



FUEL CELLS AND HYDROGEN
JOINT TECHNOLOGY INITIATIVE



AUTOSTACK Workshop
Feb8th 2011, Grenoble

Workshop on Automotive Stack Design Options, Platform Concept, and Cost Targets

F. Finsterwalder

Daimler AG

DAIMLER

Content



1. Introduction
2. Summary of system requirements and stack specification
3. Conclusions for design options and platform concept
4. Critical trade-offs - Power density vs. Pt-loading

Autostack: The Objectives



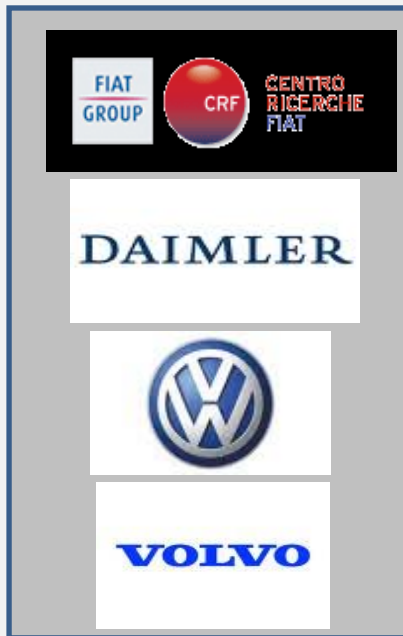
- Analyze
 - vehicle requirements
 - supply industry
 - Cost and cost drivers
- Identify
 - synergy potential
 - Research needs
- Propose
 - Consistent development road map
 - Business model

