Identifying assembly processes which accelerate PEM fuel cell degradation during their operation
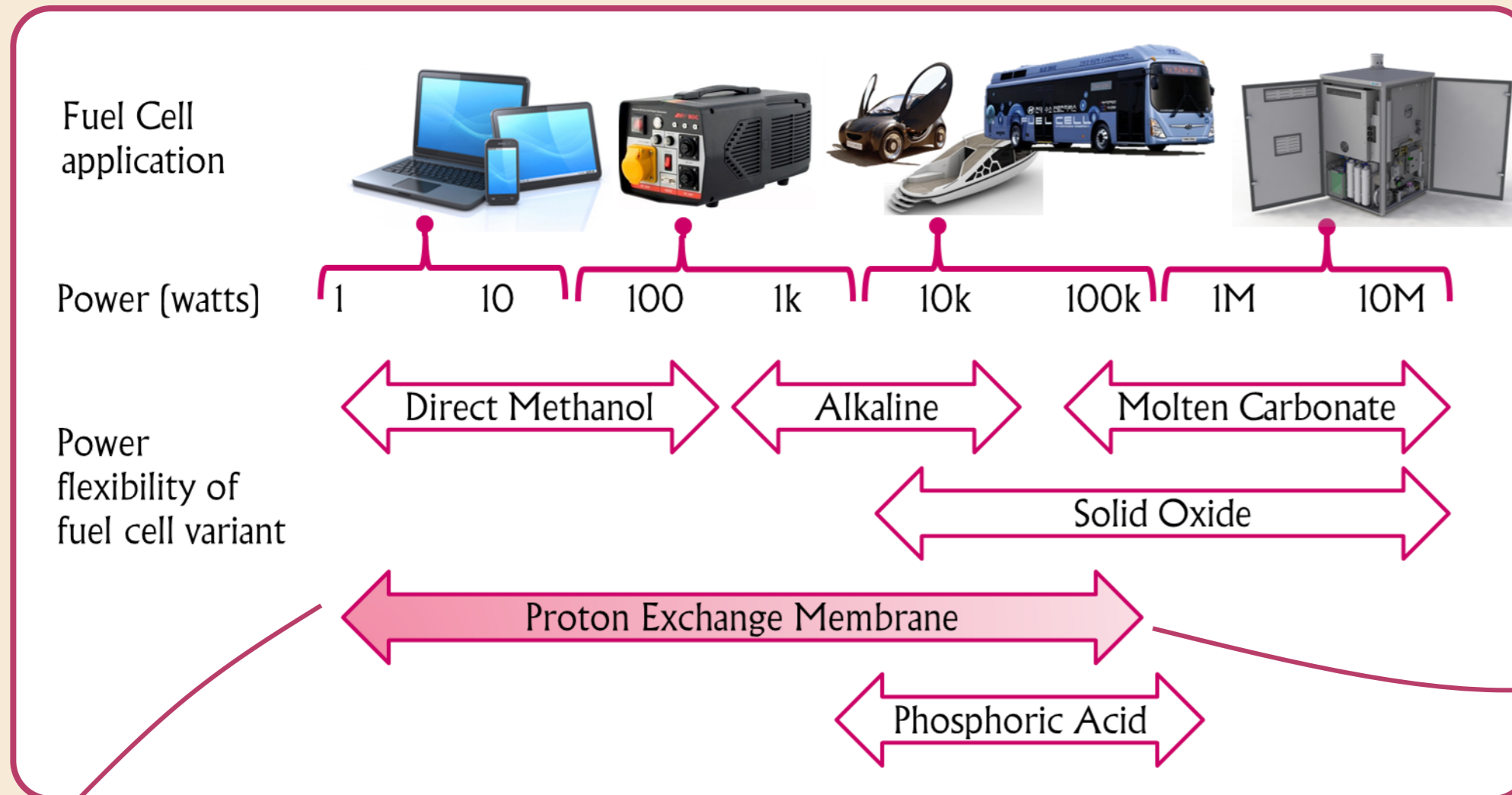
Mussawar Ahmad[I] (mussawar.ahmad@warwick.ac.uk), Prof Robert Harrison[I], Dr Stuart McLeod[I], Dr James Meredith[2], Dr Axel Bindel[3],

