STAYERS

Stationary PEM fuel cells with lifetimes beyond five years

FCH-JU 256721

Programme Review Day 2011
Brussels, 28 November

Jorg Coolegem
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€

STAYERS

1. project & partnership description

Goal:

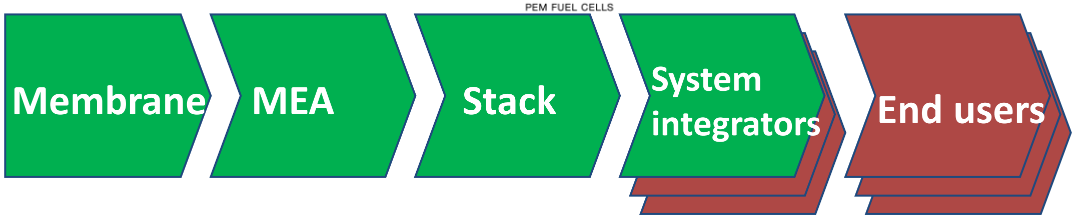
> 40.000 hours stationary operation lifetime of PEM fuel cell

Motivation:

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

Development & Commercialization:

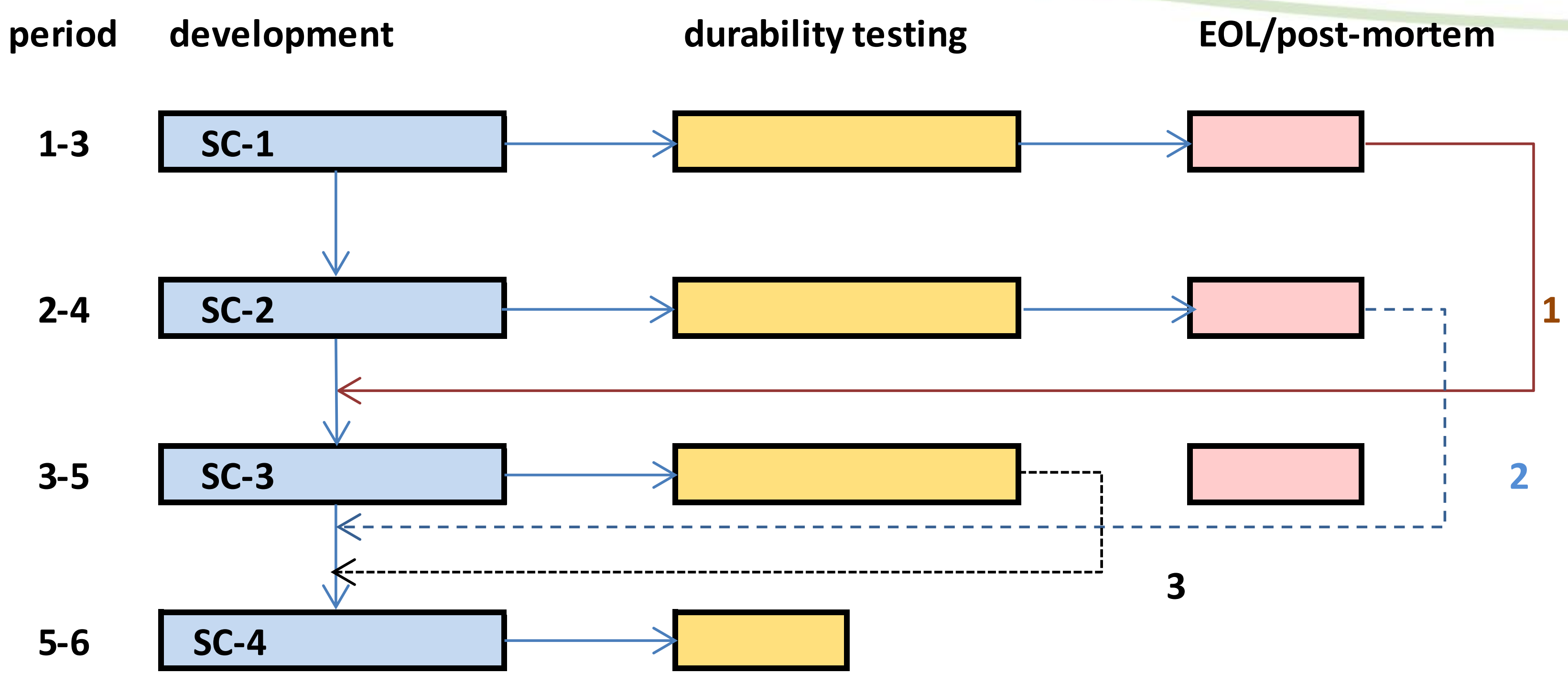
SOLVAY SolviCore Fuel Cell Technologies Nedstack PEM FUEL CELLS



