When to expect 50 $/kWh Li-ion battery prices?

Battery event
29th to 30th September, 2021
Lyon

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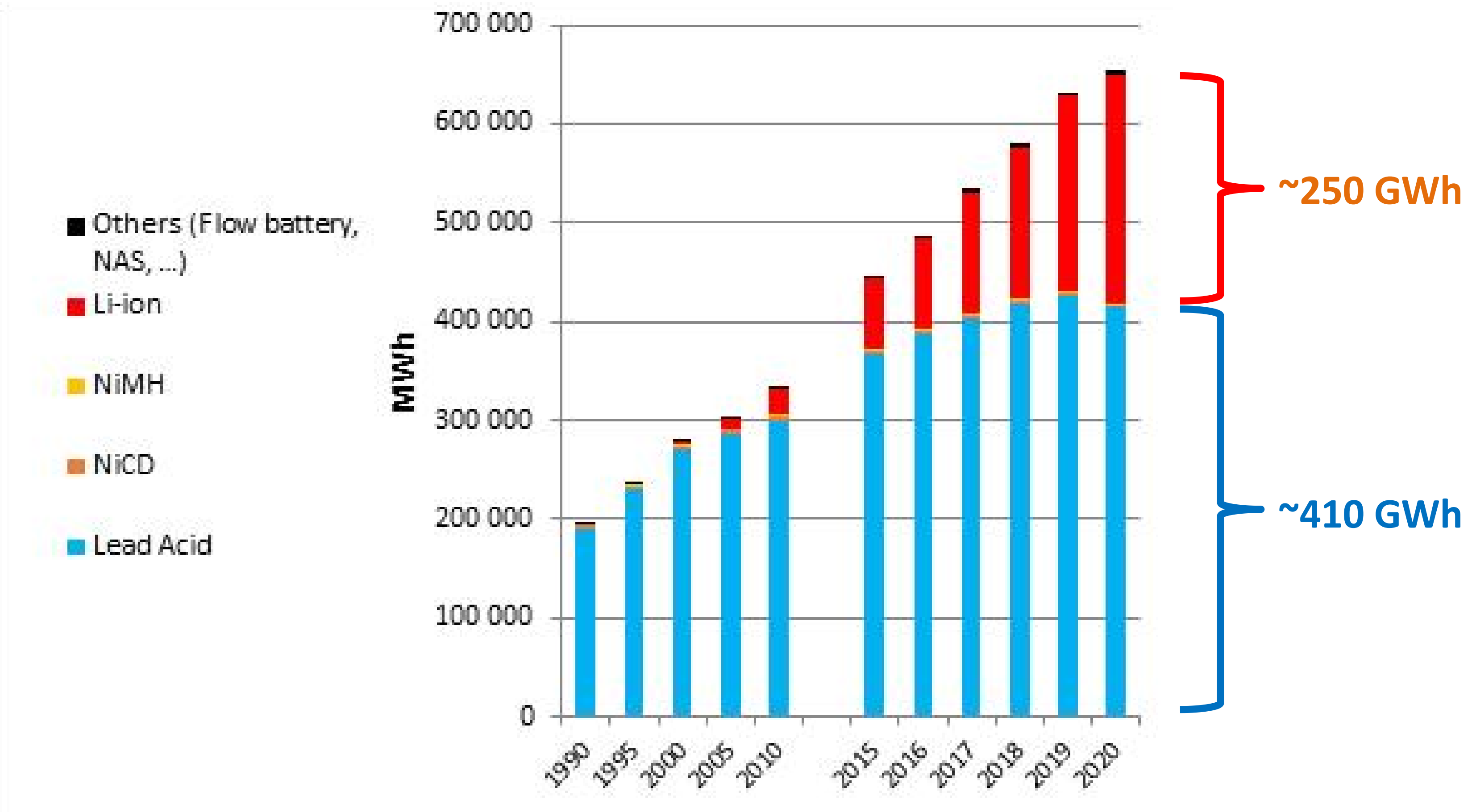
Outline

- Background
- Market growth and annual sales numbers for LIB
- PEC (Price Experience Curve) – principles and examples
- PEC for automotive LIB
- Potential market development
- Estimate for when a 50 $/kWh LIB price may arrive
- Conclusions for a 100% renewably powered world

The global battery market – and the quick rise of Li-ion technology



Source: Avicenne (Christoph Pillot, 2021)

Automotive and portable Li – ion battery applications

LIB capacity	**~10 Wh**	**50 - 100 Wh**	**100 Wh – 1 kWh**	**10 - 100 kWh**	**100 - 500 kWh**
application	Mobiles, Smart phones	laptop	e-bike	e-car	e-bus
start	mid 1990s	end 1990s	~2000	~2009	~2020

Source: Avicenne (Christoph Pillot, 2021)

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Source: Avicenne (Christoph Pillot, 2021)

The future of mobility



Airbus 350 …





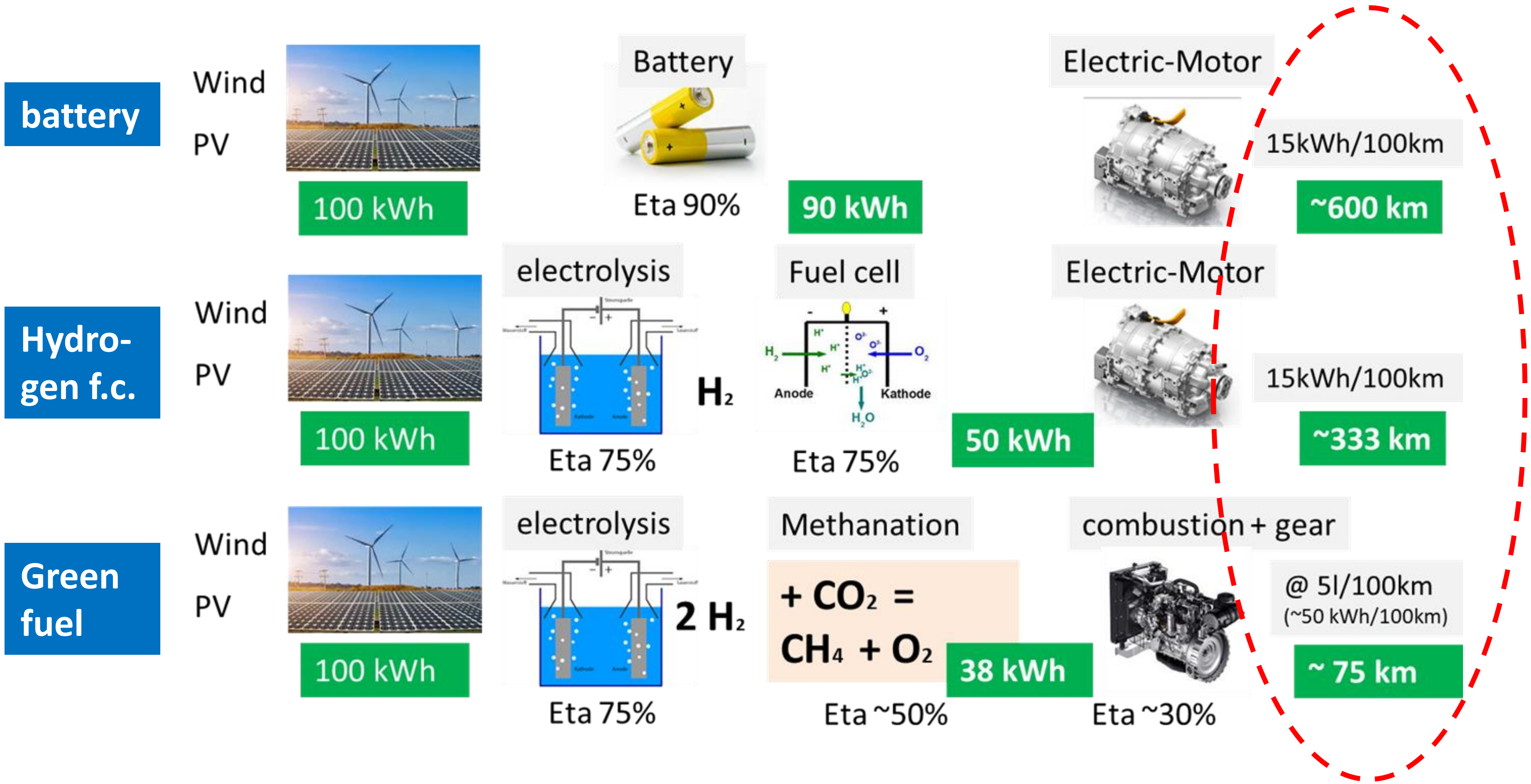
Is there a **„silver bullet“** for the **future fuel**?

Could it be **„green fuel“** where we could use all the existent infrastructure including our well developed combustion engines …?

Would **hydrogen** together with **fuel cells** be the better choice?

… or could **batteries** charged with **renewable electricity** solve any customer needs?

Battery, fuel cell and green fuel in comparison



Source: Winfried Hoffmann (2020)

The future of mobility: customer needs are decisive!

