Applied Solar Expertise

PV's significant Role to Power the Future Global Energy Needs with 100% Renewables

Becquerel Prize Award
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Content

PV‘s significant Role to Power the Future Global Energy Needs with 100% Renewables

- Future global energy needs
- Boundary conditiones for 100% Renewables
- PV‘s significant role
- The 100% Renewable World

Source: WHff

Future Global Energy Needs

- **~¾ of today's ~100,000 TWh Secondary Energy Needs are used by only ¼ of the global (~7 bn) population**

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- **Technology development allows to decrease significantly the specific energy needs : „same quality of life with much less energy"**
  examples: solid state lighting,
  electric mobility (…with renewable electricity!),
  house insolation (to decrease heating and cooling), etc

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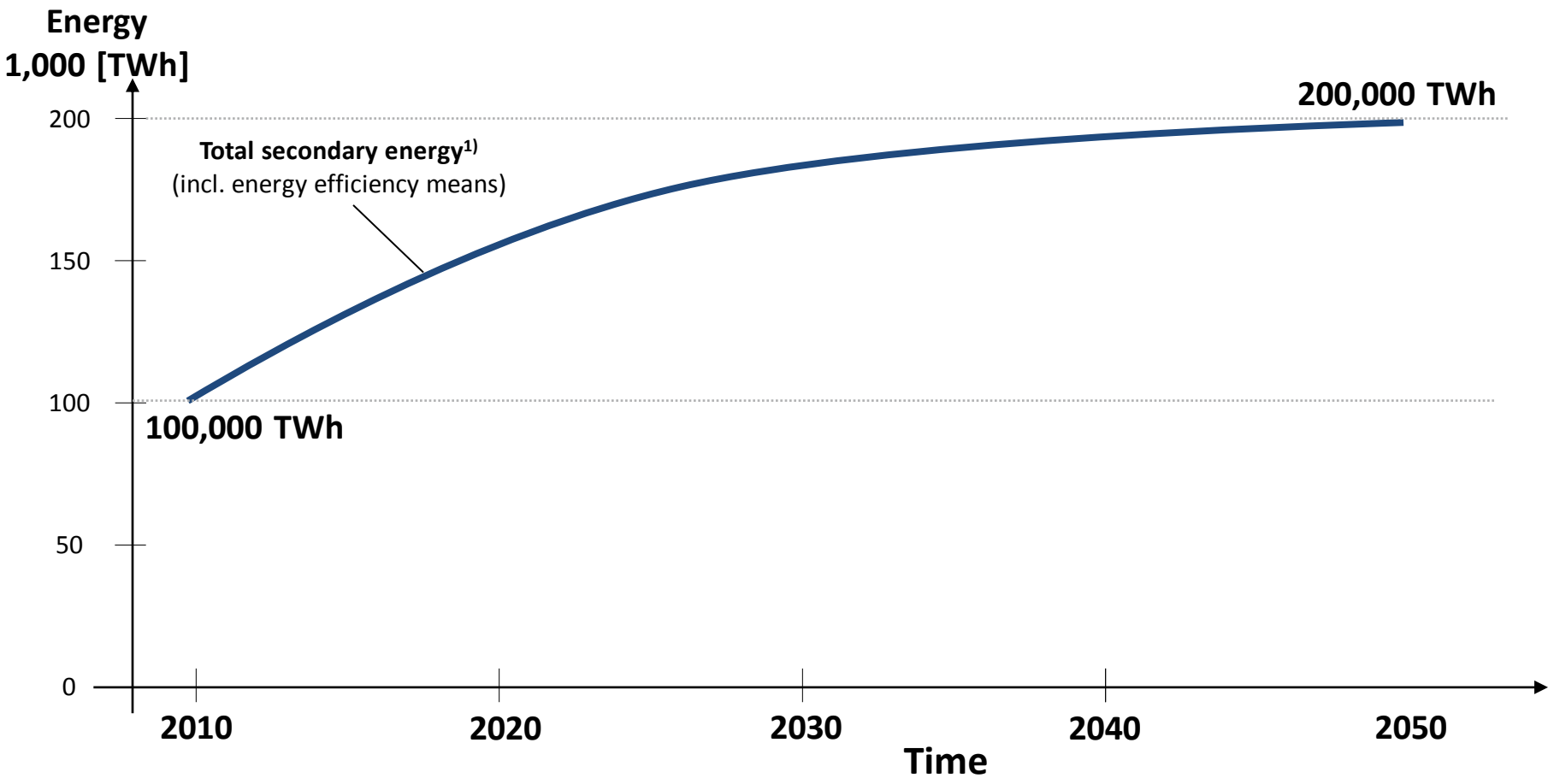
- Technology development allows to decrease significantly the specific energy needs : „same quality of life with much less energy"
  examples: solid state lighting,
  electric mobility (…with renewable electricity!),
  house insolation (to decrease heating and cooling)
  … and many, many more

- **The future 10-12 bn people can be energized with ~200,000 TWh Secondary Energy (some scientists are even projecting less, old forecasts are significantly higher) – with a similar quality of life for everyone**

