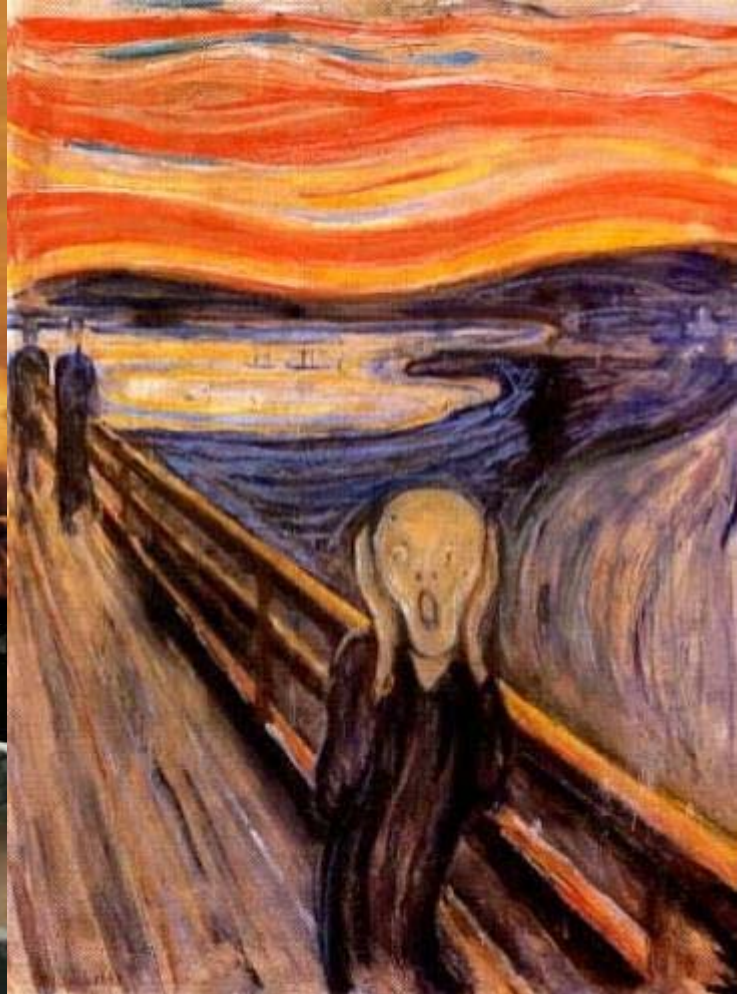




Solar cell technology – current status and challenges

Josefine Krogh Selj, research scientist IFE





Solar cells – status and challenges

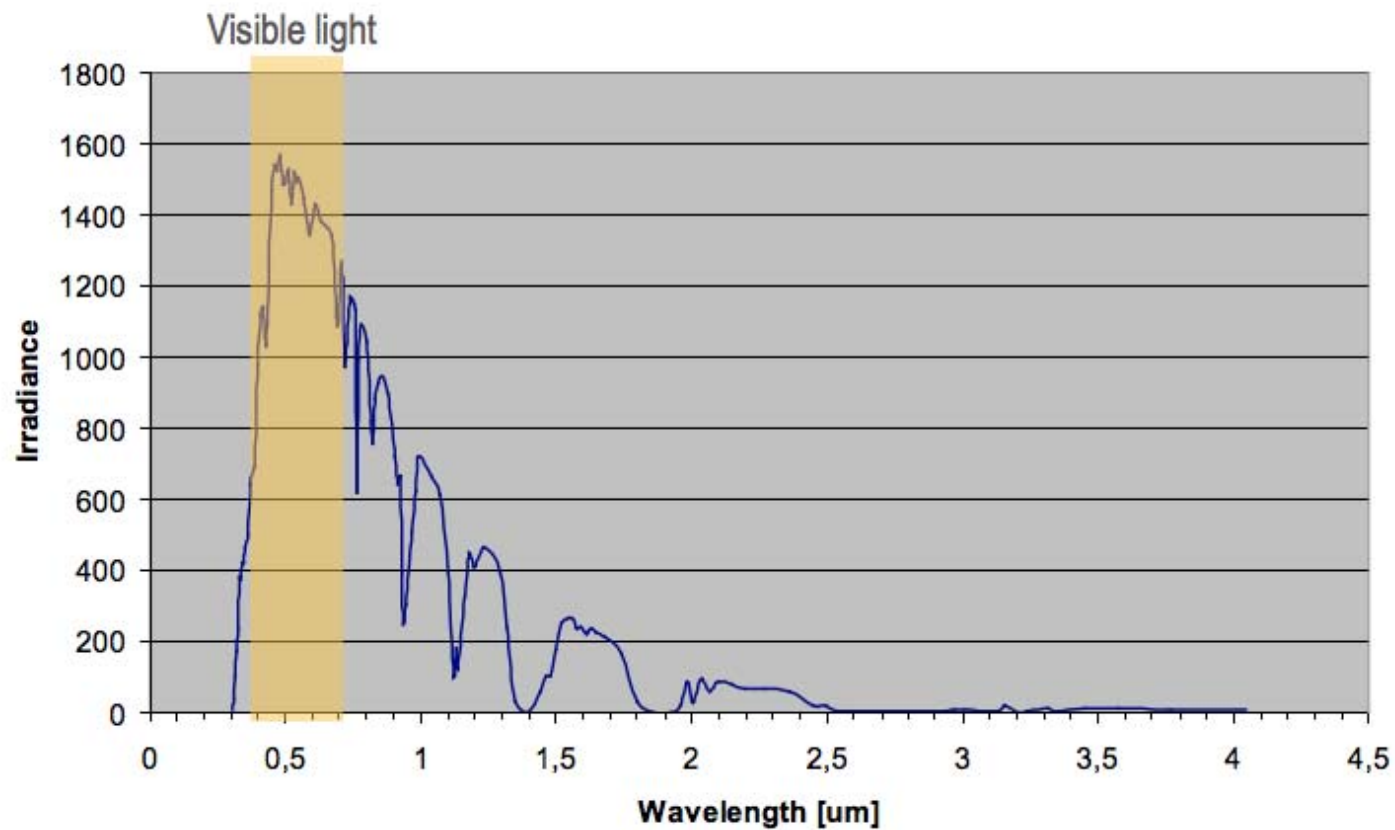
- The solar resource & why we (usually) cannot use it all
- Today's solar cell technology – facts and myths
- Tomorrow's urban power stations



The solar resource

15000 X!

The standard solar spectrum (AM1.5)



The solar resource

- + The biggest energy resource we have available
- + Renewable
- + Distributed (geographically)

- Variable (second, minute, hour, day, month, season, year)
- Distributed (geographically)
- Distributed (spectrally)
- Accurate prediction of electricity production requires insight



Solar is renewable, but that does that necessarily mean reduced carbon emissions?

Myth: Although there are no emissions during operation of a PV system, it is so energy intensive to make that it does not make a big impact on the carbon emissions.

Fact: The carbon emissions from PV is significantly smaller than that of any of the fossil fuels.

Solar is renewable





Solar is renewable, but that does that necessarily mean reduced carbon emissions?