BMW i3

Tesla Model 3

Mercedes e econic

Railway

Heavy duty truck

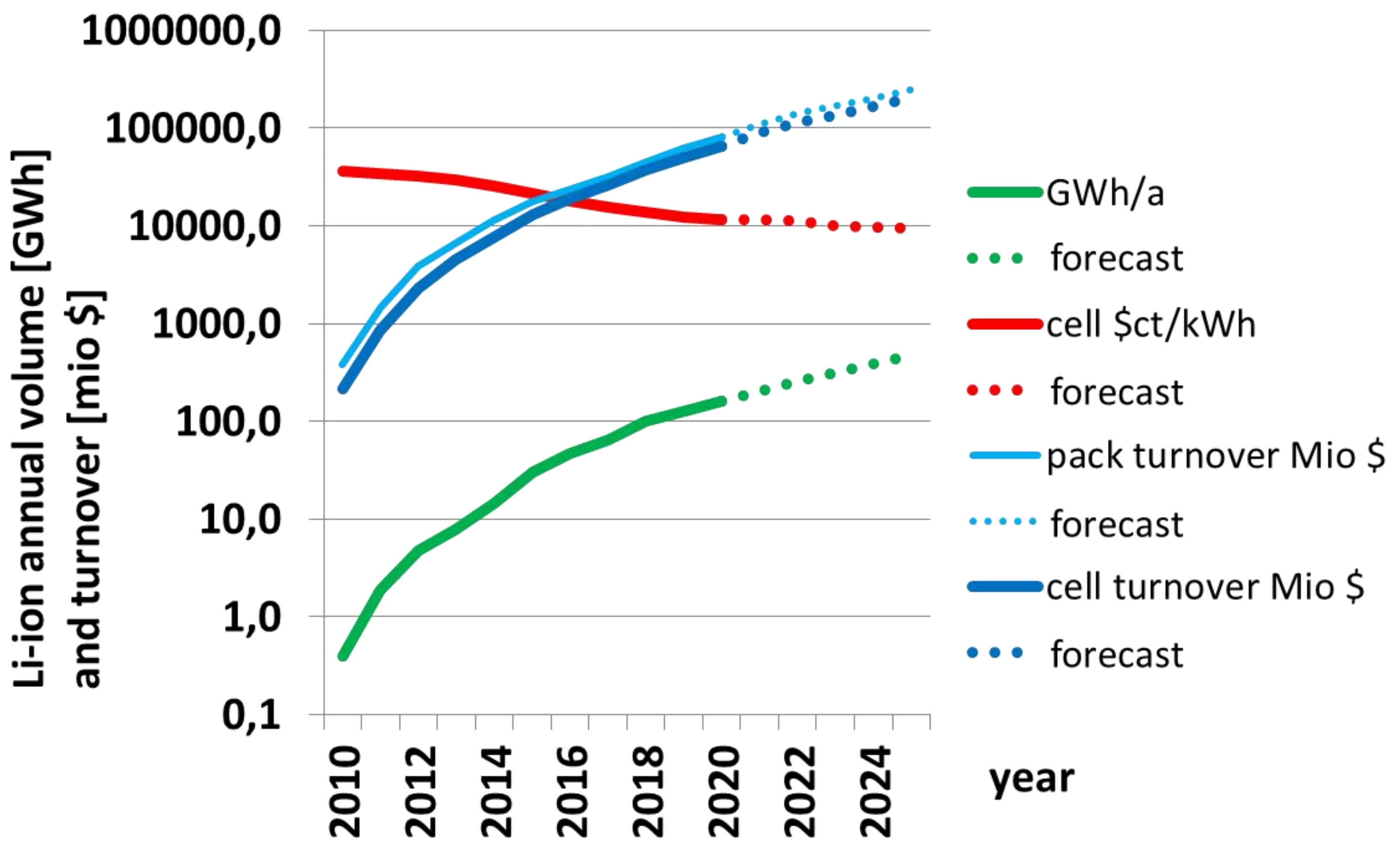
Airbus 350 ...

Global Class 1 (Dream Cruises, 9500 passengers)

battery	H_2 Fuel cell	Green fuel
500 km, charge	~1000 km, fuel	>>kWh/kg fuel

Source: Winfried Hoffmann (2020)

Li-ion annual volume and turnover



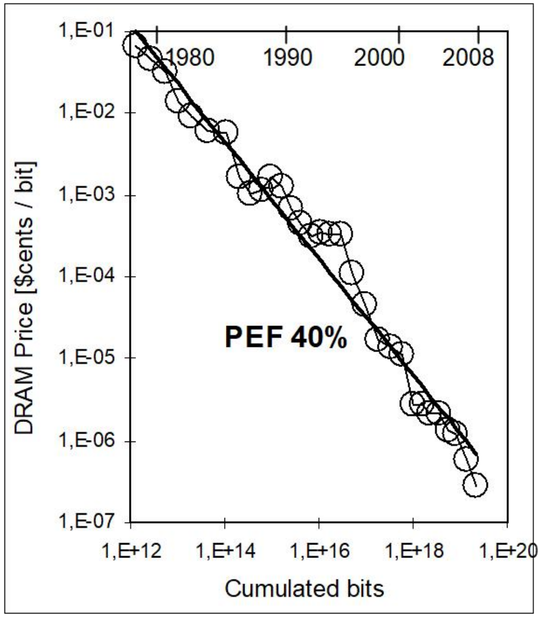
Source: Avicenne (2021)

Price Experience Curves
- PEC -

- Based on „Cost Learning Curves“ Boston Consulting Group developed for mass produced products a „Price Experience Curve“

- When plotting the log (cumulative volume produced) versus the log (global average price per specific unit), a straight line with a typical slope („Price Experience Factor“) is obtained

PEC for semiconductor products

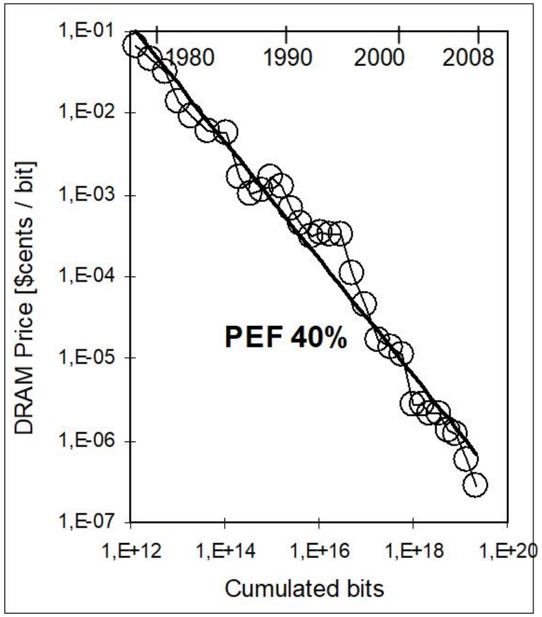


Semiconductor (DRAM)
6 orders of magnitude

„Moore‘s law“

Source: Winfried Hoffmann, ITRPV (2021)

PEC for Flat Panel Display



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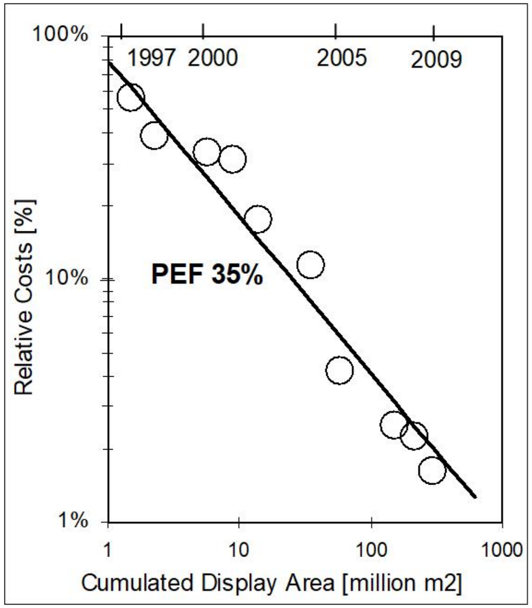
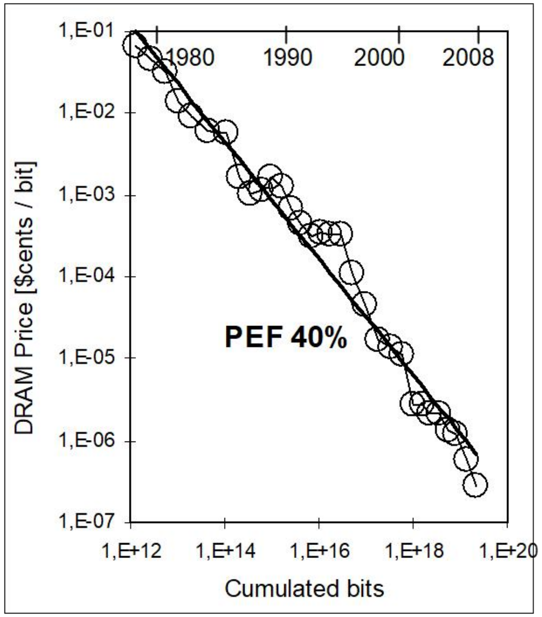


Flat panel display
2 orders of magnitude

Substrate size increase from 0,1 towards >10 m²

Source: Winfried Hoffmann, ITRPV (2021)