Combining Expertise



Autostack Consortium

Automotive
OEMs



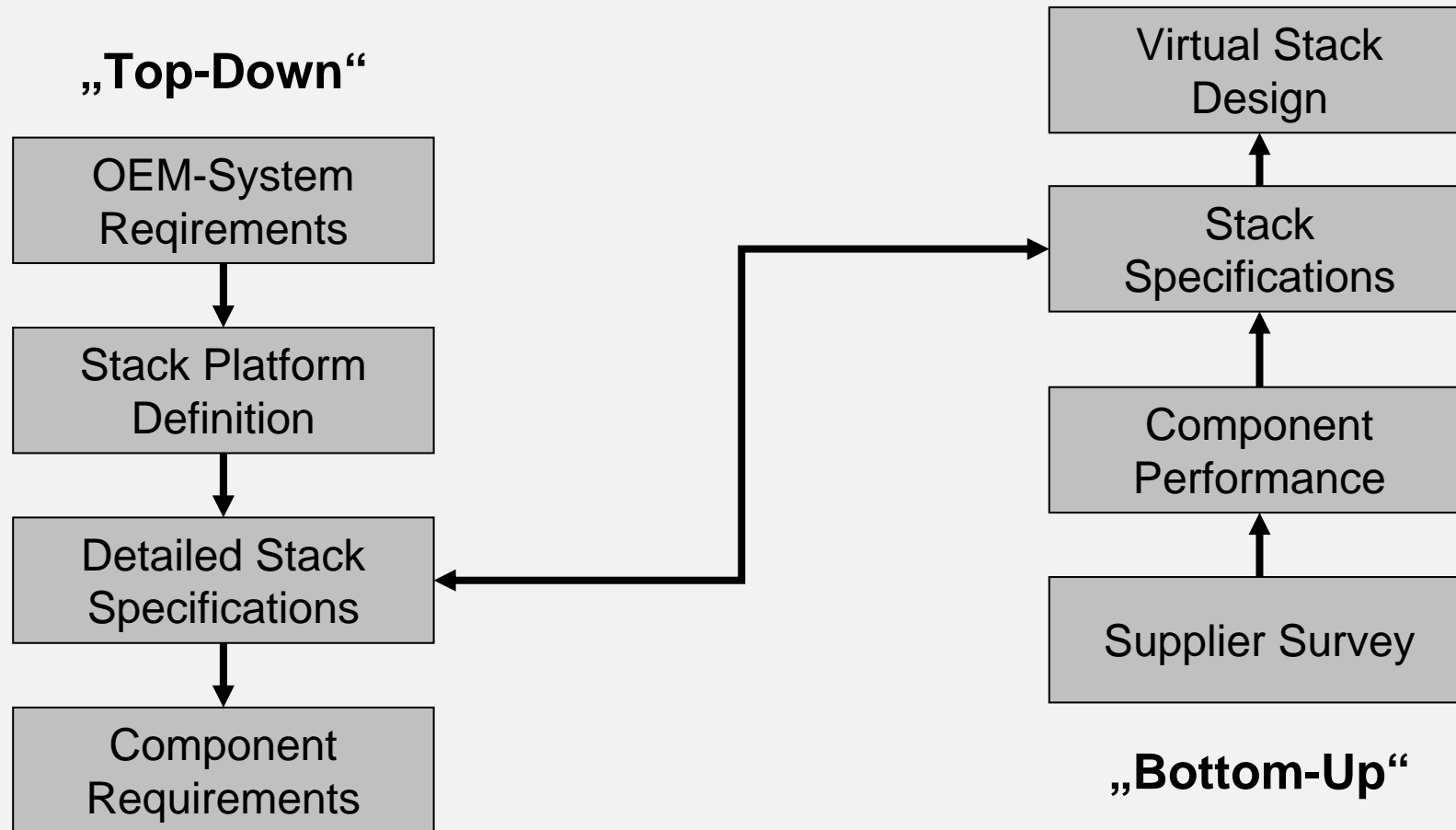
Component and
System Suppliers



Research
Institutes



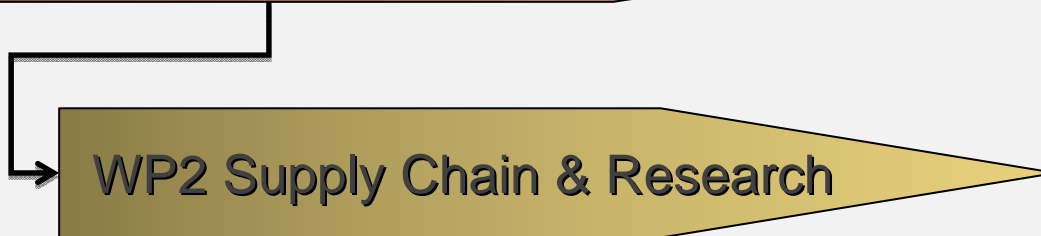
Tackling the Issue



Project Workflow



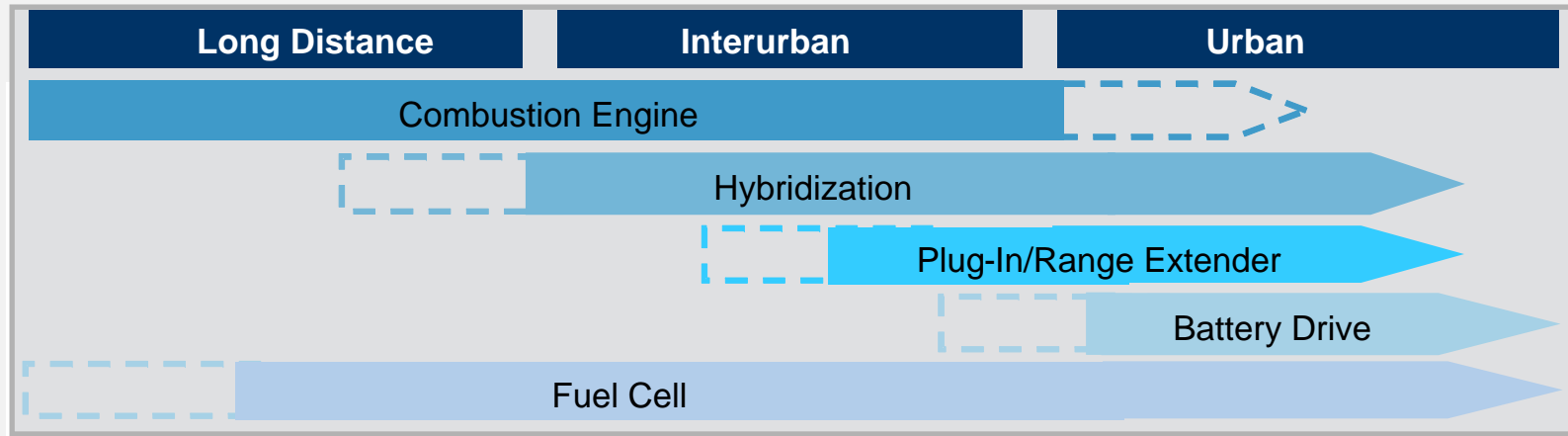
01.01.2010



30.06.2011



E-Drive-Portfolio – Opportunities and Limitations



Suitability of Battery / Fuel Cell Drive Train for Various Vehicles

	Micro-Kompakt	Kompakt-Klasse	Mittel-Klasse	Luxus- & Familien-Fzge	City-Bus	Überland-Bus	Klein-laster	Mittlerer LKW	Schwerer LKW
FC-EV	●	●	●	●	●	●	●	●	●
B-EV	●	●	●	●	●	●	●	●	●

● possible

● Possible with restrictions

● Today not possible

FC System Concept: Basic Requirements to Observe



- Power / gravimetric / volumetric Power Density
 - Cost
 - Durability
 - (Freeze)-Start-up time
 - Efficiency superior to any (hybrid)-ICE
 - One Fuel on Board (H_2)
- } comparable to ICE

