STAYERS

Stationary PEM fuel cells with lifetimes beyond five years

FCH-JU 256721

Programme Review Day 2011
Brussels, 28 November

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Nedstack fuel cell technology

0. Project description

Stationary PEM fuel cells with lifetimes beyond five years

Themes:

SP1-JTI-FCH.2009.3.2:	Materials development for cells, stacks and balance of plant
SP1-JTI-FCH.2009.3.1:	Fundamentals of fuel cell degradation for stationary power applications

Duration:	36 months; 1 January 2011 - 31 December 2013
Budget:	4.1 M€
FCH-JU funding:	1.9 M€

5TAYERS
1 2 3 4 5

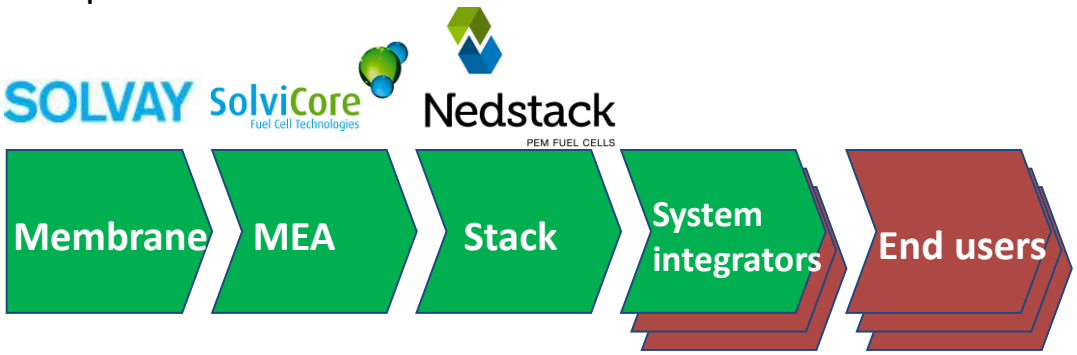
Goal:

> 40.000 hours stationary operation lifetime of PEM fuel cell

Motivation:

lower replacement frequency PEMFC stacks over economic lifetime Power Plant
→ lower cost of ownership PEMFC Power Plant

Development & Commercialization:



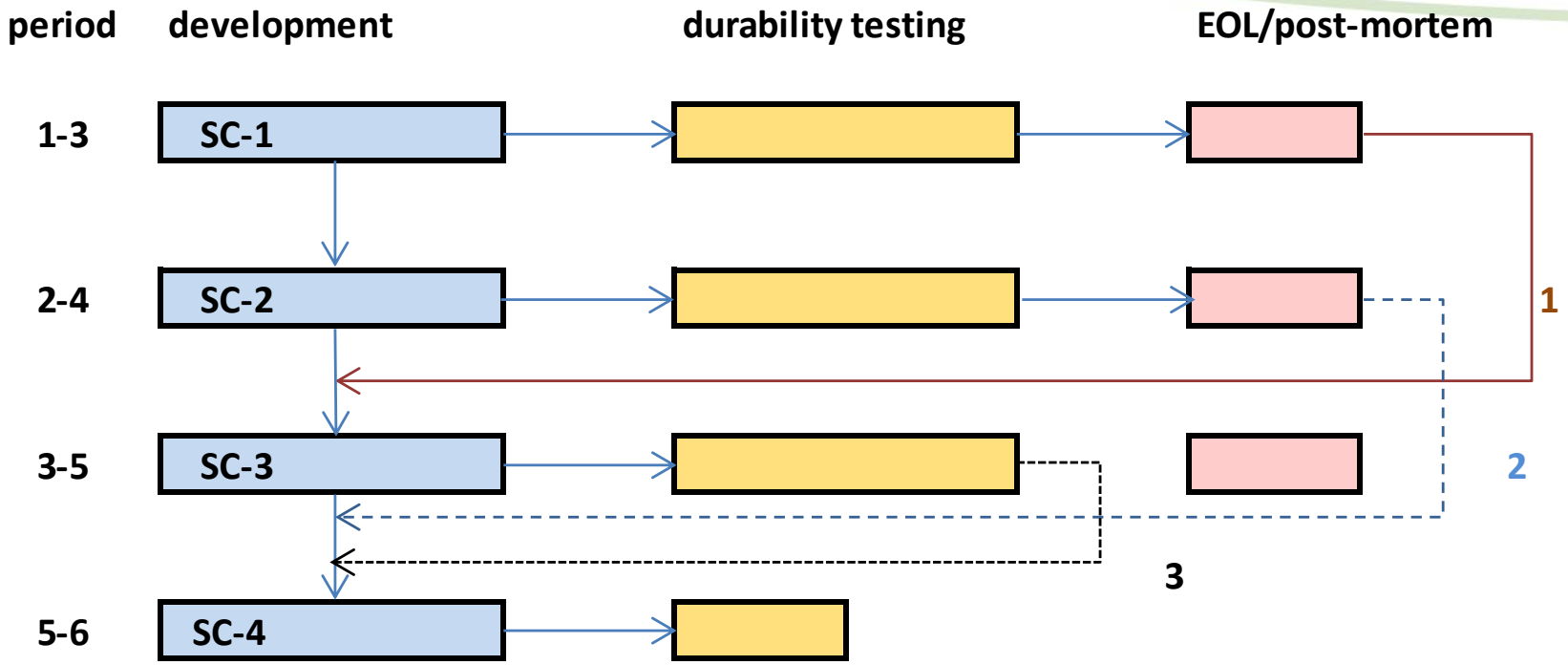
Testing + modeling:

SINTEF

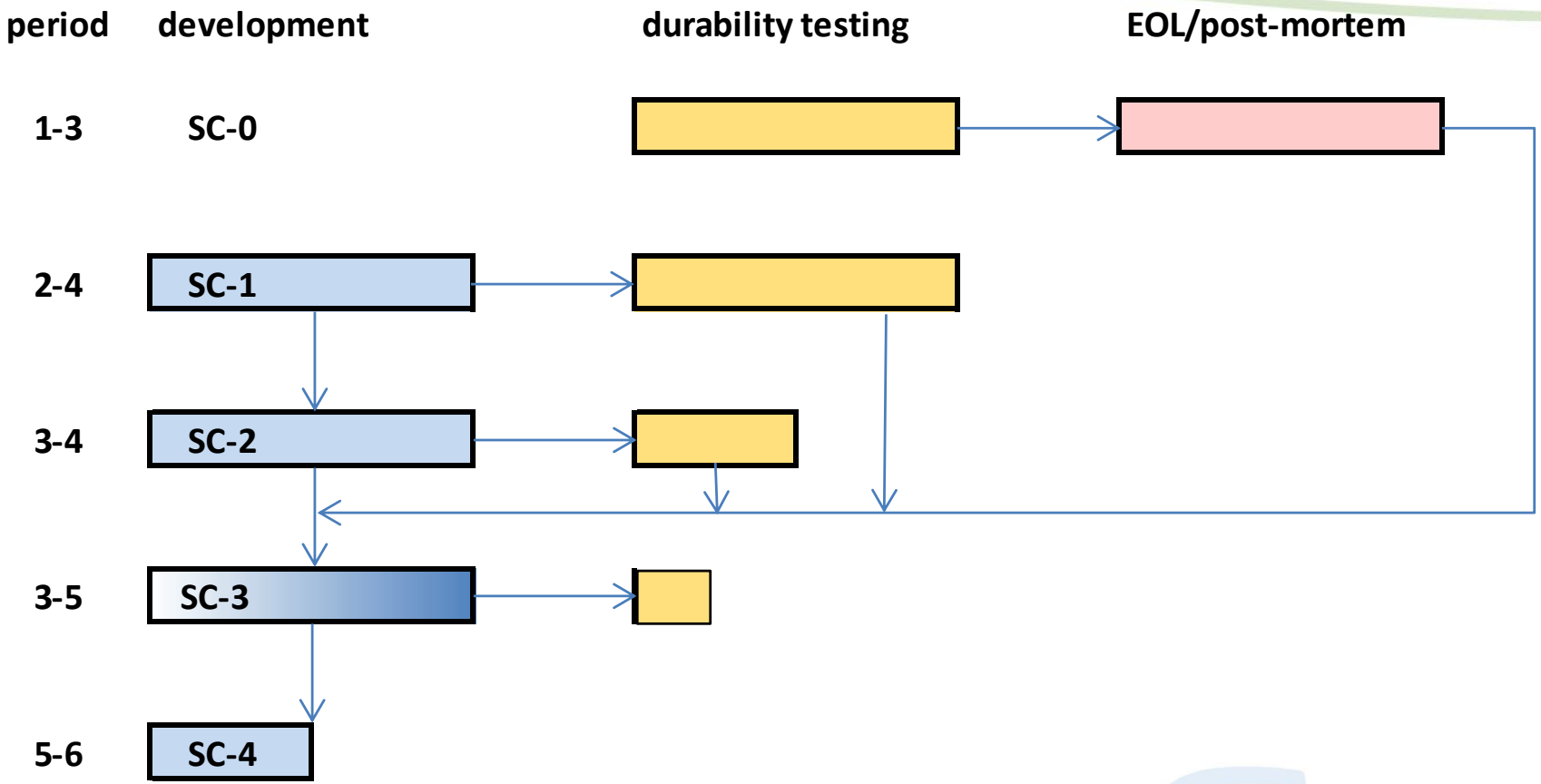
Institute for Energy
JRC
EUROPEAN COMMISSION