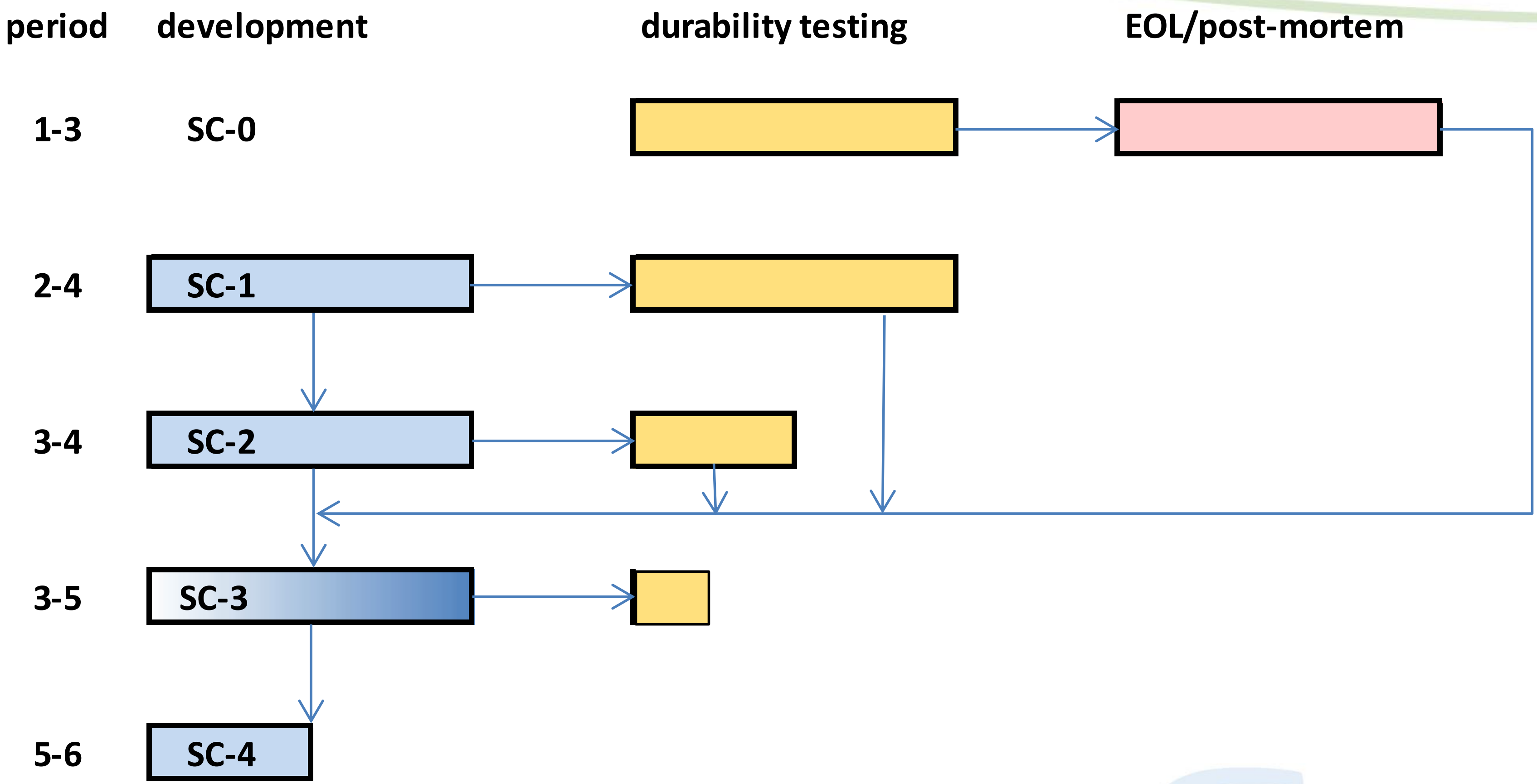
Testing + modeling:

SINTEF   Institute for Energy JRC EUROPEAN COMMISSION

1. Project achievements: original approach

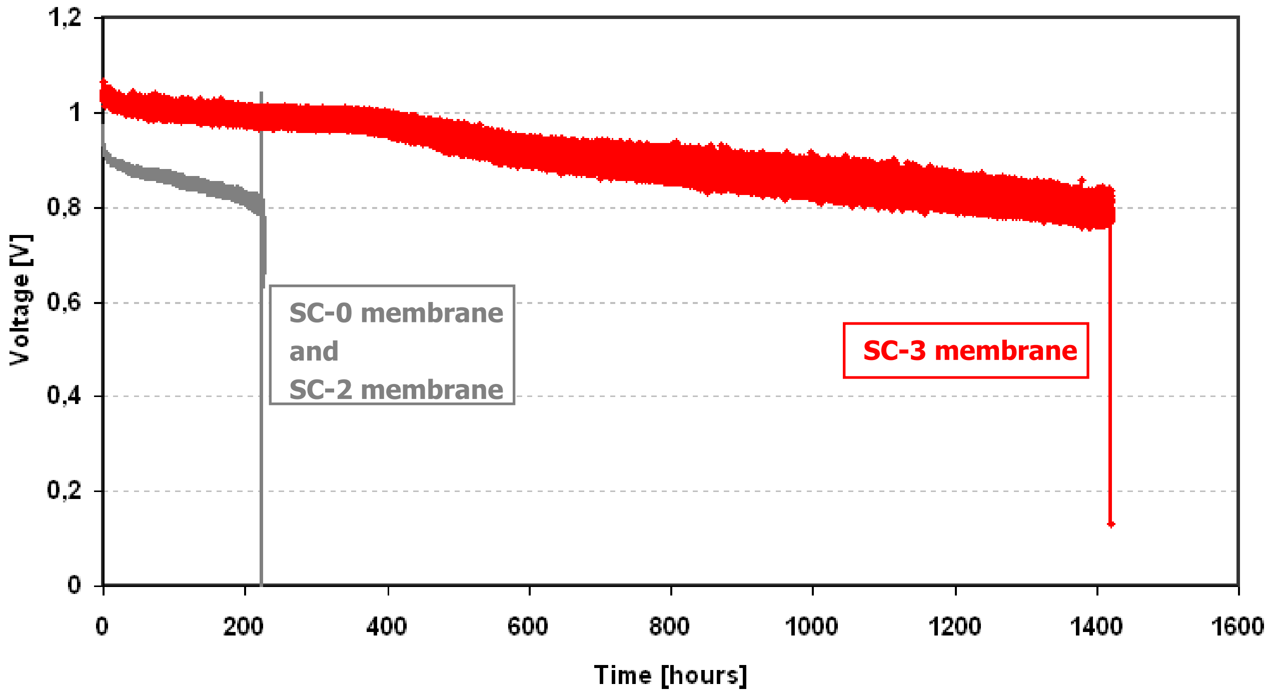


1. Project achievements: current approach

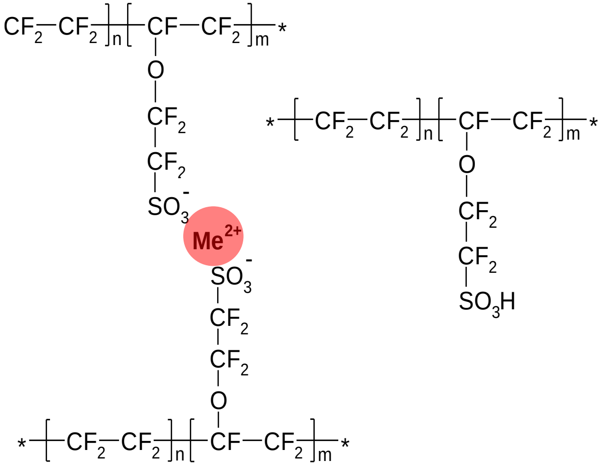


1. Project achievements:
WP-2 Membrane development

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

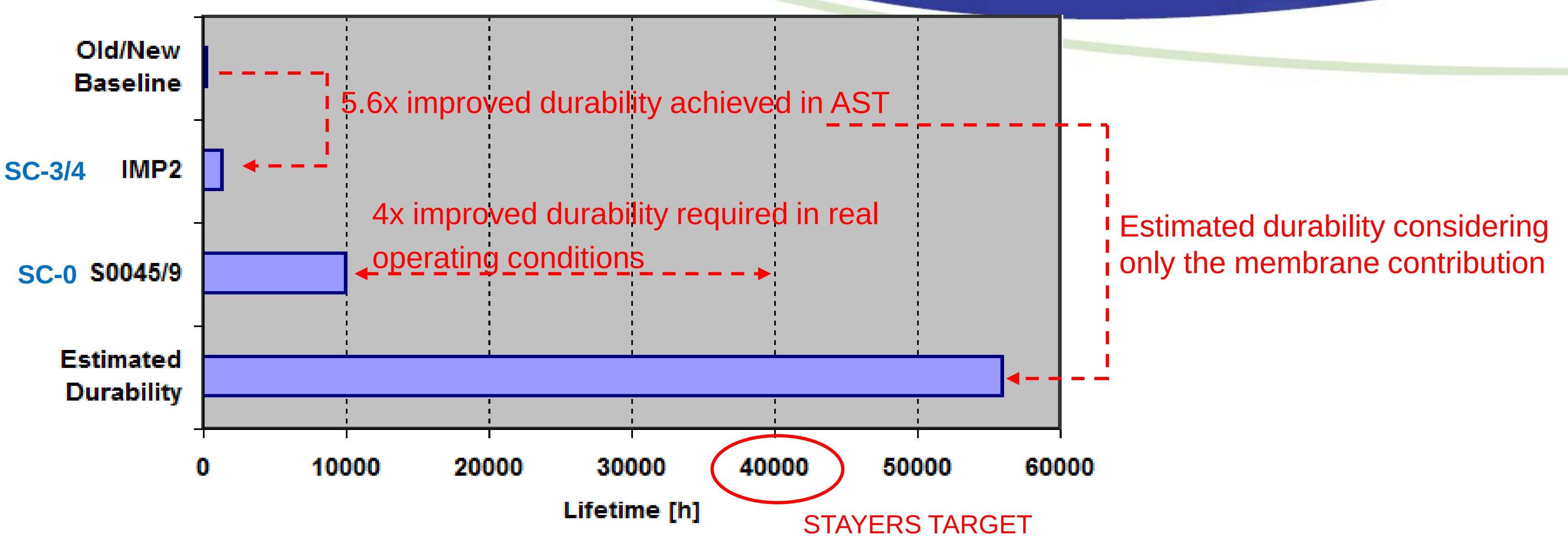