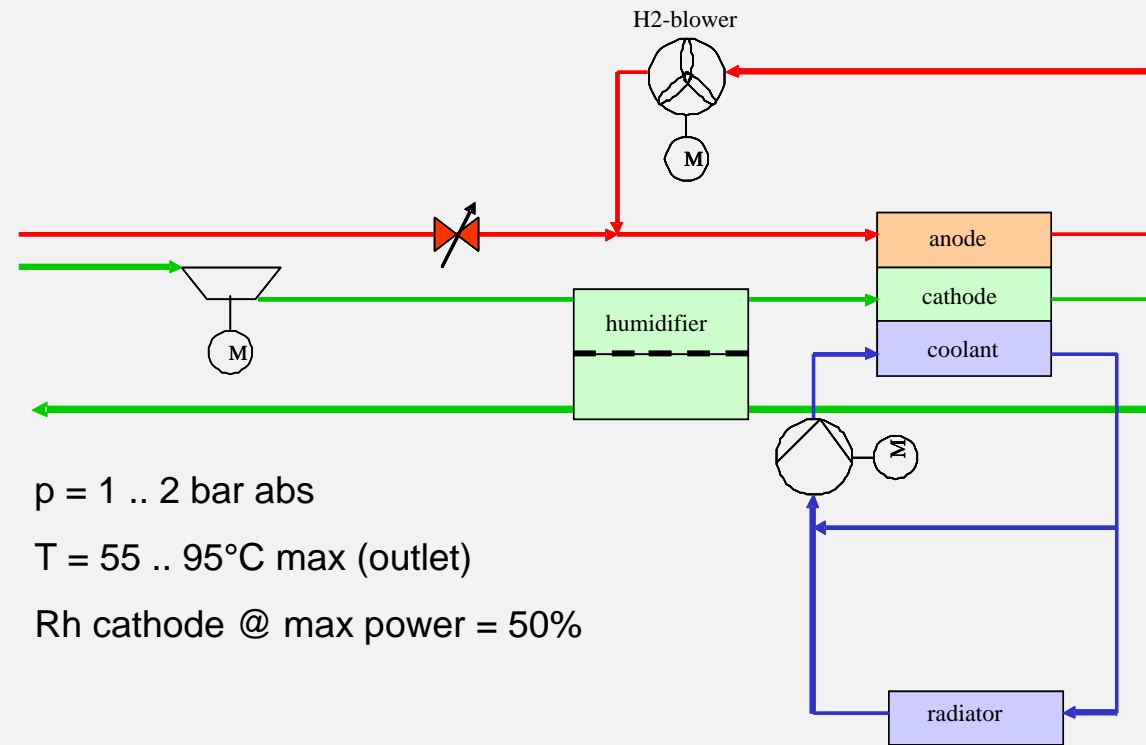
These requirements strongly reduce the number of system options...

Automotive System Architecture



Features:

- Air compressor without expander
- Gas-to-gas humidifier (cathode out \Rightarrow cathode in)
- High power density stack
- An active / passive H₂ recirculation pump



$p = 1 \dots 2$ bar abs

$T = 55 \dots 95^\circ\text{C}$ max (outlet)

Rh cathode @ max power = 50%

Simplified schematic

Conclusion

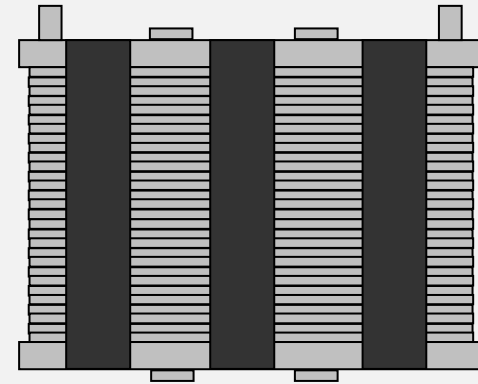


- FC-systems designers have to respect many ambitious requirements. The number of concepts able to fulfill these requirements is small
- OEMs participating in AUTOSTACK have agreed commonly on a system concept of choice
- Other promising system concepts exist, are however not broadly accepted within the automotive industry. Still, they should be further considered, in particular for the earlier markets.

Components Considered Part of the Stack



- Bipolar plates, MEA, Seals
- Current Collectors + end plates
- Stack compression kit
- Casing / Housing (also for EMC*)
- Flanges (quick connectors)
- HV-Contactors + interlock
- Vehicle mounts (brackets)
- End cell heaters (PTCs) integrated in the stack enclosure – may be used for stack discharge
- **Sensors** (also for diagnostic purposes - may be removed at a later stage):
 - Pressure: Coolant in- and outlet, Fuel in- and out, Oxidant in- and out
 - Temperature: Coolant in- and outlet; Fuel in- and out; Oxidant in- and out, End Cells
 - RH-sensors in the header (manifold part)
- **Cell Voltage Monitoring Unit:**
 - This will be required during development phase - Aim is to remove CVM
 - Already today, control strategy must be developed without the need for individual cell voltage monitoring!



