Applied Solar Expertise

Quo vadis PV –

International Roadmap, Market Development & Support Policy for PV

8th International Workshop on Crystalline Silicon for Solar Cells - CSSC-8 in Bamberg, 6th – 8th of May, 2015

Dr. Winfried Hoffmann – ASE

Chairman of Supervisory Board Solarfabrik AG
Member of Supervisory Board SMA Solar Technology AG and ISFH
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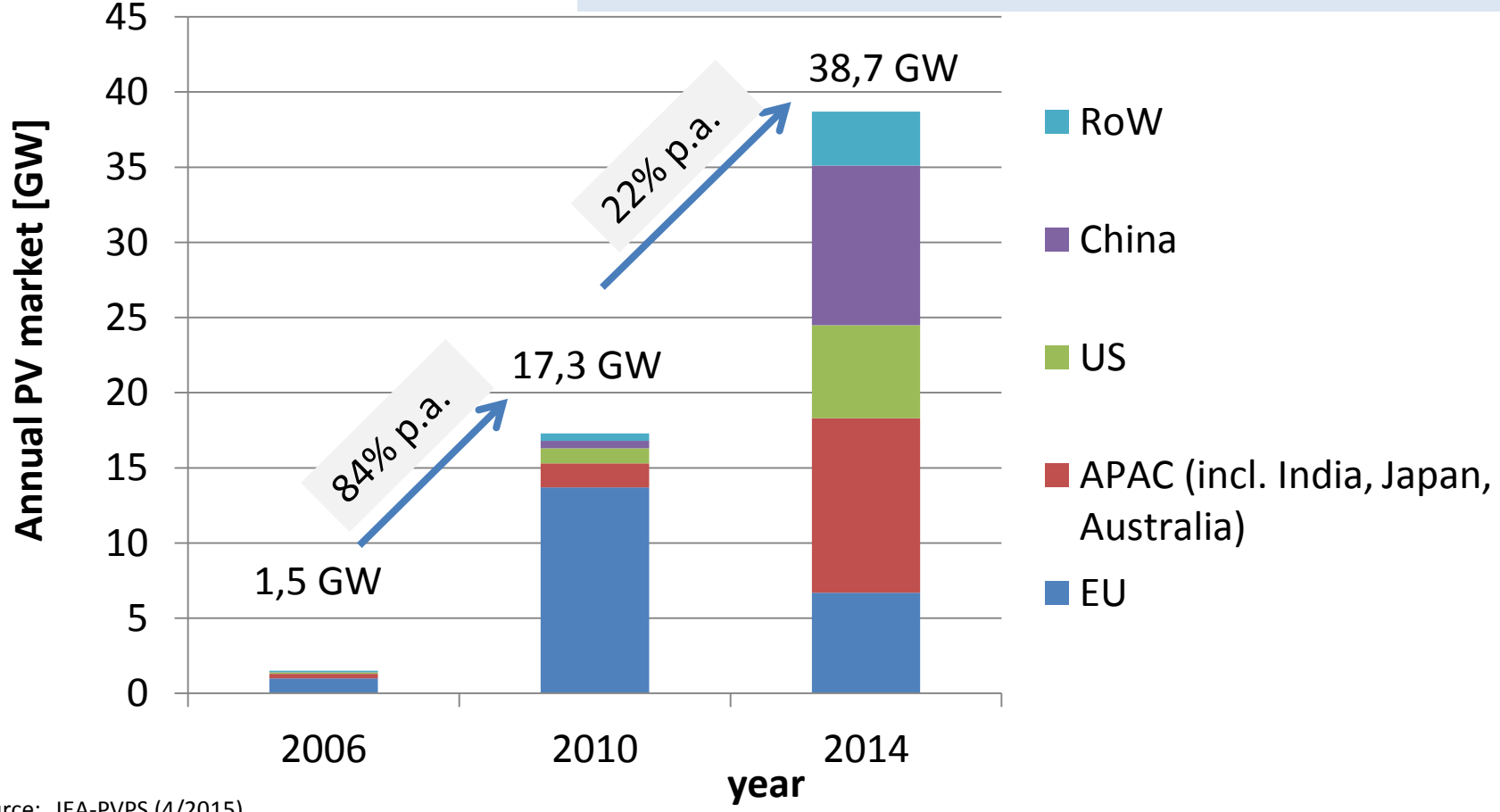
Outline

- PV market development in the major regions
- PV capacity and production for c-Si and Thin-film
- Development of the PV product portfolio
- Necessity for low cost storage
- Price Experience Curves including for Li-ion batteries
- Examples for resulting innovations

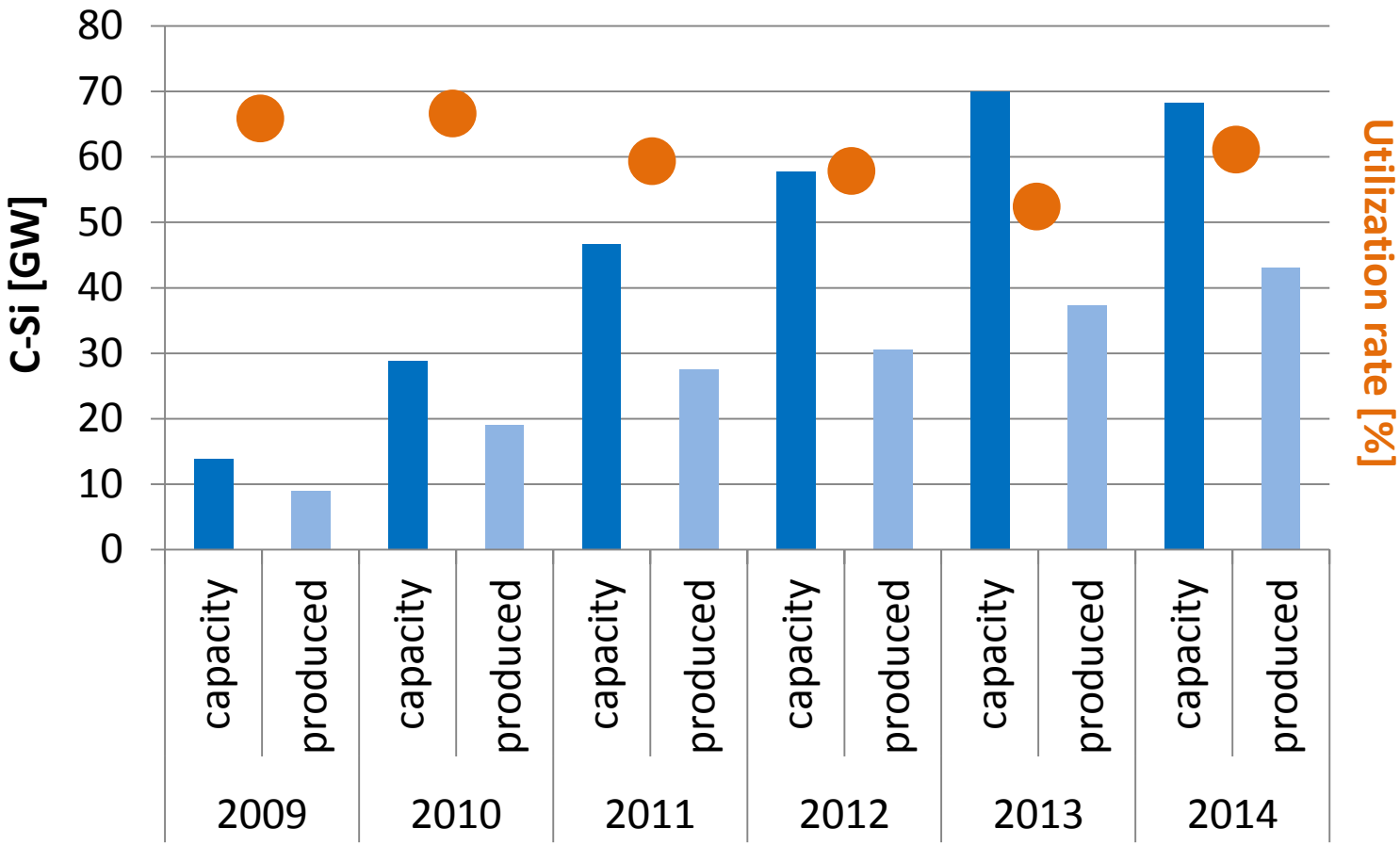
Annual global PV market development from 2006 to 2014

