# OUTLINE

> PEMWE: Working Principles
> Components:
>> Functionality/current status
>> Technology gaps
>> Suggested Improvements
> Cost breakdown (sample)
>> CAPEX projection and components' perspective
> How can we collaborate?

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## CONTENT

> Schematic Cross Section-PEMWE
>> Membrane (MEM)
>> Anode Catalyst ($CL_a$)
>> Cathode Catalyst ($CL_c$)
>> Porous Transport Layers ($PTL_a$, $PTL_c$)
>> Bipolar Plates (BPP) (×2)
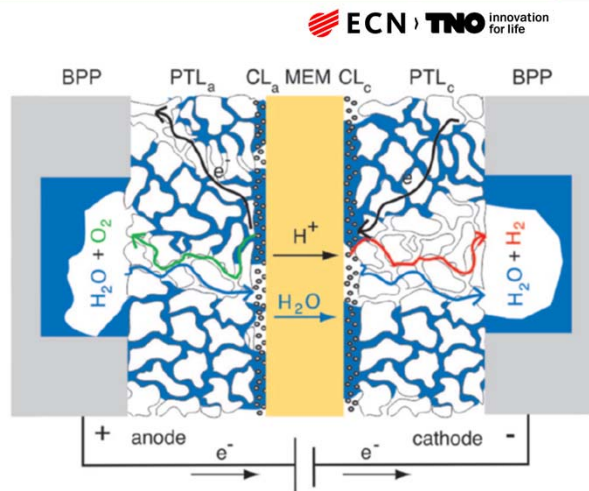


*Source: JES, 164 (2017) F387*

✓$H_2O \rightarrow H_2 + \frac{1}{2}O_2$

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## CATALYST ($CL_a$, $CL_c$)

Anode Catalyst: $CL_a$
> OER: Oxygen Evolution Reaction
> Current Status: Ir, Ir/Ru Oxide Black

Cathode Catalyst: $CL_c$
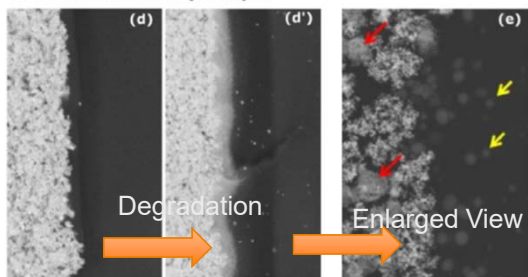> HER, Hydrogen Evolution Reaction
> Current Status: Pt/Pd NP/Support
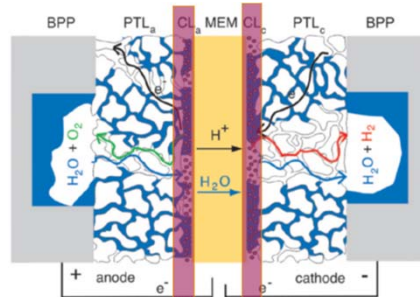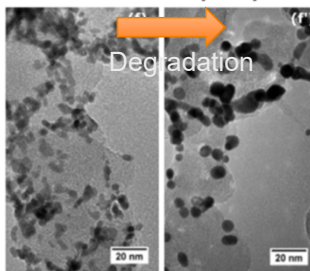
Issues:
> Cost, performance, durability catalyst/support

Suggested Remedies:
> Alloy catalyst
> Doped metal oxide support



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*Source: Curr. Op. Echem 8 (2018)118*

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## MEMBRANE (MEM)

ECN › TNO innovation for life

### Proton Exchange Membrane (PEM)

›  Conduction of protons/ (ionomer) CL binder
›  Separation of gases
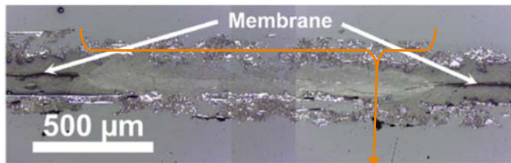›  Electrical insulation
›  Mech/Chem/Thermal stability
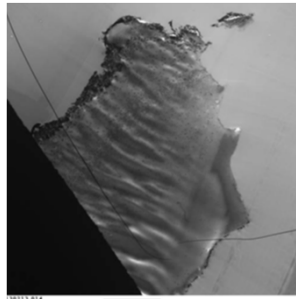
### Issues:

›  Cost, gas cross-over, stability

### Suggested Remedies:

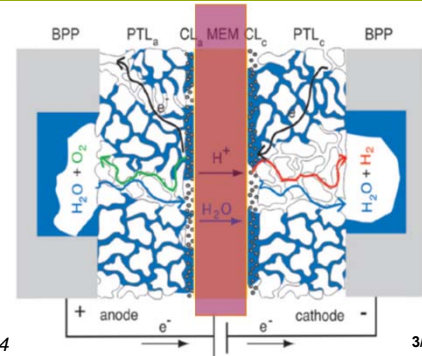›  Reinforced membranes
›  Hydrocarbon membranes



*Source: Curr. Op. Echem 8 (2018)118*

Membrane

500 µm

Hole ~ 1.5 mm

*Source: Int'l J. Hydro. Energy 39 (2014 )2044*

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## POROUS TRANSPORT LAYER (PTL$_a$, PTL$_C$)

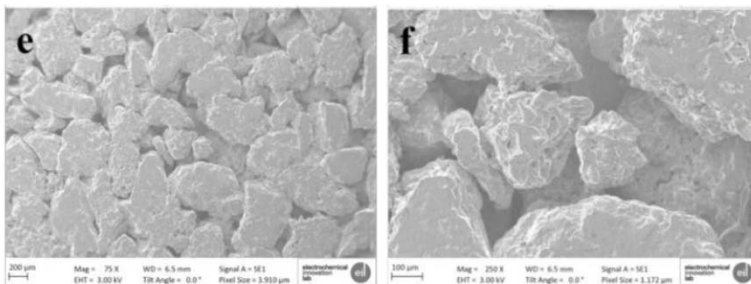ECN › TNO innovation for life

### PTL$_{a,c}$

›  Transport water to CL$_a$ and away from CL$_c$
›  Transport product gases (O$_2$, H$_2$) from CL's
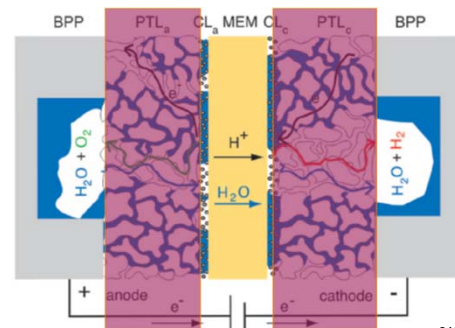›  Electrical communication with CL's

### Issues:

›  Extreme corrosion, expensive Ti

### Suggested Remedies:

›  Protective coatings
›  Alternative materials



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*Source: Energy Proc. 151 (2018)111*

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## BIPOLAR PLATES (BPP'S)
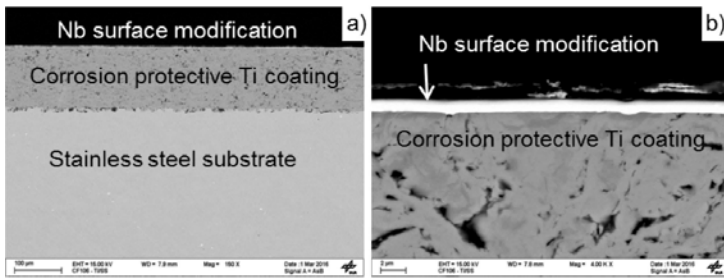
ECN › TNO innovation for life

**BPP**

▹ Transport water to/from PTL
▹ Transport product gases ($O_2$, $H_2$) out
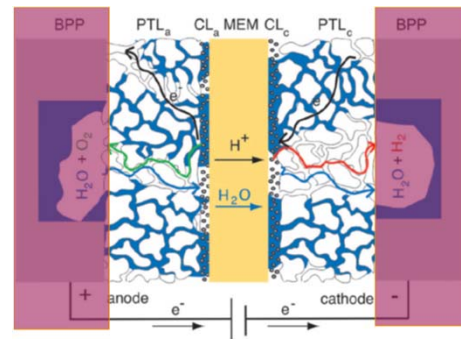▹ Electrical communication with PTL