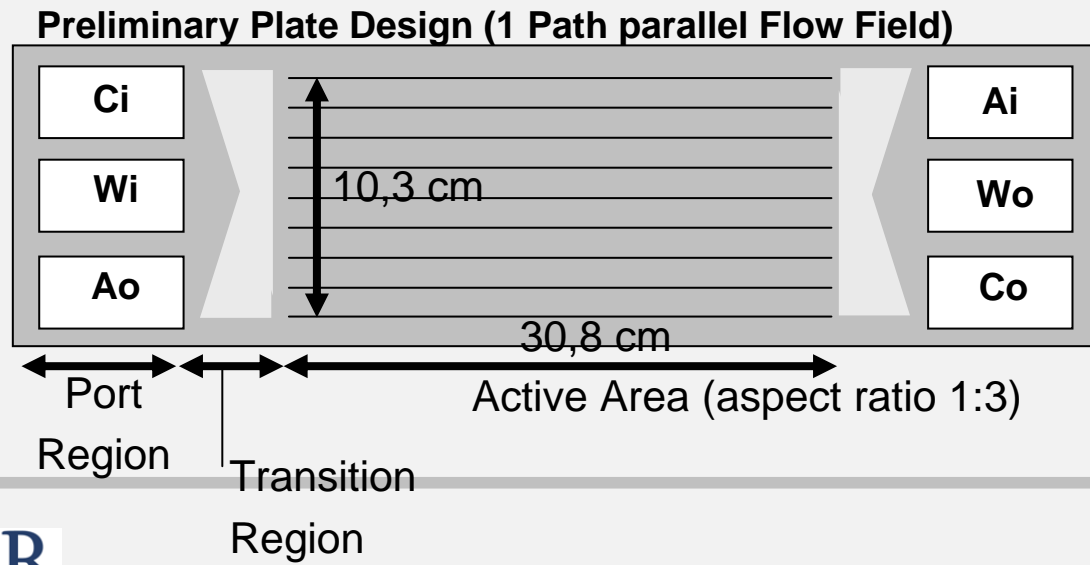
High Level Stack Requirements

Stack nominal power (gross, continuous) (System power 80 kW)		95 kW (requirement)
Stack Open Circuit Voltage (limit set by power electronics – consider OCV > 1V @ freeze T)		<430 V (requirement)
Minimum stack voltage (limit depending on E-motor and DC/DC converter characteristics)		>200 V (guidance)
Weight		<60 kg
Volume		<50 l
Operating Temperature	min max	-25°C (start capability) +95°C (outlet temp.)
Interface parameters at nominal power		
Pressure		2 bara
Air Stiochiometry		1,6
Humidification		50%

Plate Design



Area Power density	95 kW, 1 W/cm²
Cell voltage at nominal power	≥0,67 V
Current density at nominal power	1,5 A/cm ²
Active area of stack	9.5 m ²
Number of cells (1-row stack is a requirement)	<u>300</u> .. 380 (stack height!)
Active are area per cell (projected)	~317 cm ²
Plate Area (a.a. = 60% of plate area)	~ 528 cm ²
Cell pitch	≤ 1,5 mm



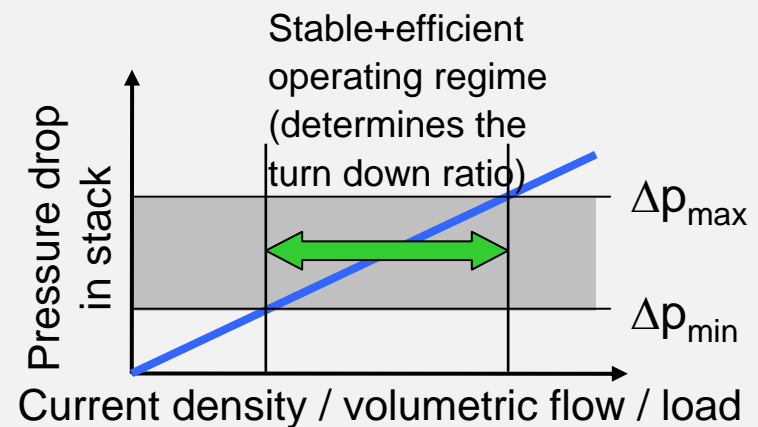
Degradation Targets



- Throughout its lifetime the stack is allowed to degrade by **10% in max. power output, i.e. $1 \text{ W/cm}^2 \Rightarrow 0.9 \text{ W/cm}^2$**
- The max power is limited by the cooling power
- Therefore, the stack will be operated at maximum waste heat during its life
- As the stack degrades, the max power point will move to lower voltage and – in order to keep the waste heat constant – to lower current density, i.e.
 \Rightarrow max power point moves along the “iso-waste heat” curve