IHS 2015: 44,2 GW and 57 GW exp. in 2015



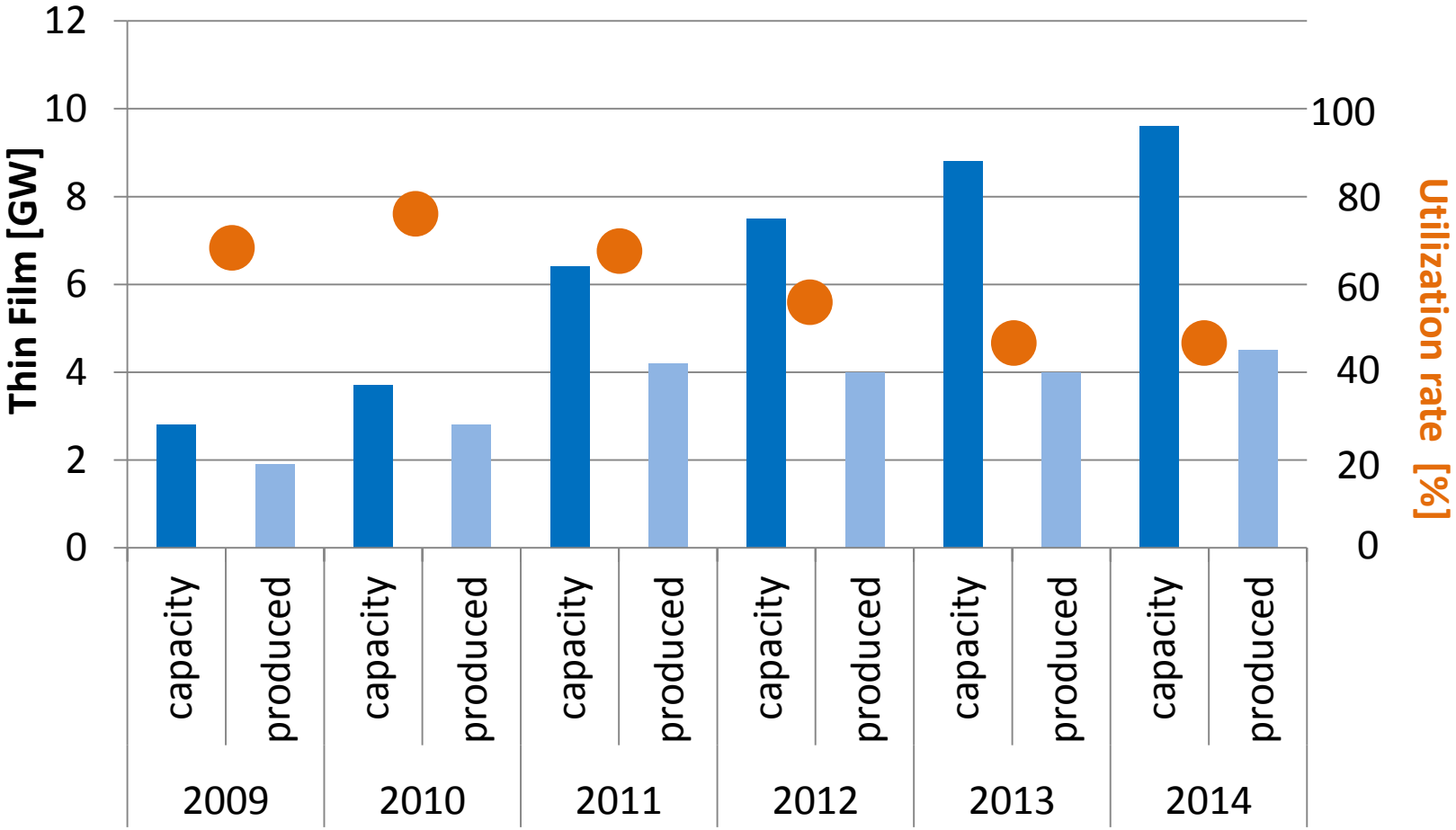
Source: IEA-PVPS (4/2015)

Capacity, production and utilization rate for c-Si modules



Source: IHS 2015

Capacity, production and utilization rate for Thin-Film modules



Source: IHS 2015

Prerequisite for differentiated PV product portfolio

- High efficiency c-Si products (HIT, IBC, tandem structures for eff >30%)

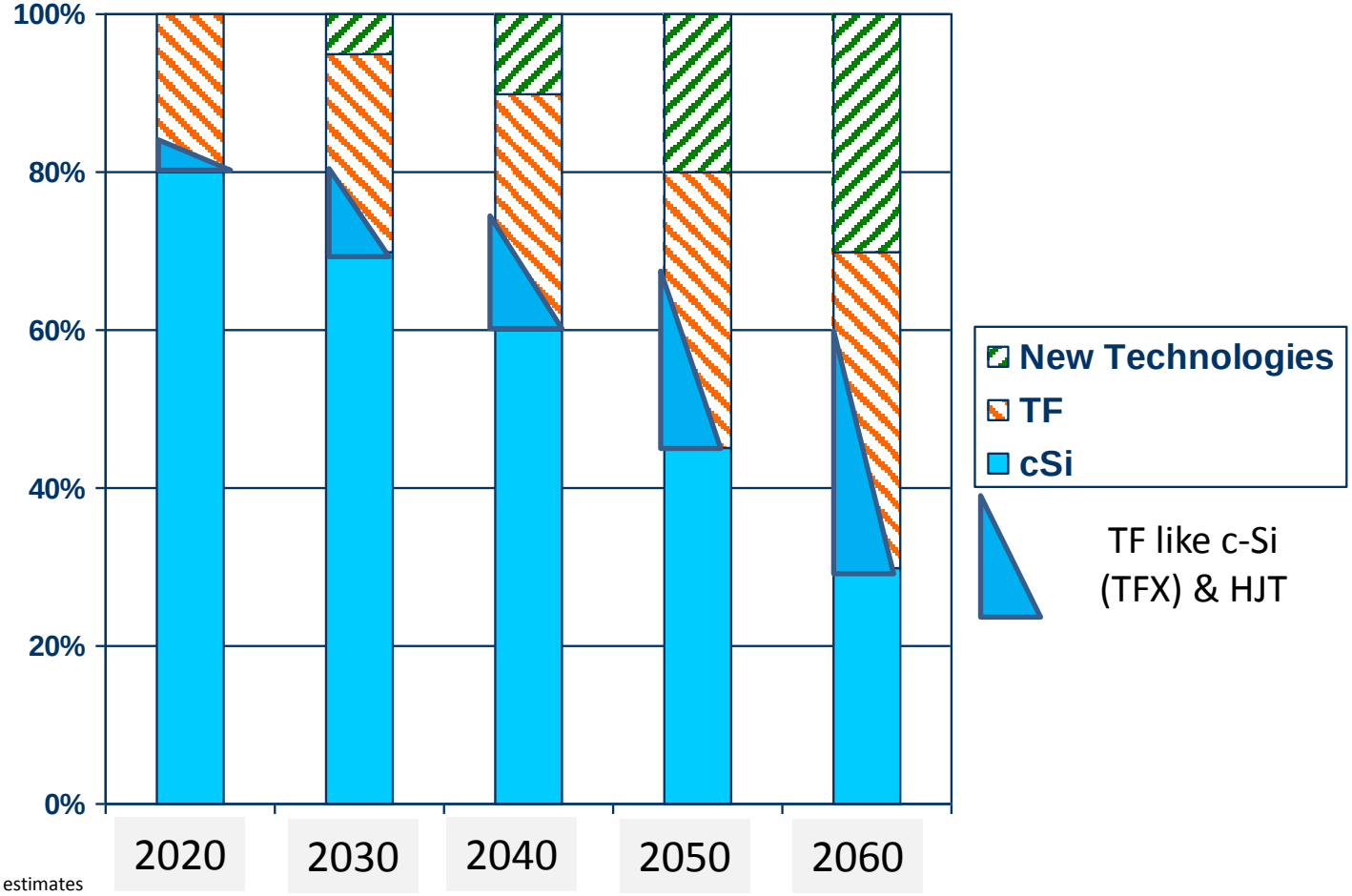
- Specific market policy requirements, where in countries (e.g. in Asia and South America) local production may be needed (Thin-film and downstream c-Si)

- Light weight and flexible products (Thin-film and OPV)