Myth

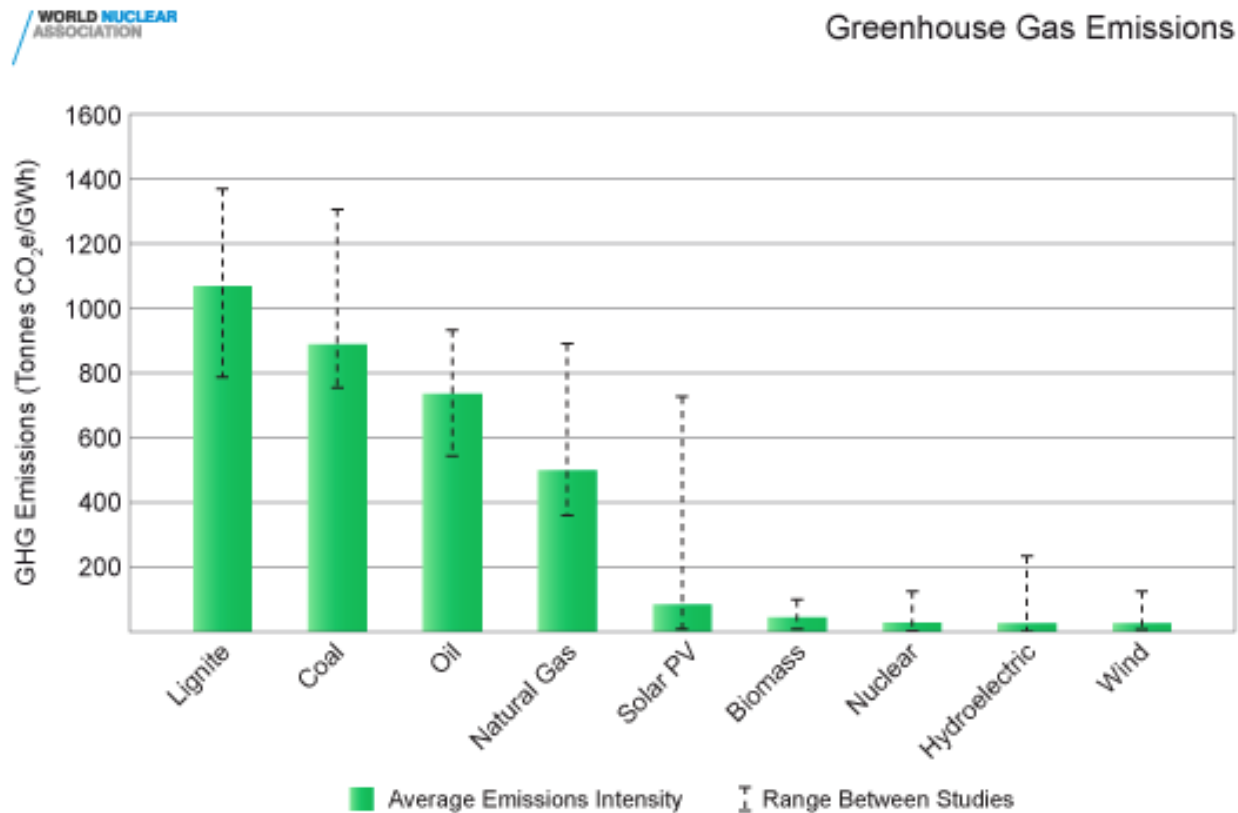
Myth: Although there are no emissions during operation of a PV system, it is so energy intensive to make that it does not really reduce the carbon emissions.

Truth

Fact: The carbon emissions from PV is significantly smaller than that of any of the fossil fuels.

But does renewable mean emission free?

- No, not emission free.
- But the reduction from emissions from fossil fuels is enormous:





How long must a solar module operate to produce the power it took to make the module?

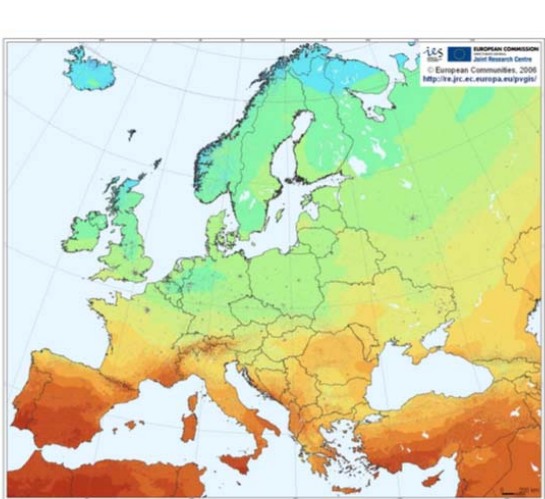
Myth: Solar cells are not helping the world to get more energy because we use too much energy to make the modules.



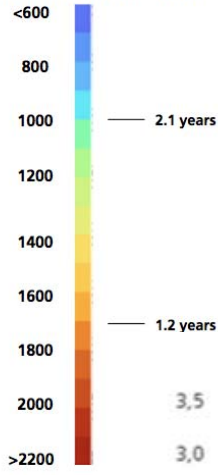
Truth

Fact: The solar module has produced the power used to make it within 1-2 years. The next 30-40 years is net production.

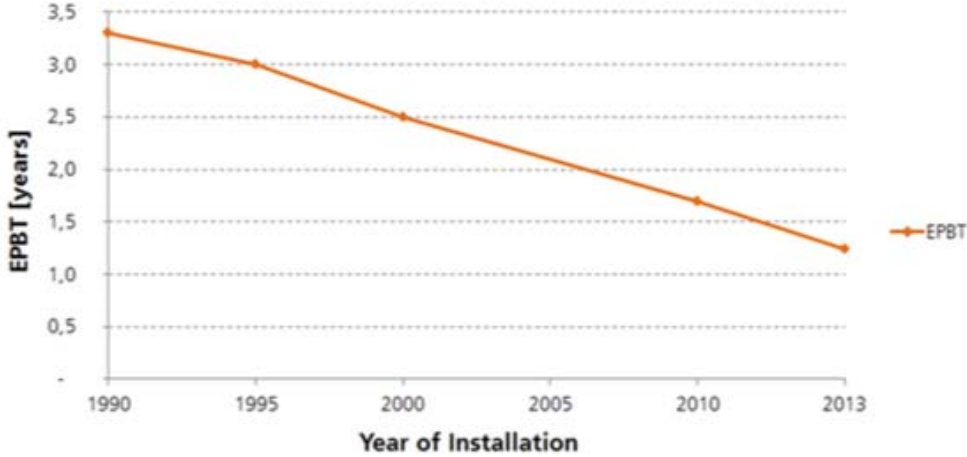
Energy pay back time: 1-2 years!



Irradiation (kWh/m²/a) EPBT



Data: M.J. de Wild-Scholten 2013. Image: JRC European Commission. Graph: PSE AG 2014 (Modified scale with updt:





The market **Myth**

Myth: Solar energy is an irrelevant technology with marginal effect on the world market

Fact: In 2015, solar energy covered:

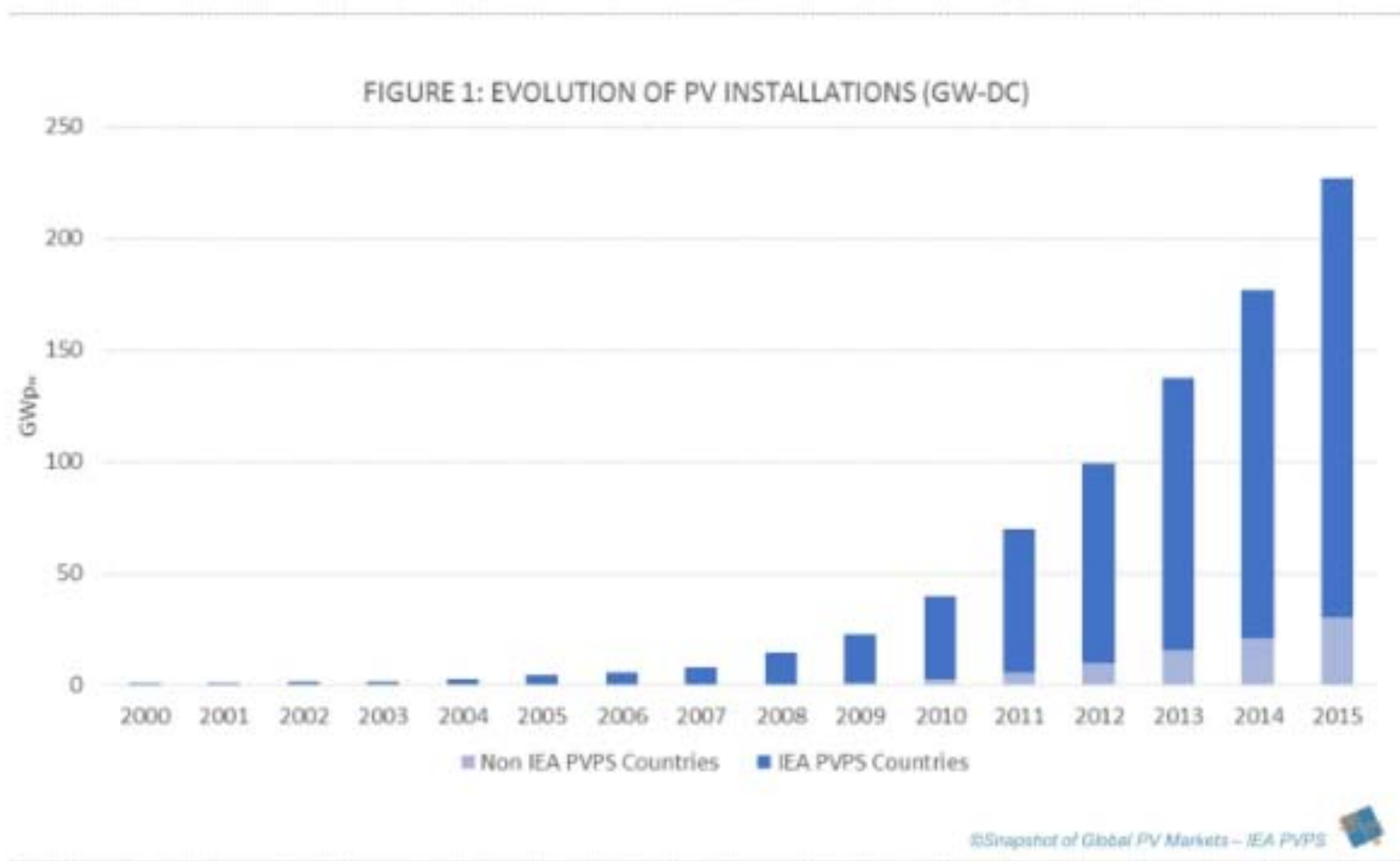
- 4 % of Europe's electricity needs,
- 8 % of Italy's electricity needs,
- 7 % of Germany's electricity needs