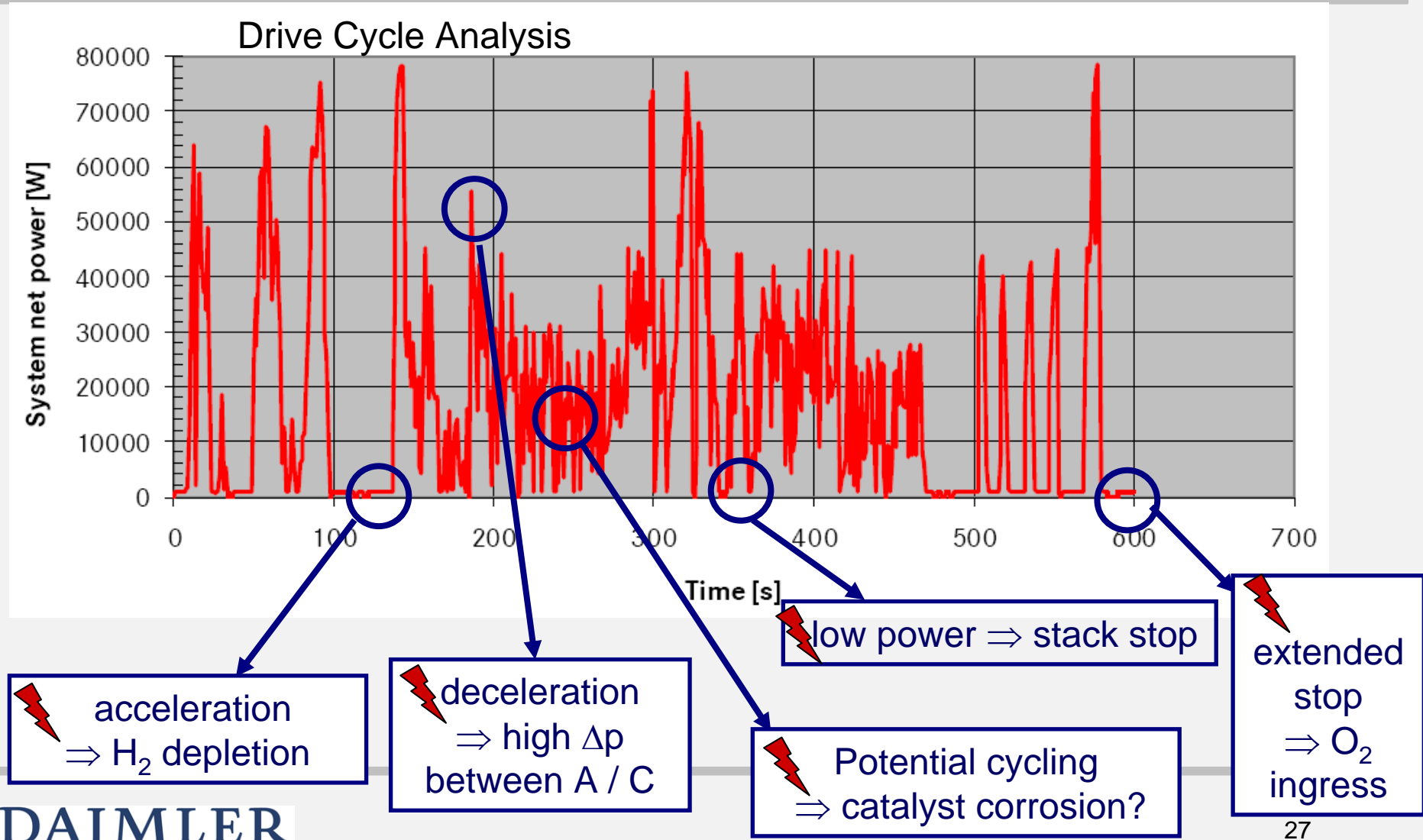
Operating Strategy and Turn-Down Ratio

- The stack can be operated efficiently and stable within certain limits (highest power/lowest power = turn-down ratio)
- This results from the conflict of flow homogeneity vs. pressure drop known in fluid dynamics
- Very low and very high power demands will be covered by the battery \Rightarrow Hybridization
- This implies a start/stop strategy for the stack
- The stack will be switched of between 5% and 10% of its nominal power, i.e. 5 kW .. 10 kW
(= the required size of the battery. This corresponding to a TDR of 1:10 .. 1:20)