- Countries with high DNI (direct normal irradiance) may be interested in CPV (III-V-multi-junction products)

Source: Own research (2015)

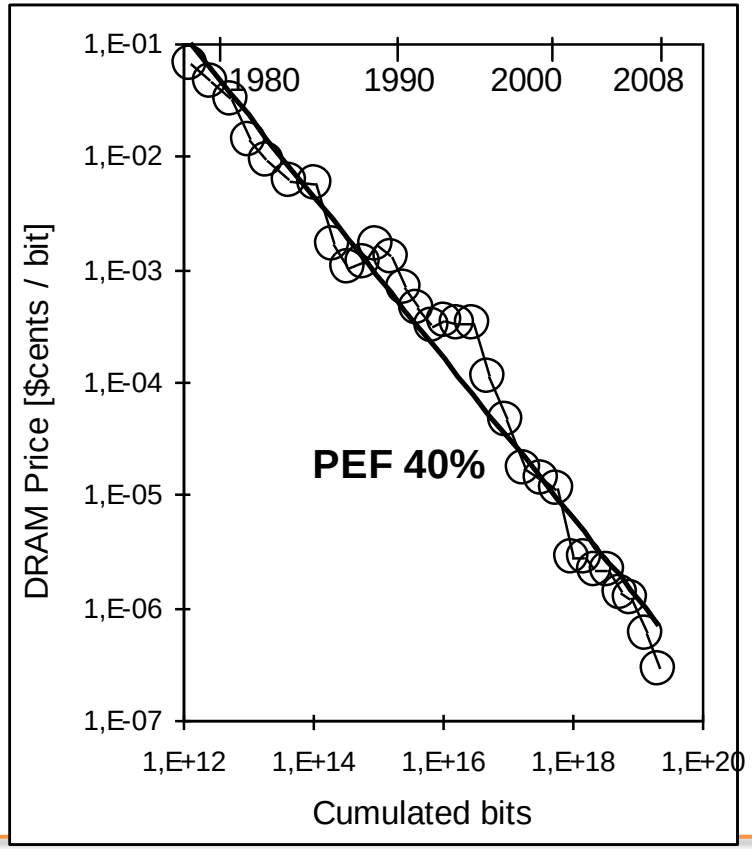
Share of PV Technologies – NEW time line as of 2014



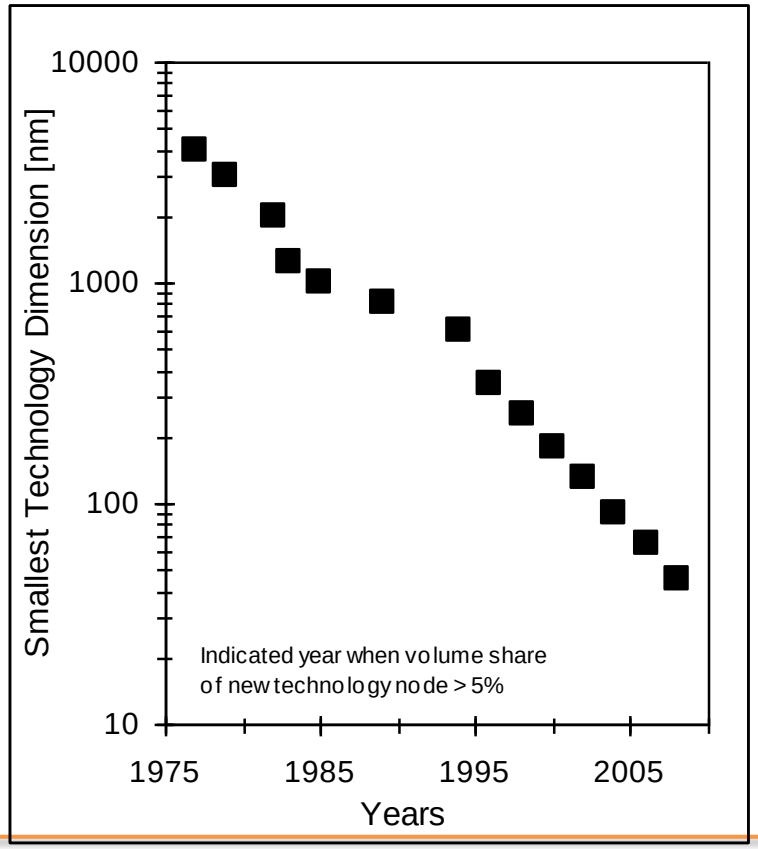
Ref: W. Hoffmann personal estimates

DRAM – Moore´s Law

Experience Curve



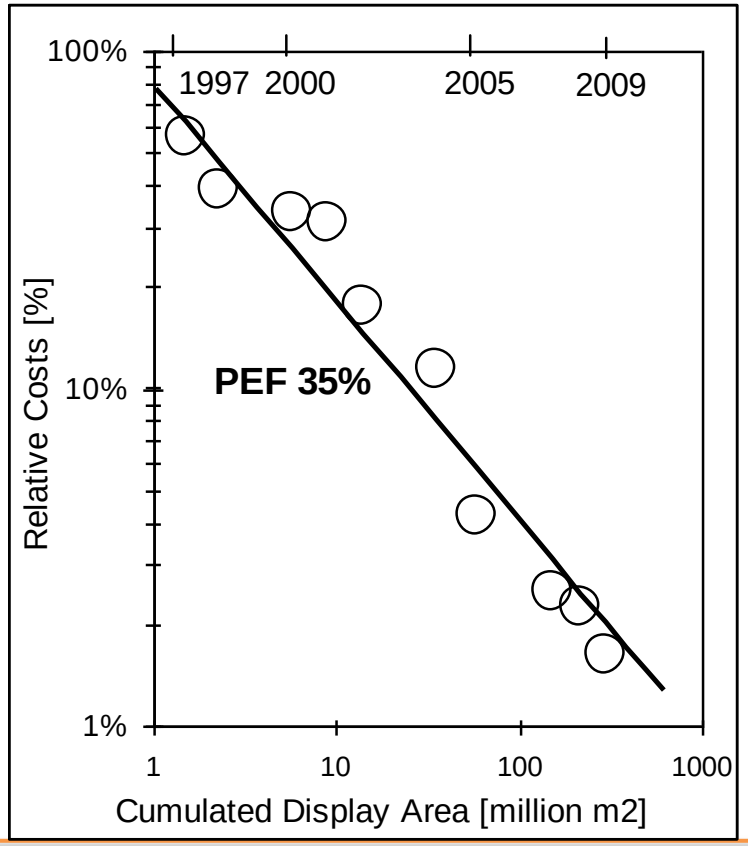
Driven by Technology



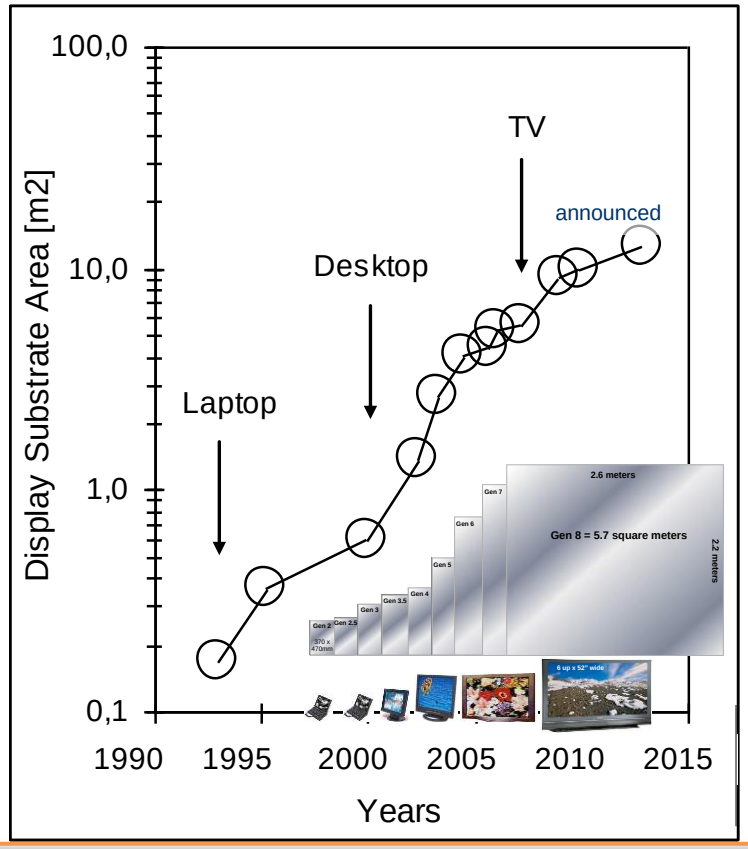
Source: Applied Materials, Semiconductors Group