PEC for solar PV modules



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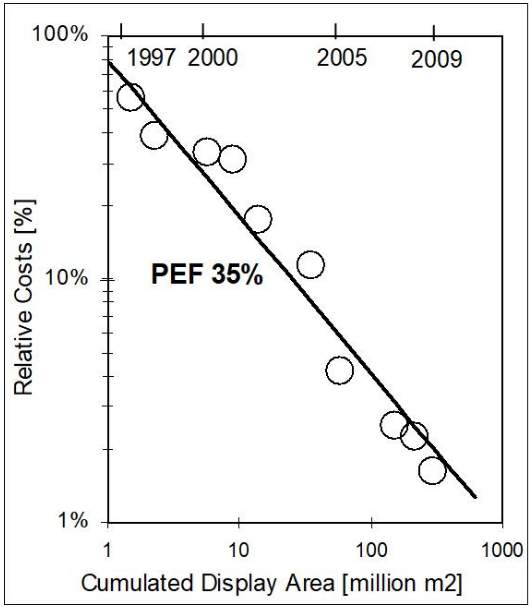

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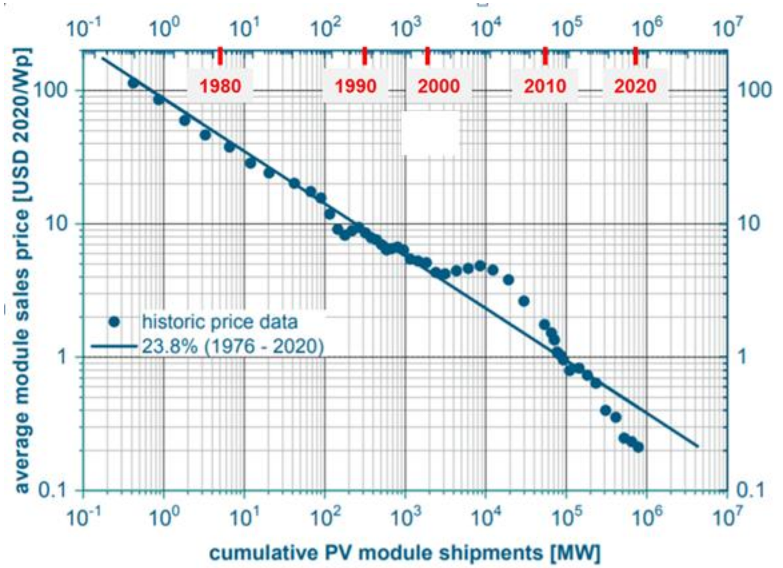


PV solar modules
3 orders of magnitude

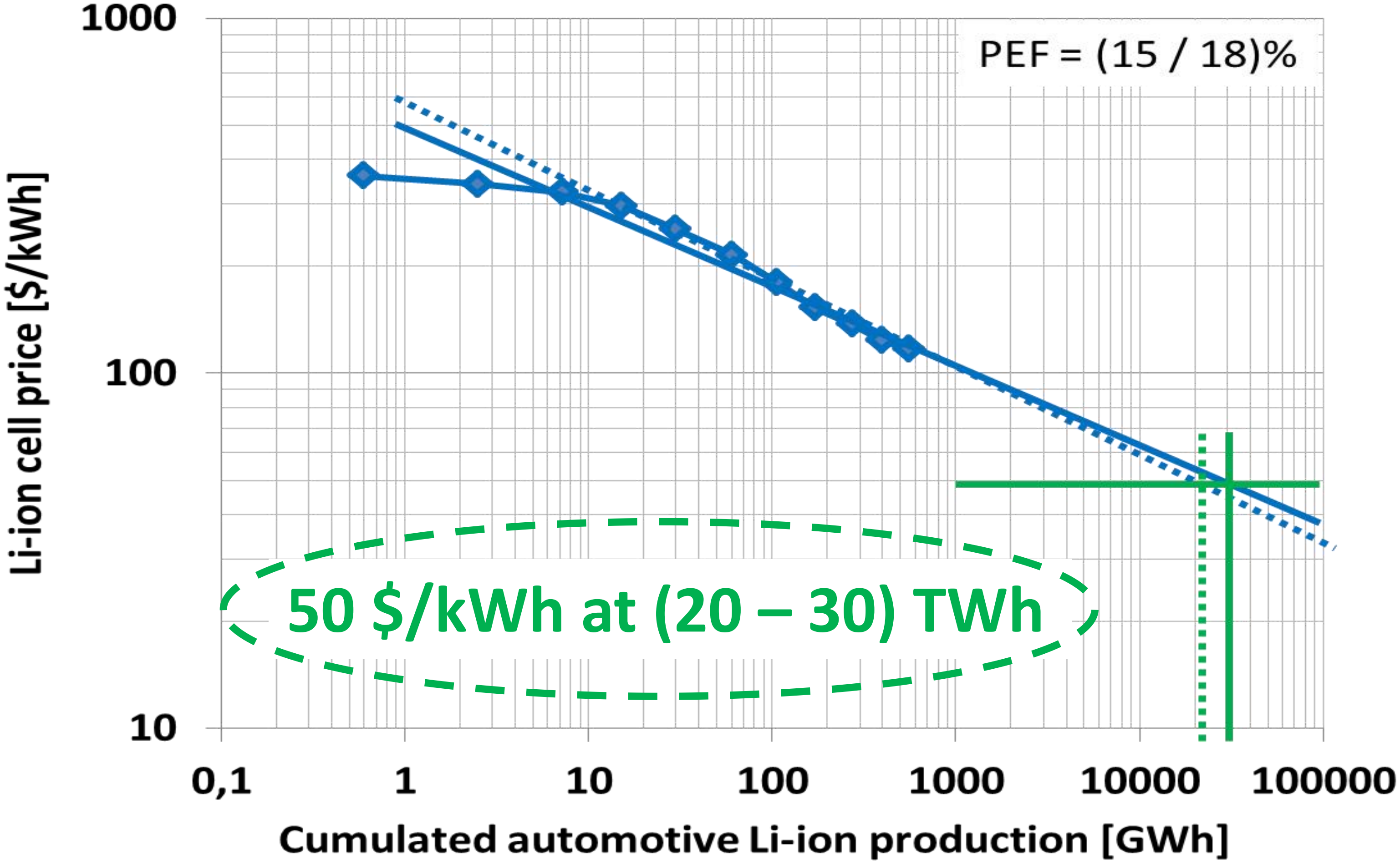
… even more complex –
comparable to the LIB case

Source: Winfried Hoffmann, ITRPV (2021)

1st step for LIB

- Construct from past data until today a Price Experience Curve for LIB
- Extrapolate the straight line
- Conclude at which cumulatice volume a price of 50 $/kWh is expected

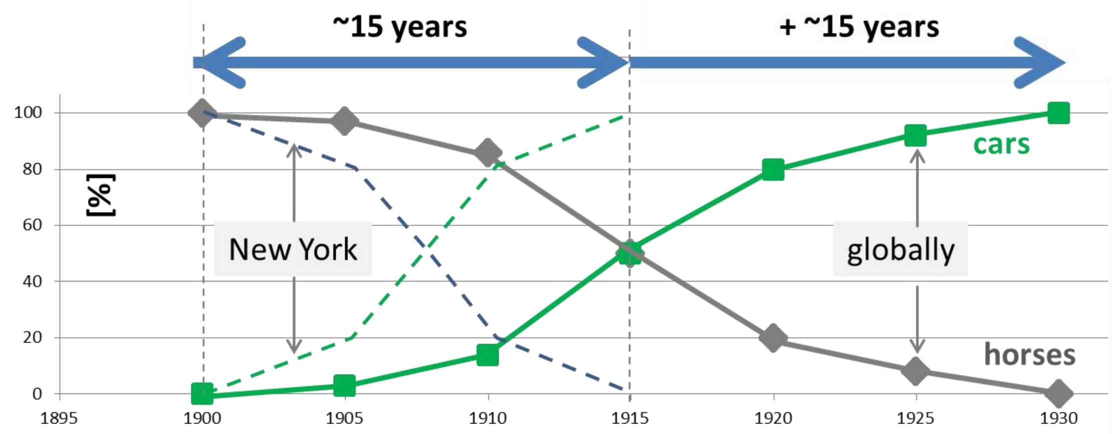
Price Experience Curve for automotive Li-ion cells



2nd step

- Find reasonable arguments for a realistic market growth
- (a) in terms of a realistic time horizon
- (b) in terms of a realistic final annual production volume

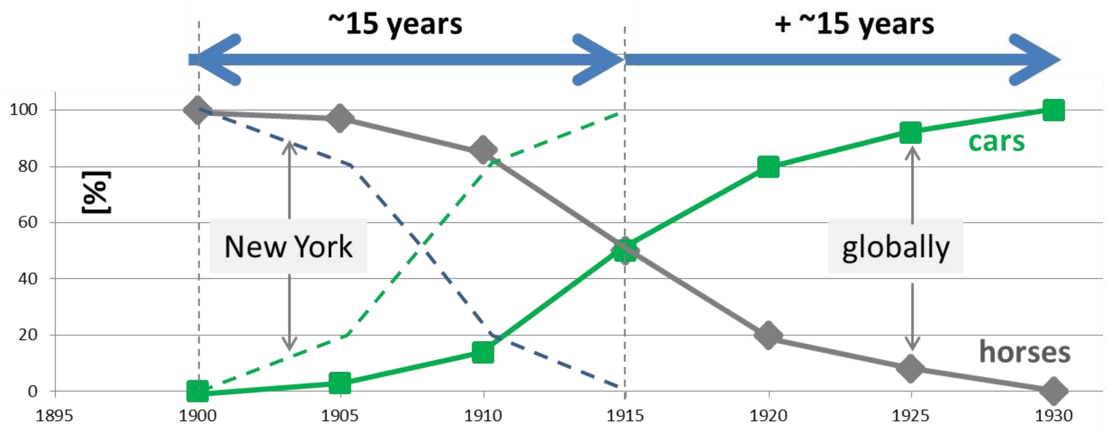
Comparison petrol cars versus horses for local and global situation