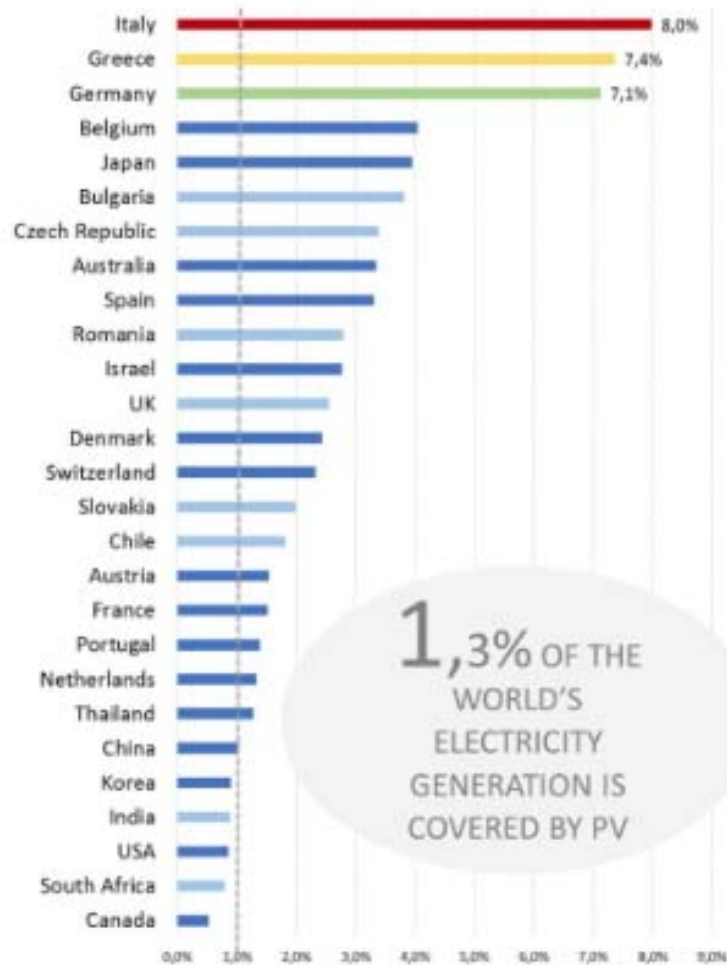
Truth

50 GW installed in 2015

1,3% of the worlds electricity generation covered by PV



2015 THEORETICAL PV PRODUCTION



1,3% OF THE WORLD'S ELECTRICITY GENERATION IS COVERED BY PV



227 GW has been installed all over the world by the end of 2015



China is the world's 1st PV market



23 countries had at least 1 GW of cumulative PV capacity at the end of 2015



7 countries installed at least 1 GW each in 2015

SOLAR PV PER CAPITA 2015 Watt/capita

1 st			491
	GERMANY		
2 nd			308
	ITALY		
3 rd			287
	BELGIUM		

©Snapshot of Global PV Markets – IEA PVPS



Market

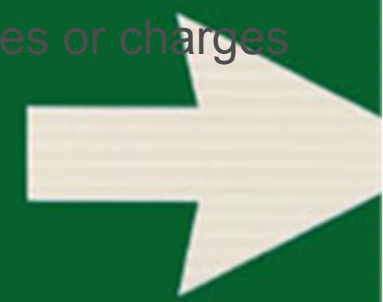
Myth

Myth II: We cannot integrate more intermittent energy in the grid

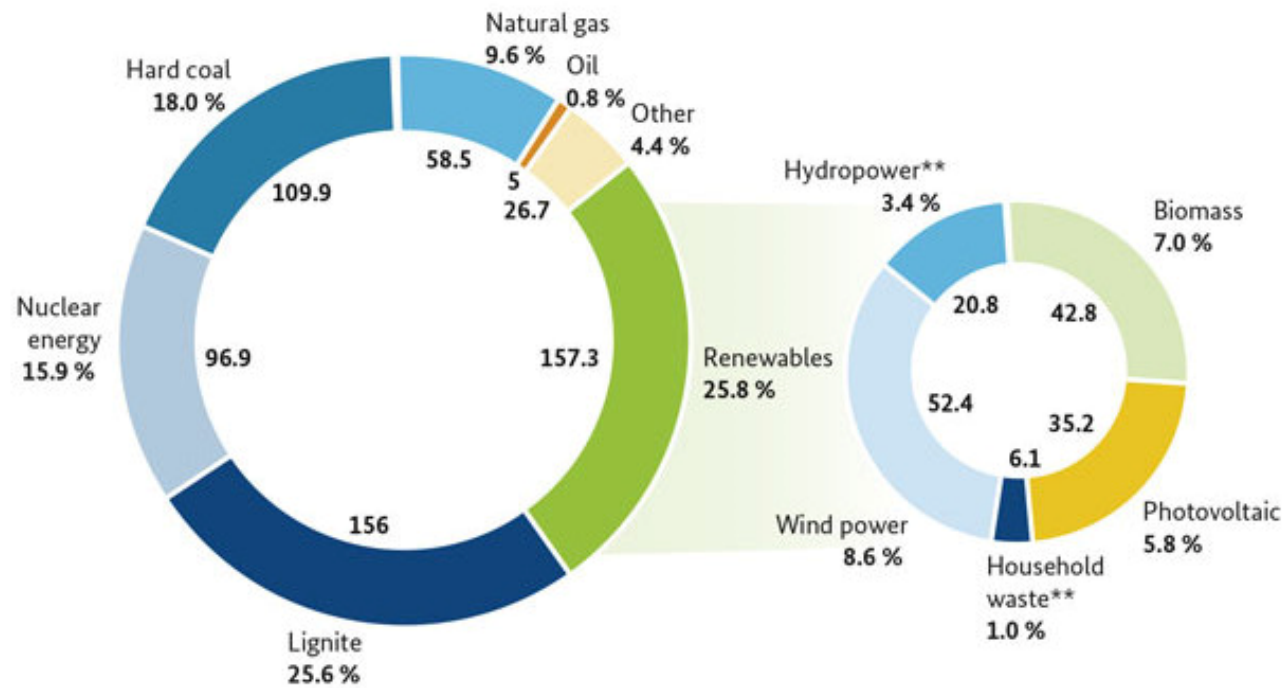
Fact: There are many excellent ways of integrating more renewable, intermittent energy in the grid:

- Smart use (house hold appliances, cars, etc. which operates or charges when there is available current in the grid)
- Increased use of batteries
- Improved transmission grids
- Wind and solar are somewhat complementary

Truth



Germany – the largest installed capacity in the world ... and one of the most stable grids



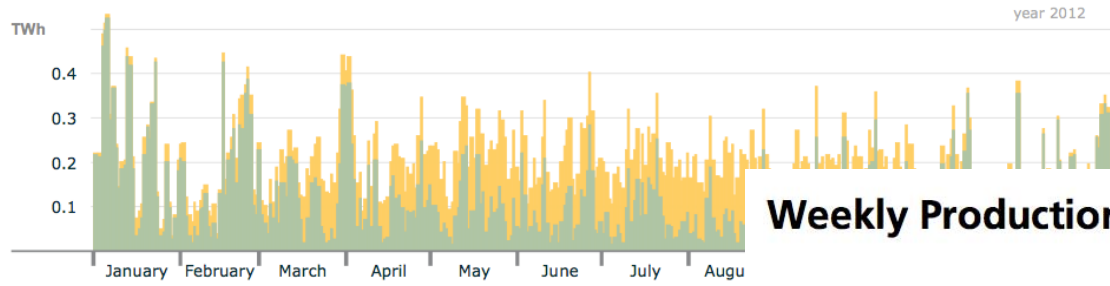
* Preliminary figures
 ** Regenerative part

Eike Weber at director at Fraunhofer ISE:

”The German distribution grid is *more* stable today than before the intermittent renewables was introduced.”