Flat Panel Display

Experience Curve

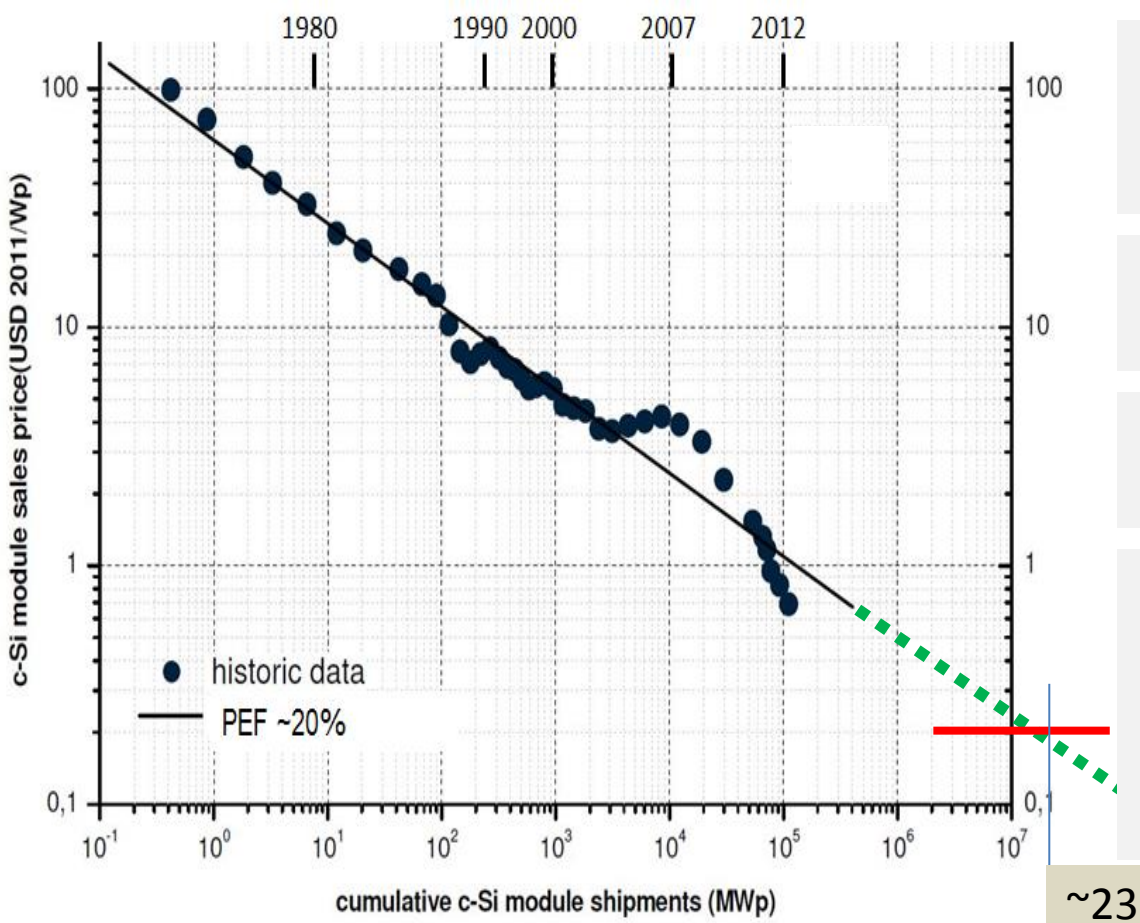


Driven by Technology



Source: Applied Materials, Display Group, 2009

Extrapolation for PV Price Experience Curve



- From today's perspective the lower price limit for sj-Si-wafer modules is ~0.2$/W
- This limit is reached at a cumulative volume of ~23TW
- With realistic growth numbers this is reached in ~2050
- No material limitation at 1TW/a in the 2040s:
  poly-Si: 1.7 Mt (20kt→0.3 Mt)
  glass: 8 bn m² (today ~4 bn m² global production)

~23 TW

Source: ITRPV 2013

… how to reach 23 TW PV?

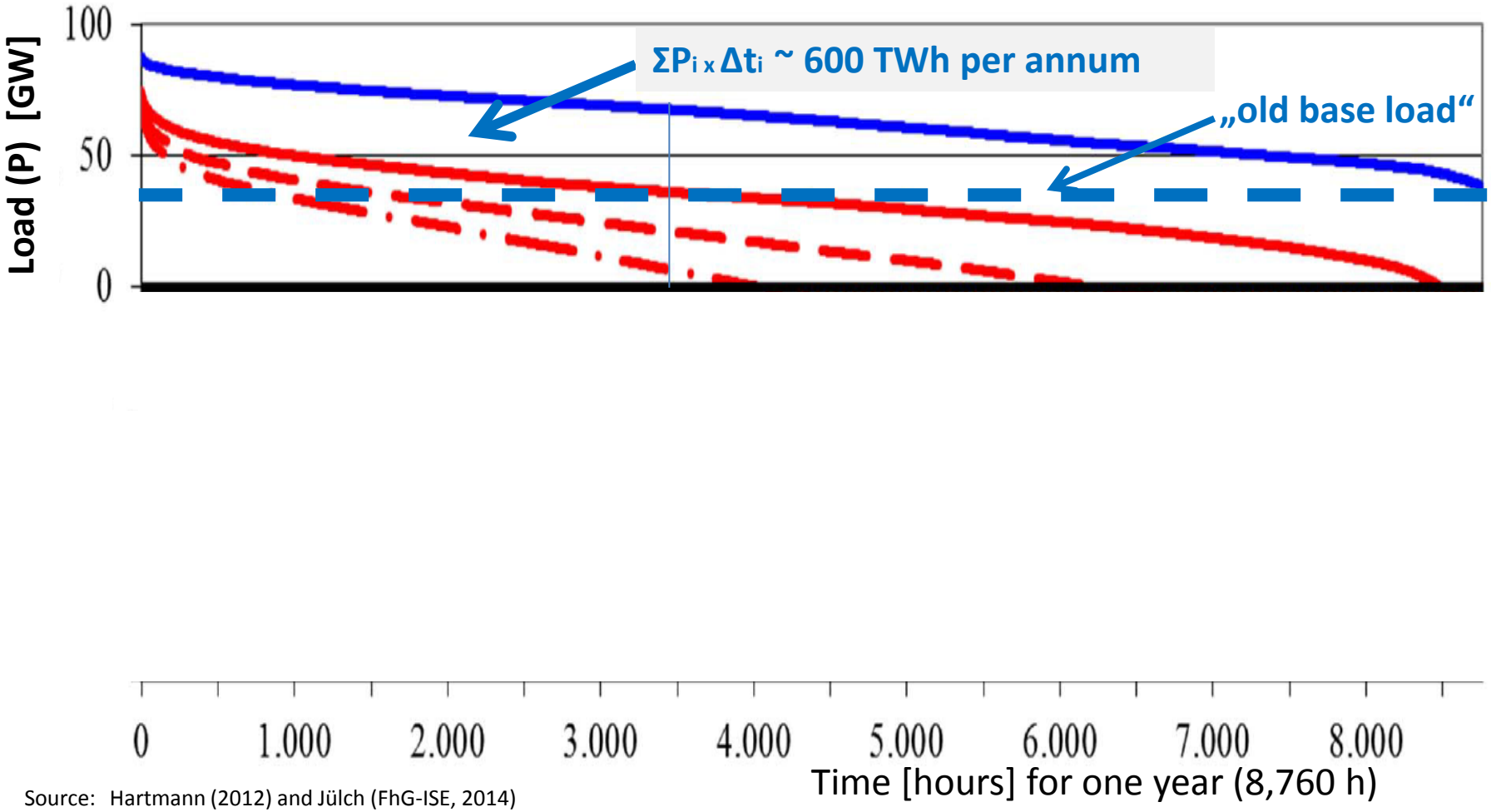
(20% PV share for the global future annual SE with 100% RE)