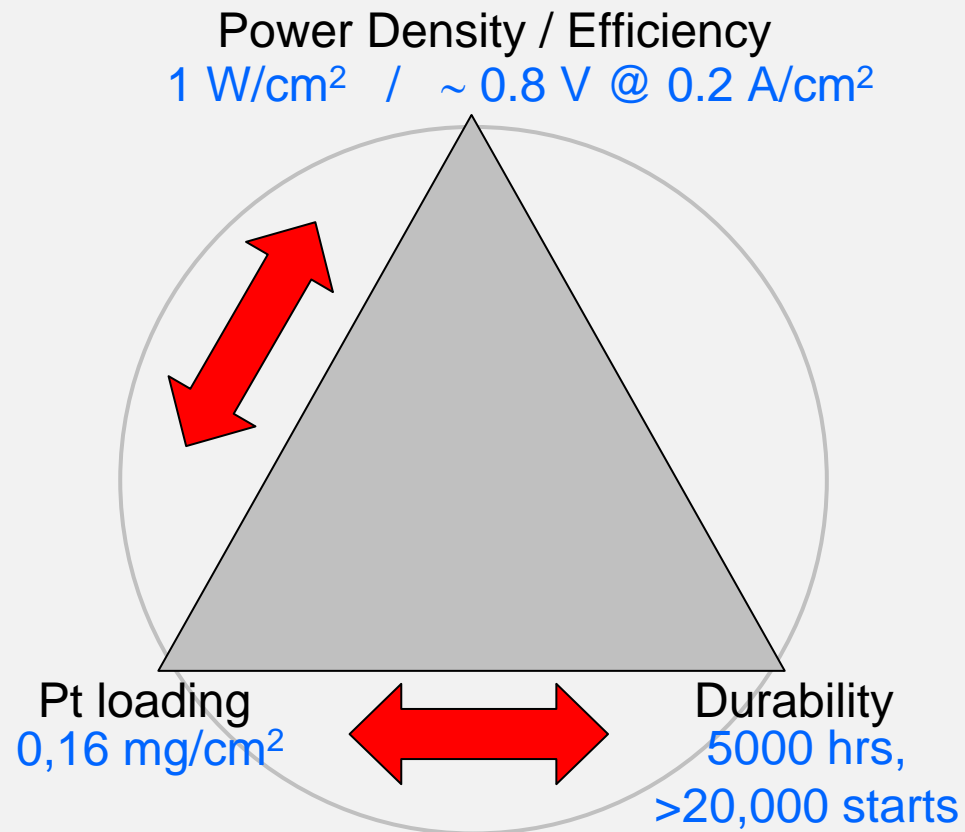


	Stable operation	Efficiency losses
Δp low	☹️	☺️
Δp high	☺️	☹️

Stress Factors in a “Real” Drive Cycle

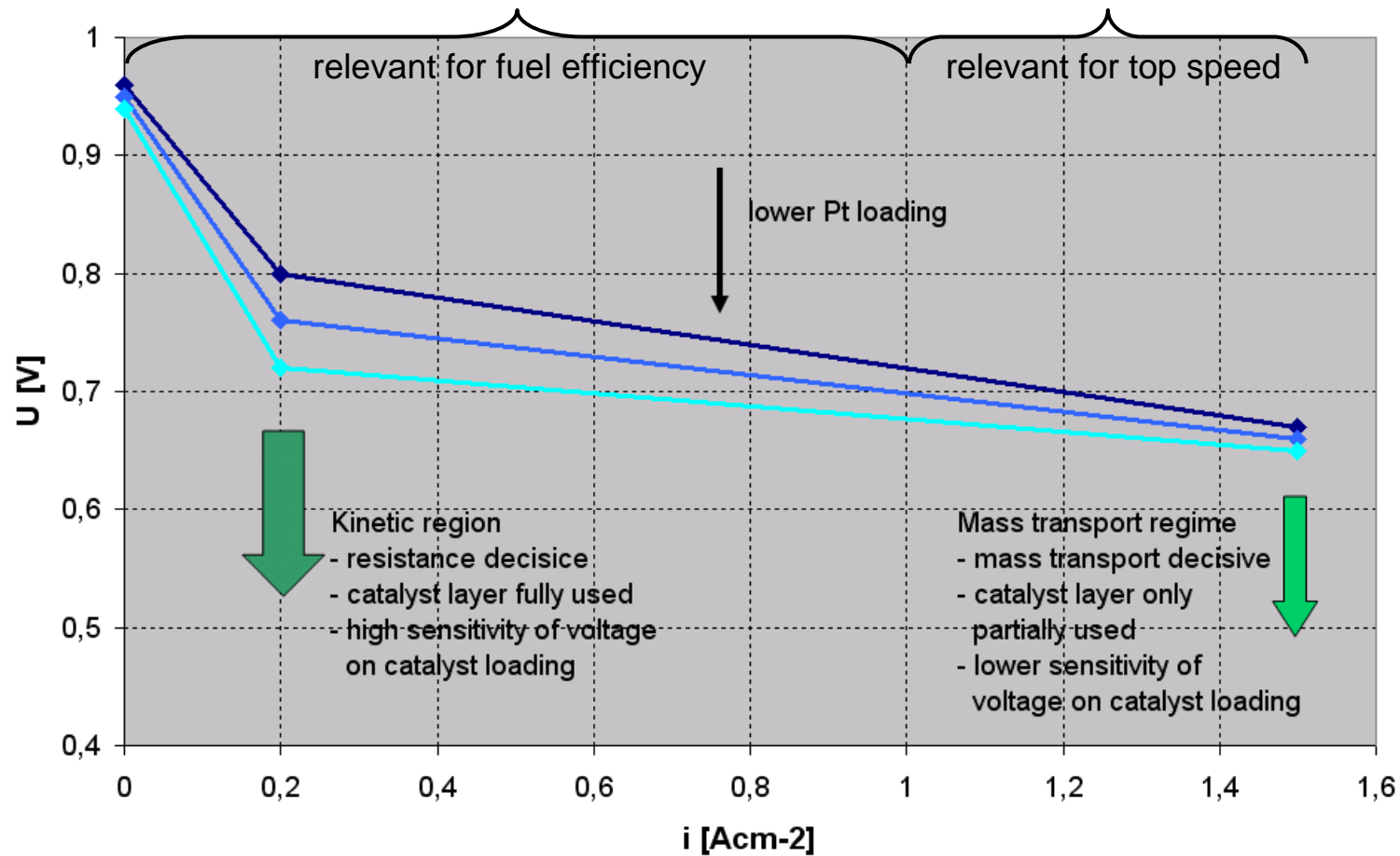


Conflicting Targets / Major Gaps

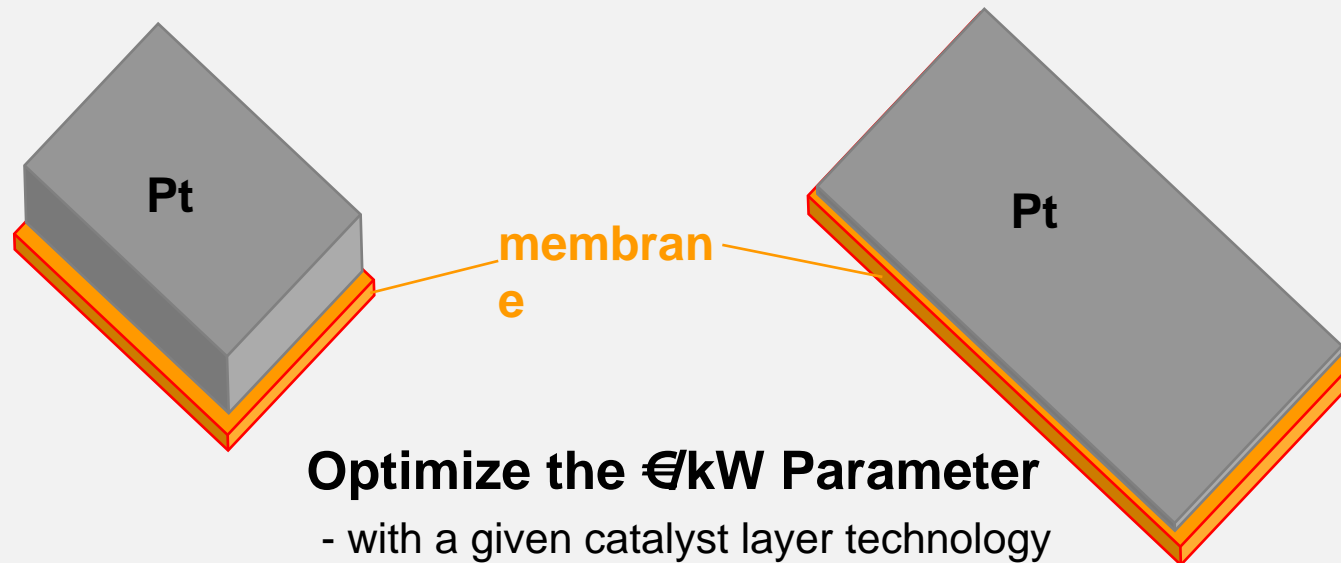


Gap Power Density / Pt Loading

Fuel efficiency targets might even be more challenging



Finding the best compromise between Pt loading and power density