1. Project achievements: original approach

MEA development iterations

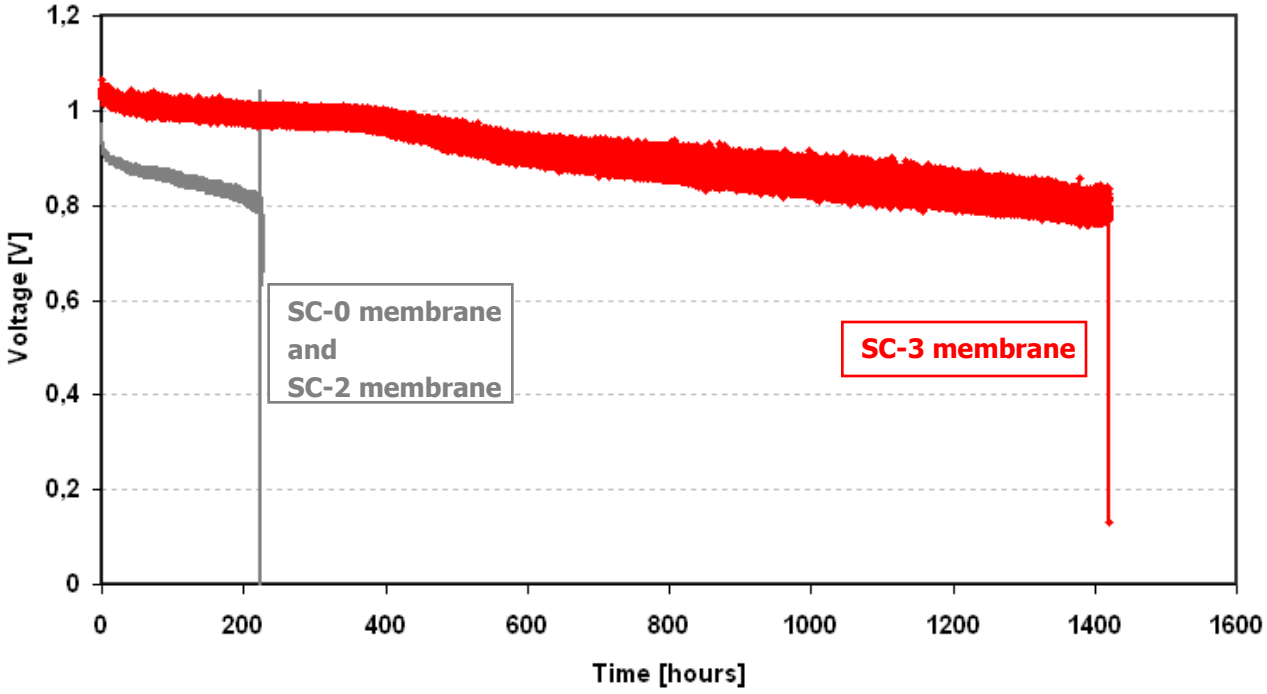


MEA development iterations

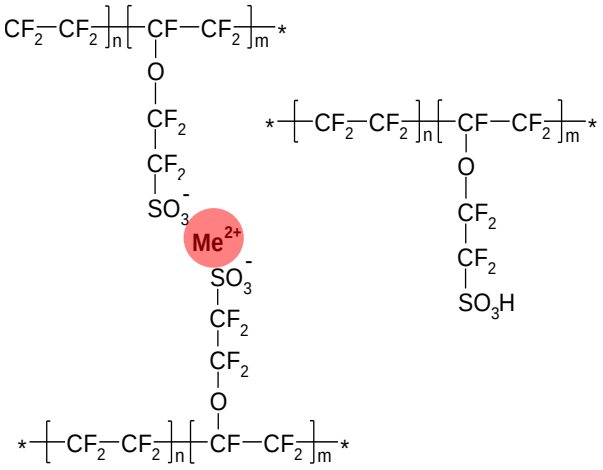


1. Project achievements: WP-2 Membrane development

Improved membrane lifetime (AST)



SC-3 membrane was obtained combining the improvements of SC-2 membrane and introducing Ce(III) as radical scavenger



