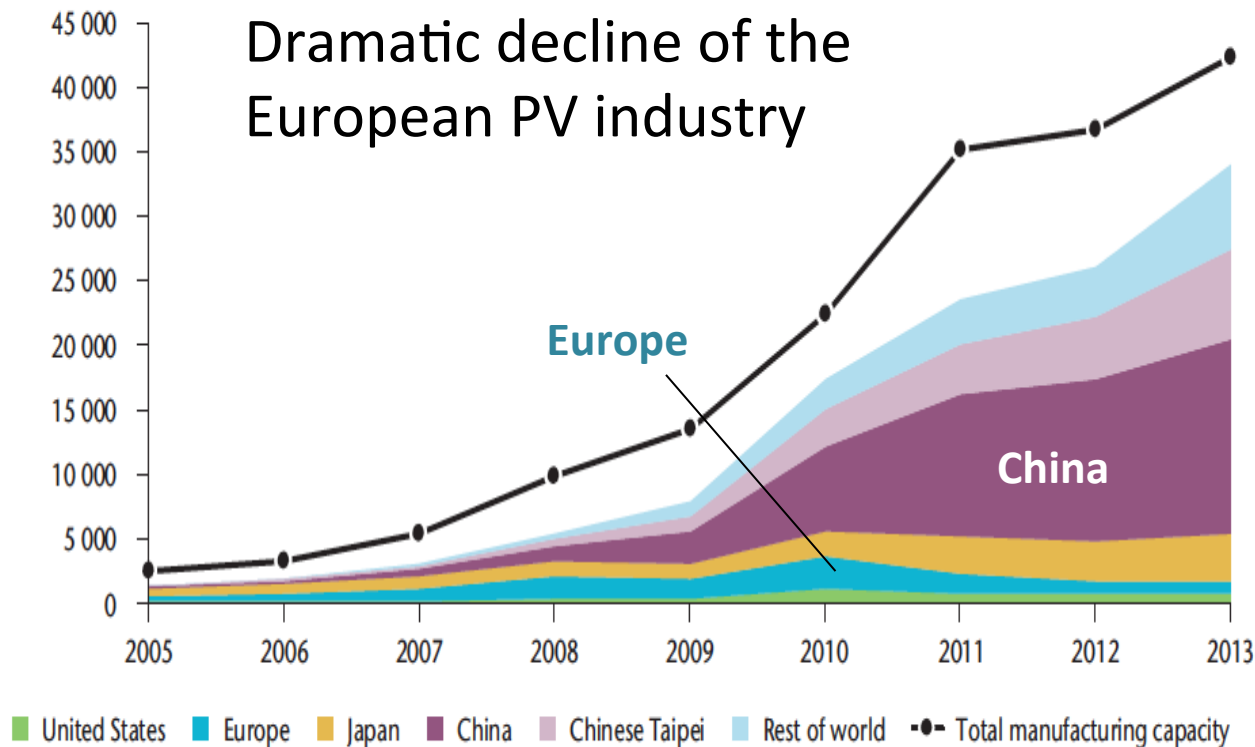
Demand Could Continue to Surprise to the Upside

While we have been generally constructive on the global demand outlook, we are raising our 2014 and 2015 demand expectations from 44.5 to 46.1GW and from ~52 to ~56GW respectively. We believe upside demand surprises from the US, Japanese and Chinese markets could continue in 2014. We expect a combination of streamlined incentive programs in China, additional subsidy cut signals in end 2014 and decreasing financing constraints to act as catalysts for upside demand surprises. While these 3 markets showed the most upside relative to expectations in 2013, we expect many more international markets to become meaningful growth contributors from 2014. Specifically, we expect India, South Africa, Mexico, Australia, Middle East, South America and South East Asia to all act as strong growth contributors. The majority of these markets are at grid parity and as such sustainable. Moreover, we believe some of the grid and financing constraints that have inhibited growth so far are set

EUROPE NEEDS BIG PLAYERS IN THE PHOTOVOLTAIC INDUSTRY

Europe was decisive in developing PV ! Really give up when it's getting a big thing ?

PV manufacturing by countries



Source: SPV Market Research (2014), *Photovoltaic manufacturer Shipments: Capacity, Price & Revenues 2013/2013*, Report SPV-Supply 2, April.