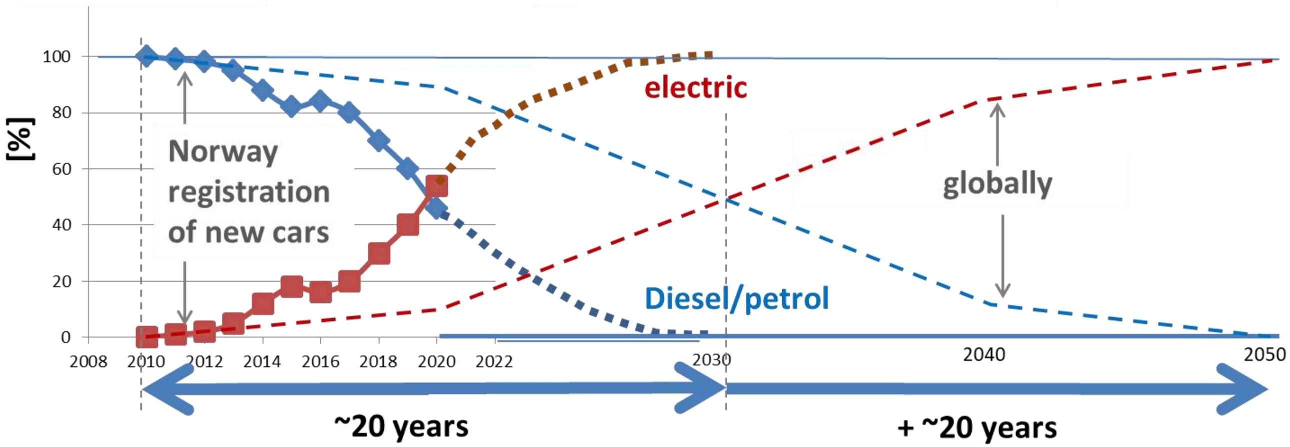


Disruption (by Tony Seba)

Source: Tony Seba (green dotted line, New York), Winfried Hoffmann (global scenario)

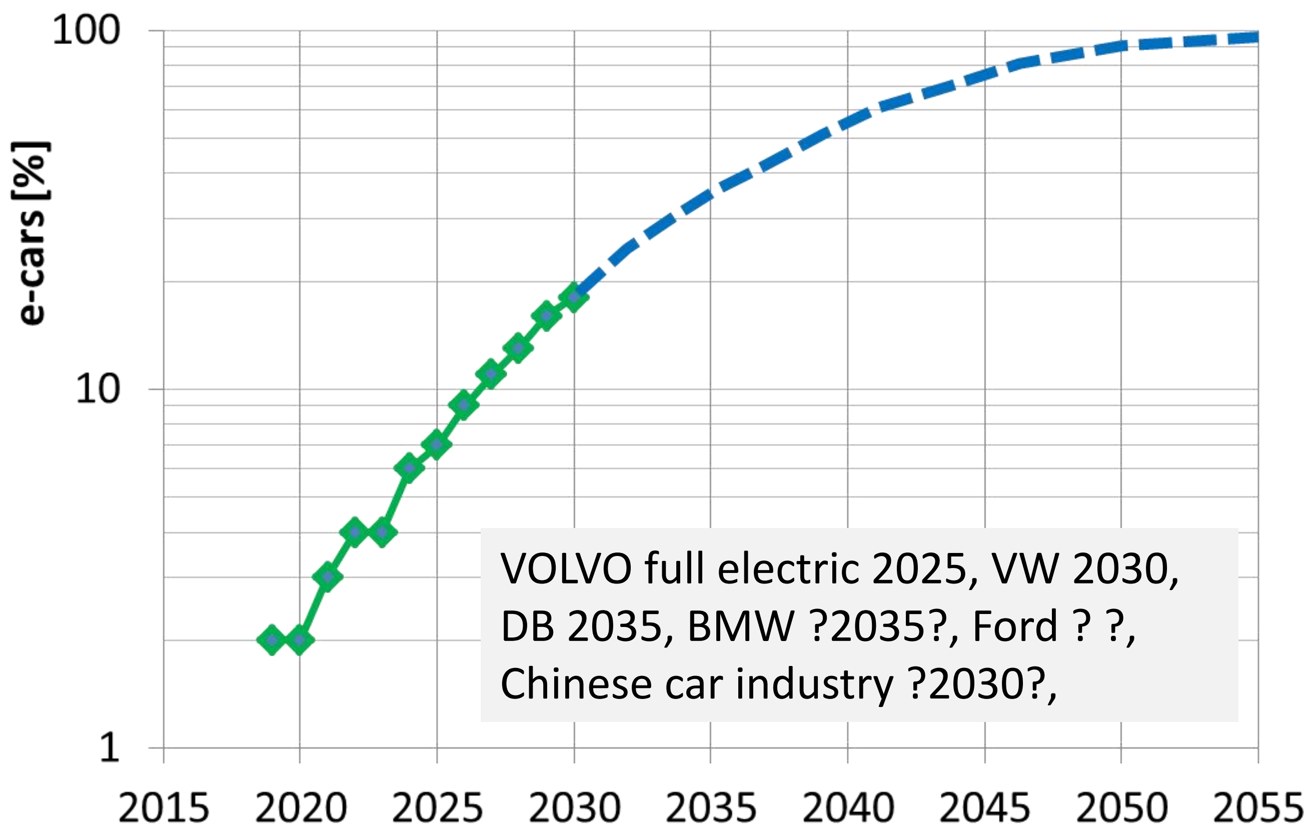
Comparison petrol cars versus horses and e-cars versus petrol cars for local and global situation





Source: Tony Seba (green dotted line, New York), Elektroauto-news (Jan 2021, Norway), Winfried Hoffmann (global scenarios)

Global penetration of e-cars (100% = all cars worldwide)



Source: BCG (green diamonds), Winfried Hoffmann (blue dotted line)

Step 2 (b)

Global development for **passenger cars**:
2017 ~80 m → ~100 m as average in future →

@ 60 kWh/car → if all cars are equipped with LIB we have 6000 GWh or **6 TWh per annum**

E-buses, boats etc. may add additional **2 TWh**
Depending on **additional applications** the maximum annual needs may be **up to 10 TWh p.a.**

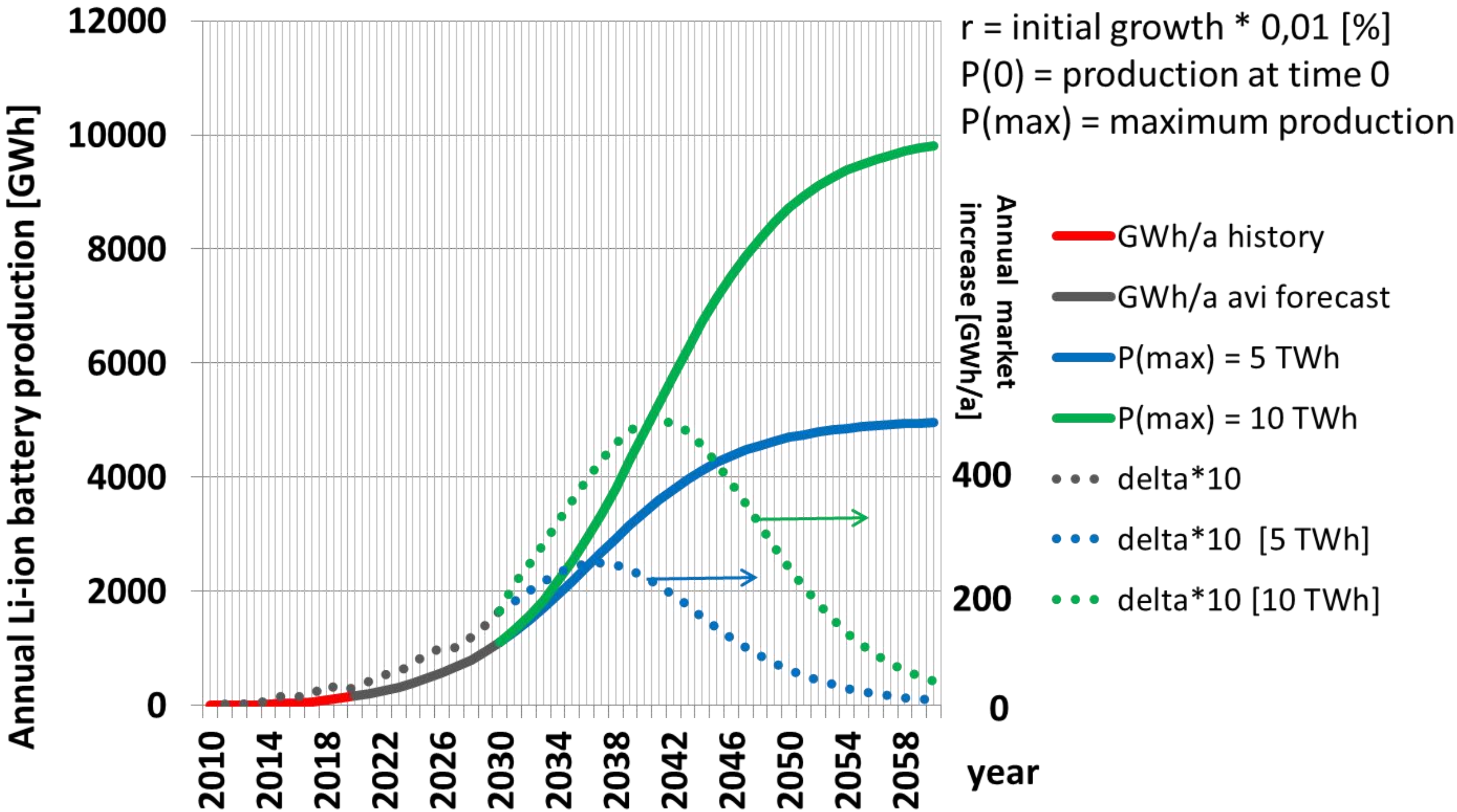
Historical and logistic annual growth for Li-ion market