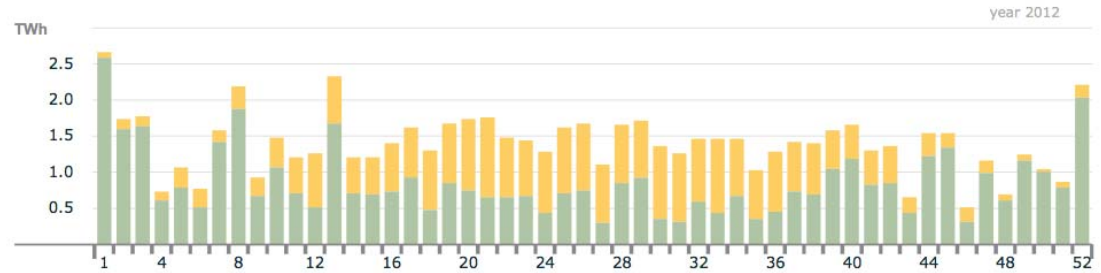
Daily production Solar and Wind

Daily production Solar and Wind



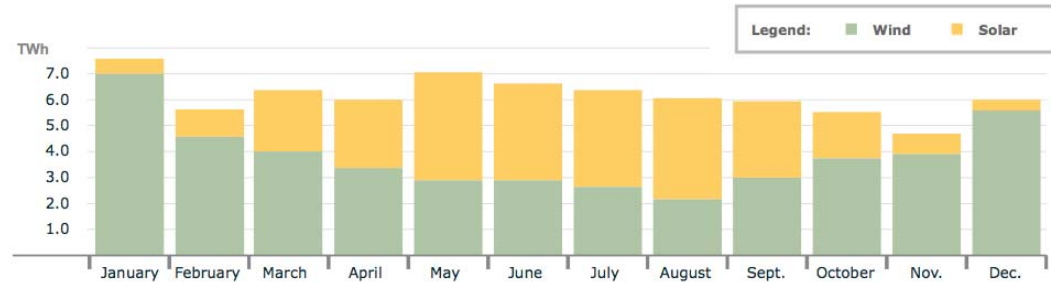
Weekly Production Solar and Wind

Weekly Production Solar and Wind



Monthly Production Solar and Wind

Monthly Production Solar and Wind



Legend: Wind Solar

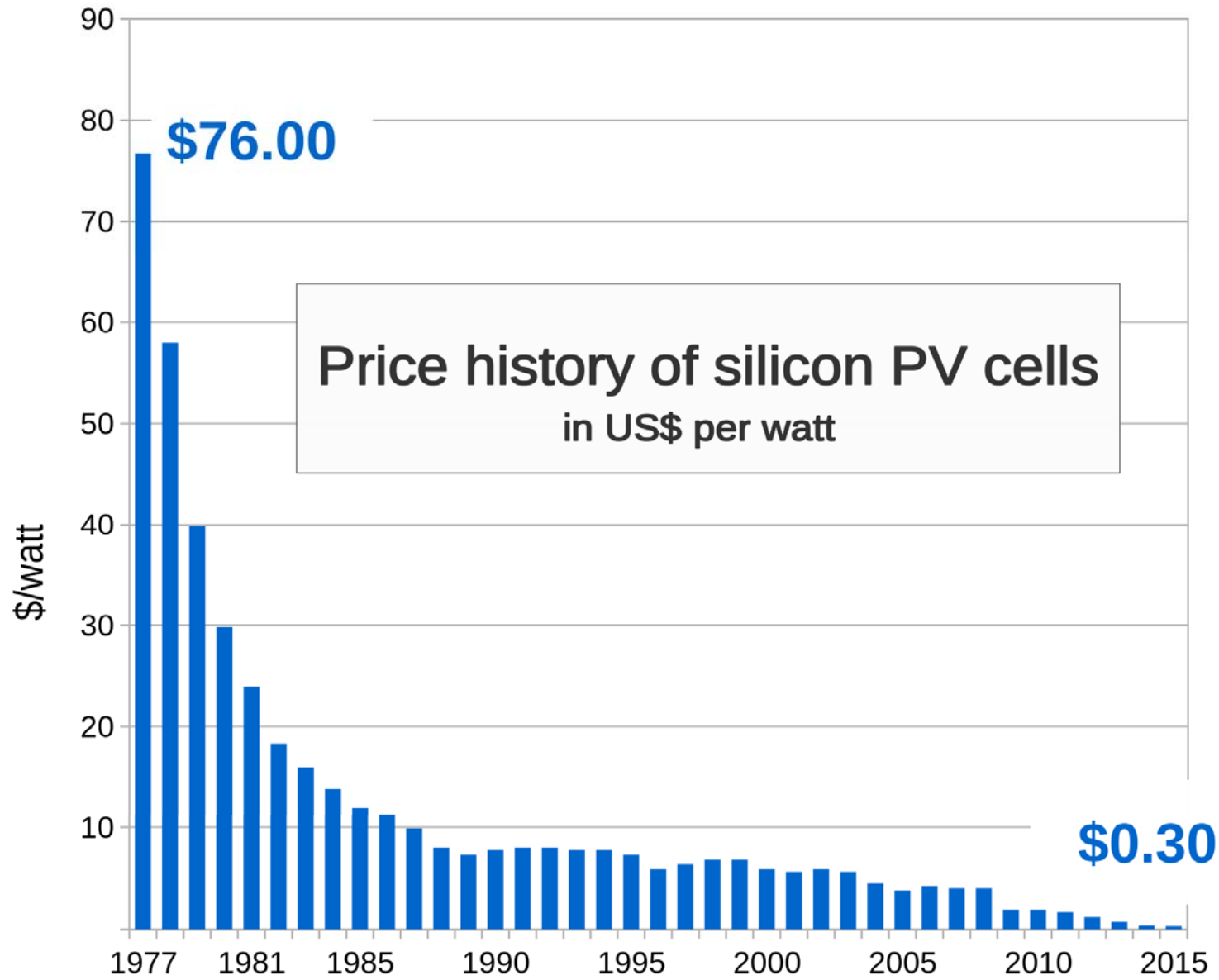
The cost

Myth

Myth: Solar energy is too expensive

Fact: Solar energy *was* too expensive

Truth



Source: Bloomberg New Energy Finance & pv.energytrend.com



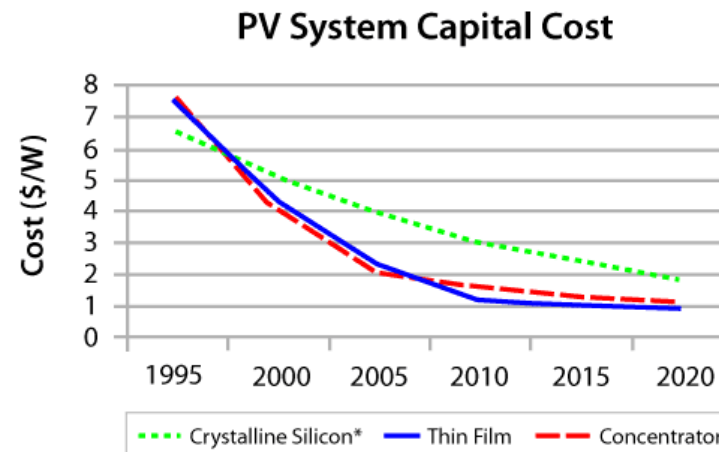
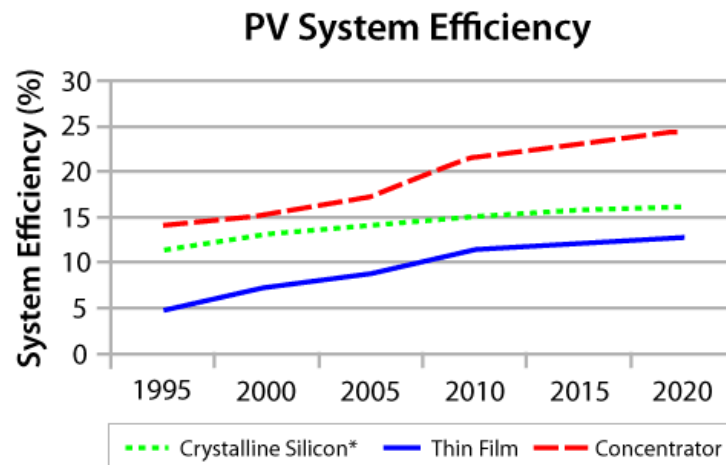
Solar cell and module efficiency

Myth: There is no point in installing PV now because the technology development is so fast it will be outdated tomorrow.