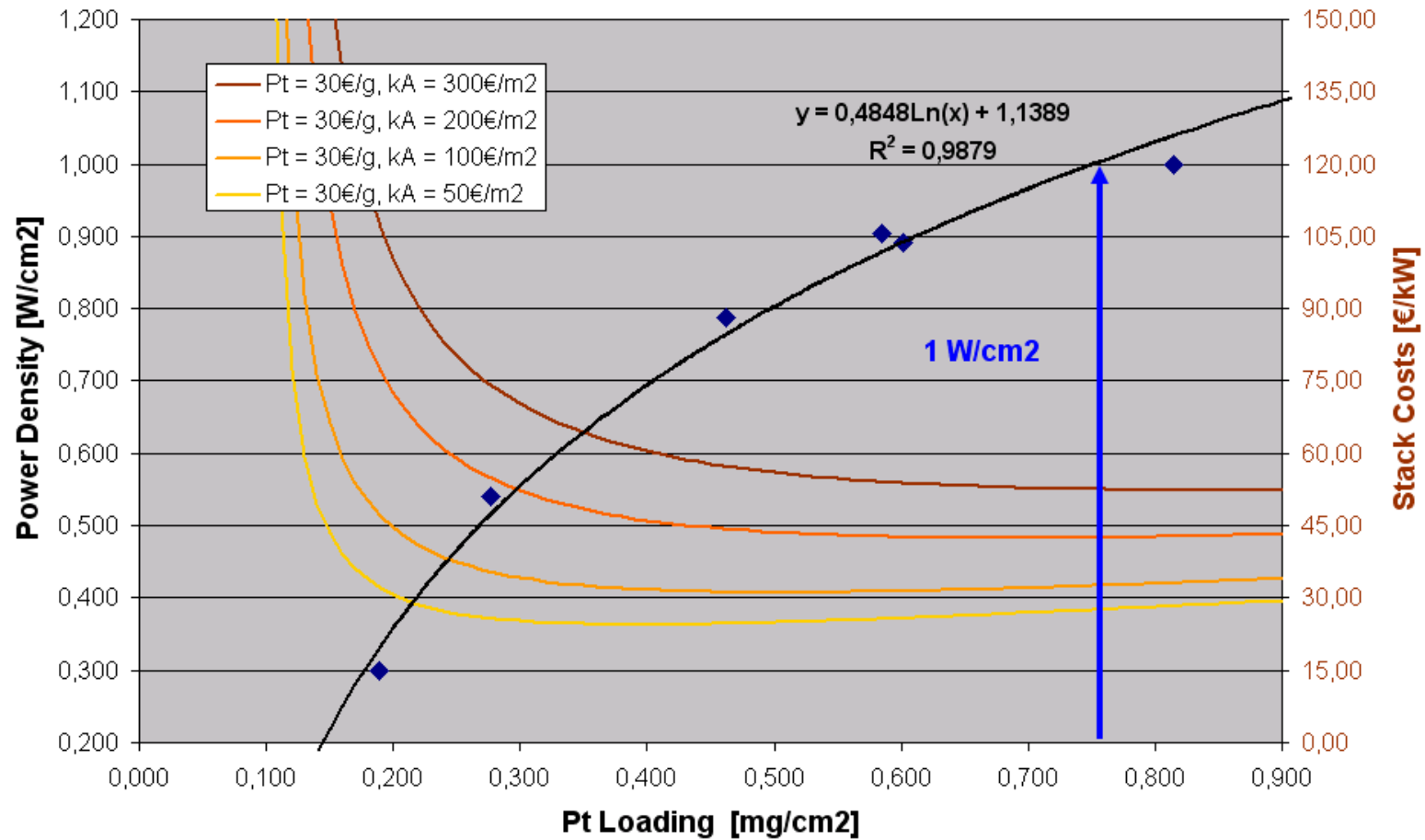


Optimize the €/kW Parameter
- with a given catalyst layer technology

Save Membrane?
high Pt loading, small membrane area

Save Platinum?
low Pt loading, large membrane area

Pt Loading Variation (logarithmic fit) and Resulting Stack Power Costs

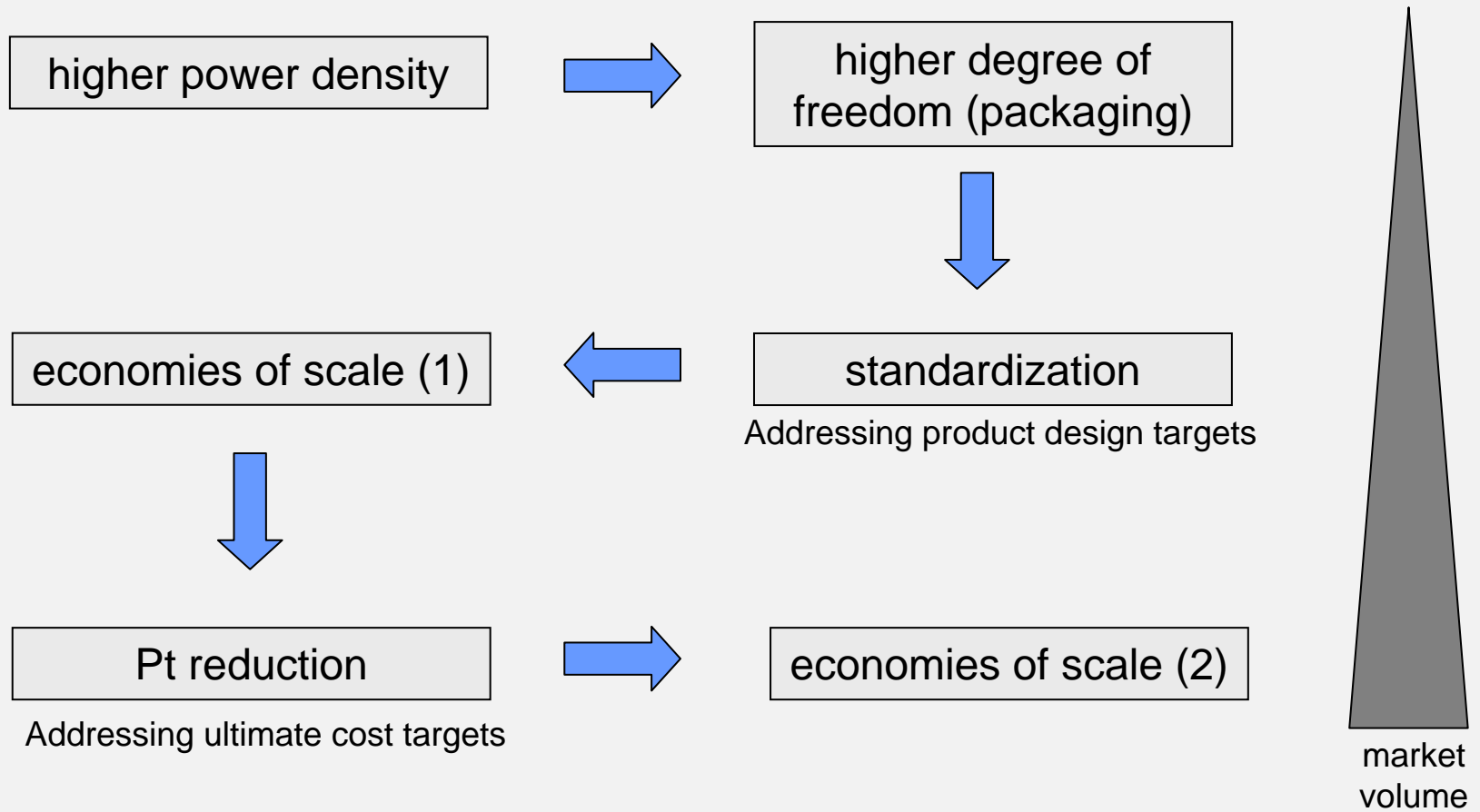


Summary & Conclusion



- The cost optimized Pt loading is influenced by:
 - the costs of membrane, GDL, BIP vs. Pt
 - the power density characteristics of the MEA
- With today's MEA technology and price structure
⇒ do not address low Pt loading at the expense of power density
- Power density is paramount target.
High power density allows standardization,
thus cost reduction

Standardization & Economies of Scale



Thank you very much for your kind
attention