Source: IEA 2014

Turnover of PV manufacturers and manufacturing equipment providers in the EU:

2010: € 20 billion

2012: € 2,5 billion

- Top Five PV manufacturers: all Chinese
- Top Ten: no European company
- Japanese, Korean, US companies expanding

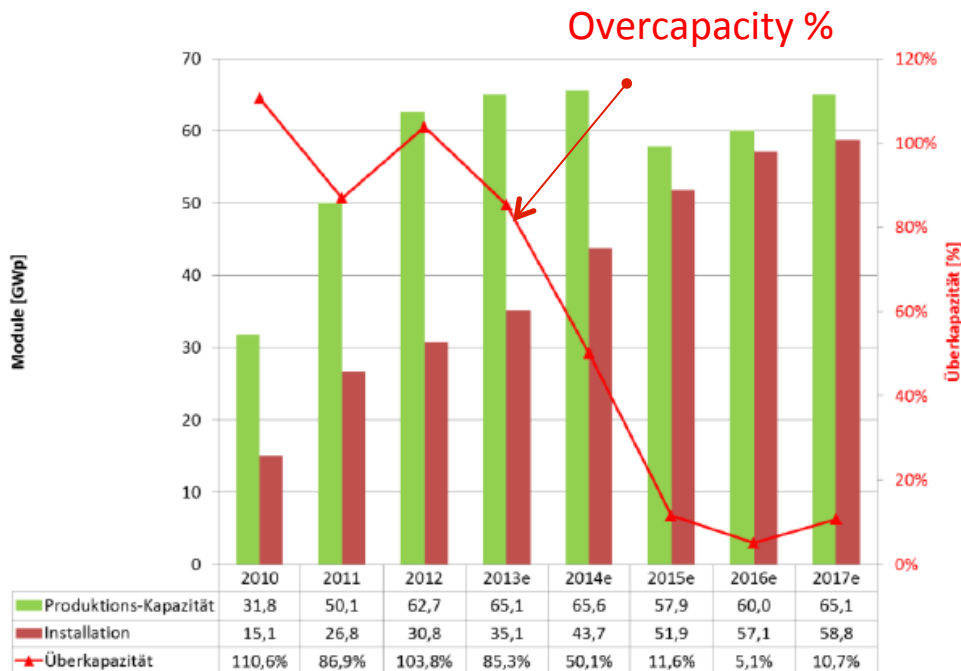
However, European Technology is still leading. For how long?

2017/18: The big opportunity for Europe

Shrinking overcapacities & new technology

The market is recovering from a heavy shakeout

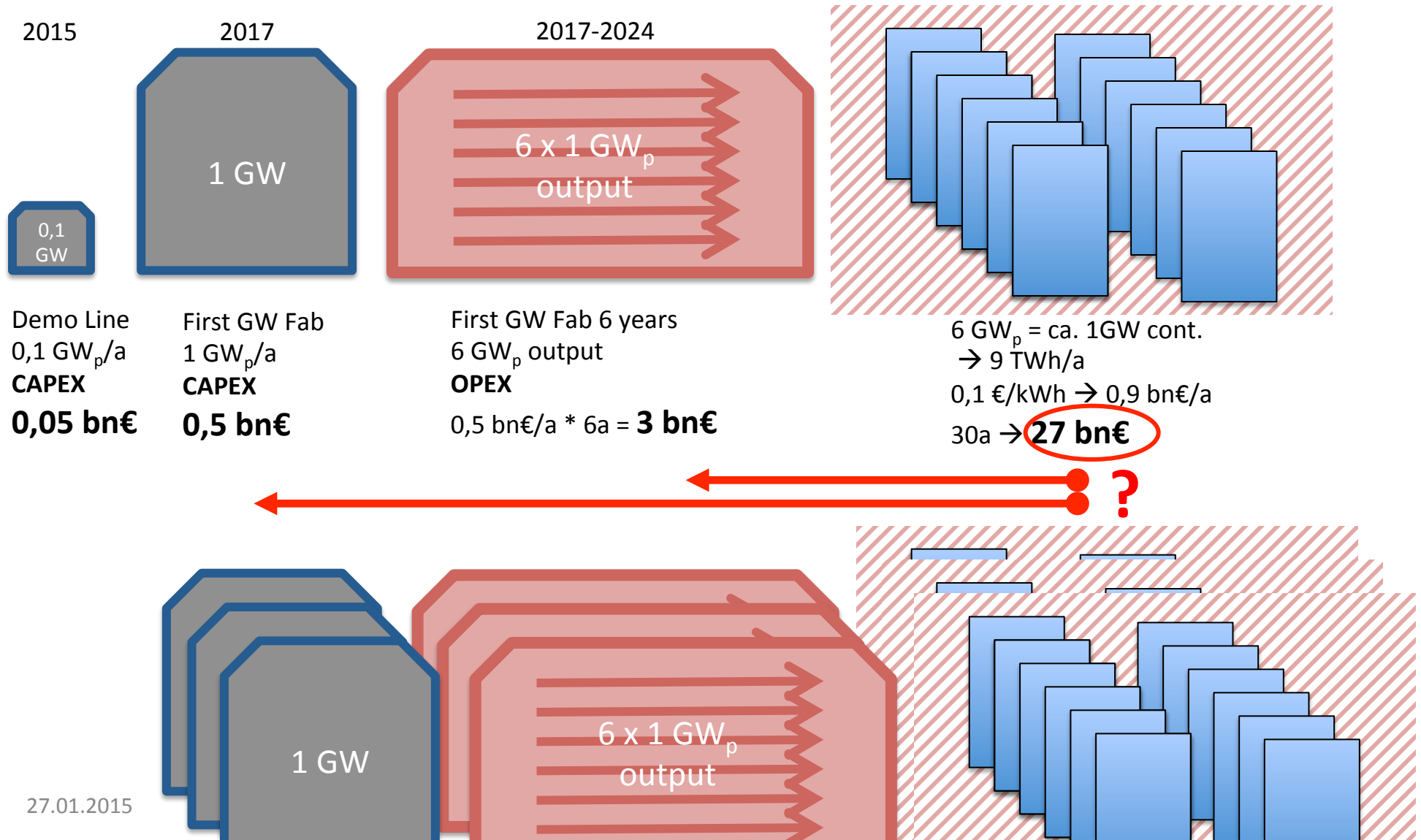
- Shrinking overcapacities → sustainable margins
- Massive growth ahead → opportunity for new approaches