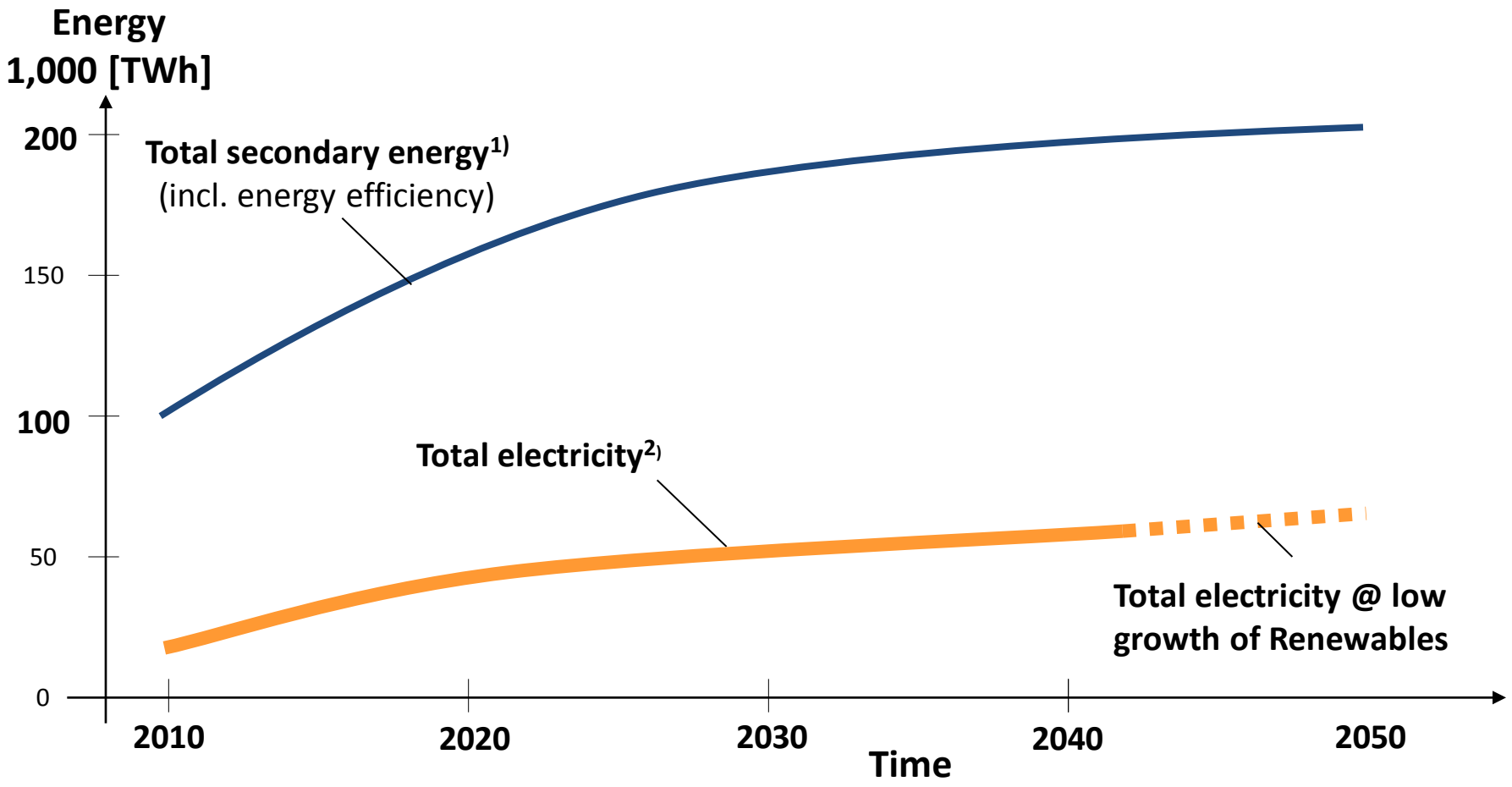
Source: WHff

Future Global Secondary Energy Needs



Source: WHff

Total electricity production will increase from 20,000 TWh in 2010 to ~ 60,000 TWh in 2050+ at low growth for Renewables



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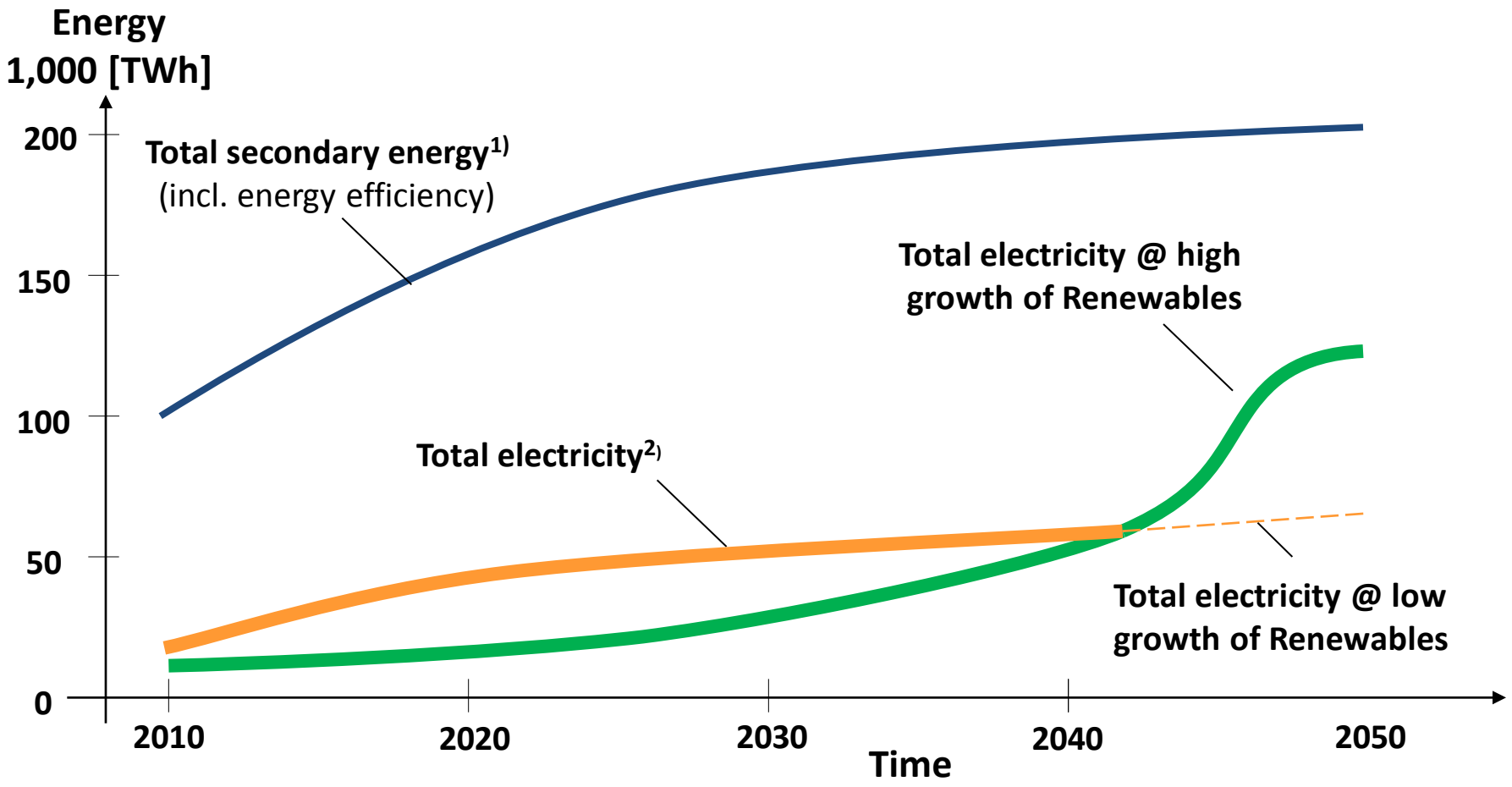
Total electricity production will increase from 20,000 TWh in 2010 to ~ 120,000 TWh in 2050+ at high growth for Renewables



Source: WHff

Boundary conditiones for 100% Renewables

- **6 €/t CO2 is not sustainable!**

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Boundary conditiones for 100% Renewables

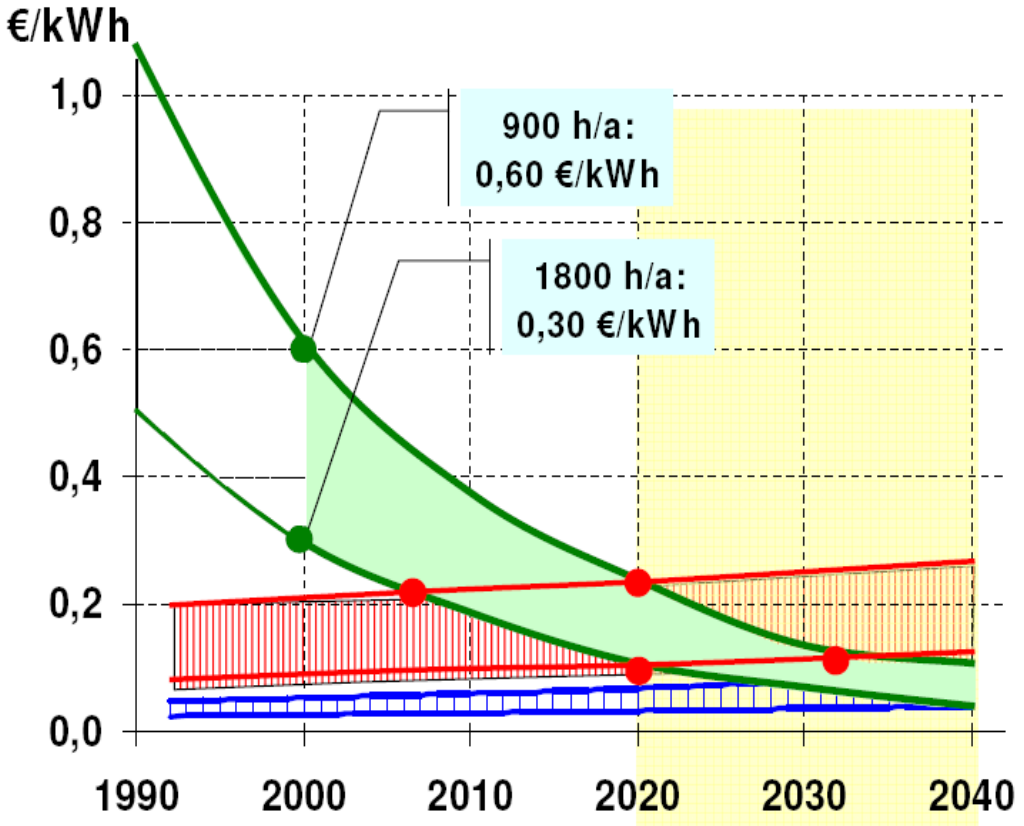
- 6 €/t CO2 is not sustainable!
- **LCOE for Renewables to become lower compared to nuclear, coal and gas (wind on-shore with 6€ct/kWh competitive to new coal, PV in sunny regions today with less than 10 €ct/kWh competitive to peak gas power)**