RH: 30%

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 - based on type 3	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

STAYERS
1 2 3 4 5

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

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

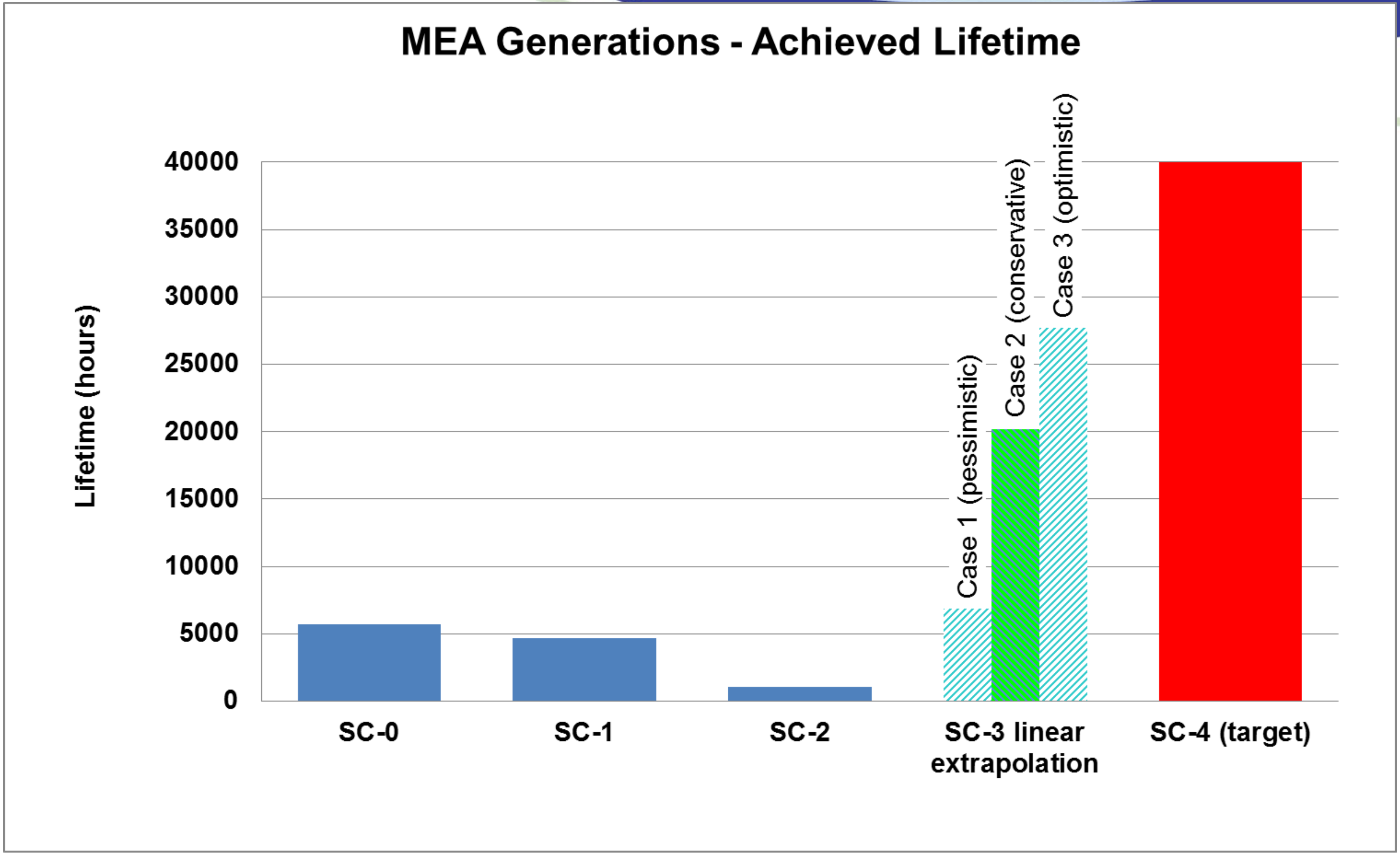
MS 3.1 Results EOL/post-mortem analyses – SC-0