New chance with new technology generation

- Large manufacturers rely on incremental improvement of present technologies
- The last large European manufacturer, **Solarworld**, invests in an upgraded high efficiency technology (PERC) which may ensure a good position for some years
- However, conventional c-Si technologies approach efficiency limit
- New ultra-high-efficiency technologies – mostly of the “Heterojunction” family – emerge in niche markets, but are still expensive
- High efficiency markets → high growth rates, no overcapacity
- **European Leaders united in xGWp have production-ready top technology package:** High efficiency, high quality, moderate cost, unprecedented low LCOE

The Challenge: Bringing downstream earnings into PV manufacturing



Why should politics support a PV Gigawatt Fab in Europe ?

A huge opportunity for technologies developed in Europe

- Europe has been at the forefront of developing PV market and technology when PV was not yet competitive
- European PV technology is still cutting edge – but at risk without manufacturers in the EU
- xGWp may be the last chance to regain an important share of a booming market

Essential for the transformation of the European energy system

- Photovoltaics will be one of the pillars of the future energy system.
- PV technology is a key enabling technology for the transformation. It will considerably evolve in the next years.
- PV needs to be integrated into smart energy systems. Europe needs the whole value chain

High value creation and employment effect

- Each year the EU spends ca. € 400 billion to import fossil fuels
- The high employment effect of substituting fossil fuels with solar power supply has been shown in many studies
- Supporting competitive PV manufacturing in Europe as the missing link in the value chain is one of the most efficient measures for employment and growth

A key approach for enhancing European energy independence

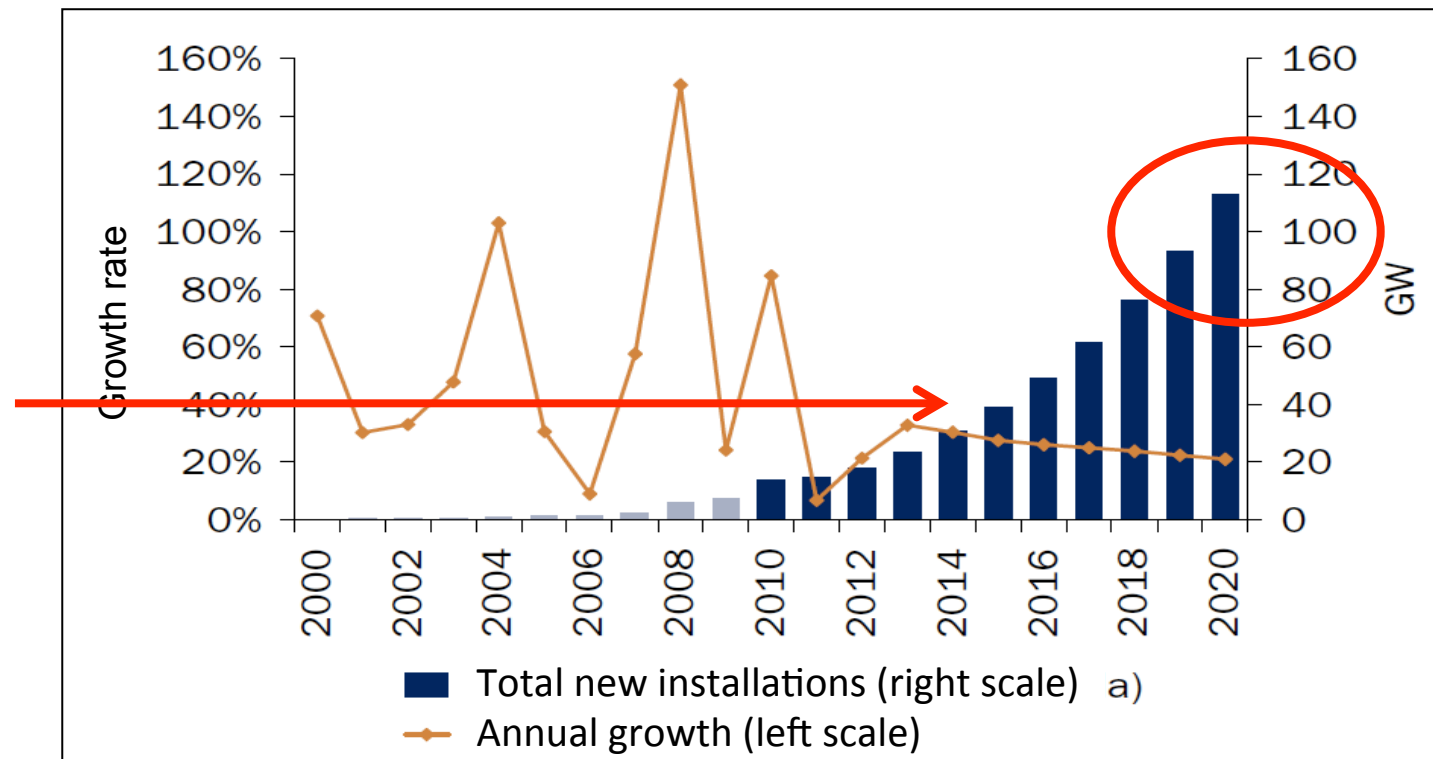
- With recent international conflicts, energy independence is back on the EU agenda
- PV with its fast deployment capabilities is able to quickly replace substantial shares of fossil fuel
- Substituting the TAP/TANAP pipeline requires 24 GWp (3 x German PV market in 2012) → expanding xGWp could deliver more quickly