Source: WHff

Competitiveness of PV Solar Electricity

… the story of „Grid parity“

- Photovoltaics
- Retail prices private and small business
- Large power consuming industries (Base-load cost & margin)



market support programs necessary:

Source: WHff 1999

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- **Old technologies – nuclear, coal and gas – will become more and more expensive (fuel price, approval procedures, CCS for fossil … if technically possible)**

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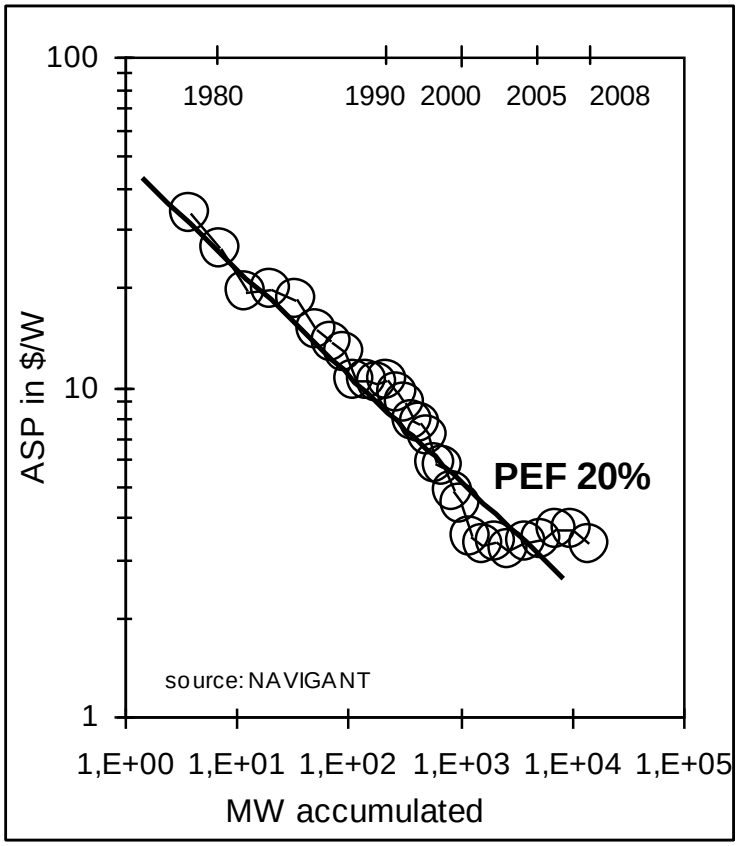
- Old technologies – nuclear, coal and gas – will become more and more expensive (fuel price, approval procedures, CCS for fossil … if technically possible)
- **Renewable technologies are „riding down“ their respective Price Experience Curve – no fuel cost, specific cost decrease due to technology development like in other high volume products (semiconductors, flat panel displays, glass coatings and many more)**

Source: WHff

PV Price Experience Curve

Price Experience Curve

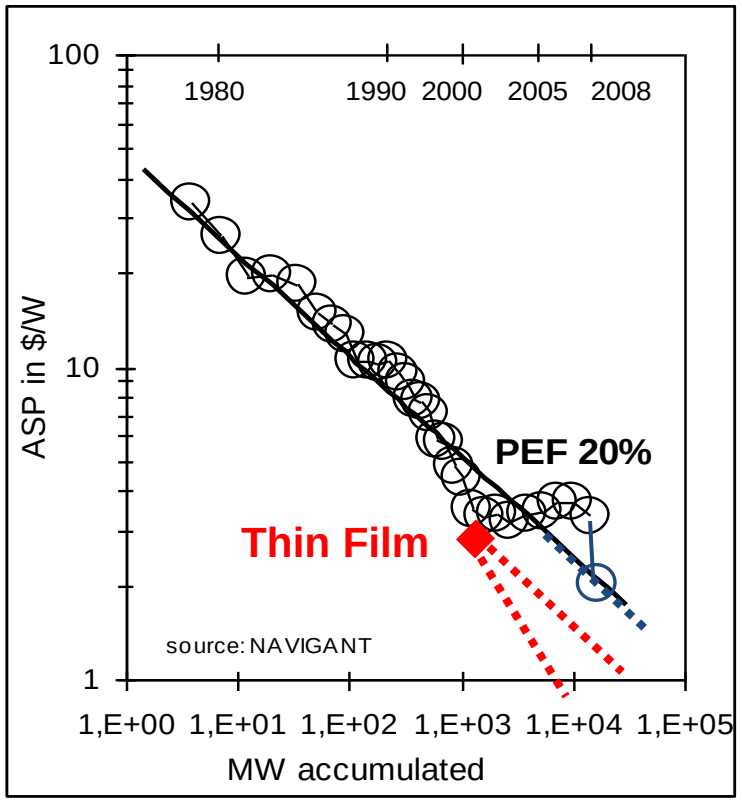


Driven by Technology

- **Wafer thickness**
  0,7mm → 0,15mm
- **Kerf loss**
  0,5mm → 0,10mm
- **Efficiency**
  8% → 22%
- **Automation**
  Industrial manufacturing
- **Economy of scale**
  0,1MW → 200MW
- **Modularity** – same building block from kW to GW systems