	V 1	
Decade	%	growth
1990 - 2000		*20*
2000 - 2010		*50*
2010 - 2020		20
2020 - 2030		14
2030 – 2040		8
2040 – 2050		4
cumulative PV power in 2050 [TW]		**23**
Annually produced energy [PWh] in 2050 at 1.3 kWh/W (average)		**30**

Annual market [GW] at start of decade
0,05
0,3
20
120
460
900

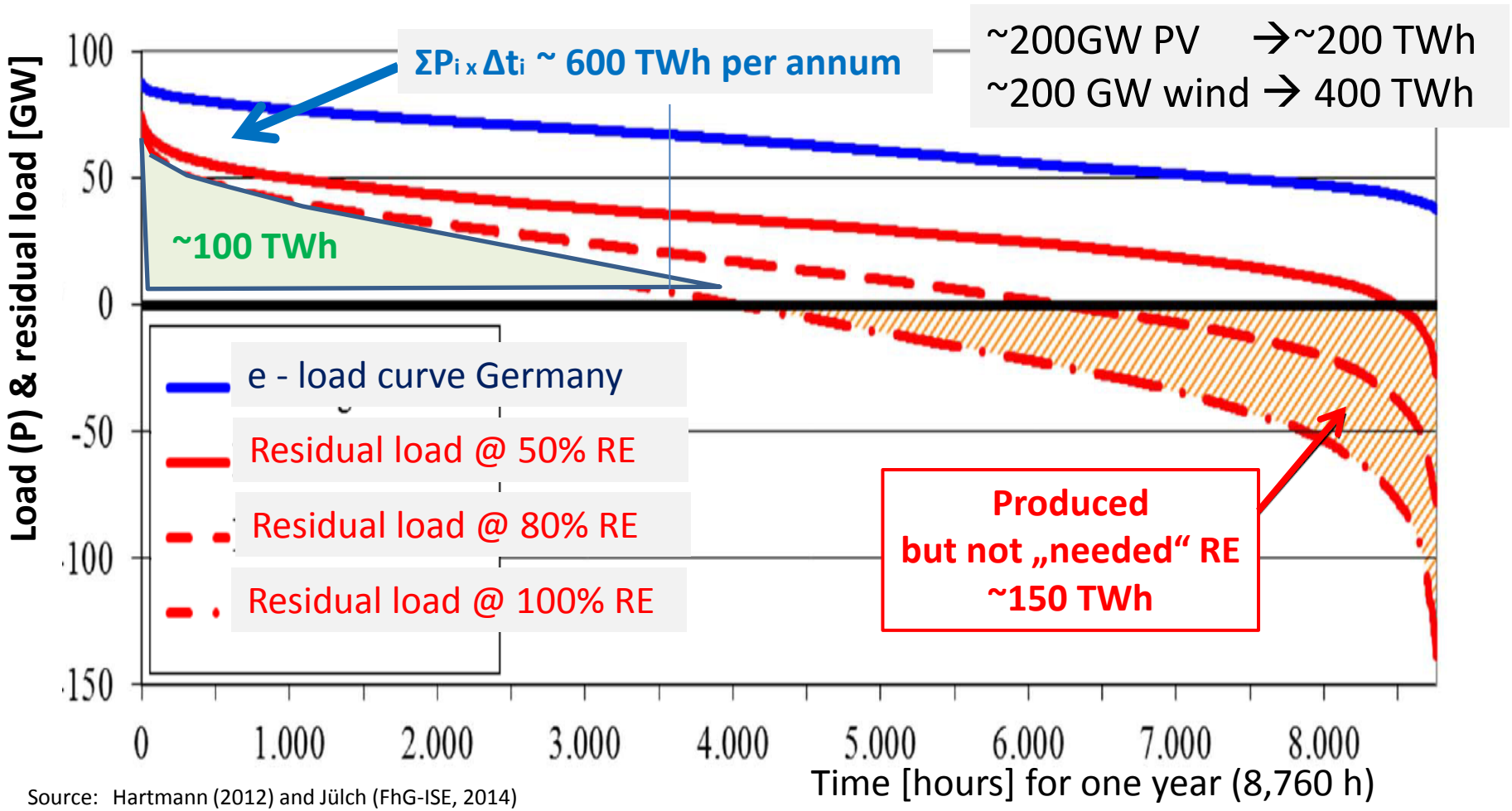
Source: Winfried Hoffmann, own data

Germany‘s load curve



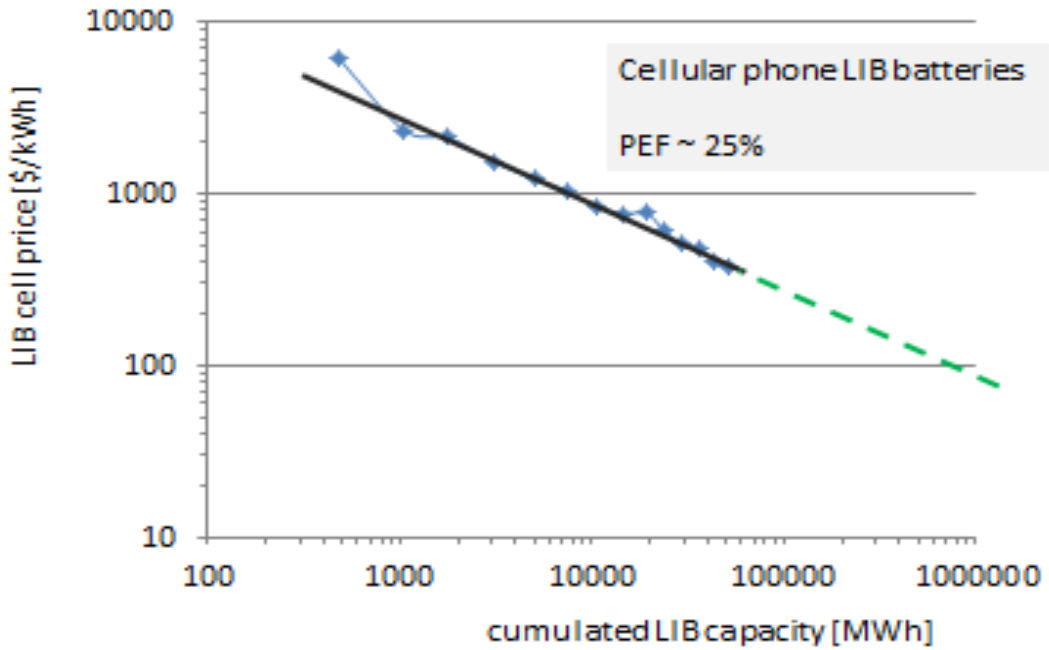
Source: Hartmann (2012) and Jülch (FhG-ISE, 2014)

Germany‘s load curve and residual load with Renewable Energy (RE)



Source: Hartmann (2012) and Jülch (FhG-ISE, 2014)