Conditions

J: 0 A/cm^2

T_{cell}: 90° C

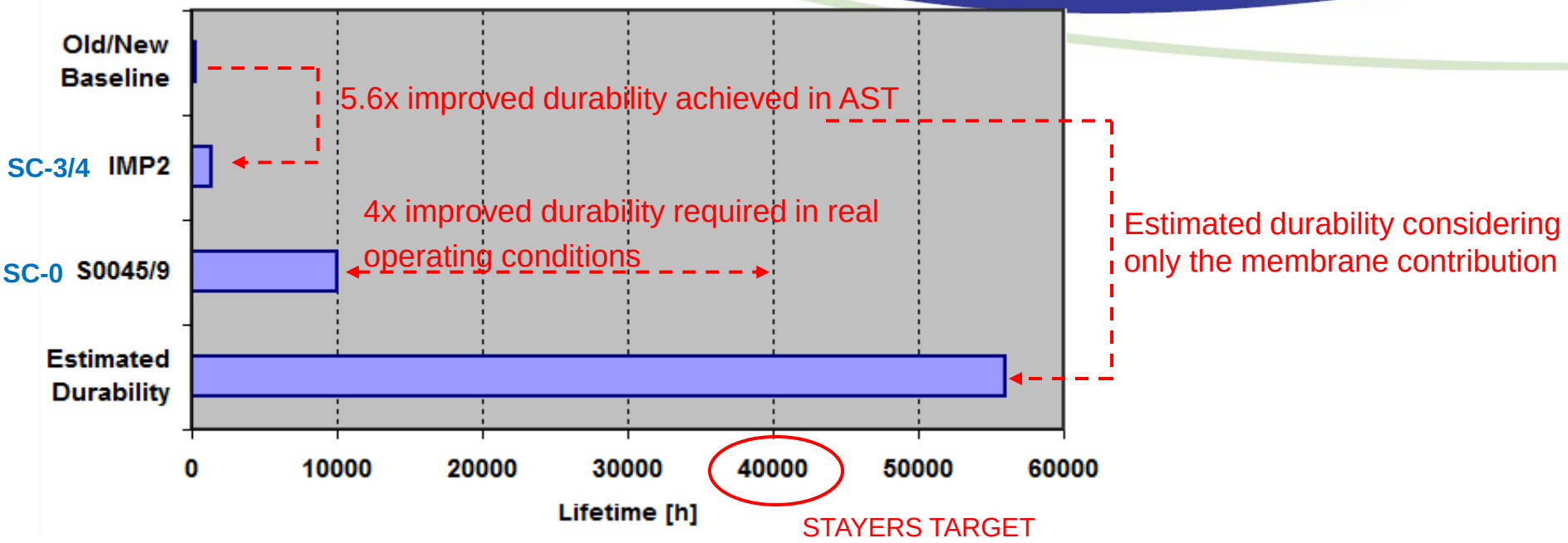
RH: 30%

P: 1 bar abs.

Feed: H_2/O_2

1. Project achievements: WP-2 Membrane development

MS 2.1/2.2 - Demo Improved Durability



- WP2 developed different generations of membranes showing improvements in membrane quality and in their durability in AST's
  - MS 2.1 First membrane (SC-0) showed proven lifetime >10.000 hrs
    - No substantial degradation observed in eol/post-mortem tests
  - MS 2.2 Last membrane estimated to surpass 40.000 hrs based on AST (SC-3+4)

Evolution of MEA generations in course of STAYERS (simplified):

MEA generation	Membrane	Electrode	RIM type	objective
SC-0	old baseline	CCB type 1/3	4-layer	reference
SC-1	new baseline	CCB type 3	2-layer	apply new baseline membrane
SC-2	IMP-1	CCM - type 3 based	simplified 2-layer	apply new membrane, CCM, process automization, improve durability
SC-3	IMP-1/2	CCM rainbow	simplified 2-layer	improve durability, conditioning, costs
SC-4	IMP-1/2	CCM multiple	simplified 2-layer	demo 40.000 hrs

- SC-3 (multiple variations) is object of current labour
- SC-4 to be selected by operational data of SC-3

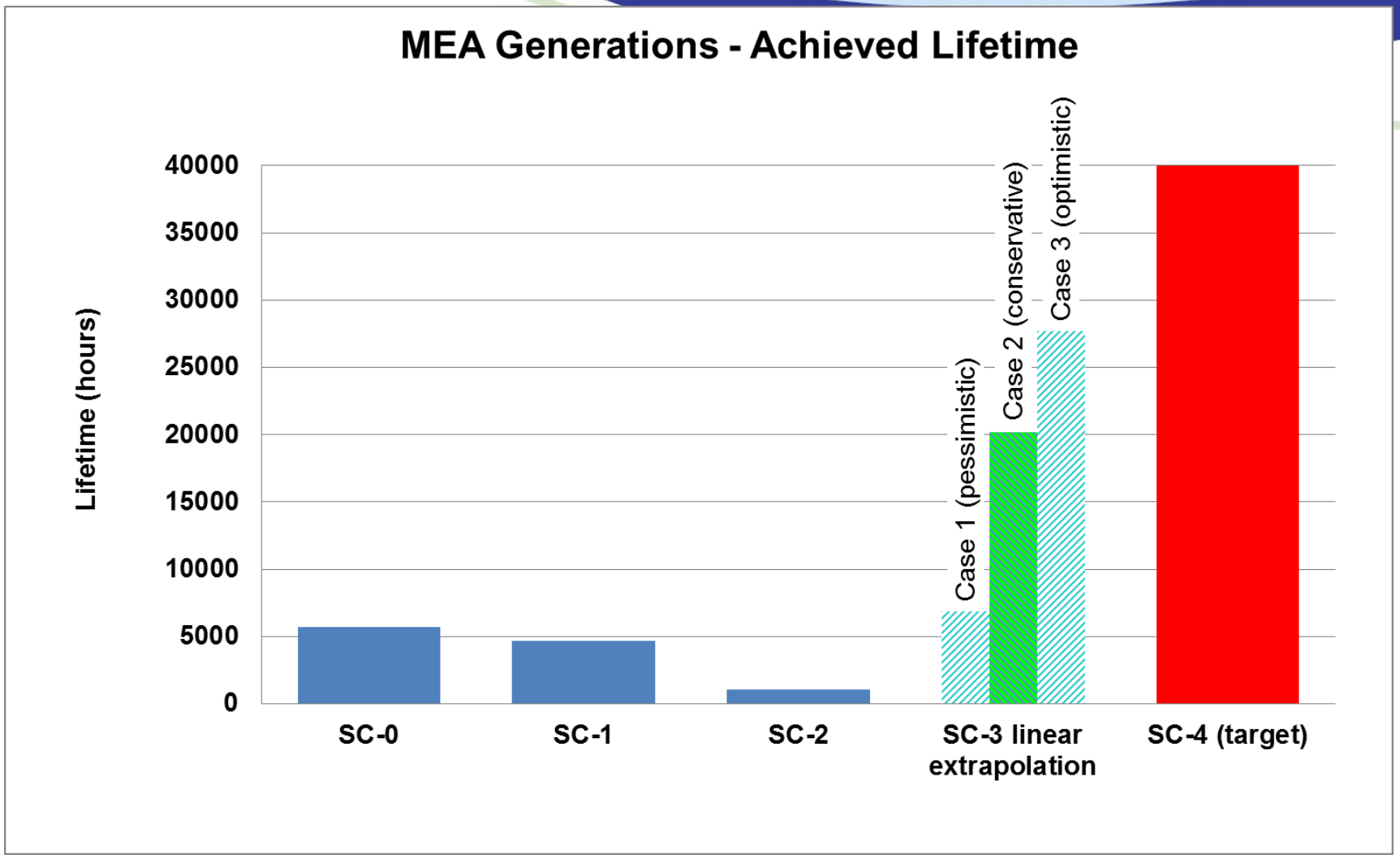
MS 3.1 Results EOL/post-mortem analyses – SC-0