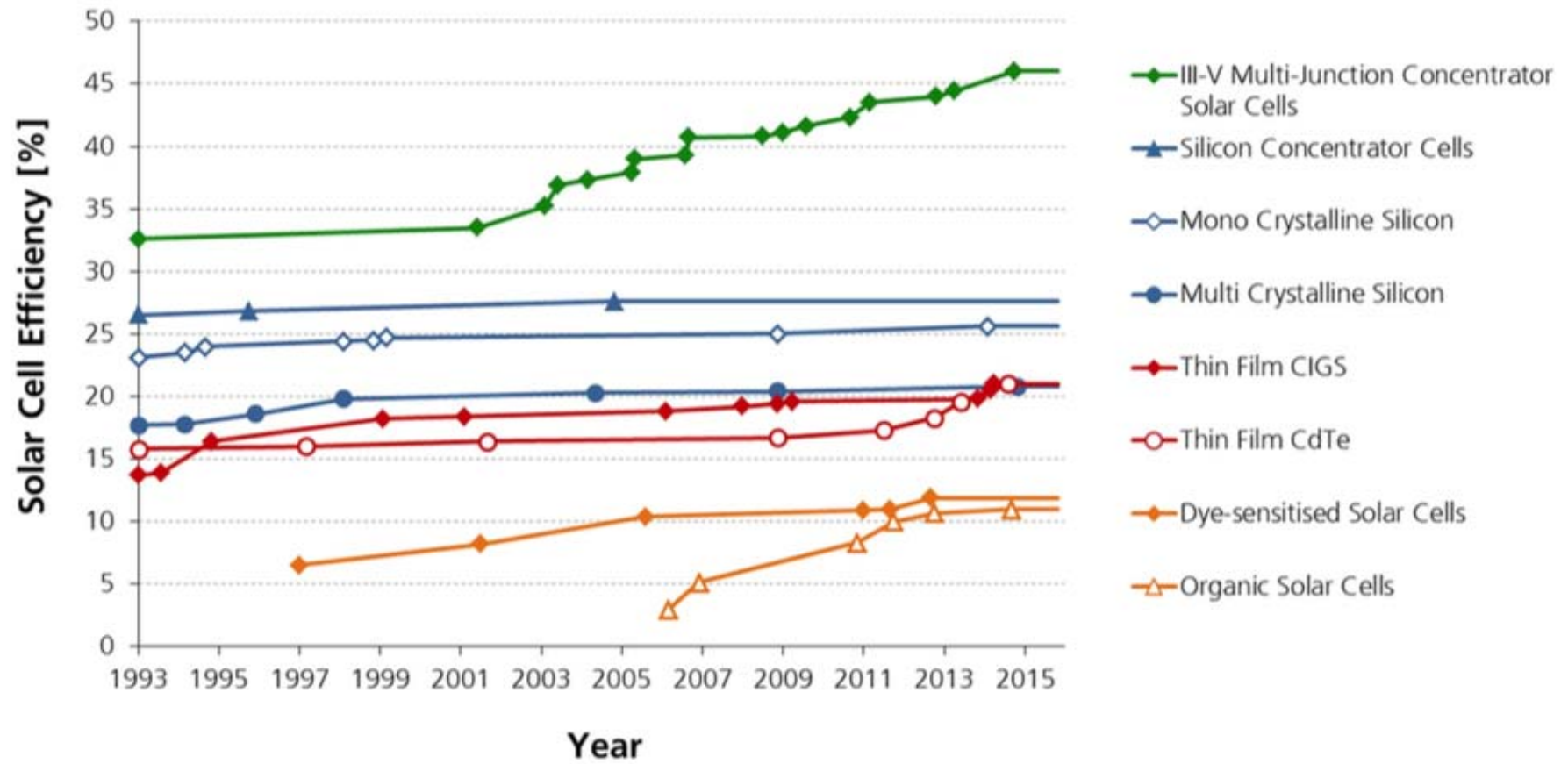
Fact: PV is a mature technology. The development will happen gradually, and today's solar cells are VERY GOOD.

Important, but gradual technology development

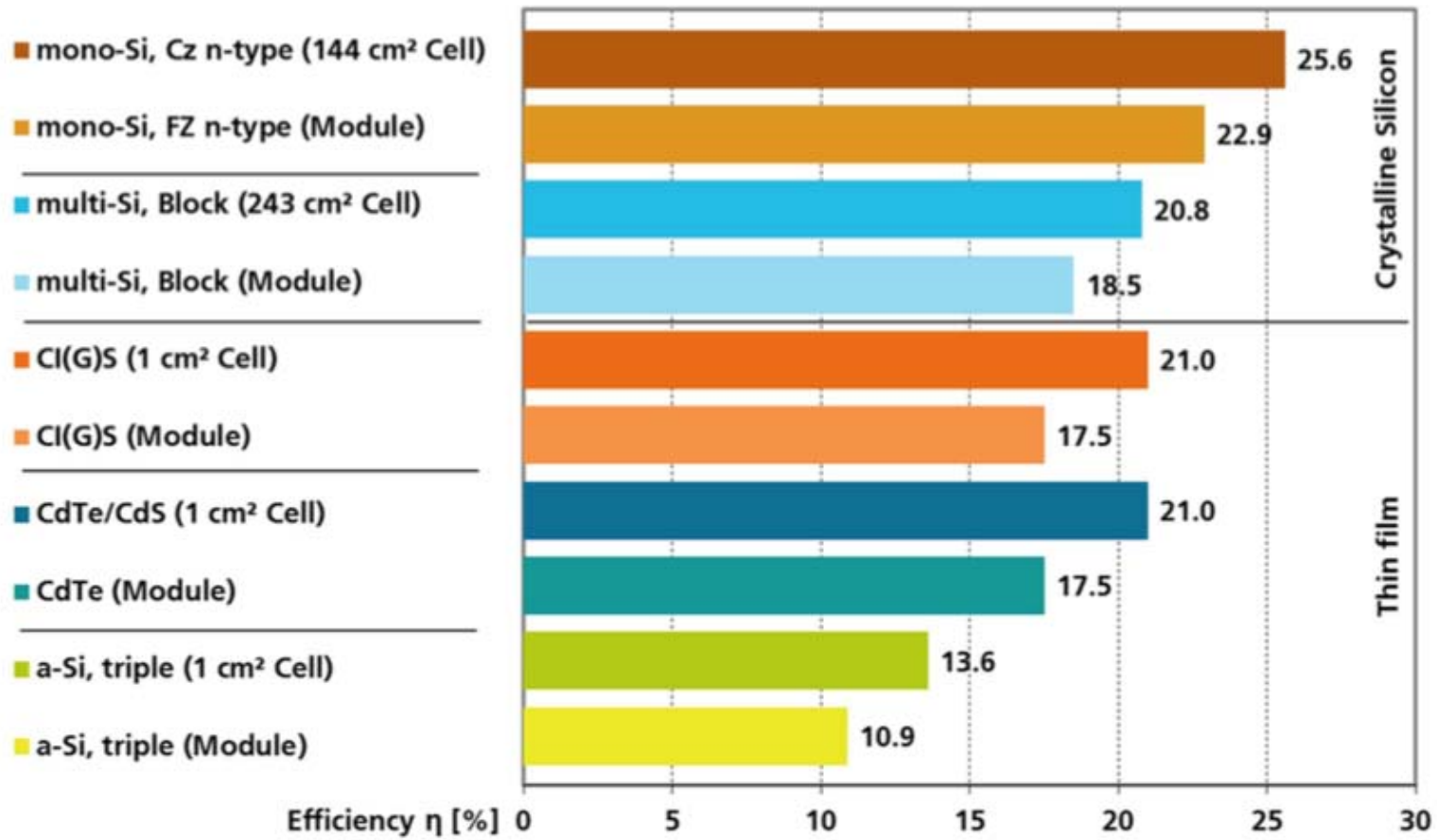


- I 2018:
 - Invertere: 20-30% billigere
 - Solcellepaneler \approx 30% billigere²
 - Solcellepaneler \approx 10% mer effektive²
 - 30 års garanti på panelene?
 - Lønnsomt med batteri/lagringsløsning?