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
- 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	in development	**expected**
	III. Housing & mounting	20.000+	20.000+	in development	**YES**
	improve leak resistance			in development	**YES**
4.3	Power plant			operational	
	improve operation & flexibility			to be investigated	**?**

STAYERS

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

Deliverable 4.1

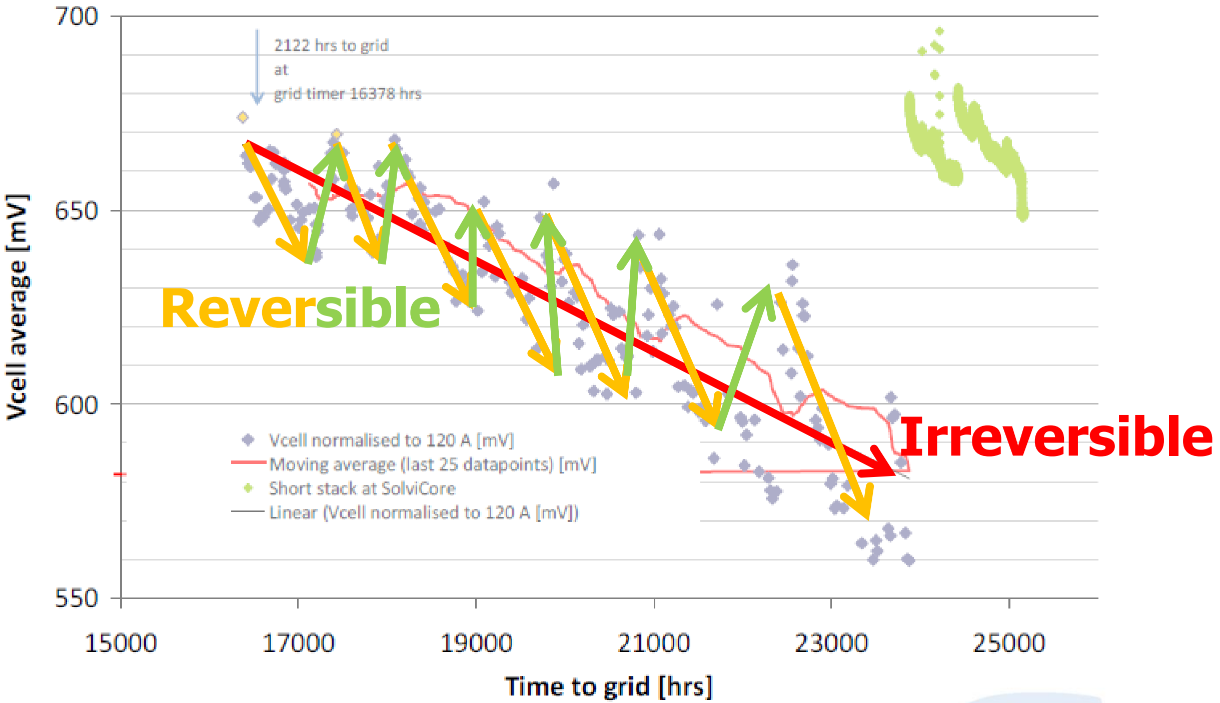
- Revised system with 2x6 stacks
- 6 positions used for Stayers
- Set point 70 kW ~120 A
- **Total hrs to grid M1-M20: >11.000**

- Software tool for data collection & analysis

1. Project achievements:
WP 4.4 data collection and analysis

Durability tests power plant SC-0

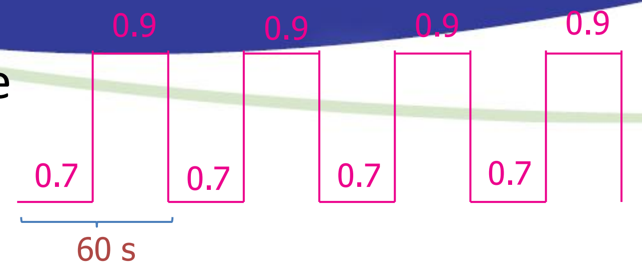
Divided in reversible and irreversible effects