**Issues:**

▹ Extreme corrosion ($\downarrow$pH, V$\uparrow$, T$\uparrow$)

**Suggested Remedies:**

▹ Protective coatings
▹ Alternative materials



*Source: Scientific Reports 7 (2017) 44035*

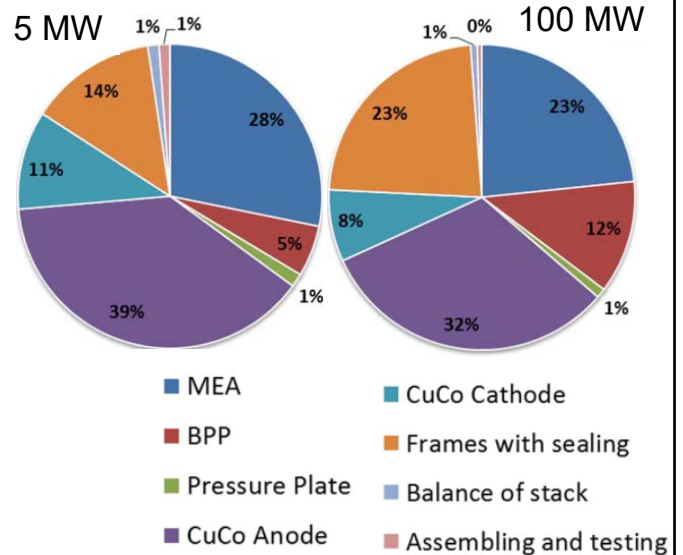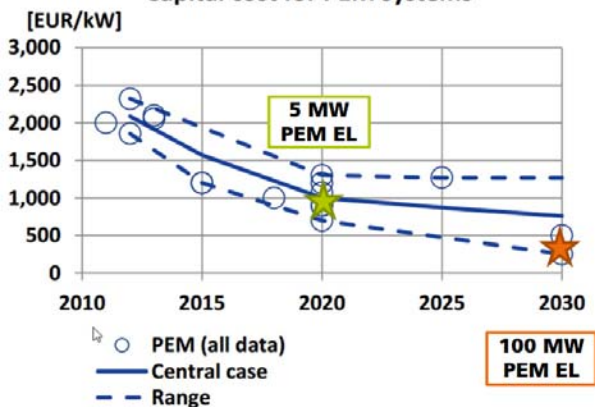7                                                                3/18/2019
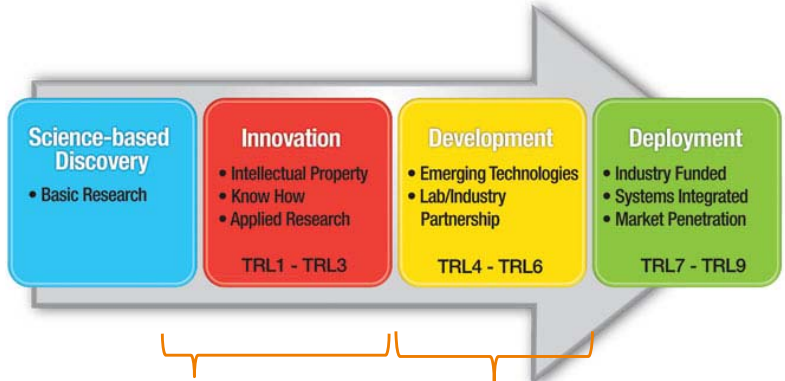
## PEMWE STACK: *Sample* cost breakdown

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Dominant stack cost: Ti CC, MEA

✓ Interdependence of cost, scale-up & performance!