Kilder: ¹US Department of Energy ²International technology roadmap for photovoltaics 2015,

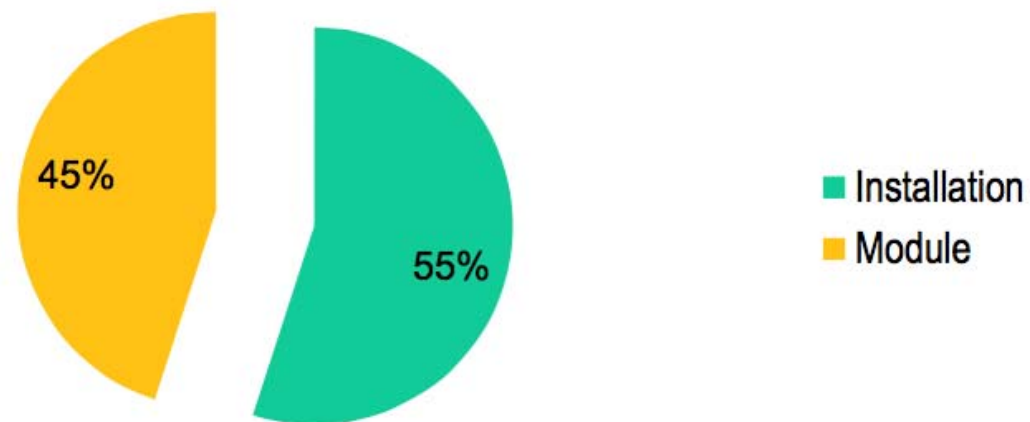


How efficient are the today's solar cells?



Efficiency *matters!*

Cost fraction

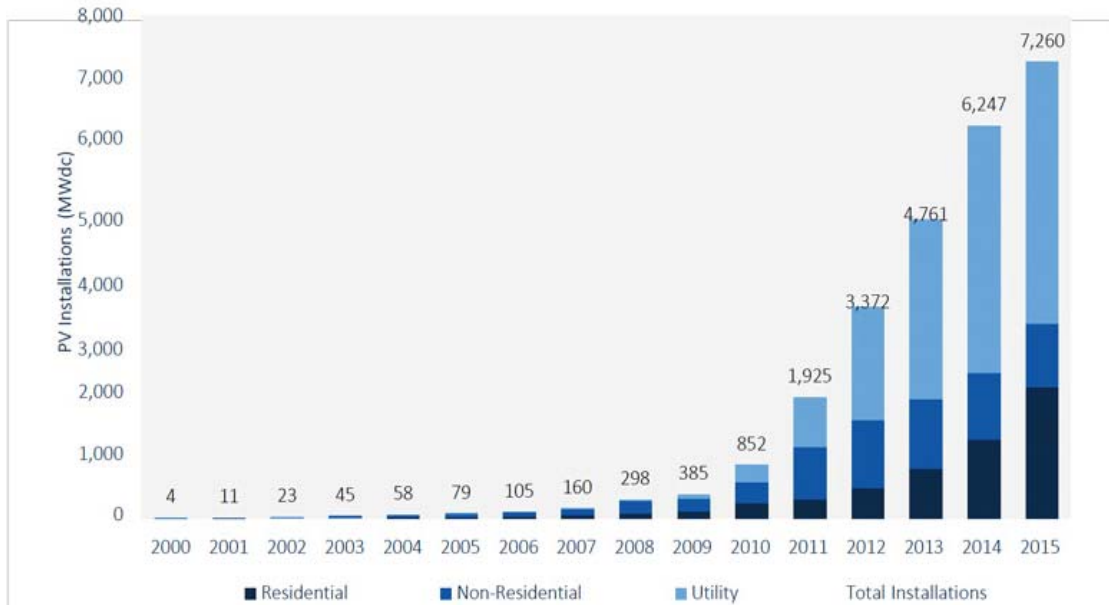


Solar cell technology today

- Crystalline silicon completely dominates the market
- Efficiencies continue to increase
- Solar cells are now increasingly mainstream
- Solar electricity costs make it competitive in many markets
- Subsidies have been crucial
 - Sufficiently large markets
 - Predictable price development
- Solar cells impose a new electricity market structure
 - Power plants are often small and privately funded
 - Increased awareness among customers
 - Variable electricity prices
- Solar electricity might become our largest electricity producer

How do we install them?

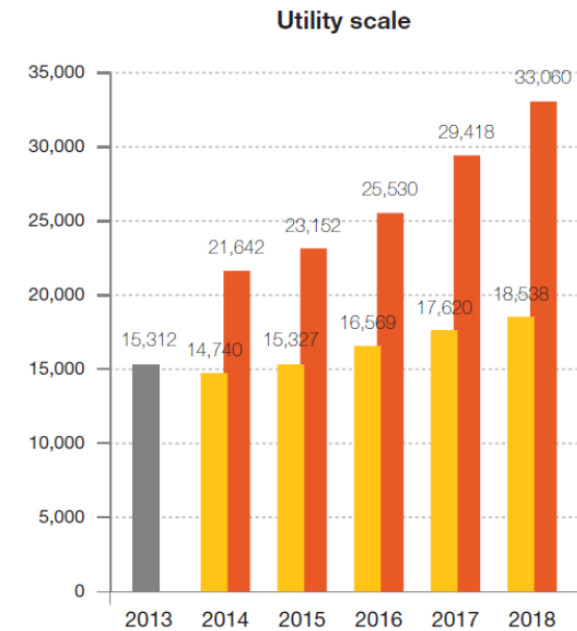
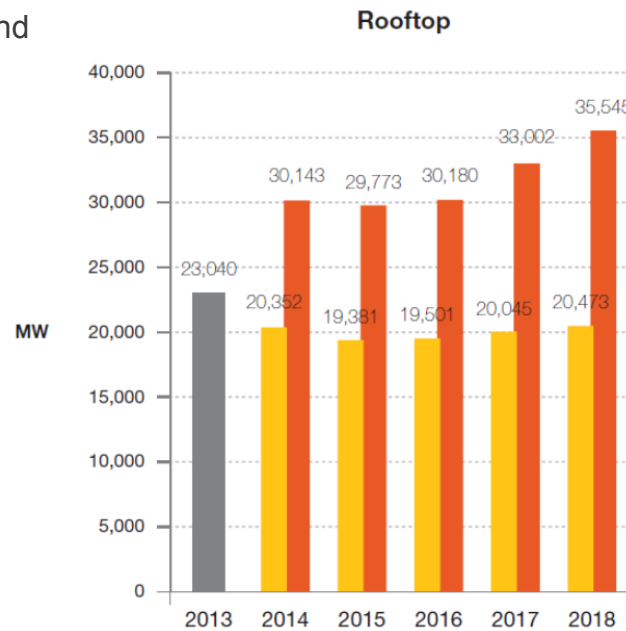




← US market
(annual installations)

↓ Global market
(annual installations)

Source: GTM research and SEIA



Source: EPIA 2015, p43.

Why rooftop, why BIPV?

- Drivers
 - increased focus on renewable energy
 - the green building movement in the construction sector
 - buildings consume 40% of electricity in Europe

Benefits of building integration:

1. Production where it is used
2. Available space
3. PV modules can be used instead of conventional building elements
-> potential cost saving
4. Aesthetics

Should we settle for this?

This is building adapted PV (at its worst)



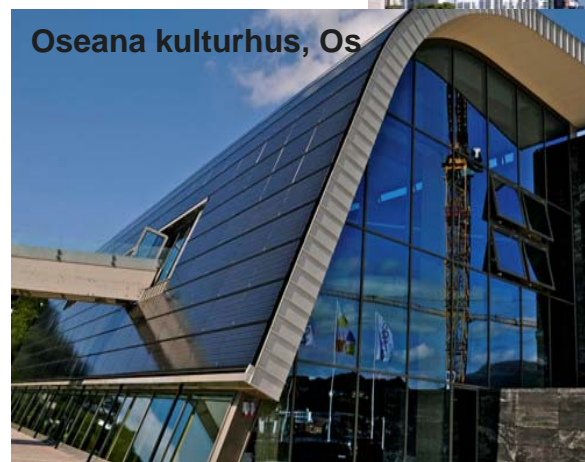
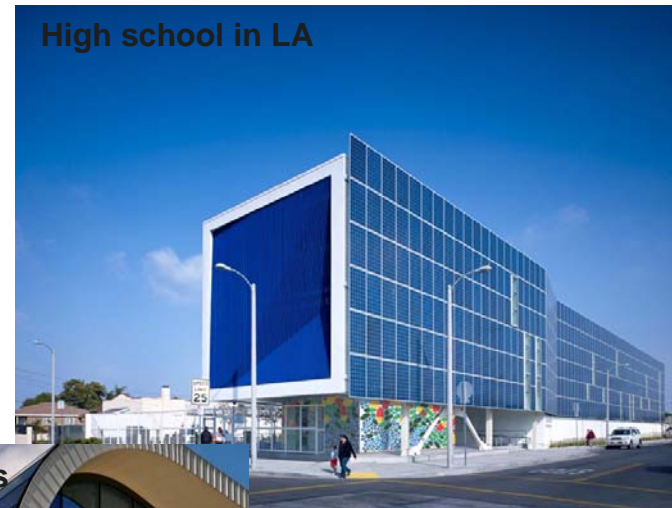
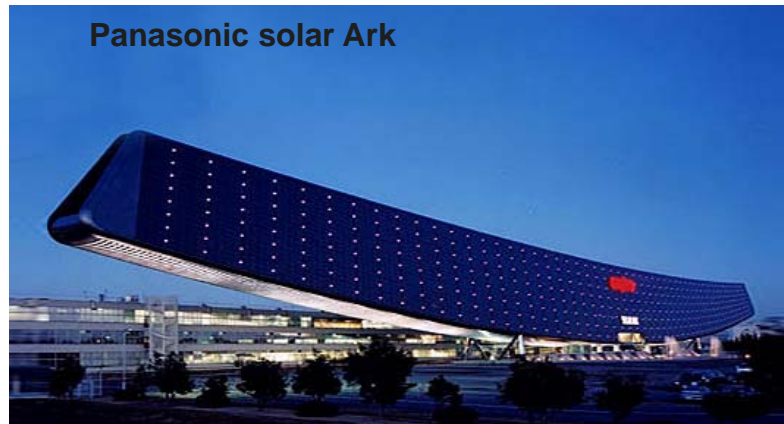
BAPV can look just fine...