Further development of PV PEC

Price Experience Curve



Source: WHff

1. PEC for c-Si will continue

2. Reason for different PEC and PEF for Thin Film PV

3. Different growth rates for global PV installations as parameter

4. Different fraction of TF/c-Si as parameter

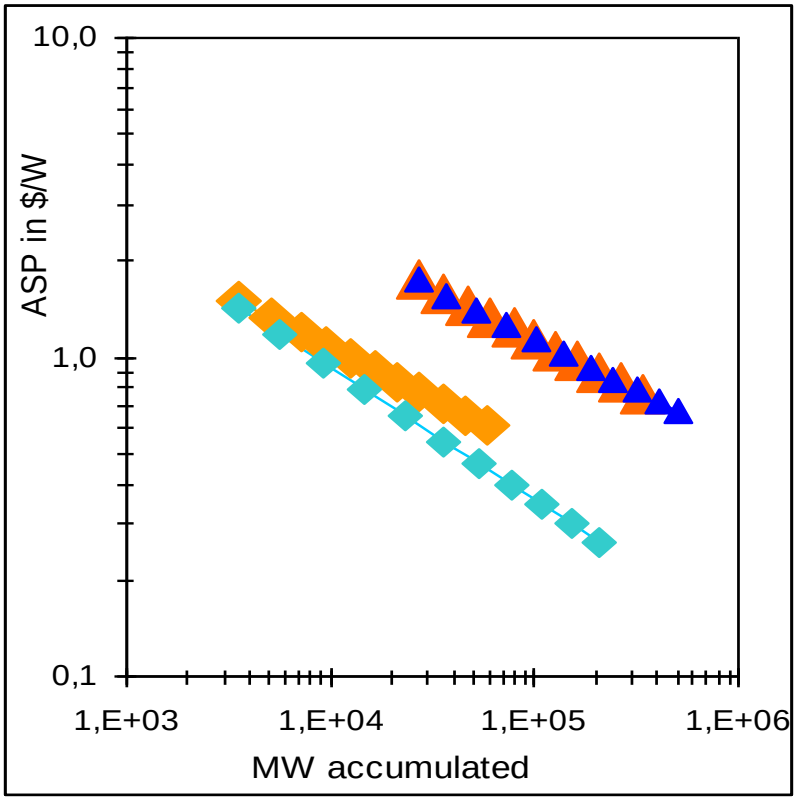
Photovoltaic – Future Price Development

… with “healthy” module prices …

PEC Scenario

Case A: Baseline
TF share 15% const
TF PEF 20%

Case B:Paradigm Shift
TF share 15% → 35%
TF PEF 25%



c-Si Technology
price expectation in 2020
~ (70 +/- 10) $ct/W

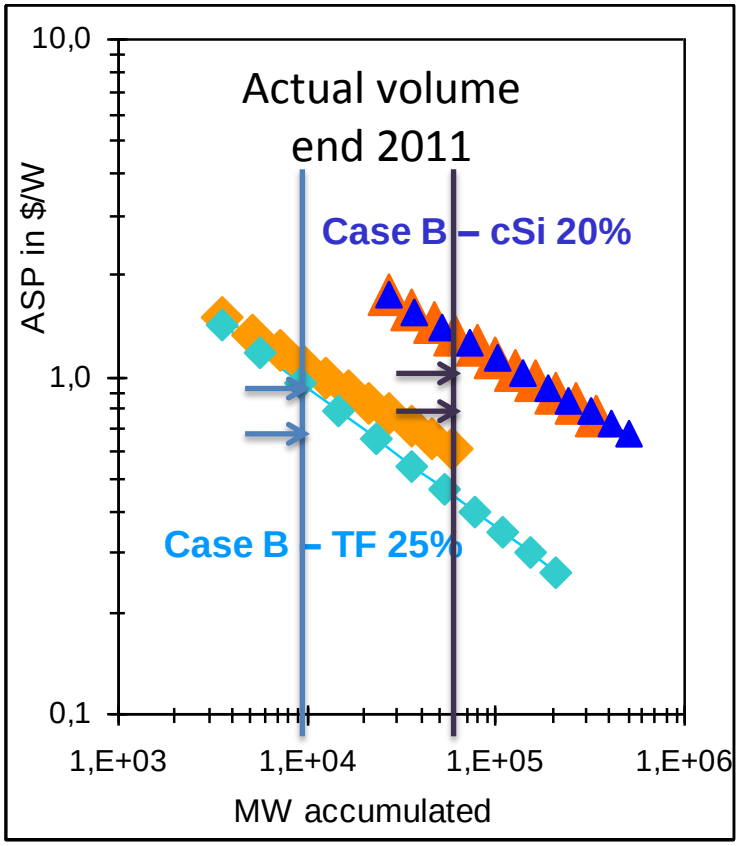
Thin Film Technology
price expectation in 2020
~ (50 +/- 20) $ct/W

Source: WHff

„Healthy“ versus „market economy driven“ prices

PEC Scenario

Case A: Baseline
TF share 15% const
TF PEF 20%



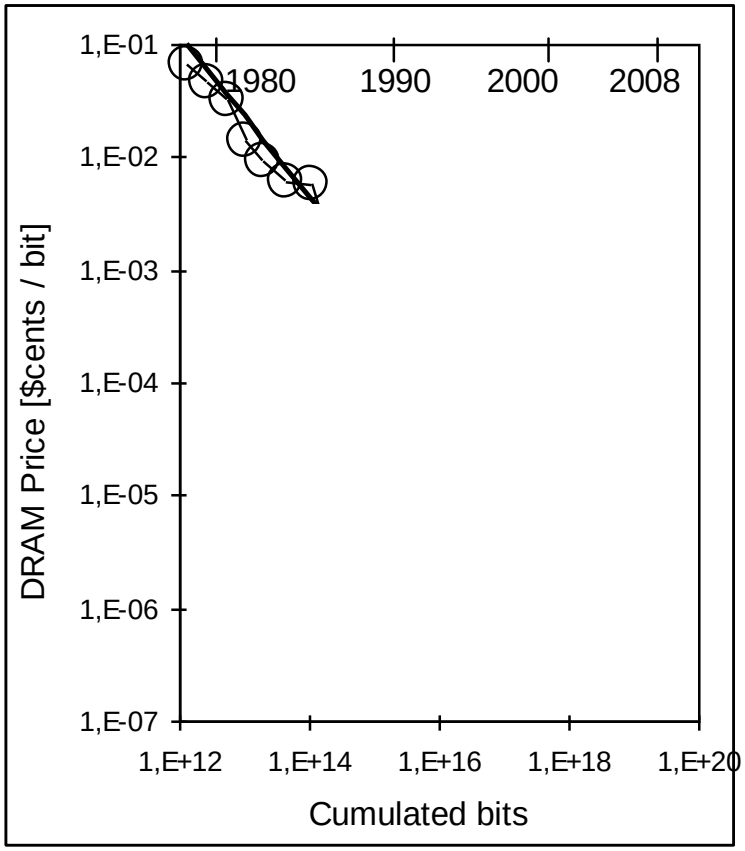
c-Si Technology
price expectation in 2020
ca. 60 – 80 $ct/W