Component	Property	Δ EOL-BOL
Cathode catalyst layer	ECSA	- 50%
Cathode catalyst layer	Proton resistance	+50%
Anode catalyst layer	ECSA	- 30%
Membrane	H_2 cross over	+5%

Conclusions

- Cathode catalyst layer dominates performance loss
- Also anode catalyst degradation
  - theoretically no contribution to decay, but substantial contribution in presence of contaminants
- Membrane shows no substantial degradation

1. Project achievements: WP 3 MEA development



1. Project achievements: WP-4 Stack development

MS 4.1	*Assesment 1 of stack performance*	**Lifetime (hrs)**			**improvement**
WP 4	**component**	**proven**	**estimated**	**status**	**required**
4.1	coolant FF	> 17.000	40.000	ok	**NO**
	Anode FF	> 17.000	?	under investigation	**?**
4.2	I. cell plates	> 17.000	40.000		
	permeability & dimensional stability			under investigation	**?**
	hydrophobicity			under investigation	**?**
	conductivity			ok	**NO**
	II. Seals	> 17.000	20.000	materials selected	**expected**
	III. Housing & mounting	20.000+	20.000+	in development	**YES**
4.3	Power plant			operational	
	operation, flexibility & diagnostics			to be investigated	**?**

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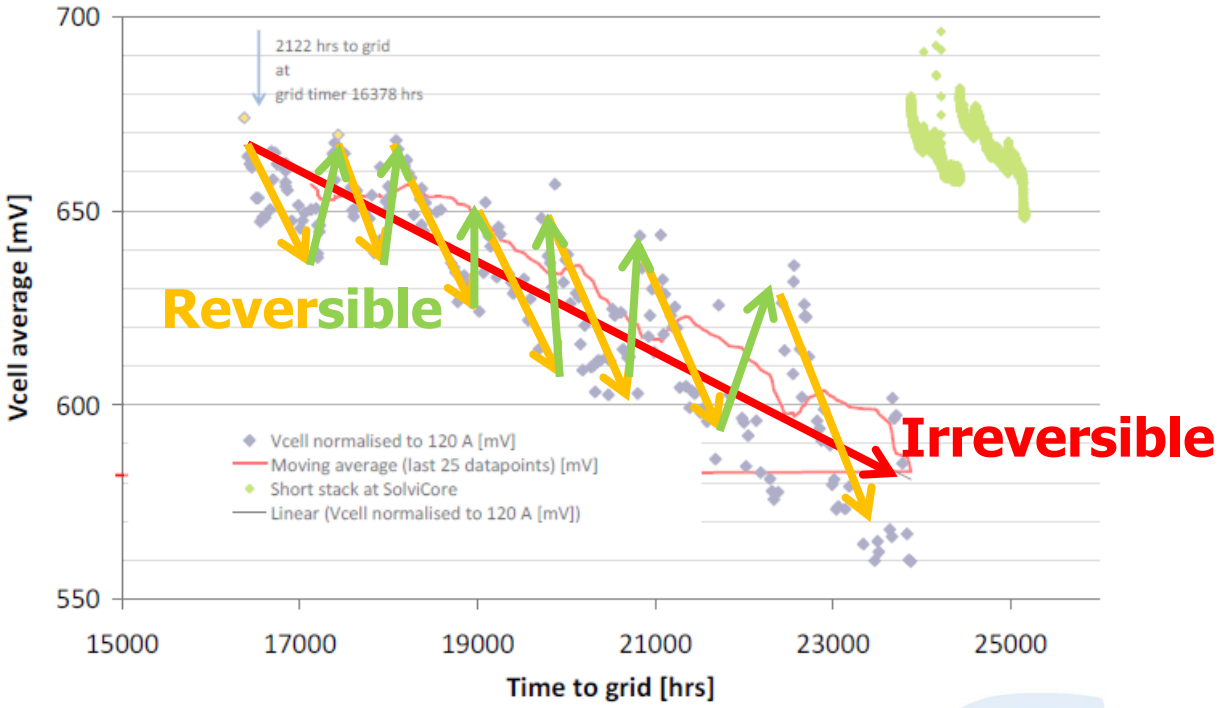
1. Project achievements: WP 4.3 Set up and stack duration tests

Deliverable 4.1

- Revised system with 2x6 stacks
- 6 positions used for Stayers
- Operating point 60 kW ~ 100 A
- **Total hrs to grid M1-M20: >11.000**
- Software tool for data collection & analysis