BIPV can be aesthetically very pleasing



And give some nice opportunities for architectural design



Tomorrows urbane solar power station



26.05.2016



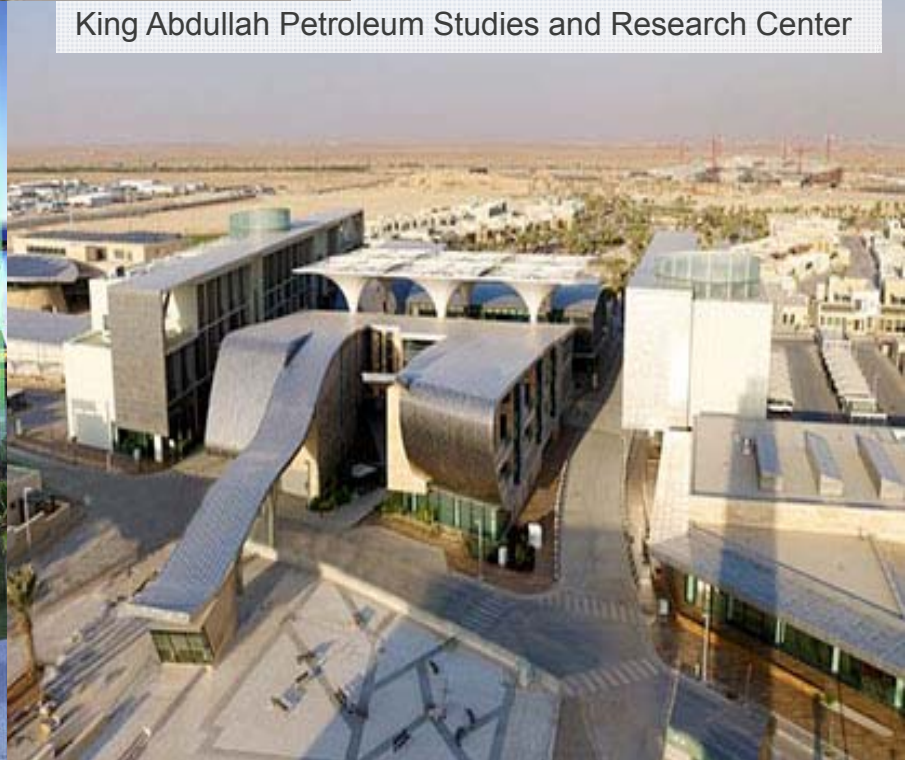
OsloSolar



Power station!

Masdar, Abu Dhabi

King Abdullah Petroleum Studies and Research Center



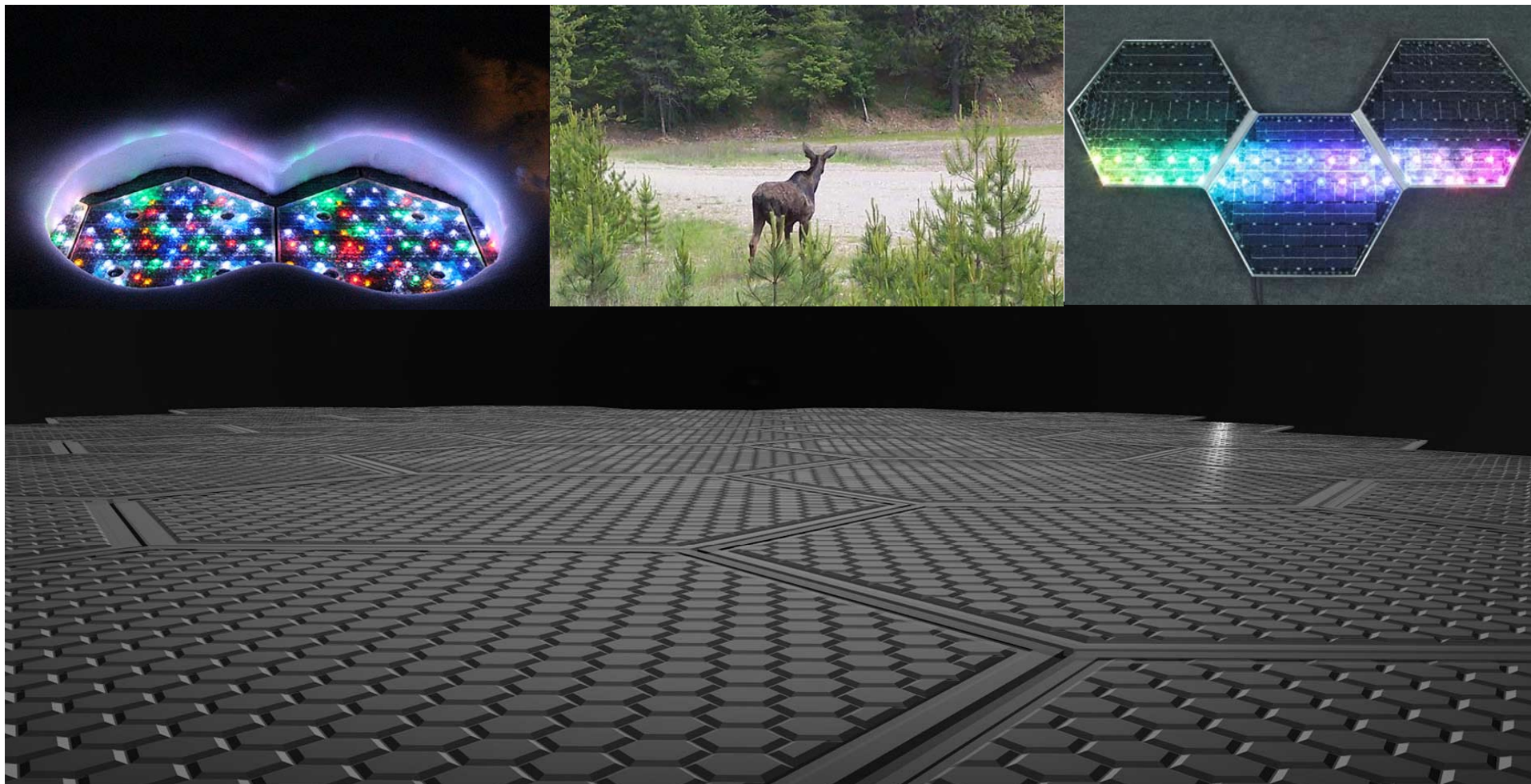


Thank you for the attention!

www.ife.no

Solar roadways (USA)

- Solar roadways <http://www.solarroadways.com>



Solar road (Netherlands)

- <http://en.solaroad.nl>
- SolaRoad is being developed as prefabricated slabs.
- It consists of concrete modules of 2.5 by 3.5 meters with a translucent top layer of tempered glass, which is about 1 cm thick.
- Underneath the glass are **crystalline silicon solar cells**.
- The top layer immediately shows an important difference from the traditional road surface.