5 MW       100 MW

**Capital cost for PEM systems**

Legend:
- ■ MEA
- ■ CuCo Cathode
- ■ BPP
- ■ Frames with sealing
- ■ Pressure Plate
- ■ Balance of stack
- ■ CuCo Anode
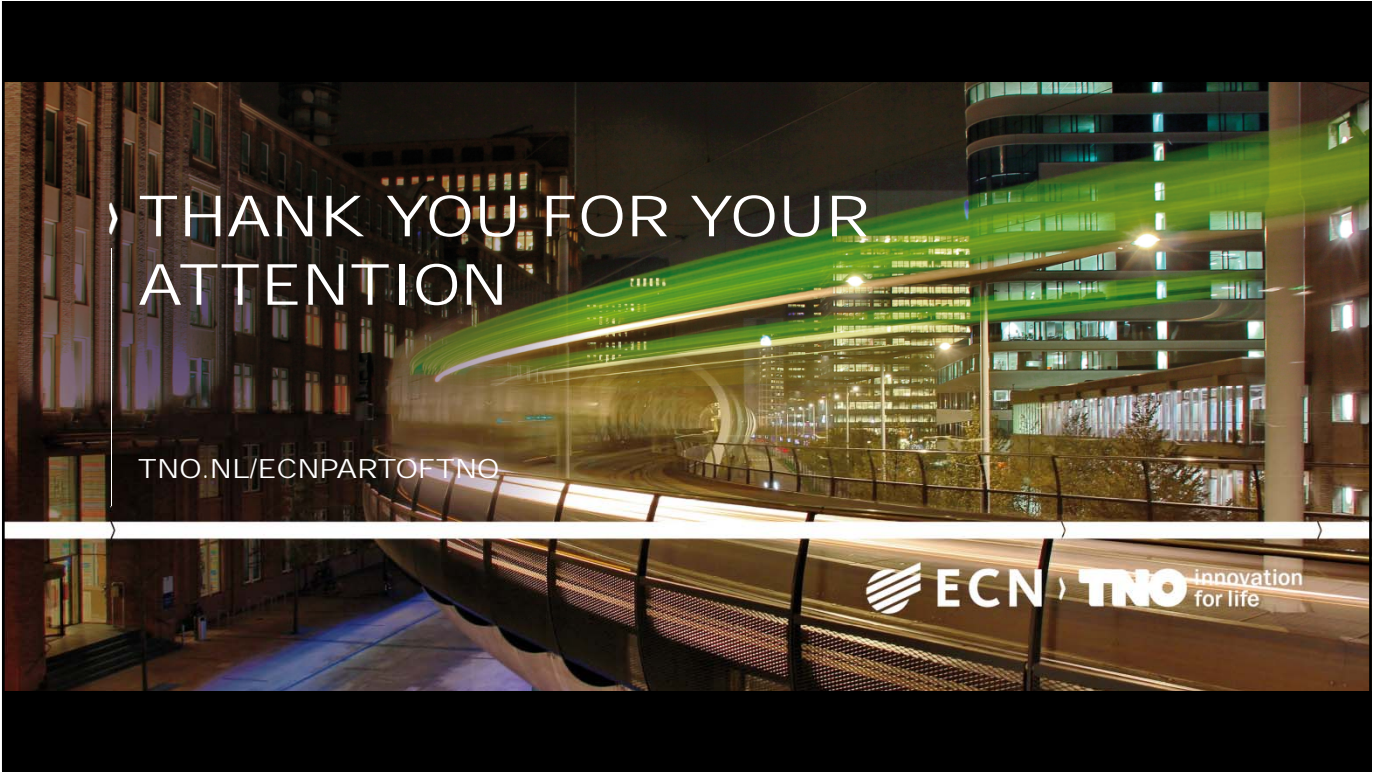- ■ Assembling and testing

*Source: Fraunhofer-Institut für Solare Energiesysteme*        3/18/2019

# HOW CAN WE COLLABORATE?



- IP development
- JDA/proposals w/Research Labs., Academia

- JDA/proposals
- Business development Lab/Industry
  - Testing/Scale up

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# THANK YOU FOR YOUR ATTENTION

**TNO.NL/ECNPARTOFTNO**