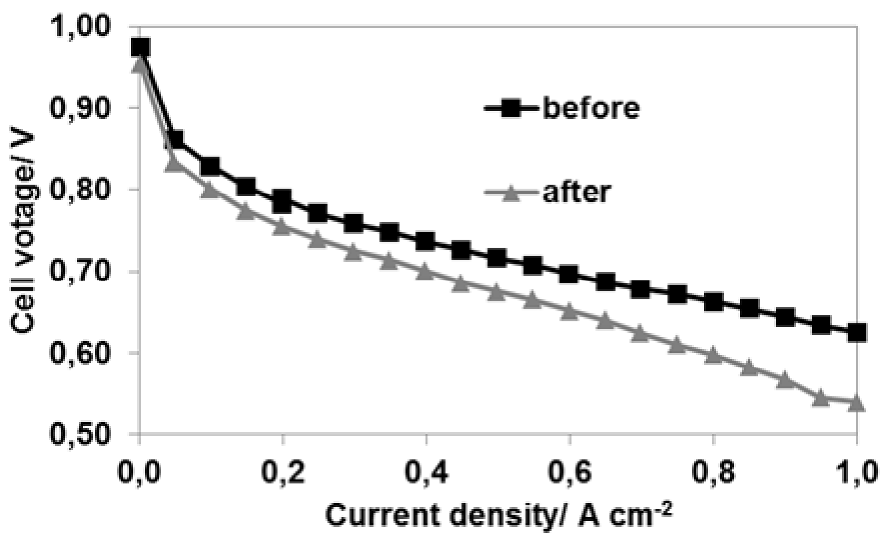


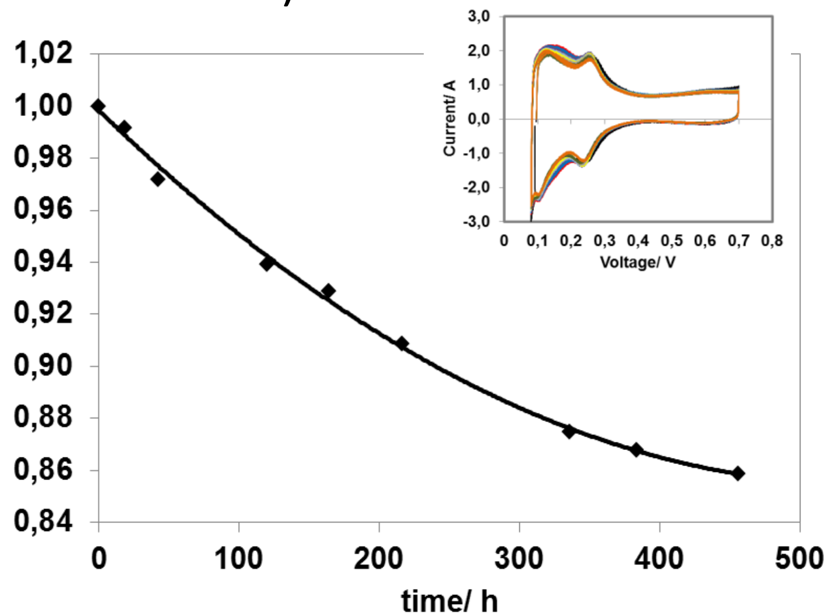
1. Project achievements: WP 5 accelerated durability investigations

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)