Durability tests power plant SC-0

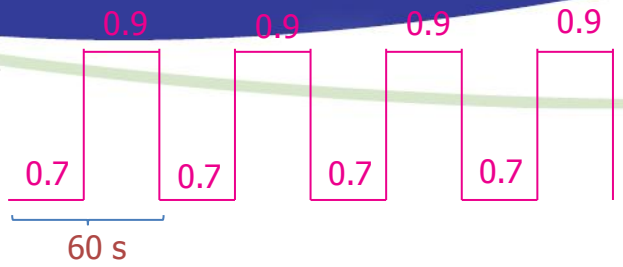
Divided in reversible and irreversible effects

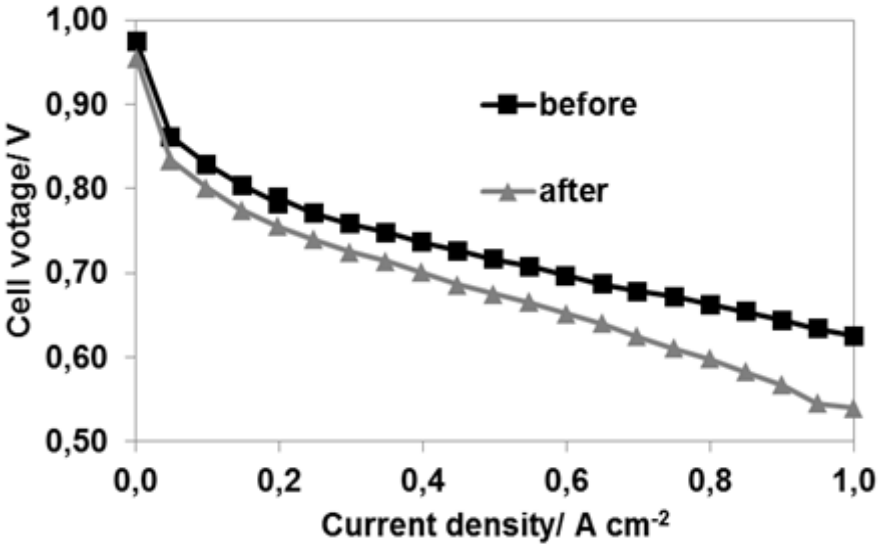


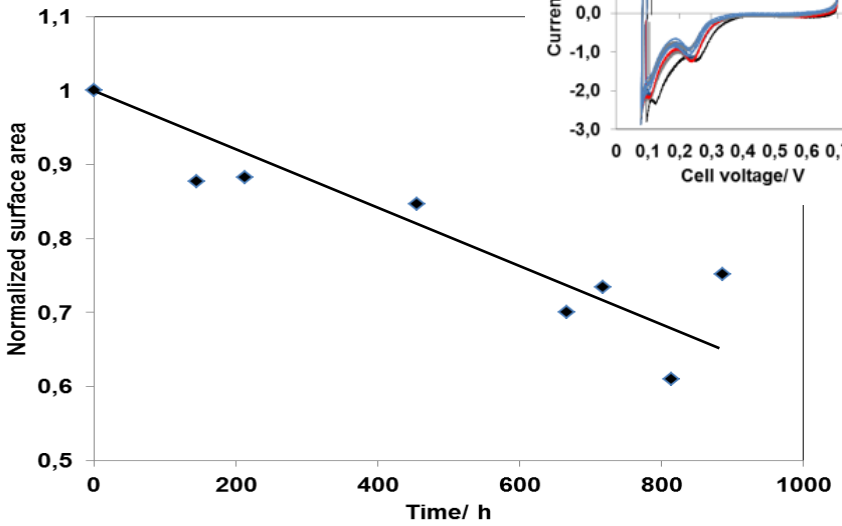
1. Project achievements: WP 5 accelerated durability investigations

Irreversible decay: Accelerated stress tests for cathode electrode

- Representative AST derived from operating profile
- 900 hours cycling 0.7 V – 0.9 V
- clear performance decrease
- Cathode catalyst active surface area decreases 30% in 900 hours (ref Delfzijl 25-35% in 6-10.000 hrs)