Logistic growth: P(t) = P(0)*exp(rt) / {1 + P(0)*[exp(rt) – 1]/P(max)}

r = initial growth * 0,01 [%]

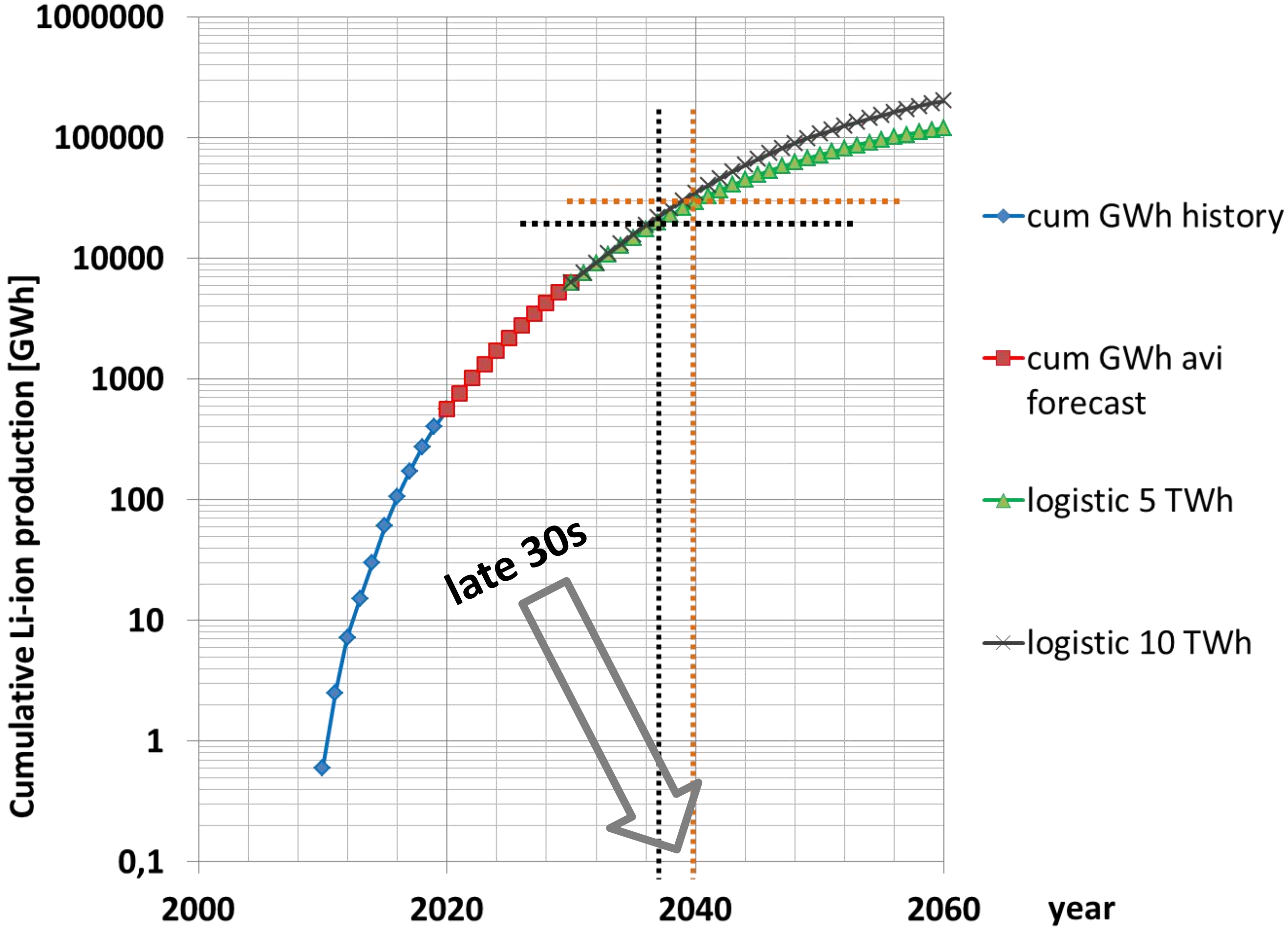
P(0) = production at time 0

P(max) = maximum production



Source: Data from 2010 to 2030 by avicenne, after 2030 logistic growth with max 5TWh and 10 TWh in the 2060s

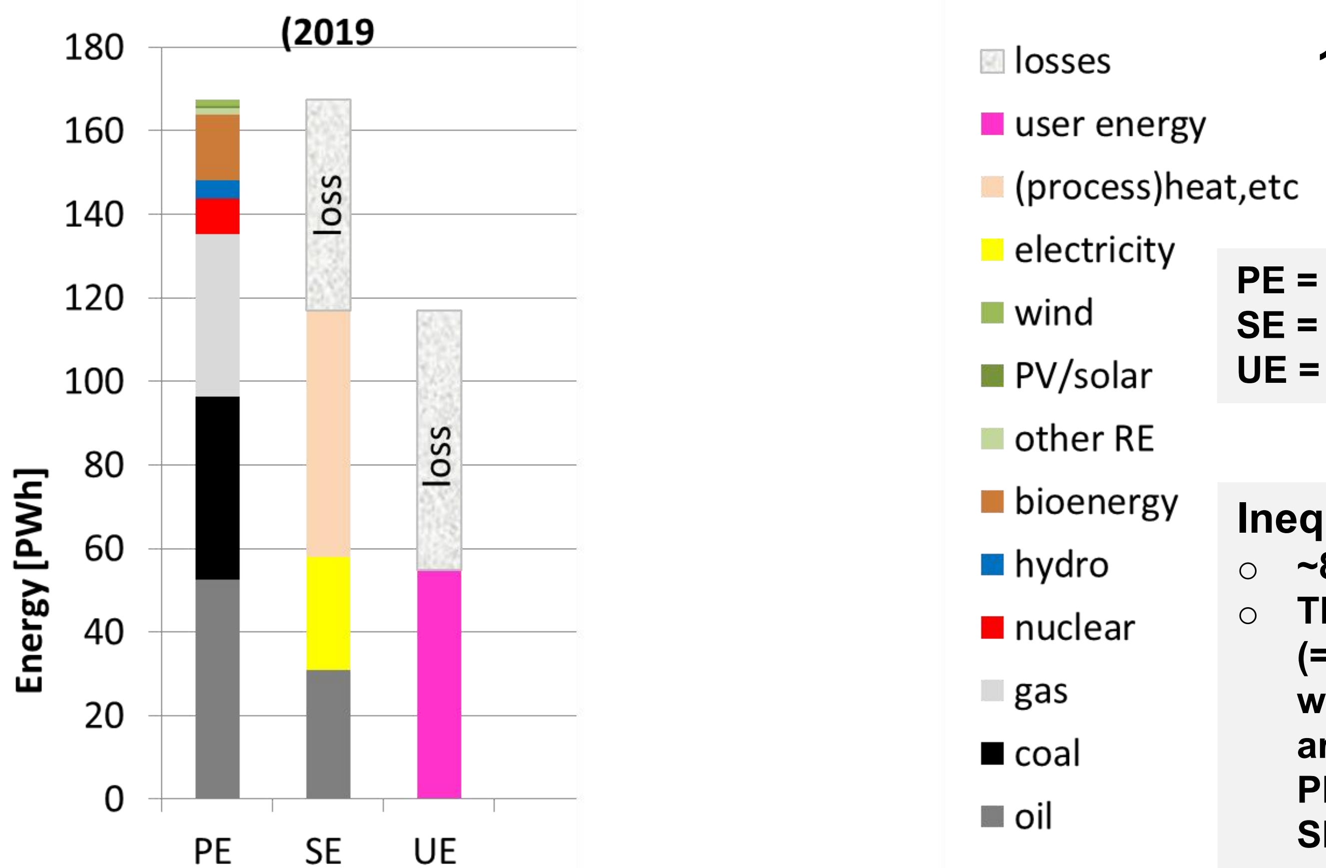
Cumulative Li-ion production and time for 50 $/kWh cell price



Conclusion

- Step 1: 50 $/kWh are expected at ~(20-30) TWh p.a.
- Step 2 (a): realistic time horizon for a ~100% coverage for e-cars is expected in the 2050's
- Step 2 (b) realistic annual volume is in the range of 5 up to 10 TWh
- With these boundary conditiones we expect a price of 50 $/kWh at around 2040