World Market Outlook: Experts are Optimistic

Example Sarasin Bank, November 2010

- market forecast (2010): 30 GW_p in 2014, 110 GW_p in 2020**
annual growth rate: in the range of 20 % and 30 %

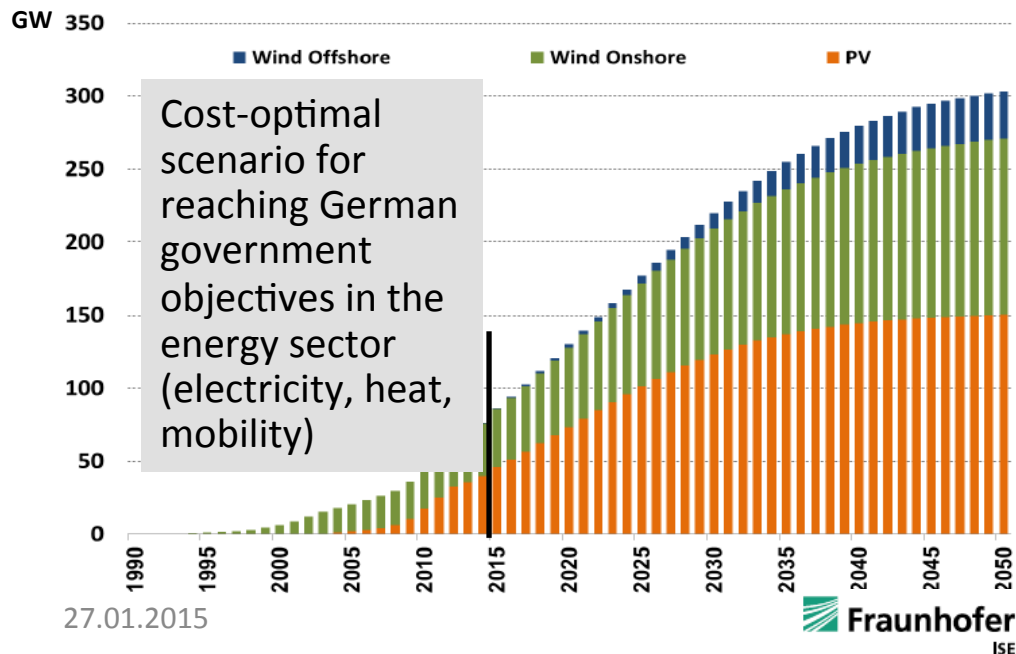
2014:
ca. 46 GW_p,
50 % above
forecast!



Least cost energy system & political targets require massive PV growth in the EU

Modelling the whole energy system in Germany

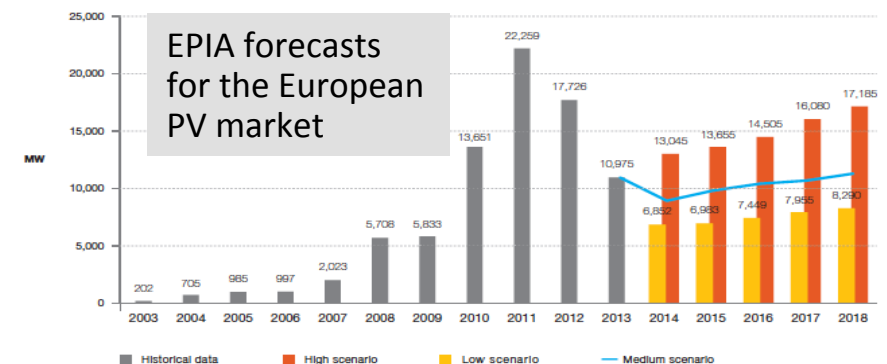
- Target: Reduce CO2 emissions by 80% by 2050
- Includes: electricity, heat, mobility
- Hour by hour modelling: considers fluctuations & storage
- Least cost solution: PV around 150 GWp in 2050
- Import savings soon nearly compensate invest
- Investments pay back: before 2040 the least-cost scenario starts to be cheaper than the fossil path