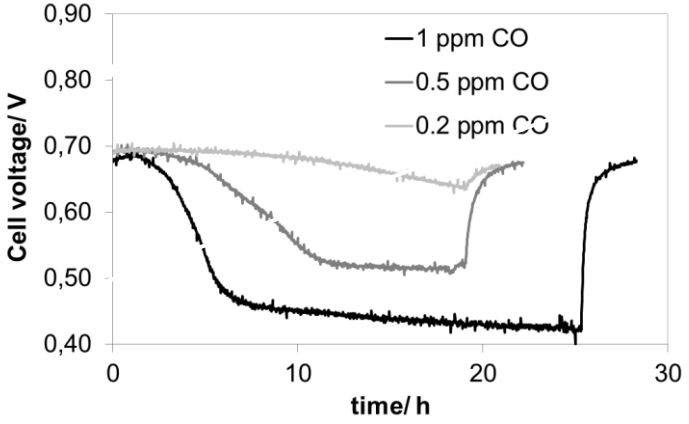


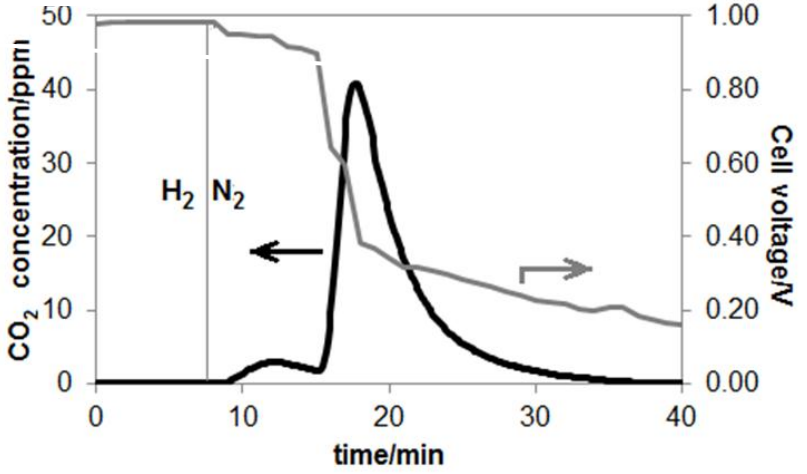
1. Project achievements: WP 5 accelerated durability investigations

Reversible decay: CO stripping of electrode after anode poisoning

- CO added to anode gas (SC-2)
- Reversible effect, performance back to normal when CO is removed
- FTIR analysis (CO_2) of anode gas outlet shows typical CO stripping when flushing anode with nitrogen

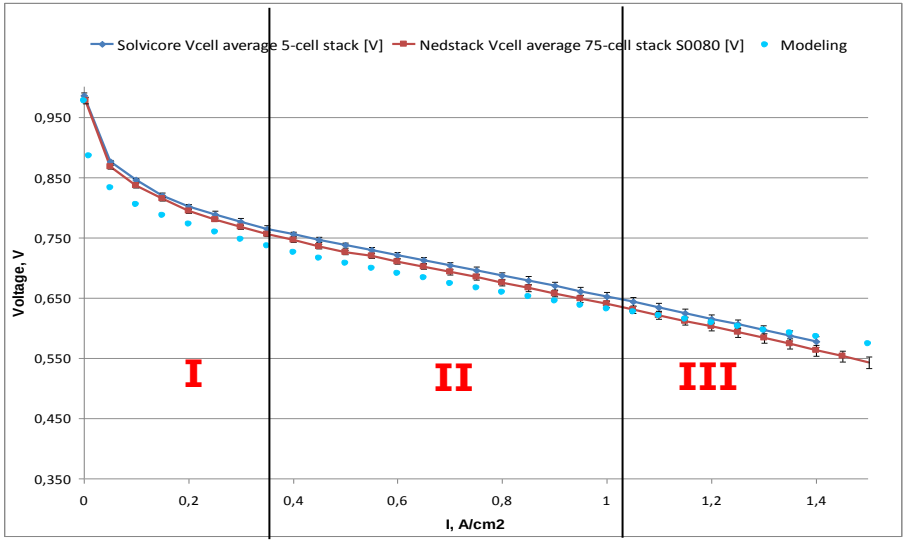
  => Large amounts of CO left on the catalyst despite performance is back to normal

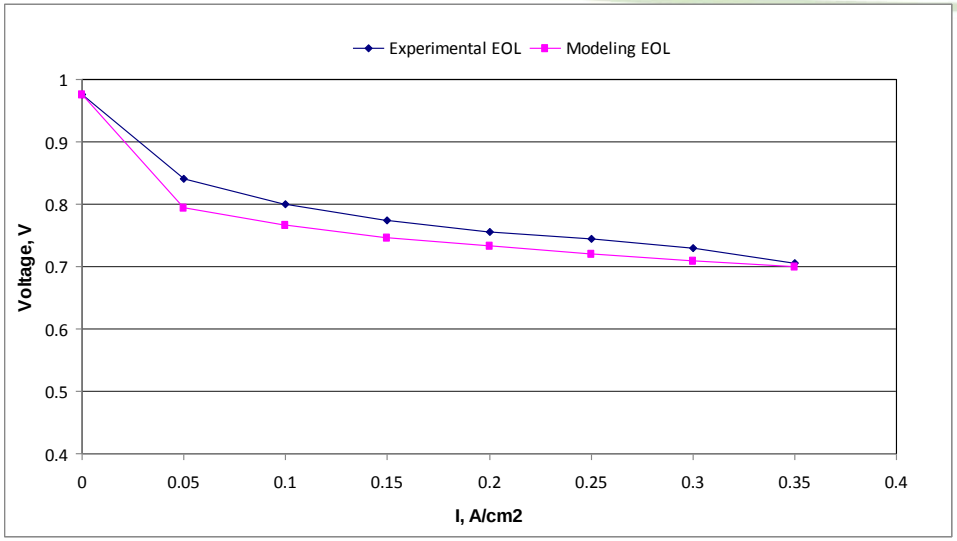




1. Project achievements: WP-6 Modeling and data analysis

MS 6.1: Model validated with experimental data SC-0 (BOL resp EOL) of IV-Polarization curves