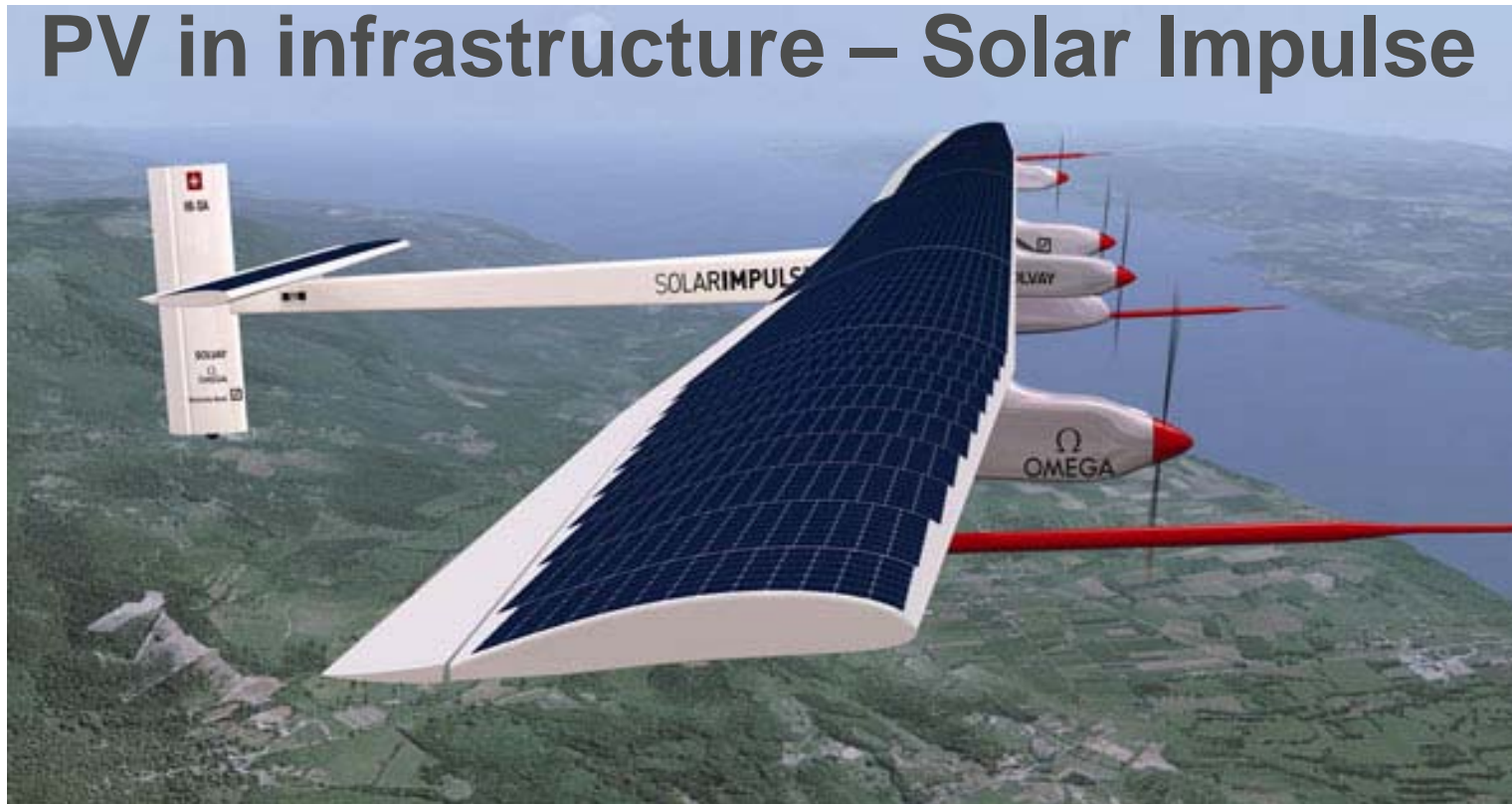


WattWays (France)

- <http://www.wattwaybycolas.com/en/>
- C-Si cells, with special lamination
- Efficiency not given
- Will install 1000 km of road in France
- <http://www.forbes.com/sites/federicoguerrini/2016/02/07/france-wants-to-install-1000-km-of-solar-roadways-over-the-next-five-years/#44662632857e>

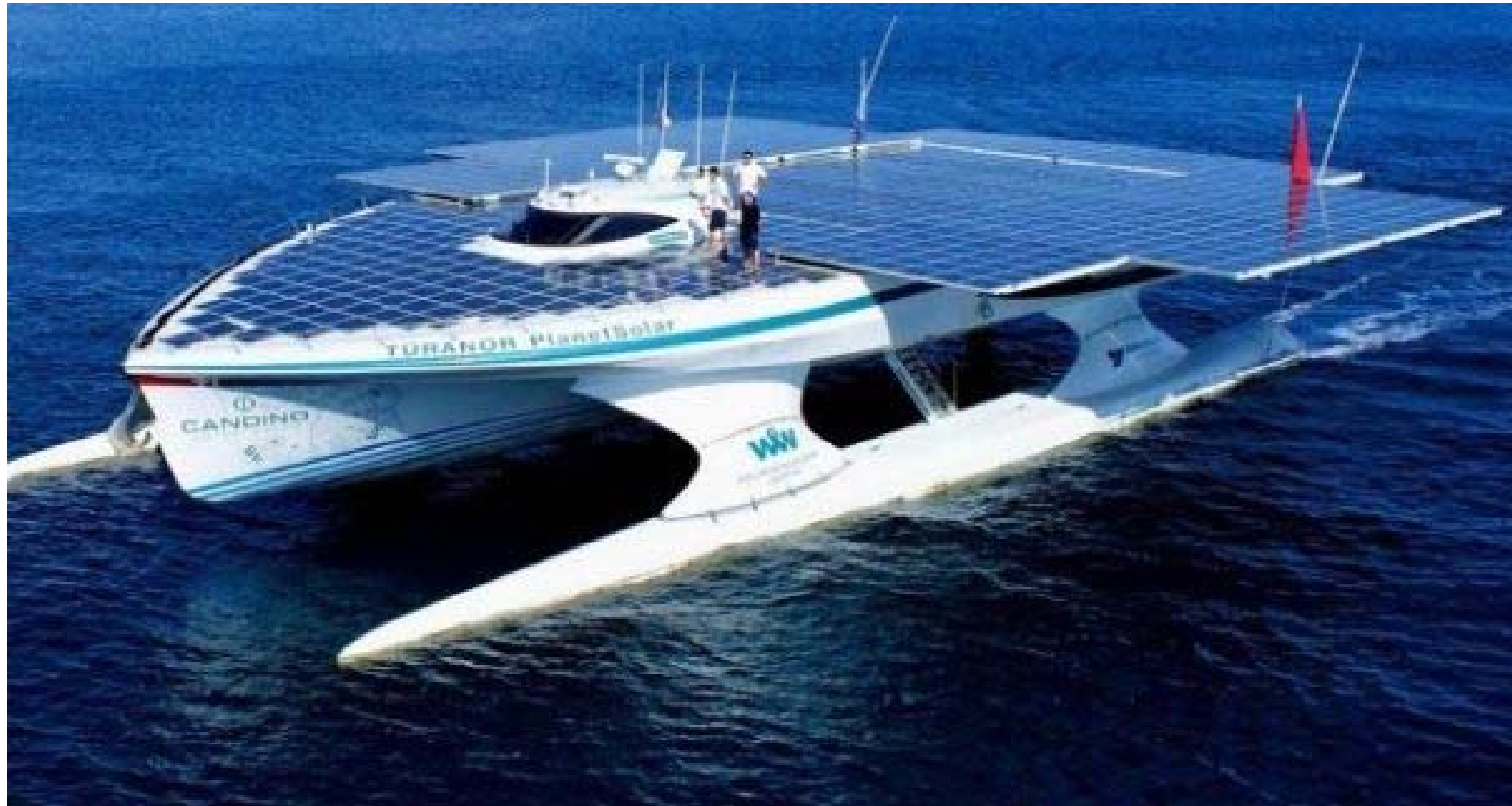


PV in infrastructure – Solar Impulse



- In 2015 started the attempt of the First Round-The-World Solar Flight, from Abu Dhabi to Hawaii, already achieving the longest solo solar flight ever achieved in aviation history.
- Bertrand Piccard and André Borschberg will continue to fly around the world with no fuel in 2016
- <http://www.solarimpulse.com/#airplane>

PV in infrastructure - boats



PV in infrastructure - boats



Solcellerevolusjonen oppsummert (1)

- Den globale solcelleindustrien er plutselig viktig
 - <0.1 % av global strømproduksjon så sent som i 2009
 - 1% i 2014
 - 2% i 2017
 - 5% i midten av tjuåra, litt avhengig av vekstrater
 - ...
- Den raske veksten fortsetter
 - ~56 GW_p i 2015 (Årlig omsetng ~1000 milliarder kroner!)
 - ~70 GW_p i 2016
 - ~80 GW_p i 2017 (2* produksjonen i 2013/2014!)
 - ...