Thin Film Technology
price expectation in 2020
ca. 30 – 70 $ct/W

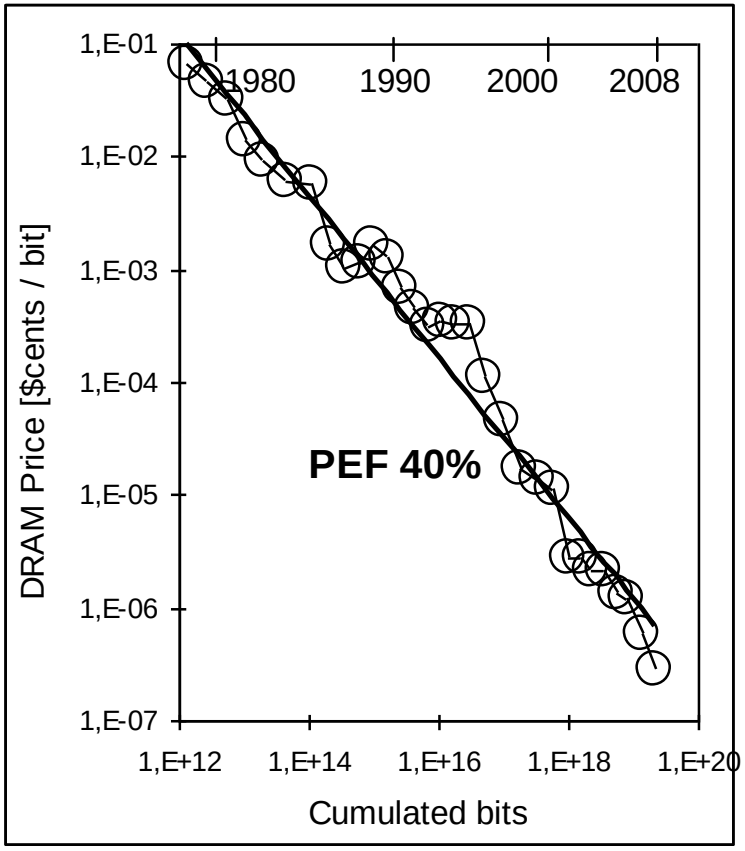
2011 price range

DRAM – Moore´s Law

Experience Curve

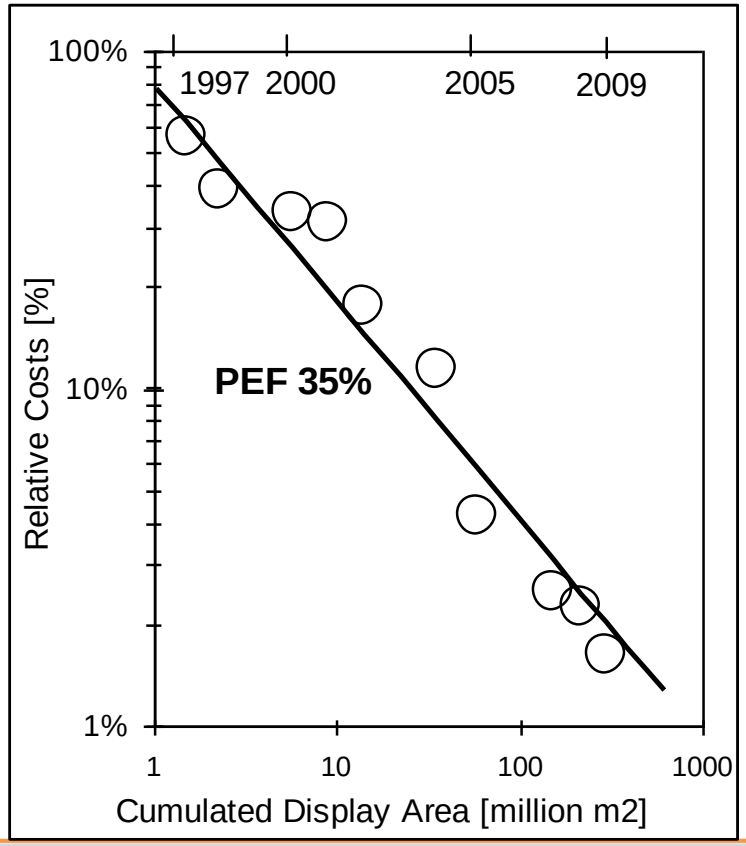


Experience Curve

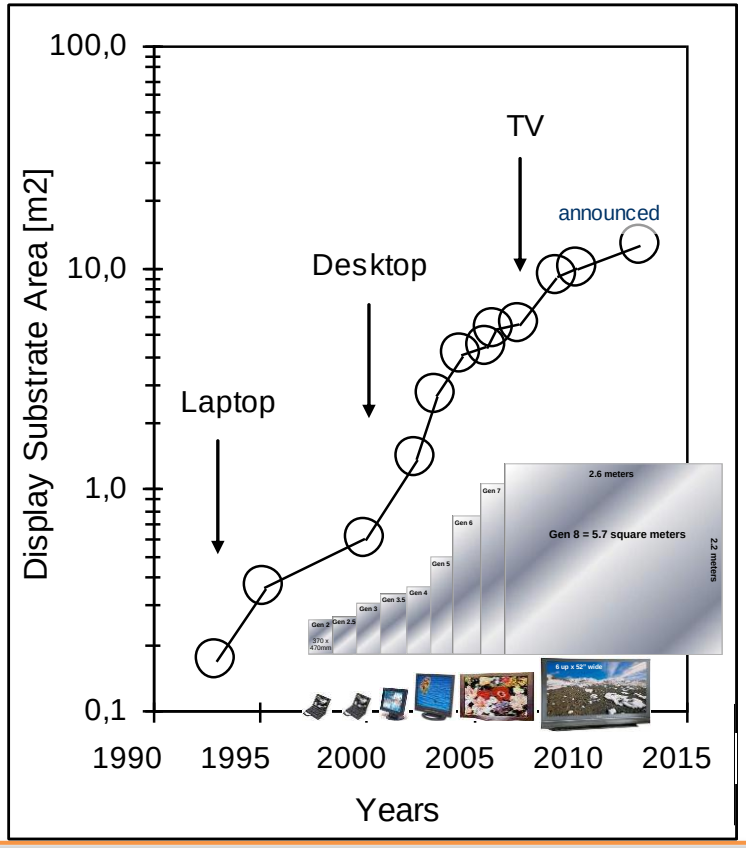


PEC for Flat Panel Display

Experience Curve



Driven by Technology



Customer Needs served by PV

on-grid	off-grid	consumer	high efficiency
			
€/kWh	€/hr light	W/m²	g/W
			
€/m² / aesthetics	€/W	flexibility	W/mm²

Source: Fraunhofer ISE

Source: WHff

Technology Evolution

r ribbon

mg metallurgical grade Silicon

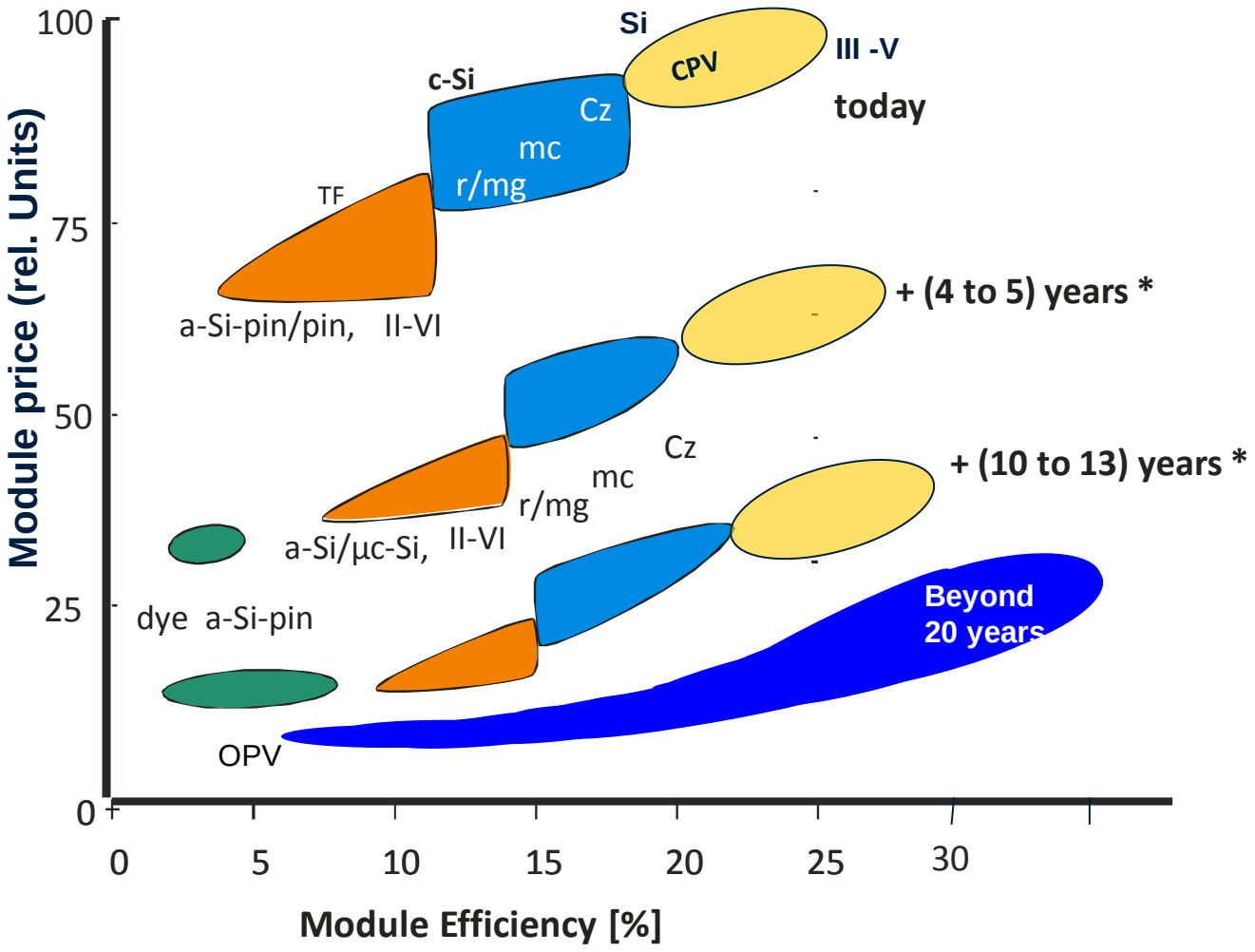
mc multicrystalline

Cz Czochralski