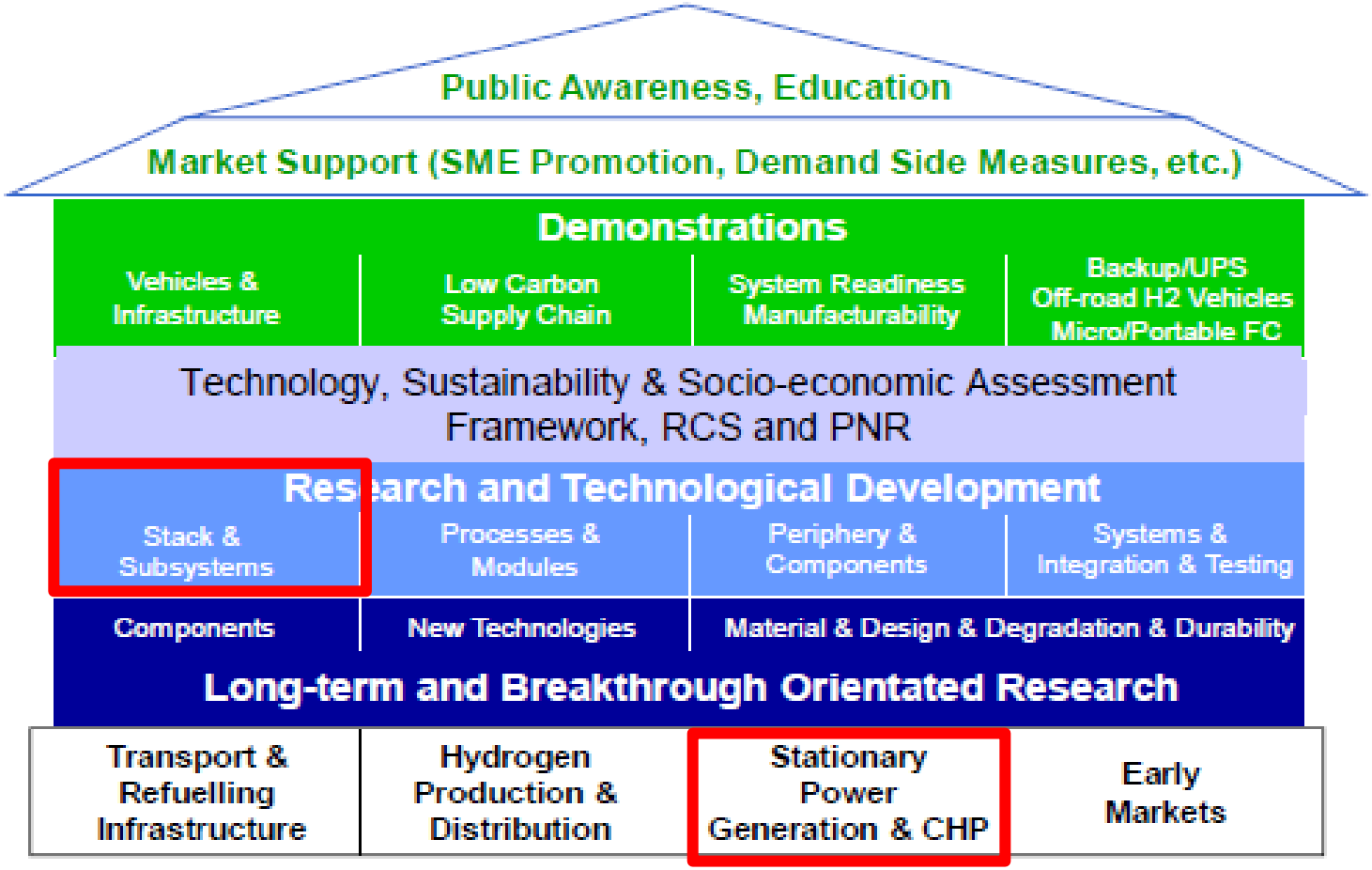


I - kinetic regime – differences attributed to effects associated with unknown kinetic constants

II –voltage drop due to ohmic losses

III – mass transfer limitations

STAYERS in the Multi Annual Implementation Plan Structure



2. Alignment to MAIP

Stationary Power Generation & Combined Heat & Power

"Long-term and breakthrough orientated research will concentrate on **degradation and lifetime fundamentals related to materials and typical operation environments for all power ranges**. The aim will be to **deliver new or improved materials as well as reliable control and diagnostics tools both at a component and at system level."**

"Research and technological development will be directed towards **developing components and sub-systems (including BoP)** as well as **novel architectures for cell and stacks** leading to step change **improvements** over existing technology in terms of **performance, endurance, robustness, durability** and cost for all three technologies." *(PEMFC, MFC, SOFC)*

2. Alignment to MAIP

Goal:

- **40.000 hours lifetime in stationary operation of PEM fuel cell**
  - lower replacement frequency PEMFC stacks → lower cost of ownership PEMFC Power Plant

STAYERS contribution to MAIP:

- Understand degradation mechanisms in current generation PEMFC
  - Membrane → successful introduction of scavengers
  - MEA – identification of predominant degradation mechanisms
  - Stack components – flow field, cell plate, sealants, stack housing
  - Modeling & AST development
- Delivery improved materials
- Development diagnostic tools:
  - Components: membrane, MEA, stack
  - System: software tool combining stack performance with process conditions, diagnostic system tests to be implemented
- Operating conditions to be optimized
  - Recovery protocols
  - Reactant purity