The global energy picture



1 PWh = 10^^15 Wh

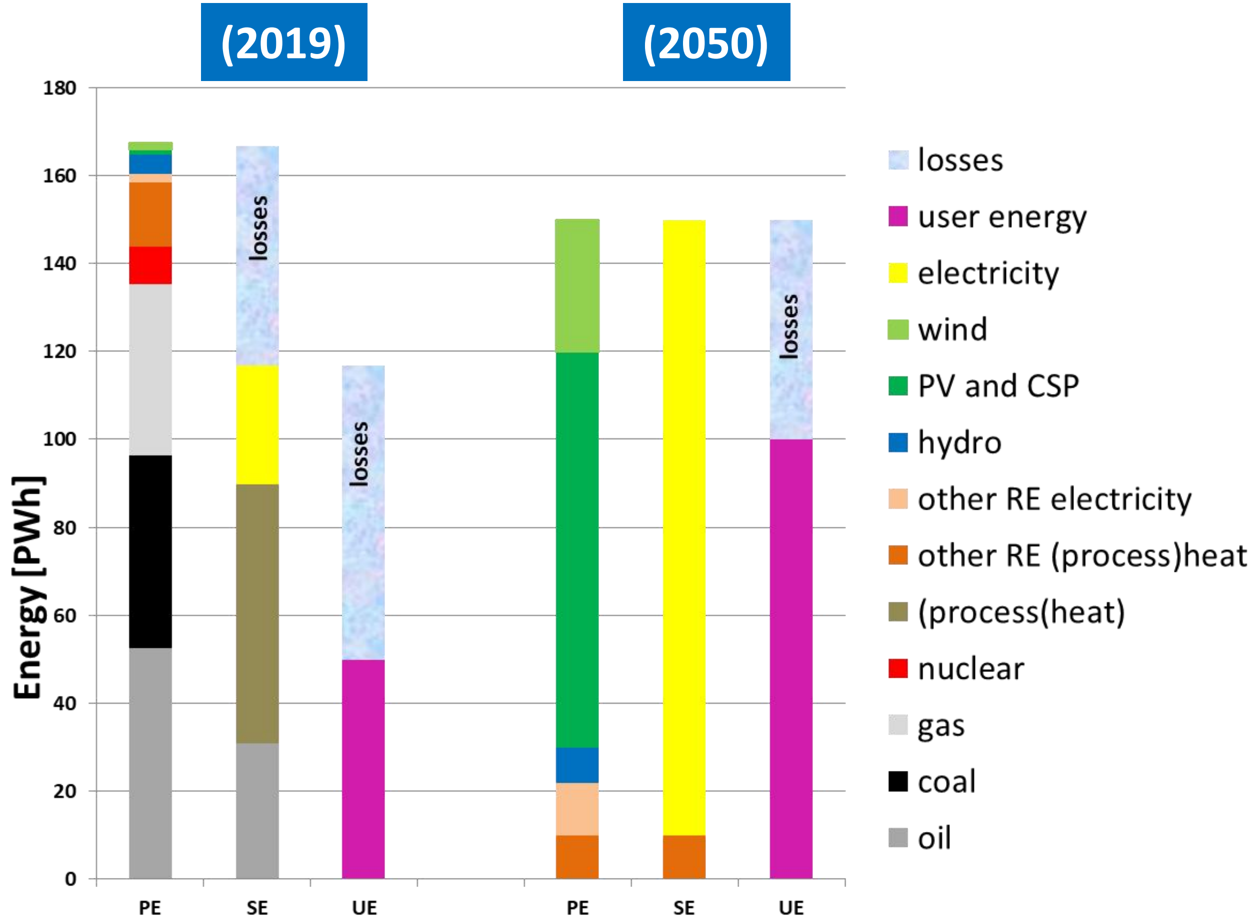
PE = primary energy
SE = secondary energy
UE = (end) user energy

Inequity today:

- **~8 bn people**
- **The ¼ „privileged's" (= ~2 bn mostly we in the western hemisphere) are using ¾ of PE (~120 PWh) and SE (~ 90 PWh)!**

Source: 2019 data IEA WEO (2020)

The big change from today (~2019) towards 2050+



Electricity for 2050 includes P2G(&X)