Translating the results to the EU

- The model has not yet been transferred to the European scale
- Rough guess for the EU scaling up German results in proportion to electricity generation:
- Installed PV required in 2050: 800 GWp
- average installation over the next 25 years: **ca. 30 GW/a** (not counting replacements)

➔ The EPIA scenario is far from being up to the challenge (max. 17 GW installations in 2018)

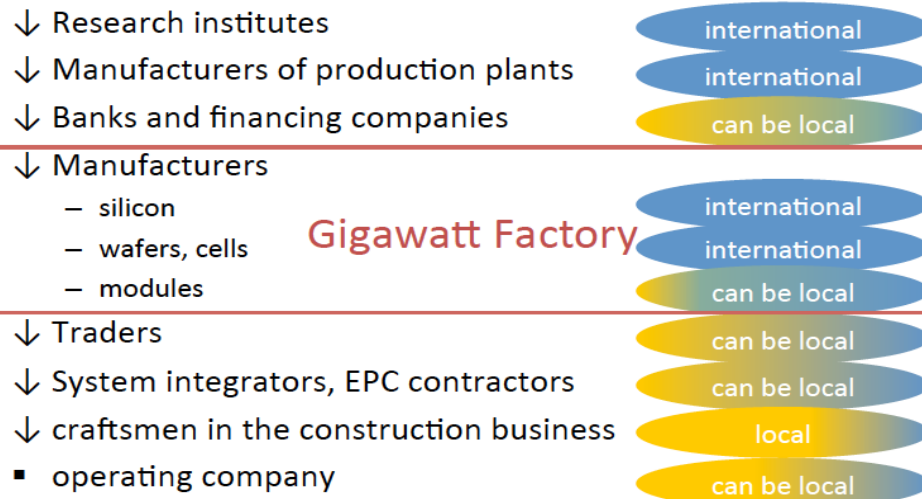


XGWP: CAPITALISING ON STILL EXISTING EU TECHNOLOGY LEADERSHIP

Whole PV value chain in EU is threatened: xGWp – Technology leaders take action

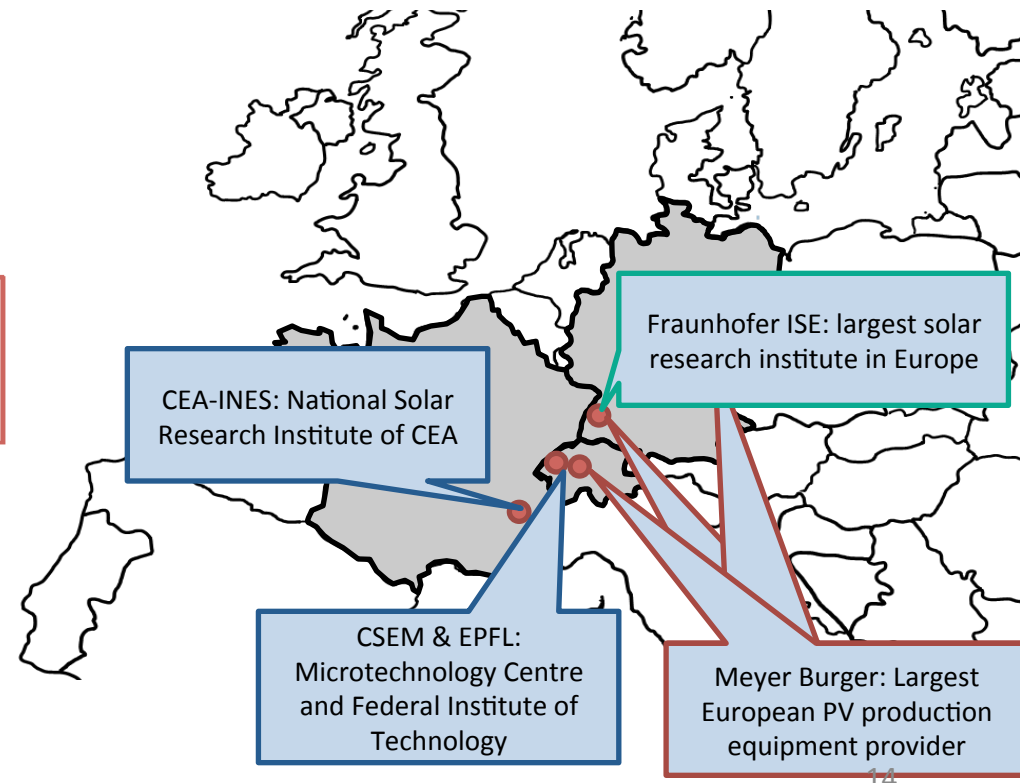
European technology leadership at risk:

- Missing PV manufacturing networks also threaten the future of research centres and equipment manufacturers
- China requests 80% local sourcing for manufacturing equipment
- Large manufacturers are buying downstream companies



2013: Technology leaders take action

- Founding Partners of an industrial initiative for a Gigawatt PV factory in the EU
- New technology generation: high efficiency, high quality, high speed, high volume, low cost



Innovation

VISION: European PV system industry as column of European energy transformation and competitiveness

Political innovation

- European cooperation
- Motor: Germany & France
- European innovation network

Business model innovation

- Industrial network
- Close partners downstream & upstream
- New business models

- leading research institutes directly involved
- Permanent high level of innovation

Entrepreneurial innovation

- **Cheaper Solar Power**
- Higher efficiency
- Lower costs
- Better characteristics

Product innovation

- Less material needed
- Less process steps
- Higher automation
- Higher quality

Process innovation

Technical innovation

- **Technological Package**
- Cells: Heterojunction
- Modules: Smart Wire
- Wafering: Diamond Wire
- Integrated process on large-scale machines

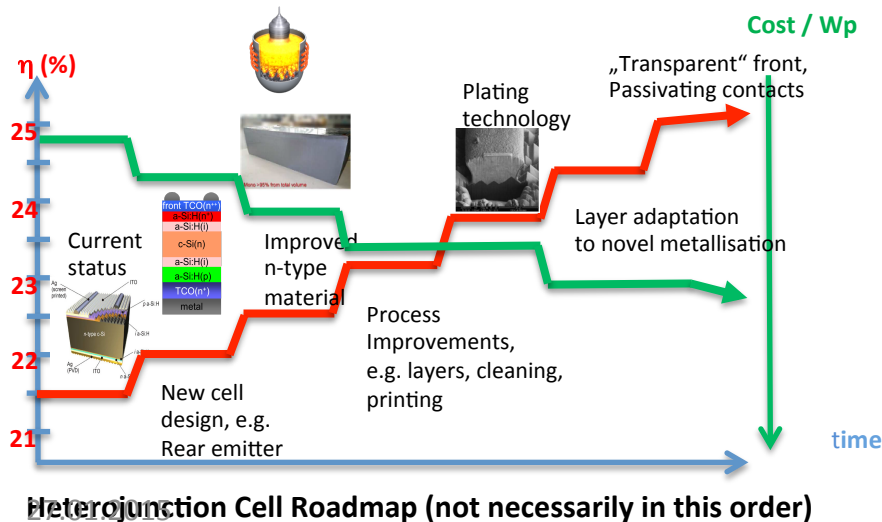
VISION: Disruptive PV with next technology generation

Combining experiences: PV silicon technology, microelectronics, nanotech

Starting with a winning technology package – and further improving...

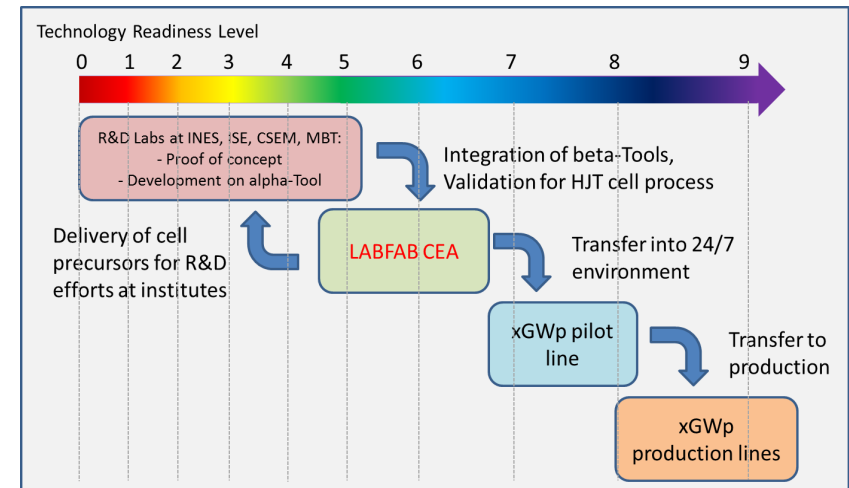
The technology package

- Core: a specific variant of the Heterojunction technology family (crystalline + thin-film silicon)
- Combination with diamond wire sawing of extra-thin wafers + Smart Wire Contacting Technology SWCT
- Excellent characteristics: high efficiency, low temperature dependency, good low-light sensitivity, very low degradation, long lifetime
- High throughput, high reliability equipment