CPV concentrated PV

OPV organic PV

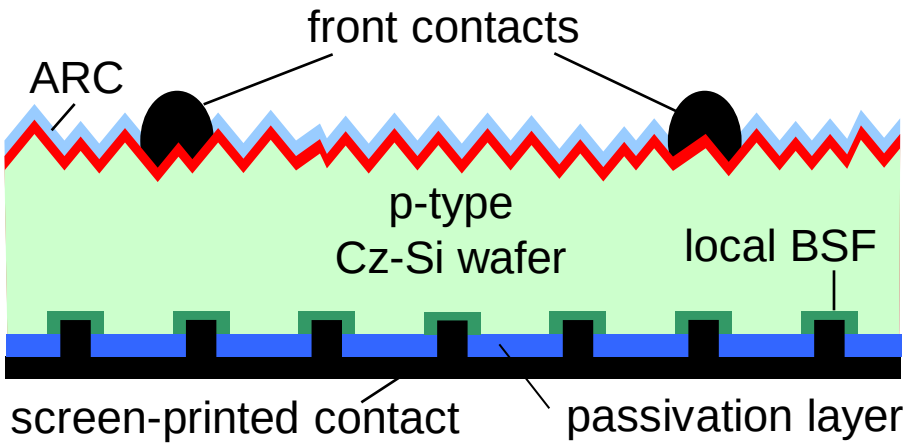
@ - (8 to 10) % price decrease per year



Source: WHff 2008

Record cell efficiencies of up to 21% on large area p-type Cz Si wafers achieved by SCHOTT Solar

Cell design



Results (best cells)

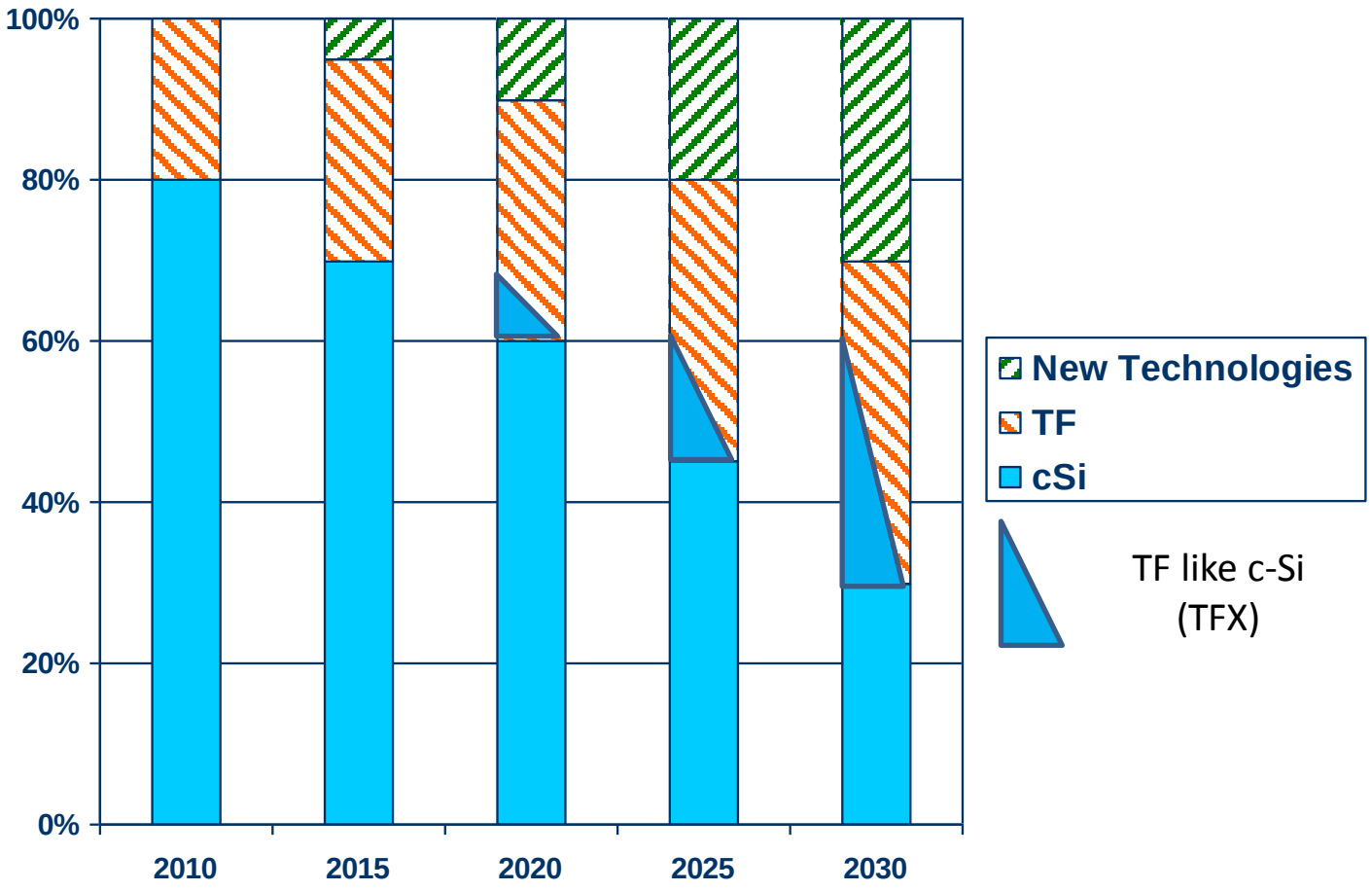
	Efficiency [%]
Screen-printed Ag front contacts	21.0*
Electroplated NiCu front contacts	20.9*

* independently confirmed by ISE Callab

- **Next generation manufacturing technologies demonstrate potential to reach 21% cell efficiency with simple and cost effective process sequences**
- **All steps are available in multiple process options**