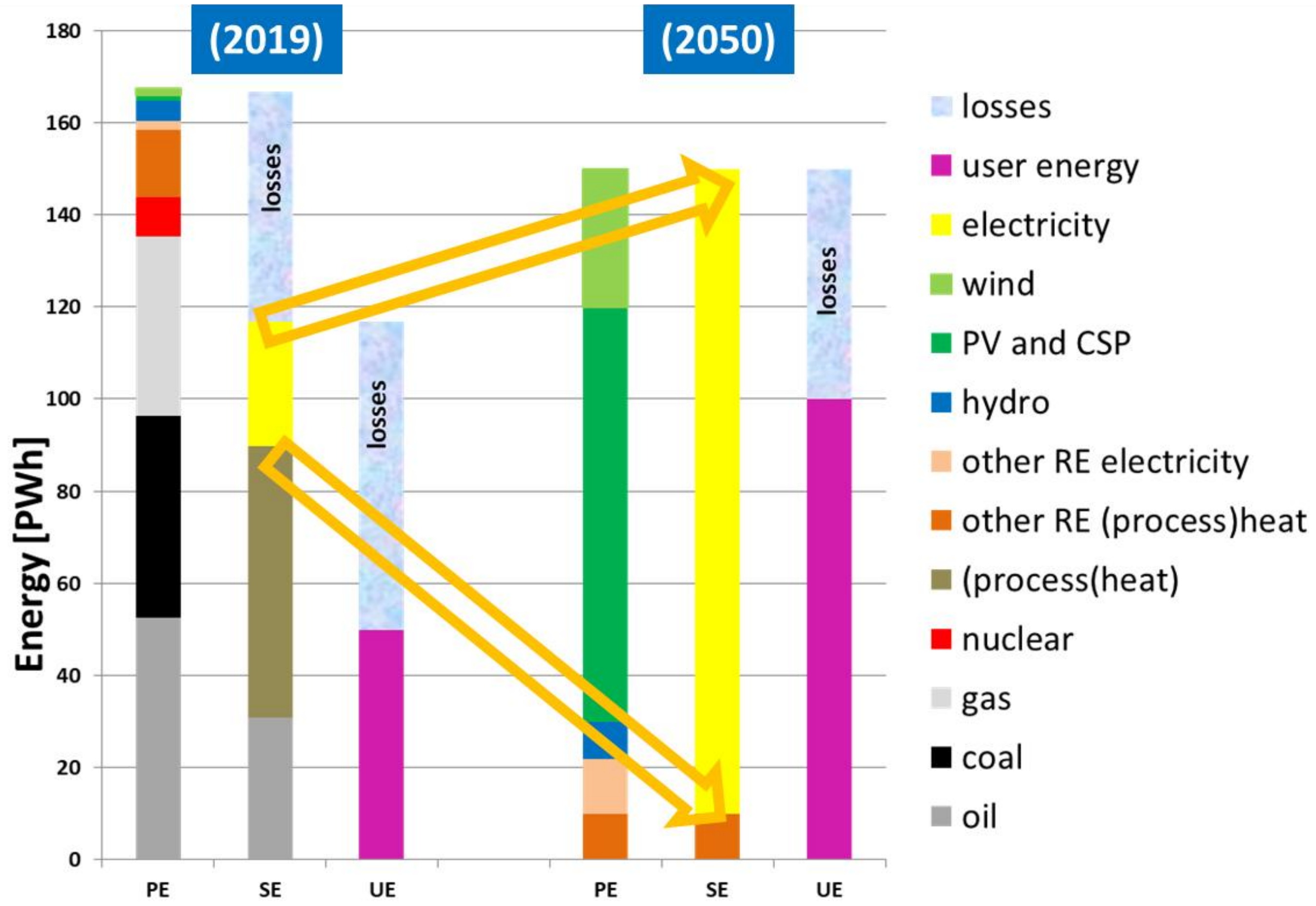
Zero Carbon

Same energy for everyone of the 10 bn people

Efficiency & only RE

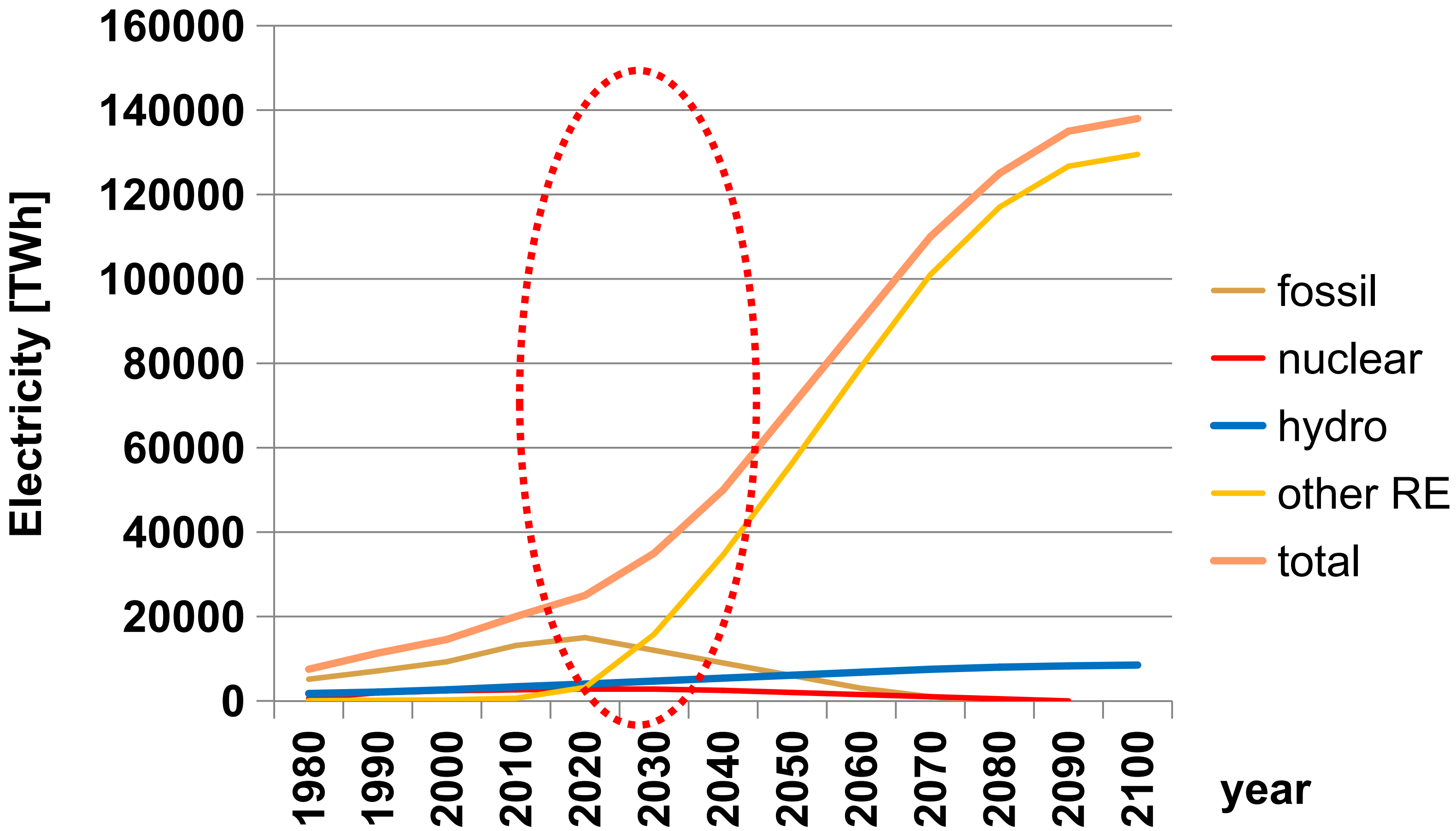
Source: 2019 data IEA WEO (2020), 2050 data Winfried Hoffmann (2021)

The big challenge …



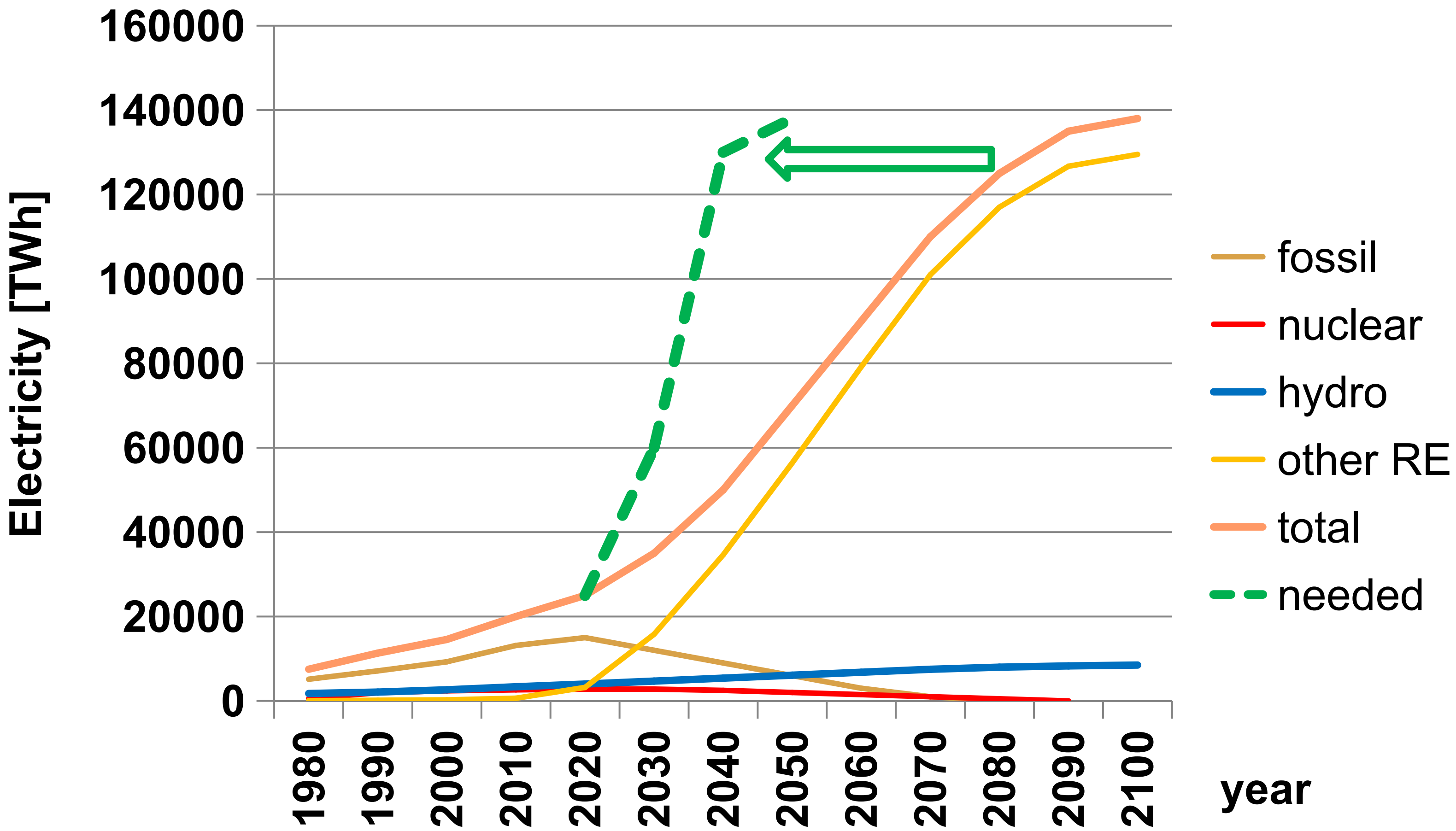
Source: 2019 data IEA WEO (2020), 2050 data Winfried Hoffmann (2021)

the simple consequence for the future electricity production …



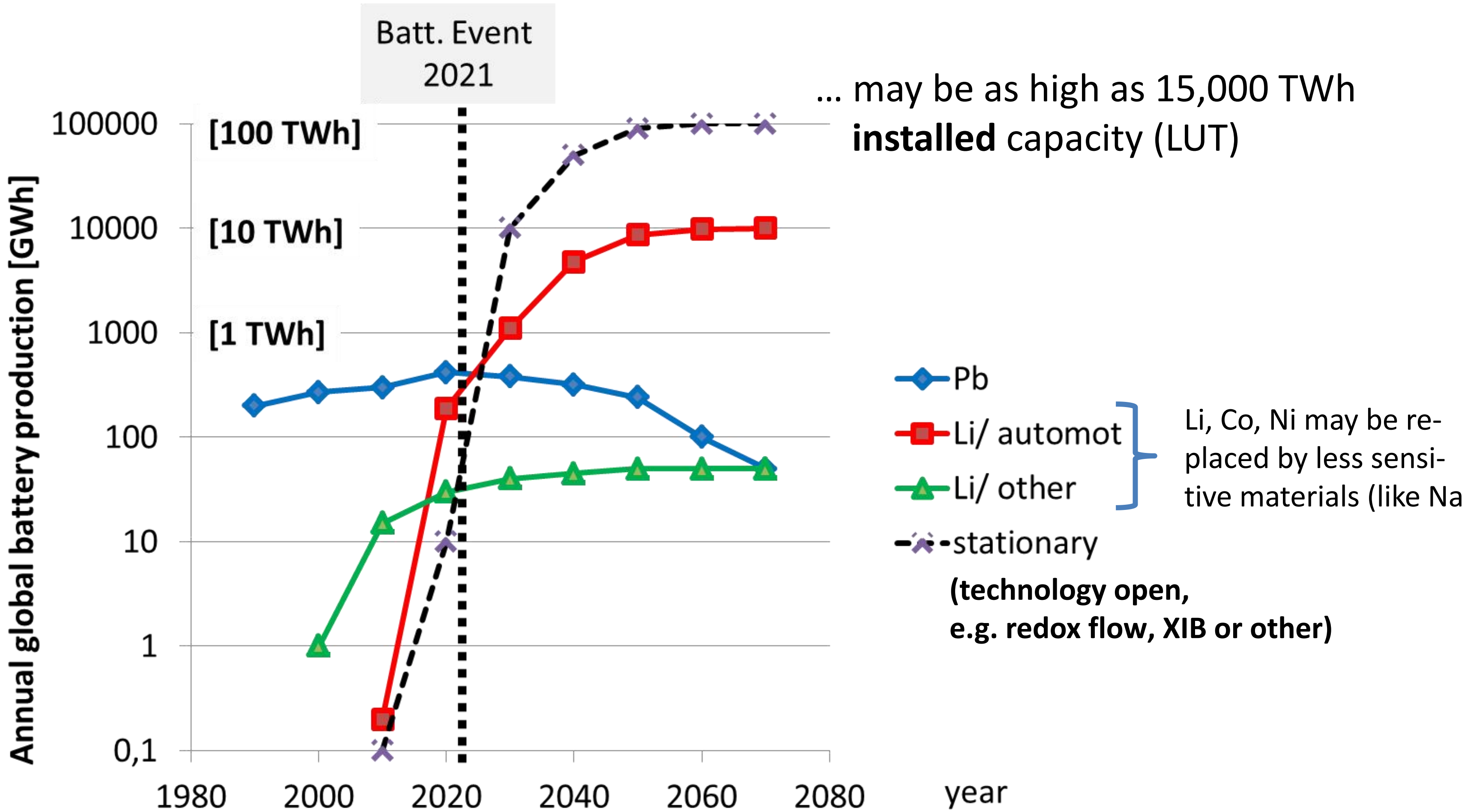
Source:

… and even more challenging!