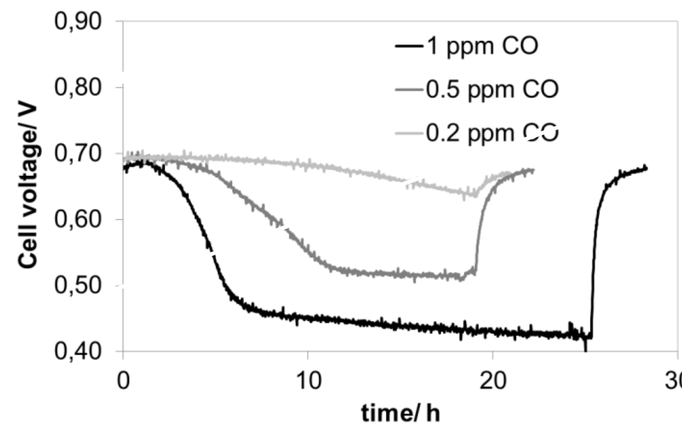






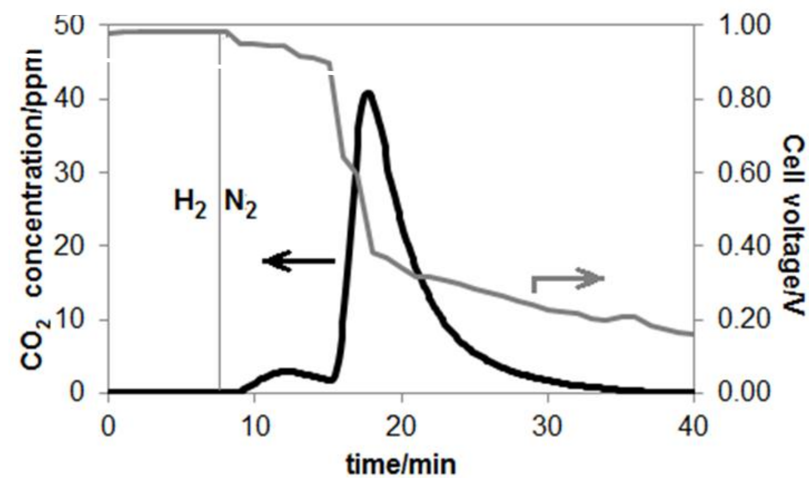
Reversible decay: CO stripping of electrode after anode poisoning

- CO added to anode gas (SC-2)
- Reversible effect, performance back to normal when CO is removed



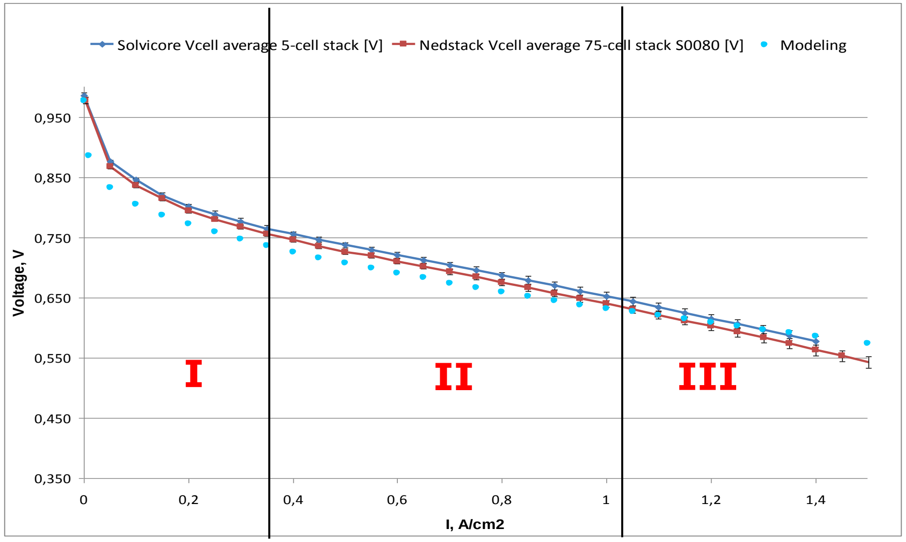
- FTIR analysis (CO_2) of anode gas outlet shows typical CO stripping when flushing anode with nitrogen

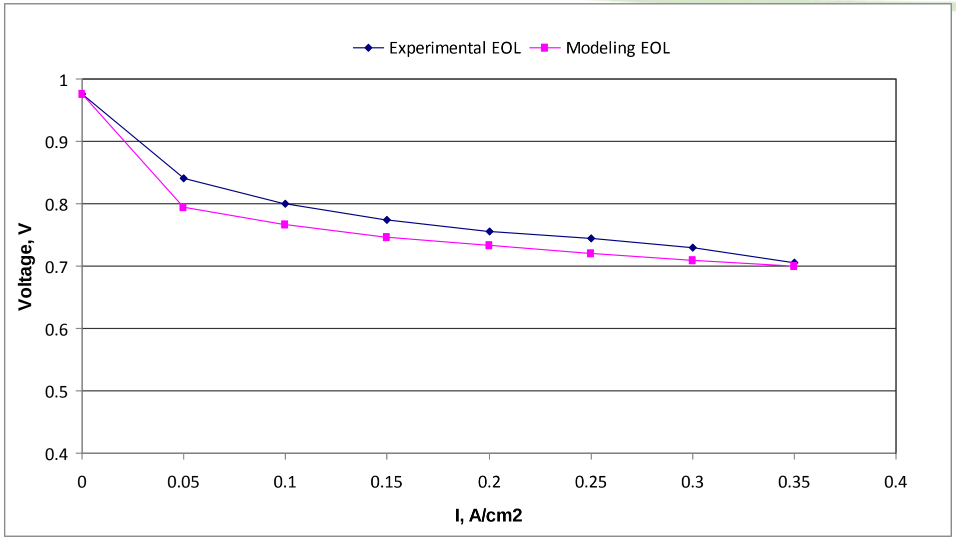
  => Large amounts of CO left on the catalyst despite performance is back to normal