Rapid further improvement with leading research institutes involved

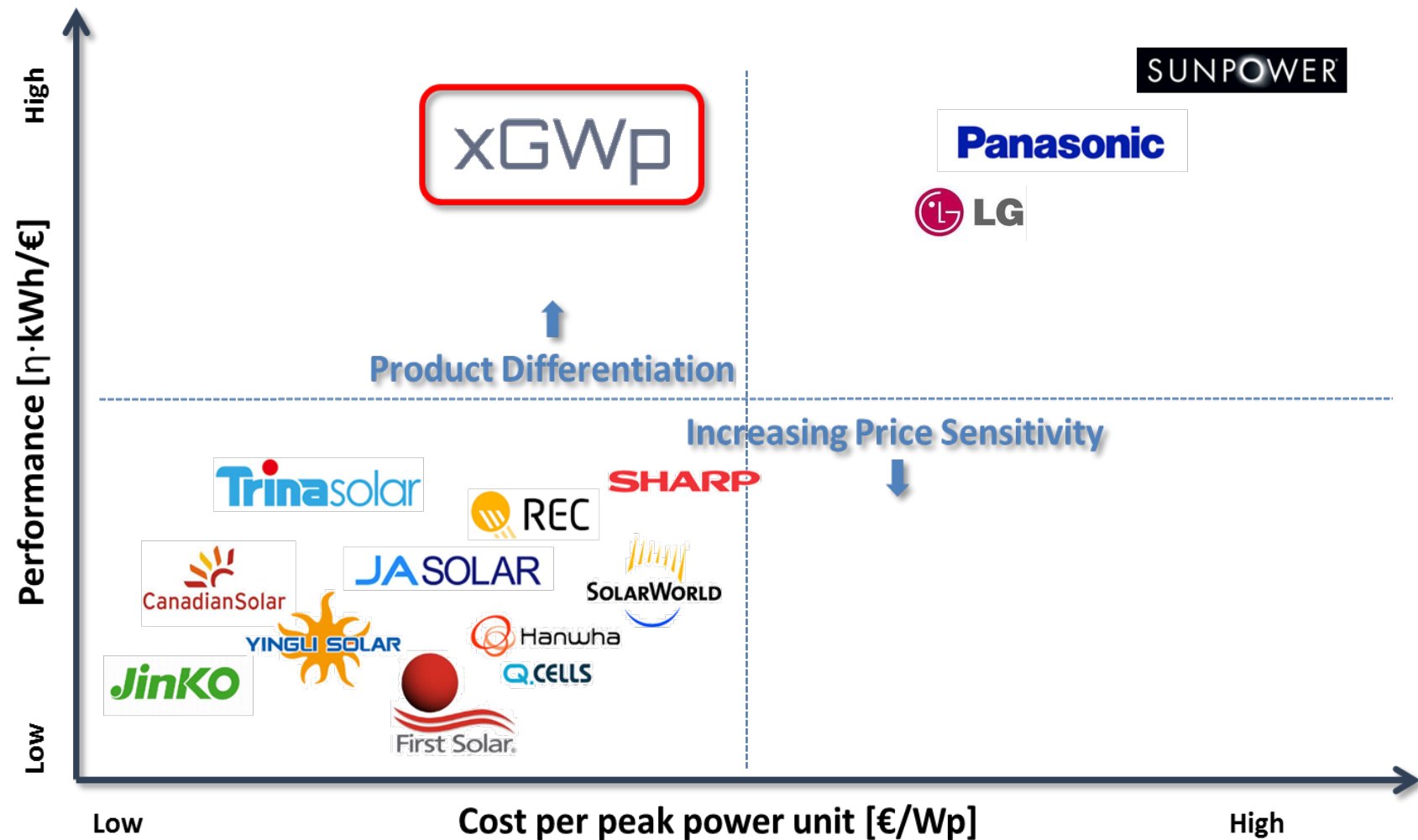
- Heterojunction (HJT) allows for important efficiency improvements without changing the equipment
- Present efficiency record 25,6% (Panasonic) under lab conditions
- xGWp has very low process costs – Good chances to keep the cost advantage through intensive research



Why xGWp will be able to resist global competition

- Process and product innovation: Novel technologies allow for high performance products at low processing costs.
- Production-ready highly efficient tools constitute advance over competitors
- Highly automated mass production with high volumes reduces costs
- Ongoing intensive cooperation of research institutes and industry allows to maintain leadership
- However: speed is key for keeping a cutting edge role

Positioning in the market



xGWp products are no commodity: Exceptional qualities, new system options

High energy yield justifies price premium

Several effects lead to a lower LCOE :

- High efficiency → smaller surface → less BOS
- Better low light sensitivity
- Less degradation
- Less efficiency loss at higher temperatures

These effects result in a justified premium on top of average market module €/kWp prices:

- Freiburg 2018: 27%
- Sevilla 2018: 31%

Additional potentials not accounted for

- Bifaciality (sensitivity on both sides)
- Longer lifetime: 40 instead of 25 years

Unprecedented low LCOE with xGWp 2018

100kW plant, monofacial, rooftop or ground mounted (larger plants less, smaller more):

- Freiburg: ca. 6 ct/kWh
- Sevilla: ca. 4,5 ct/kWh

27.01.2015

First PV noise barrier near Zurich with conventional bifacial cells. TMC calculated a potential of 1,2 GW in Europe for noise barriers (lower efficiencies)
© TMC



xGWp modules open new opportunities

- Low temperature dependence, high yield on small space, high aesthetic quality and variable geometry ideal for building integration (BIPV), integration into vehicles etc.
- Low temperature dependence ideal for use in hot countries
- High low-light sensitivity ideal for northern countries
- Bifaciality allows for completely new highly efficient system designs, e.g. on industry rooftops, vertical modules for maximum morning/evening yield etc.