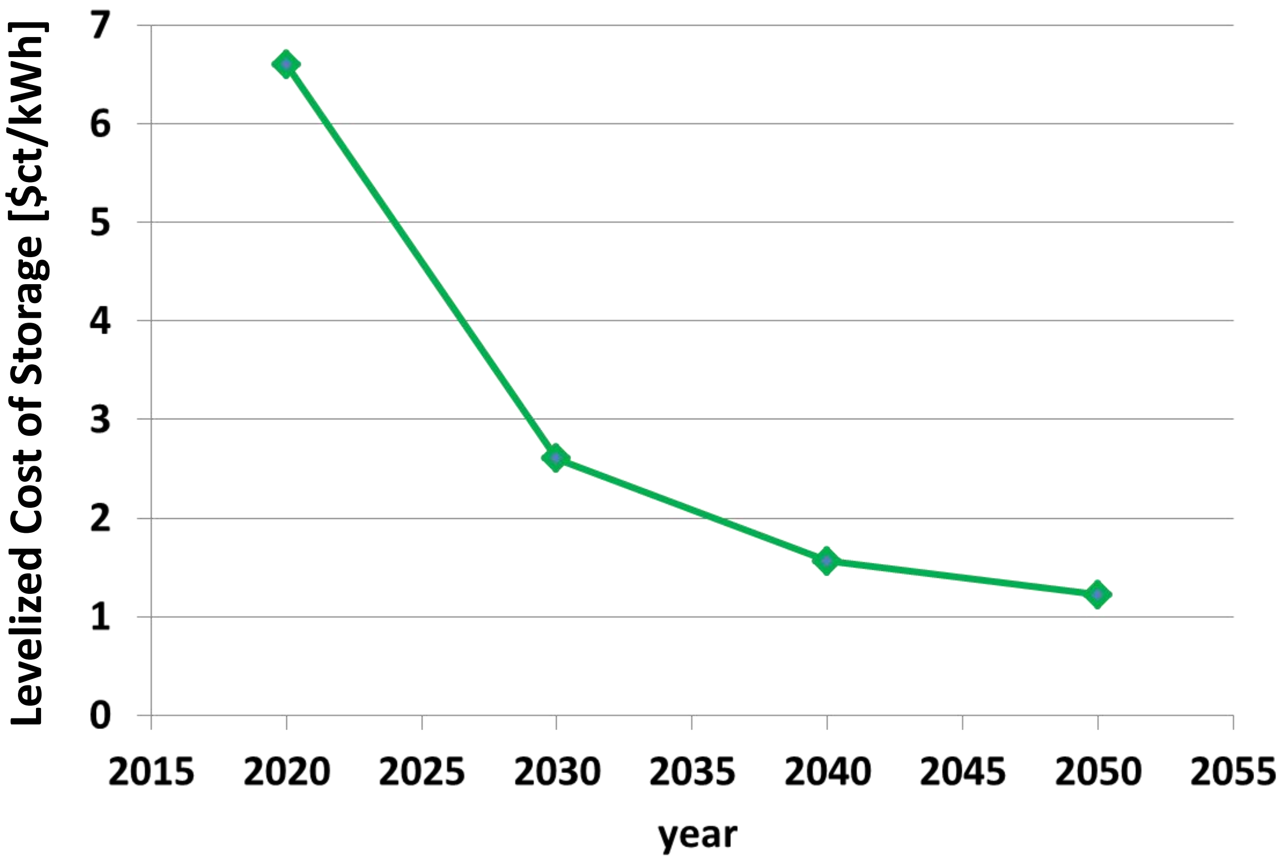
Source:

Hypothetical development for the global battery storage market



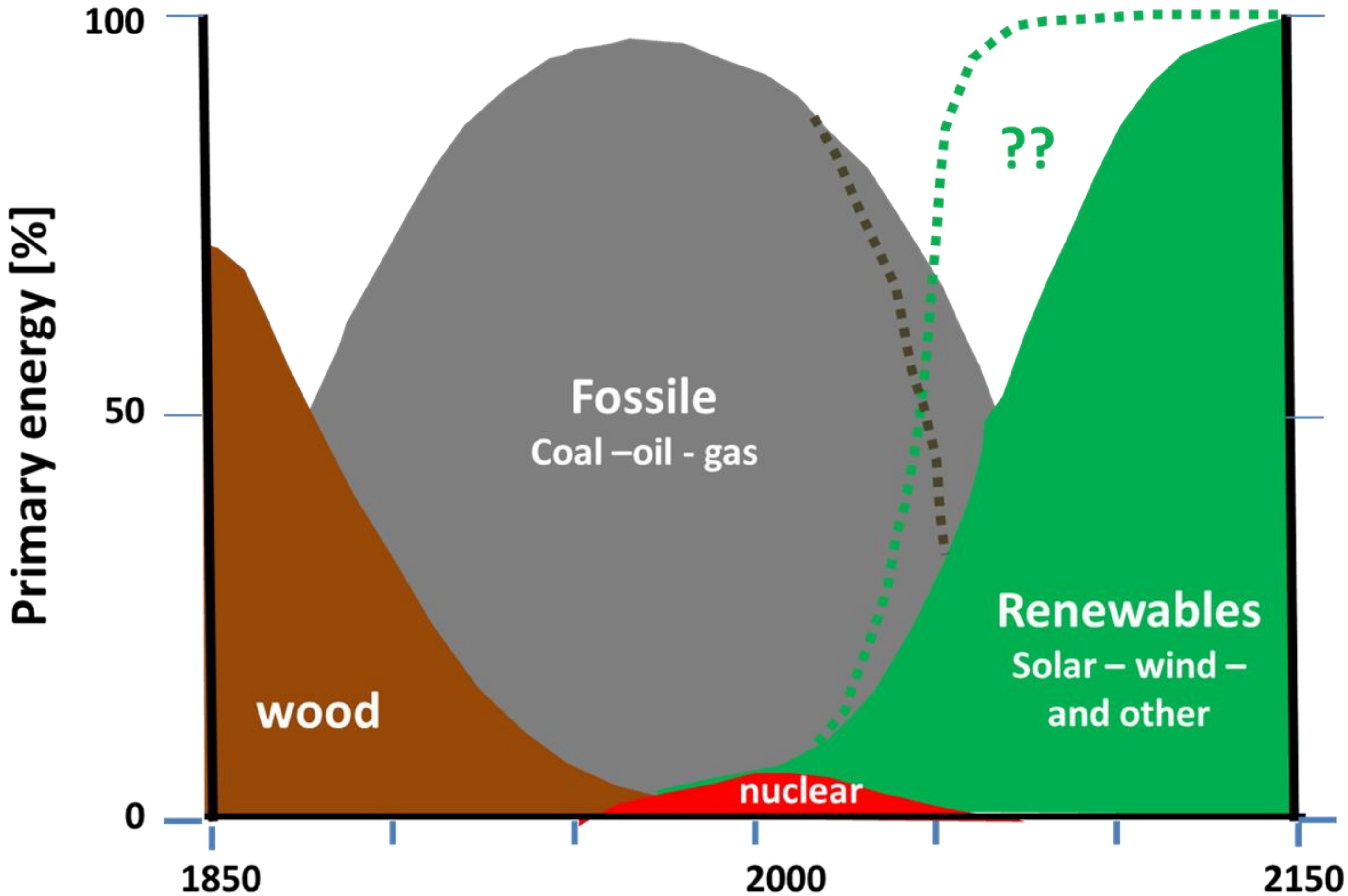
Source: Data until 2020 from avicenne, further development estimate by Winfried Hoffmann

Estimated LCOS for battery storage



Source: Winfried Hoffmann (2021)

From the old renewables (wood) to the new ones (solar & wind a.o.)



Conclusions

Extrapolation of historical Price Experience Curves indicates that a Li-ion cell price of 50 $/kWh will be reached at ~(20 – 30) TWh cumulative production volume

The future annual Li-ion market for automotive applications is estimated to saturate at around 5 TWh, with additional applications up to 10 TWh in the 2060s may be possible

With reasonable growth numbers 50 $/kWh LIB cell prices can be reached at around 2040 for both scenarios

Corresponding storage price will develop from ~7 $ct/kWh today to ~6 in 2025, 3 in 2030, <2 in 2040 and will eventually approach 1 $ct/kWh in the 2050s

Battery development and price decrease enables the energy disruption towards 100% renewables in the 2050s

Thank you very much
for your interest!

Acknowledgement:
The authors would like to acknowledge the coloured temperature band from Greenpeace showing the temperature increase from blue cold in 1850 (left) to dark red hot in 2017 (right)!