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

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





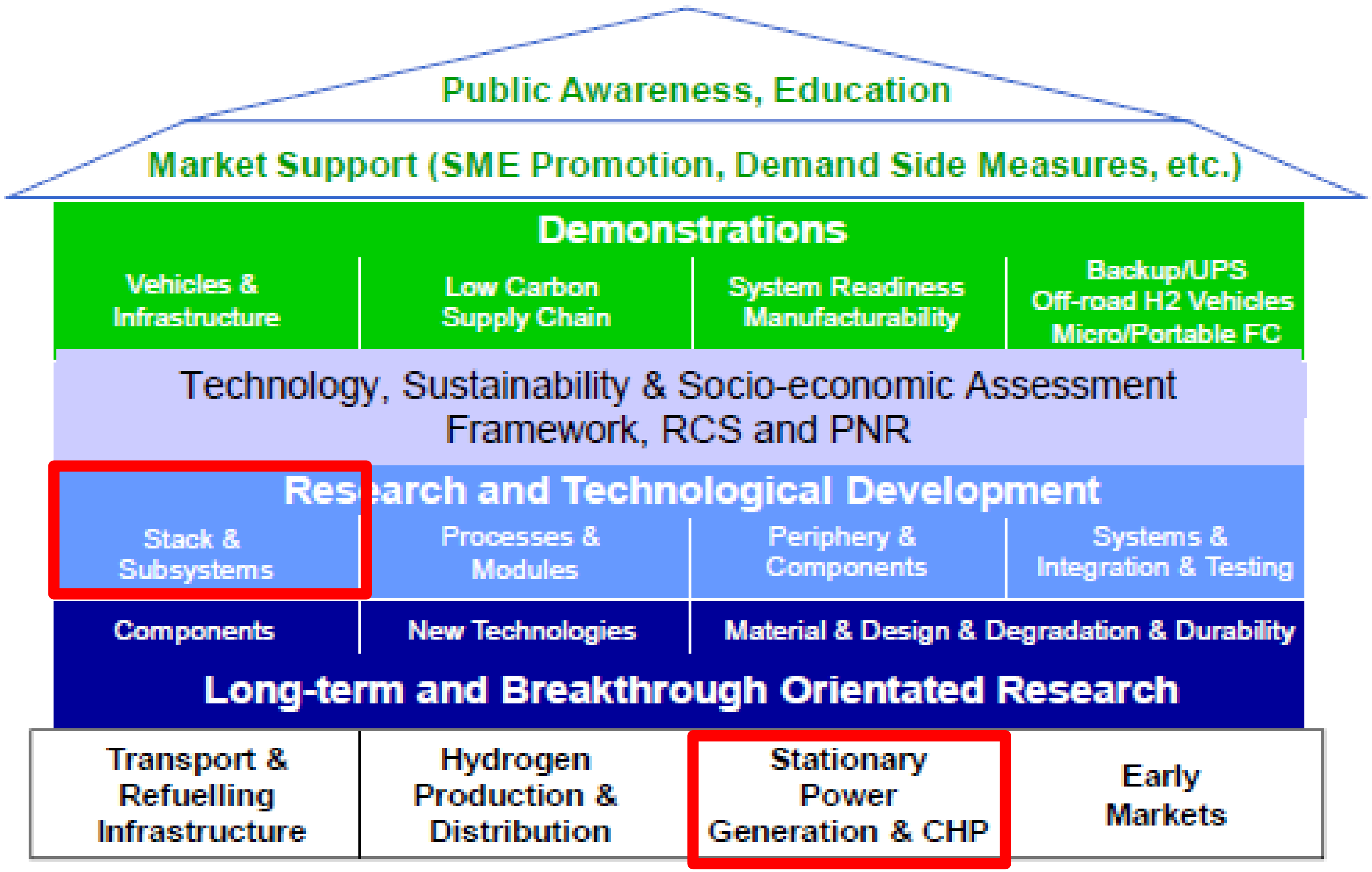
I - kinetic regime – differences attributed to effects associated with unknown kinetic constants

II –voltage drop due to ohmic losses

III – mass transfer limitations

2. Alignment to MAIP

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

<u>Goal</u>:

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

<u>STAYERS contribution to MAIP</u>:

– 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

– Deliver improved materials

– Develop diagnostic tools:
  - Components: membrane, MEA, flow field, cell plate, sealant, stack housing
  - System: software tool combining stack performance with process conditions, diagnostic system tests to be implemented

– Operating conditions to be optimized
  - Recovery protocols
  - Reactant purity