Not yet efficient and elegant as could be: solar power for cooling, heating & the increasing number of assistance systems in all kinds of vehicles. (Example of a niche market)
© sunplugged 19

Project phases: rapid growth

- **2015:** Establishment and full-load operation of an industrial demonstration line of 90 MWp/a
- **2017:** Gigawatt Factory for wafers, cells and modules running at full combined capacity of >1000 MWp/a, probably at two sites (each > 500 MW)
- **Perspective:** rapid further expansion with more gigawatt factories and increasing downstream activities

Present planning stage

- Technology is ready for production. Phase 1 infrastructure & manufacturing fully planned
- Phase 2: detailed calculations & business plan

Capital required:

- Phase 1: ca. € 50 M
- Phase 2: ca. € 500 M

A profitable investment

- The first Gigawatt Fab is highly profitable and shows short capital payback times
- The demonstration line will not make losses

Initiators and investors:

- Initiators: Three leading research institutes: **Fraunhofer ISE** (DE), **CEA/INES** (FR), **CSEM** (CH). The leading European equipment manufacturer: **Mayer Burger** (with Roth&Rau). Singulus provides the chemical section.
- Main Investors:
 - x medium size companies ready for phase 1
 - x Negotiations with big financial investors for phase 2 under way
 - x Search for leading industrial investor (phase 2)

Partners for off-take

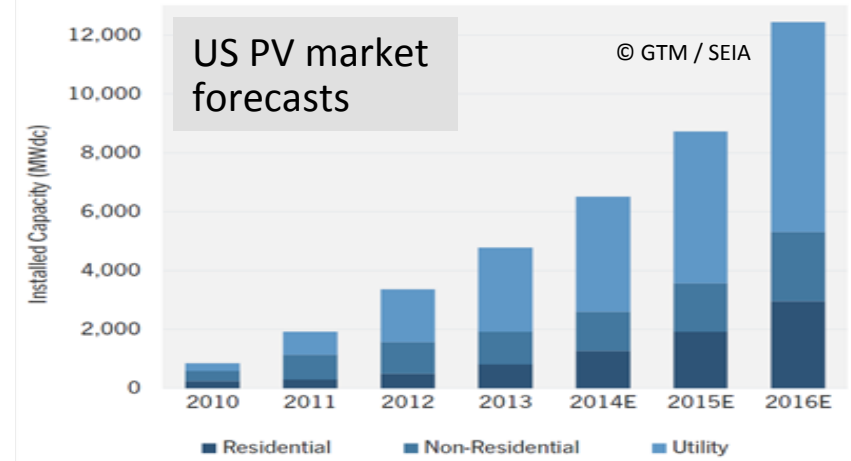
- Off-take for Phase 1: ok
- Talks with a series of interested off-takers and system development partners for Phase 2

WHAT CAN THE EU DO FOR FOSTERING EUROPEAN GIGAWATT FABs?

Focus on a clear PV development roadmap

Competitors are not sleeping.
The EU needs a determined effort
for re-conquering a leading role

1. Upgradig of present c-Si lines:
PERC, PERT, IBC etc.
2. Investing in the next wave:
**Heterojunction, SWCT,
Gigafactories**
3. Research & Development for
emerging technologies:
CIGS, CPV, Perovskite etc.



The US are waking up

- The US are now among the three globally leading PV markets, growing strongly
- Vertically integrated players play a key role: First solar, SunEdison, SolarCity
- Photovoltaics is a key field for “re-industrialising America”
- Example: SolarCity, sister company of Tesla, leader (39%) in residential solar installations, has bought PV manufacturer Silevo and builds a high efficiency Gigawatt Fab near New York. NY state helps with \$ 750 M

Overcoming the obstacles aligning R&D, industrial and energy policies

Speed is key

- Every year prices decline by 5-7%. xGWp technology is production-ready and must enter the industrial improvement process.
- Competitors are not sleeping, several are working on ultra-high-efficiency cells

A political signal is important for encouraging investors

- The energy sector still strongly depends on politics
- The up and down of PV market and PV industry policies in Europe has profoundly unsettled many potential investors. They are missing a stable outlook.
- There is money, there is interest, but not enough confidence yet.
- A clear political signal that PV and a strong PV industry are part of the energy future in Europe would trigger investments

EU commitments can help to overcome doubts

Most important:

- **Research grants for a demonstration line**
- **Loan guarantees and favourable credits from public banks**
- **Financing under Juncker's 300 billion investment program (xGWp is on the German project list)**

xGWp is the only sizeable, ready-to-invest industrial initiative for re-launching the PV industry in Europe in the upcoming next technological wave

It could be the decisive trigger for growing a thriving industrial ecosystem in the starting massive PV growth phase