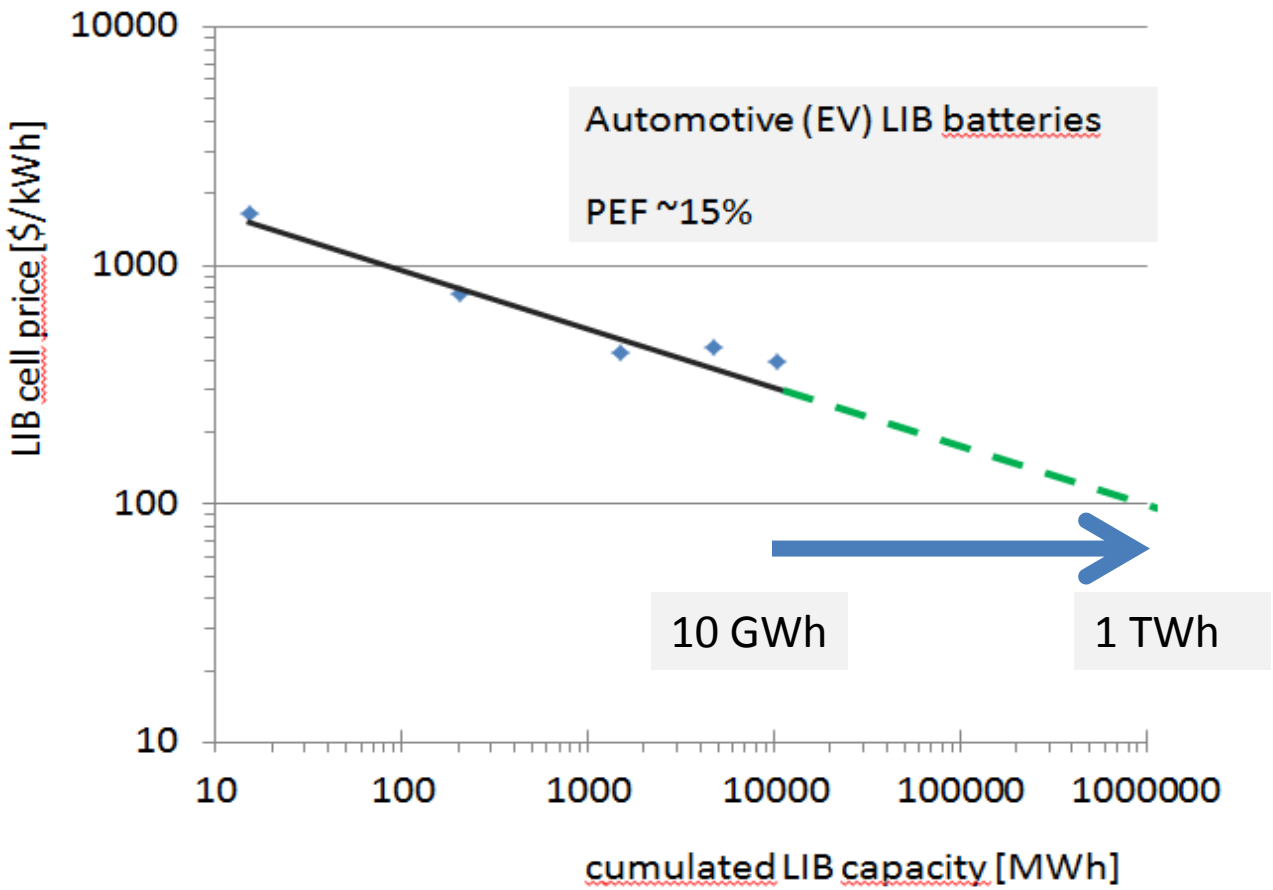
PEC for cellular phone LIB's



green dotted line is extrapolation of past PEC

Source: raw data from personal communication C. Pillot, Avicenne

PEC for LIB batteries for automotive applications

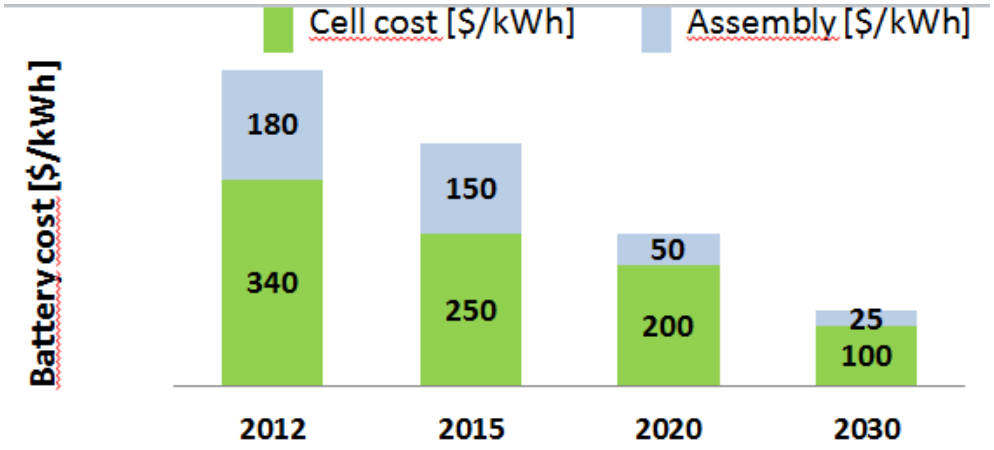


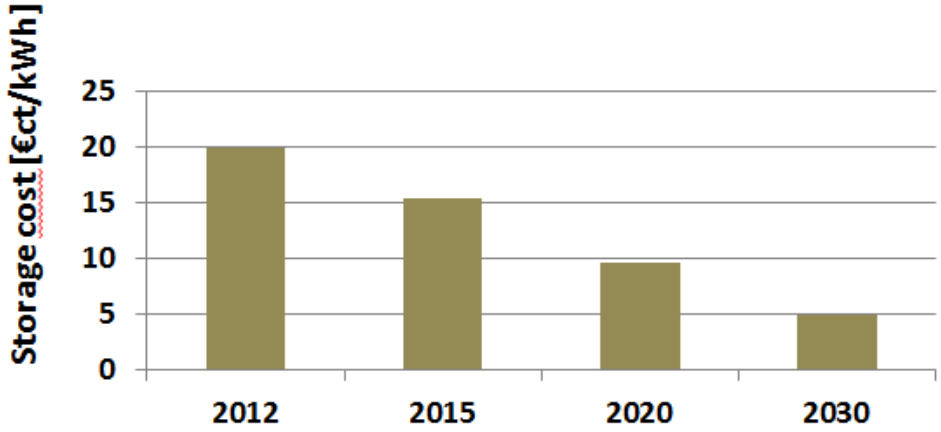
For comparison: PV between 2000 and 2010 had CAGR (cum) of 41%

CAGR (cum. Vol.) = 31 p.a. for 2030

Source: Raw data from personal communication C. Pillot (2014), avicenne; PEC curve constructed by author

LIB cell- and battery cost and resulting storage cost





LCOS (Levelized Cost of Storage) can be up to a factor of two higher depending on application (installation, BOS, power electronics)

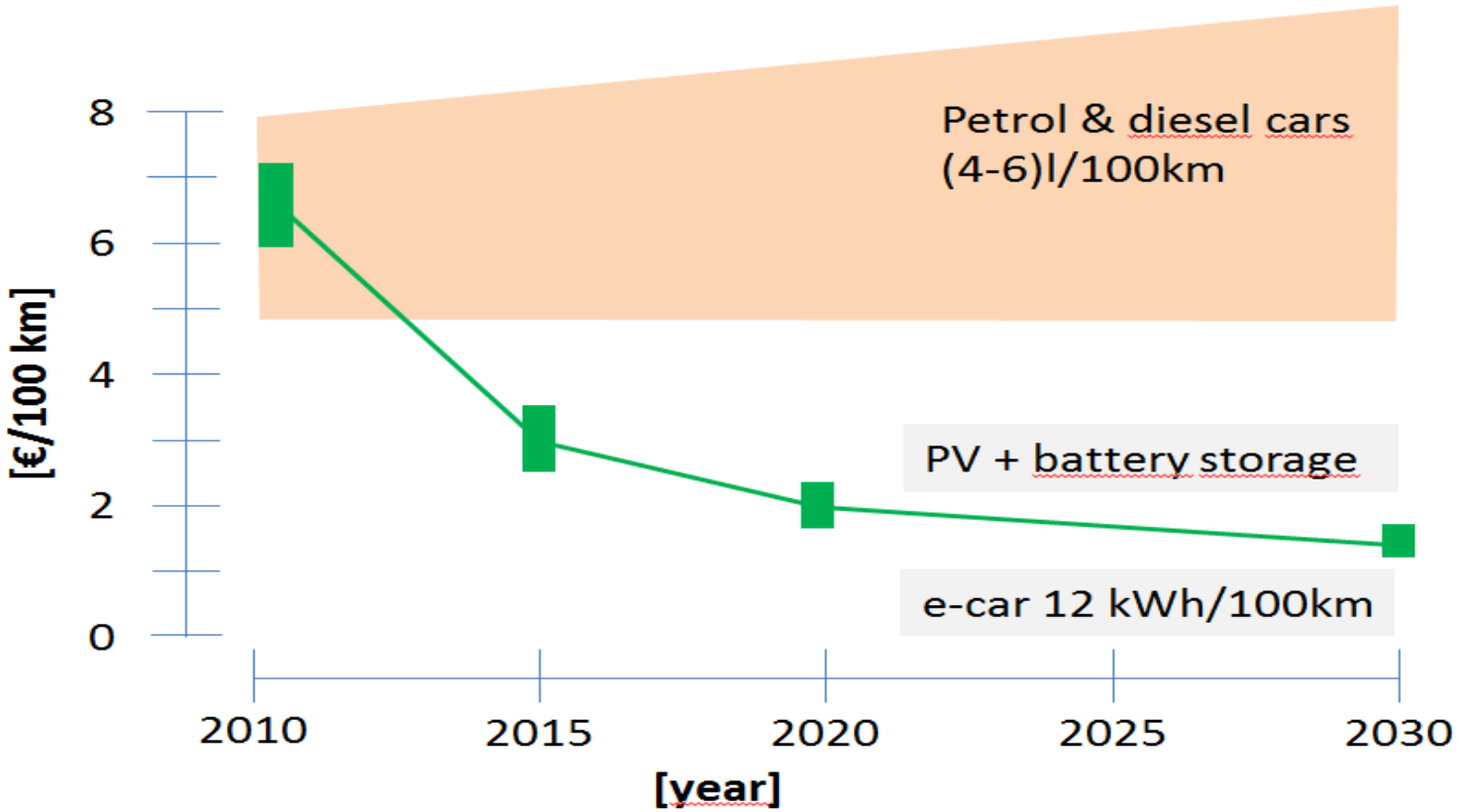
Simplified calculation for the cost of a stored kWh by a LIB battery:

- Lifetime 5,000 cycles
- Financing cost ~ same as investment
- Usable capacity per cycle ~80%

Cost per kWh = (I x 2)/(5,000 x 0.8)

Source: LIB cost 2012, 2015 and 2020 from C. Pillot (2014), avicenne; 2030/35 LIB cost, storage cost and conclusions are own estimates

Fuel cost per 100 km for conventional cars and electricity & storage cost for e-cars



BSC [€ct/kWh]	40	15	10	5
PV [€ct/kWh]	10-20	7 -14	5 -10	4 -7

Longer term electricity price development

Own	Technology	LCOE in today's currency [$ct/kWh]
Traditional	Clean coal with CSS	~10
	Nuclear fission	>~10
Photovoltaics	Southern areas (~2 kWh/W_{PV})	3 – 4
	Northern areas (~1 kWh/W_{PV})	6 – 8
Wind	On-shore (~2 kWh/W_{wind})	3 – 4
	Off-shore (~4 kWh/W_{wind})	4 – 5
Storage	Small (~kWh+)	5-10
	Large (~MWh)	<~ 5

Source: Own data

..from „Solar Home Systems“ in the 1980s to „Pico-PV“ today ..

		light	PV	battery	total	radio	tele	www	refr
1980s	[P]	3 x 25 W	50 W				CRT		
	[E]	x 4h ~300 Wh		0,3 kWh					
	[€]/ unit	x 2 ~6	~x 5= 250	~x1000 = 300	~550			-/-	
2010s	[P]	3 x 5 W	10 W				FPD		
	[E]	x 4h ~ 60 Wh		~0,06kWh		<	<		<
	[€]/ unit	x 10 = ~ 30	~x 1 = ~10	~x750 = ~ 45	~ 85			√	

Source: Own data (2015)

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… und für alle, die mehr zum Thema PV, PEC und 100% Erneuerbare Energien lesen wollen:

- Physik Journal, February 2014, W. Hoffmann „Perspektiven der Photovoltaik“

- Book by Wiley -Scrivener, W. Hoffmann
- „The Economic Competitiveness of Renewable Energy – Pathways to 100% Global Coverage“ (ISBN: 978-1-118-23790-8)

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Thank You & vielen Dank!

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The author want to thank:

- Christophe Pillot from AVICENNE ENERGY (Paris) for providing the raw market data for the LIB-battery products
- Josefin Berg from IHS for providing the capacity and production data for c-Si and Thin-Film modules

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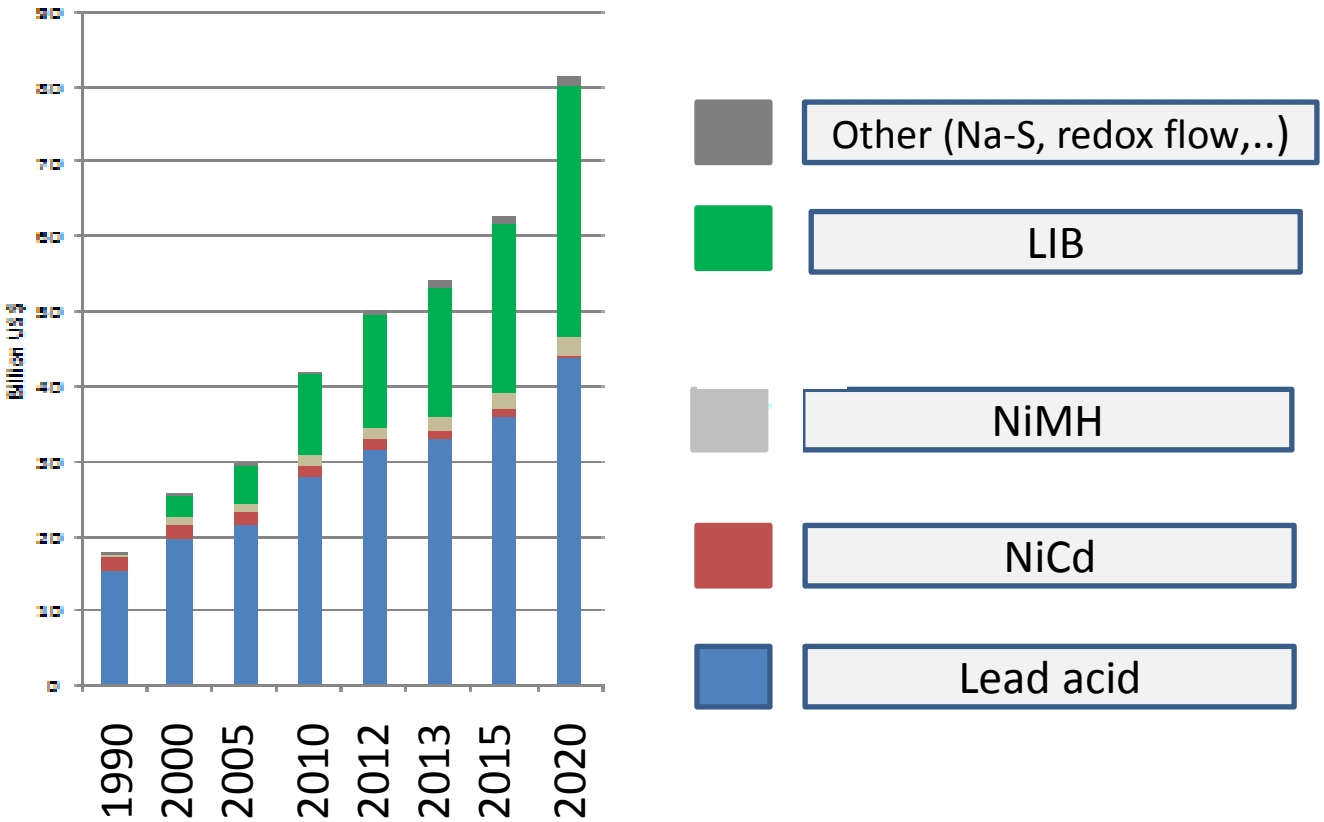
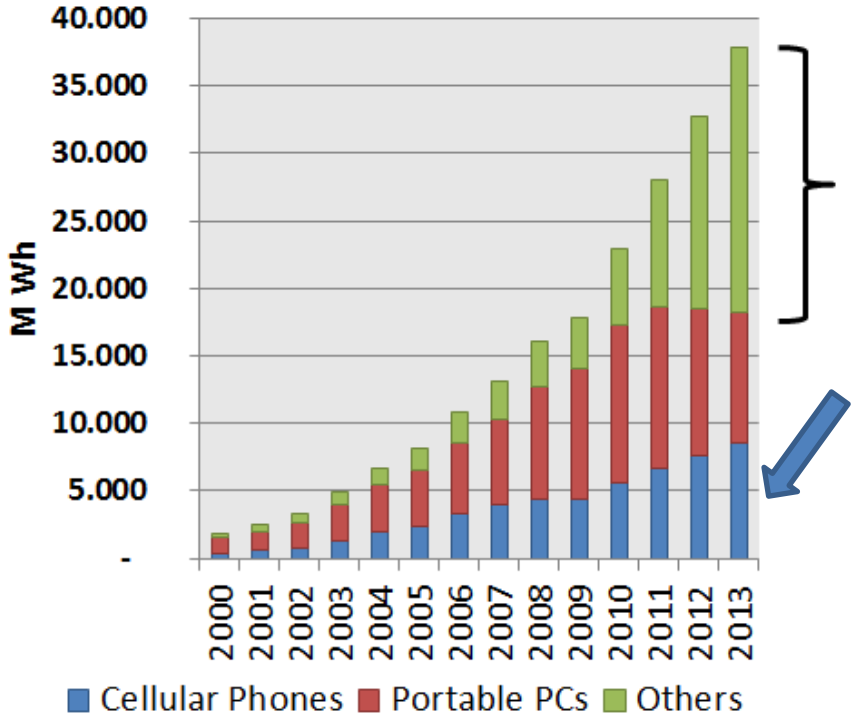
Development of the global battery market for all technologies