Source: SCHOTT Solar AG

Share of PV Technologies

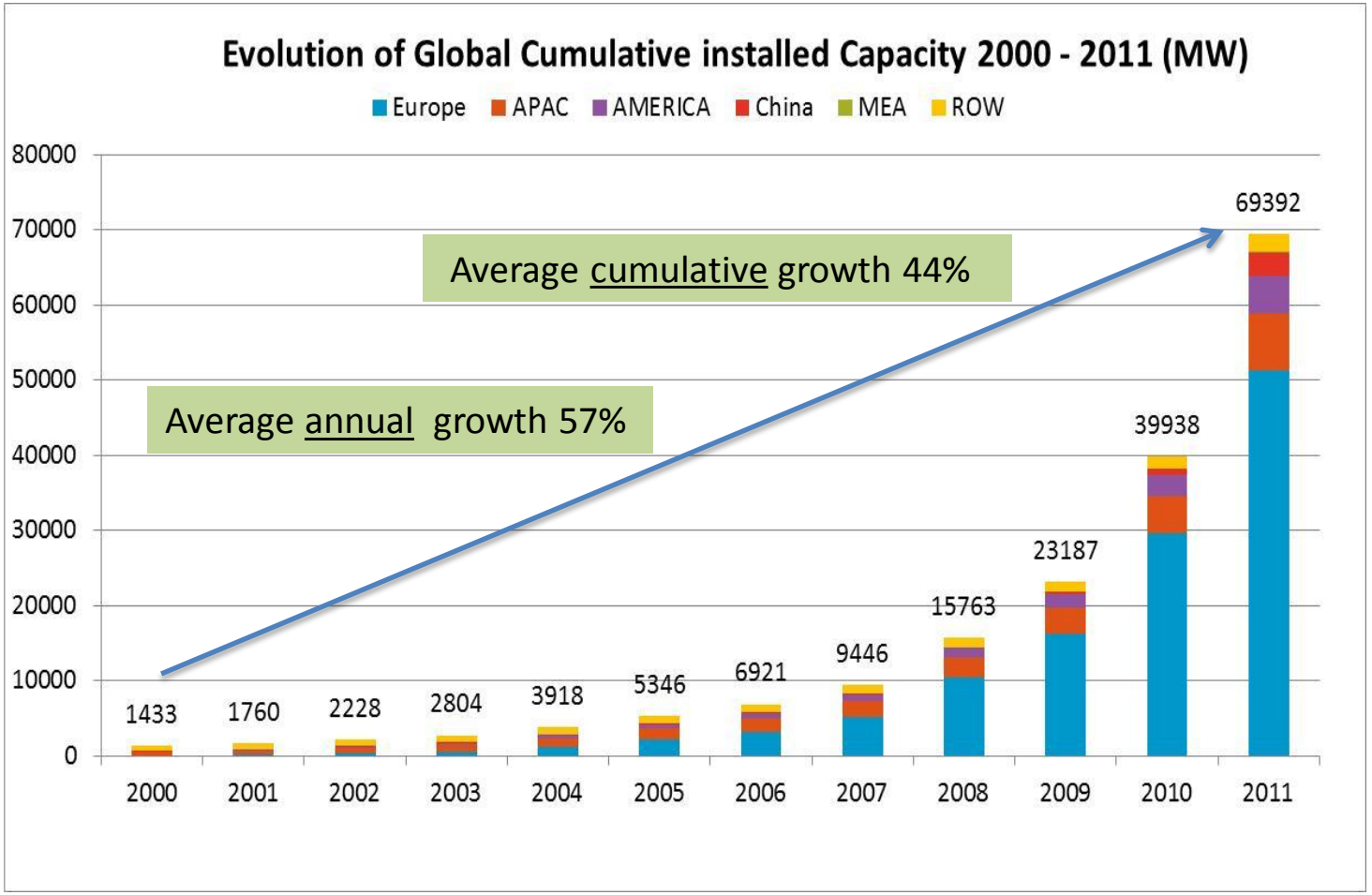


Source: WHff 2008

PV 2011: ~70 GW (~ 80,000,000 MWh)

Corresponding to 53 full size 1,300MW nuclear reactors

… and energy wise to the annual output of 9 such reactors



Source: EPIA Market Workshop 2012

Actual annual growth for PV

Decade	% growth p.a.
1990 - 2000	*20*
2000 - 2010	*52*
2010 - 2020	
2020 - 2030	
2030 – 2040	
2040 – 2050	

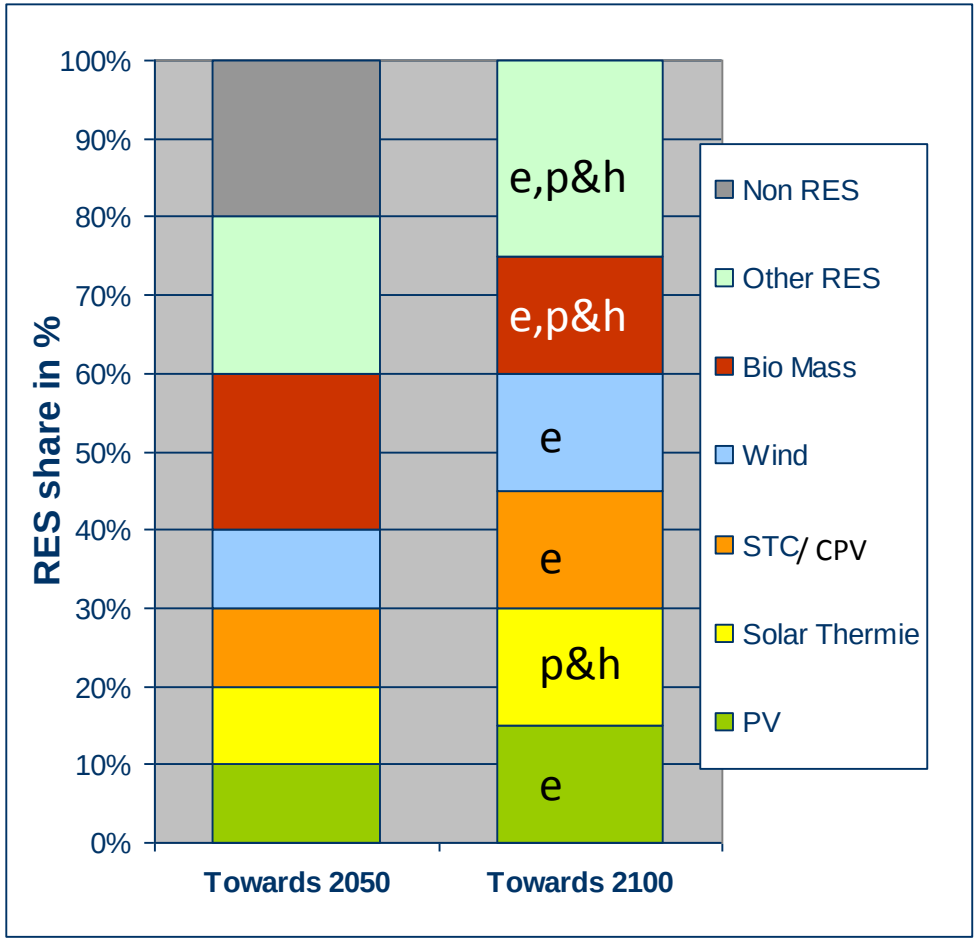
Source: WHff

Assumed growth rates and resulting power installed and energy produced

Decade	% growth p.a.
1990 - 2000	*20*
2000 - 2010	*52*
2010 - 2020	**20**
2020 - 2030	**15**
2030 – 2040	**10**
2040 – 2050	**5**
	Result:
Cumulative PV power 2050	**22,000 GW**
Annual energy production in 2050 at 1.3 kWh/W (average)	**29,000 TWh**

Source: WHff

Projection for Future RE Portfolio for a 100% Global End Energy Coverage



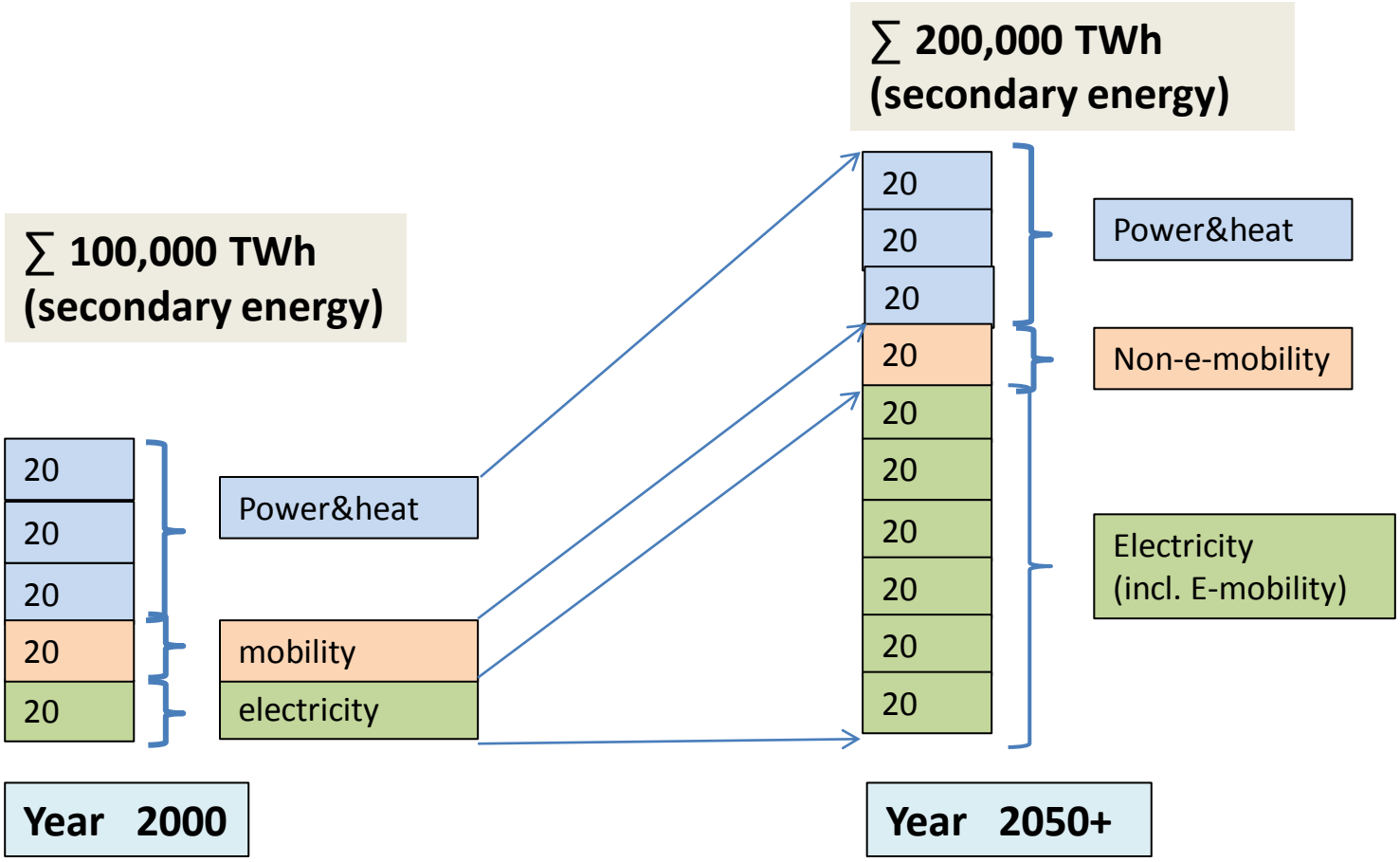
e electricity

p power

h heat/cool

Source: WHff

Development of the various energy sectors (approximate)



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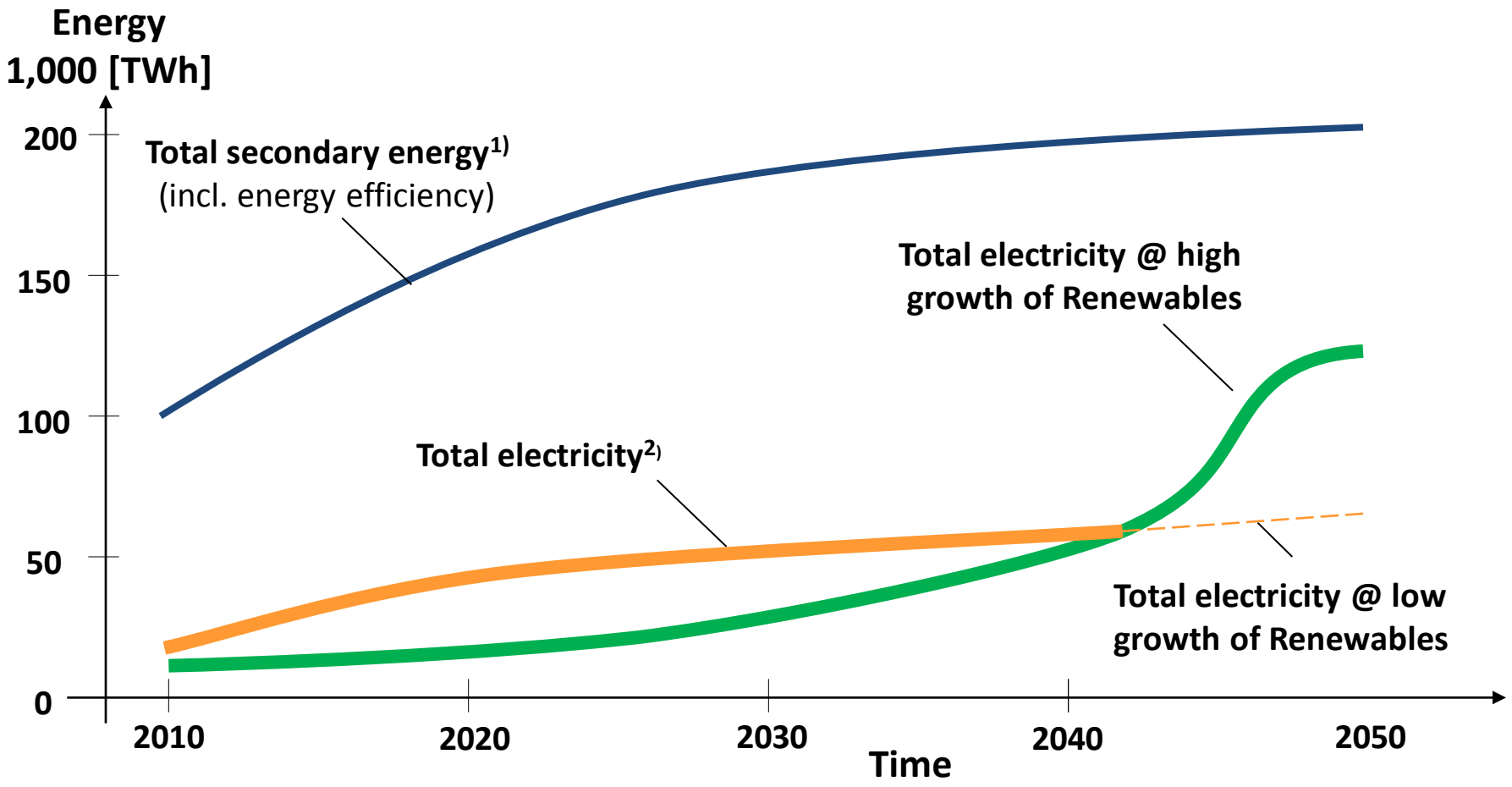

Source: WHff

… getting interested in these thoughts?

Wiley is waiting for my story and the book should be ready around summer 2013

For better remembering take a flyer at the Wiley booth

Source:

Acknowledgements and thanks

- **to all friends, colleagues and supporting seniors**

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- **to my family**
  wife Anneliese with children Tobias and Elisabeth plus
  our sunshine & grandson Elija with his mother Miriam