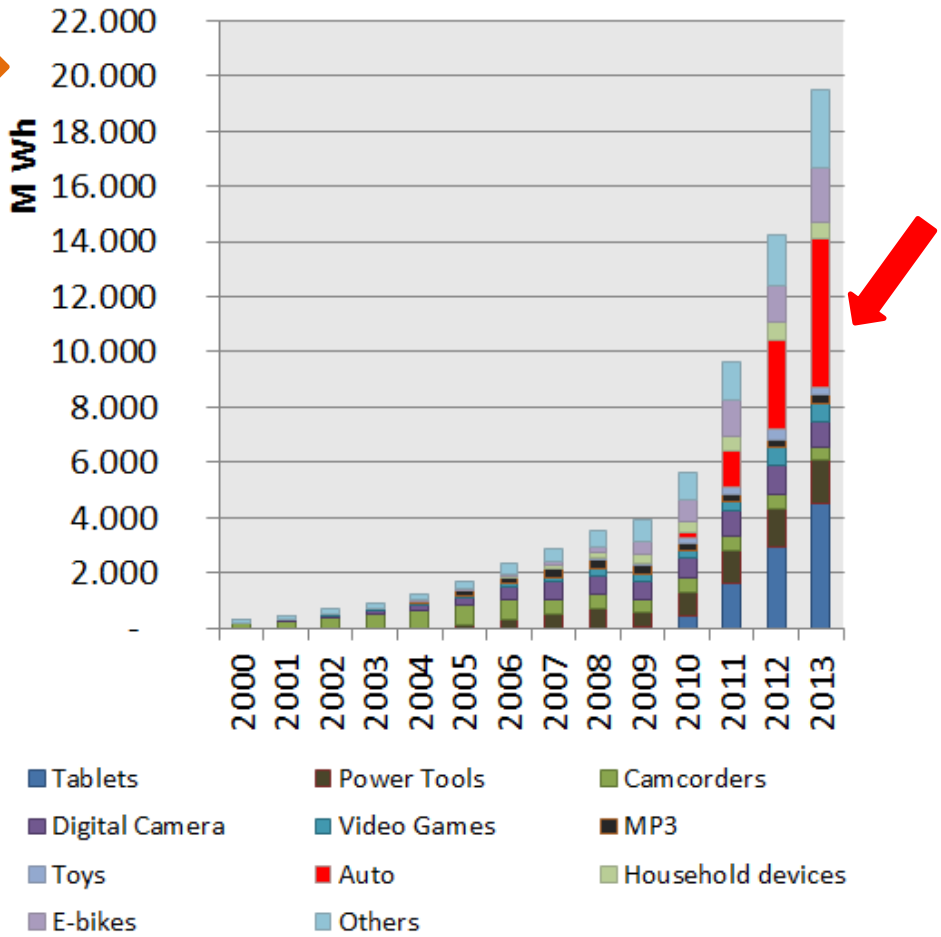


Source: until 2013 real data, afterwards estimates, graph from C. Pillot (2014), avicenne

LIB sales for all applications in sold MWh

„Others“ detailliert

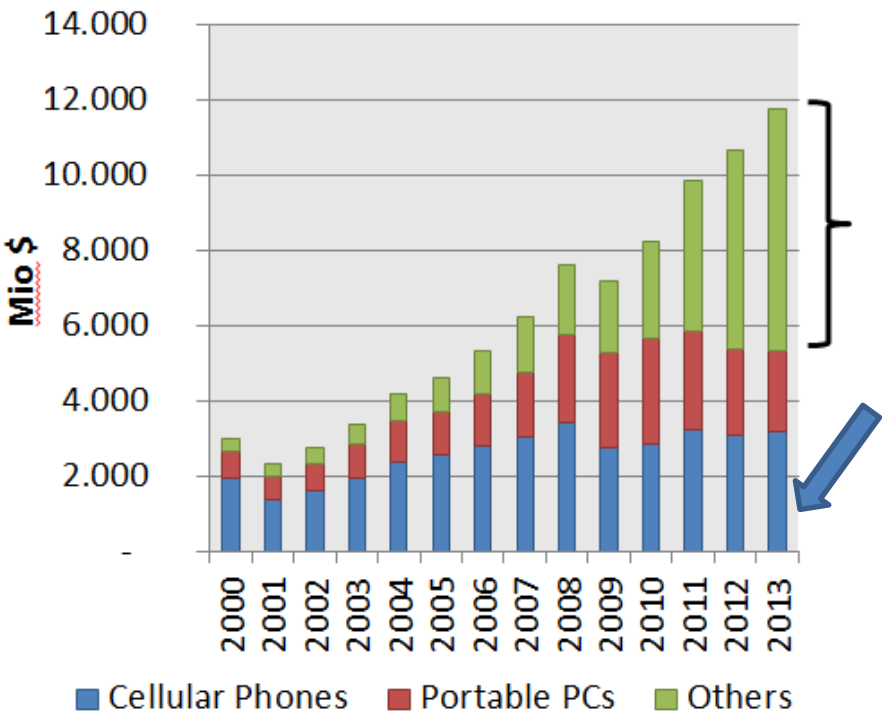


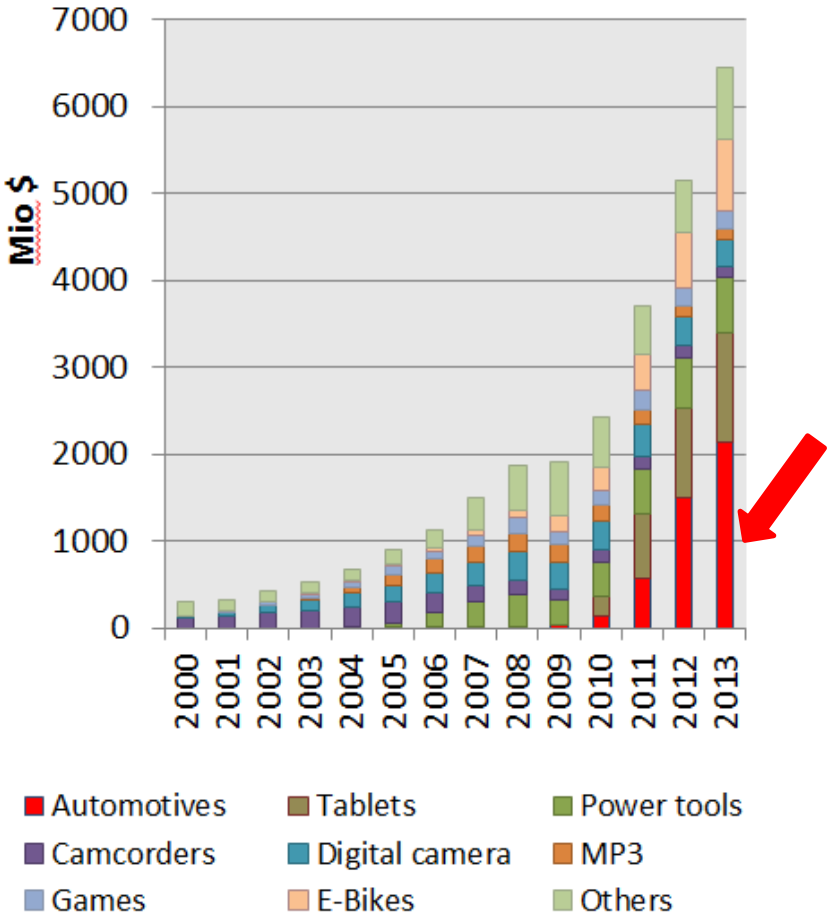


Source: **C. Pillot (2014), avicenne**

LIB sales for all applications in sold M$ (million $)

„Others“ detailliert





Source: C. Pillot, avicenne (2014)