[I] Automation Systems Group, International Manufacturing Centre, WMG, University of Warwick, Coventry, CV4 7AL, United Kingdom
[2] Mechanical Engineering, University of Sheffield, Garden Street, South Yorkshire, S10 2TN, United Kingdom
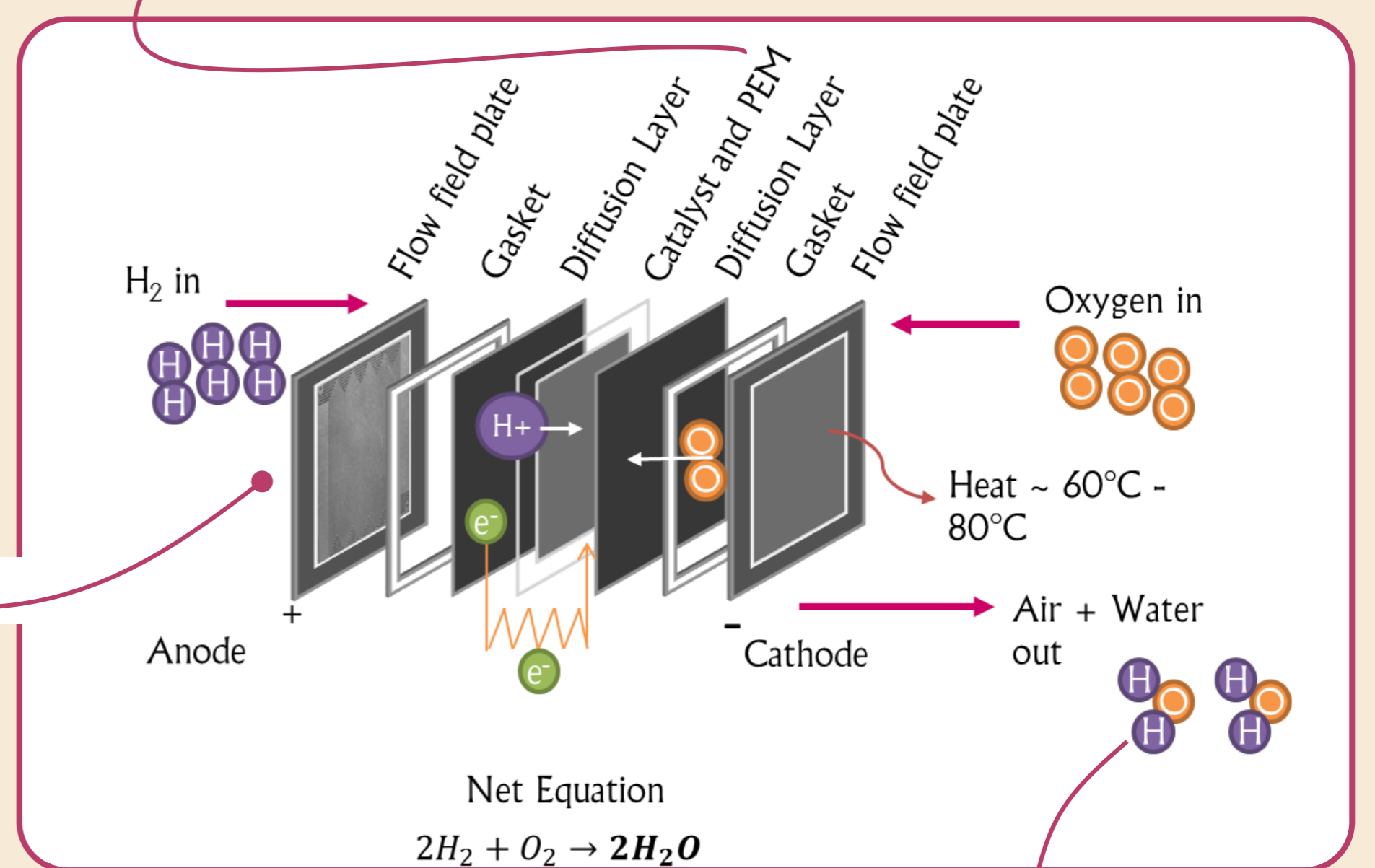[3] HSSMI, CEME Campus, Marsh Way, Rainham, RM13 8EU, United Kingdom

1. Fuel Cell Applications and Operating Principle

PEM stands for proton exchange membrane. The membrane and electrodes form the heart of the fuel cell

Fuel Cell application

Power (watts)   1   10   100   1k   10k   100k   1M   10M

Power flexibility of fuel cell variant

- Direct Methanol
- Alkaline
- Molten Carbonate
- Solid Oxide
- Proton Exchange Membrane
- Phosphoric Acid

H_2 in — Flow field plate, Gasket, Diffusion Layer, Catalyst and PEM, Diffusion Layer, Gasket, Flow field plate — Oxygen in

Anode +   H+   e−   − Cathode

Heat ~ 60°C - 80°C

Air + Water out

Net Equation
$$2H_2 + O_2 \rightarrow 2H_2O$$

At volumes of 100,000 per annum cost is $67/kw compared to $10/kw for combustion engine[3]. The high cost is attributed to fuel cell reliability, durability and stability concerns. These stem from performance degradation arising from material choice, operating environment and manufacturing processes employed.

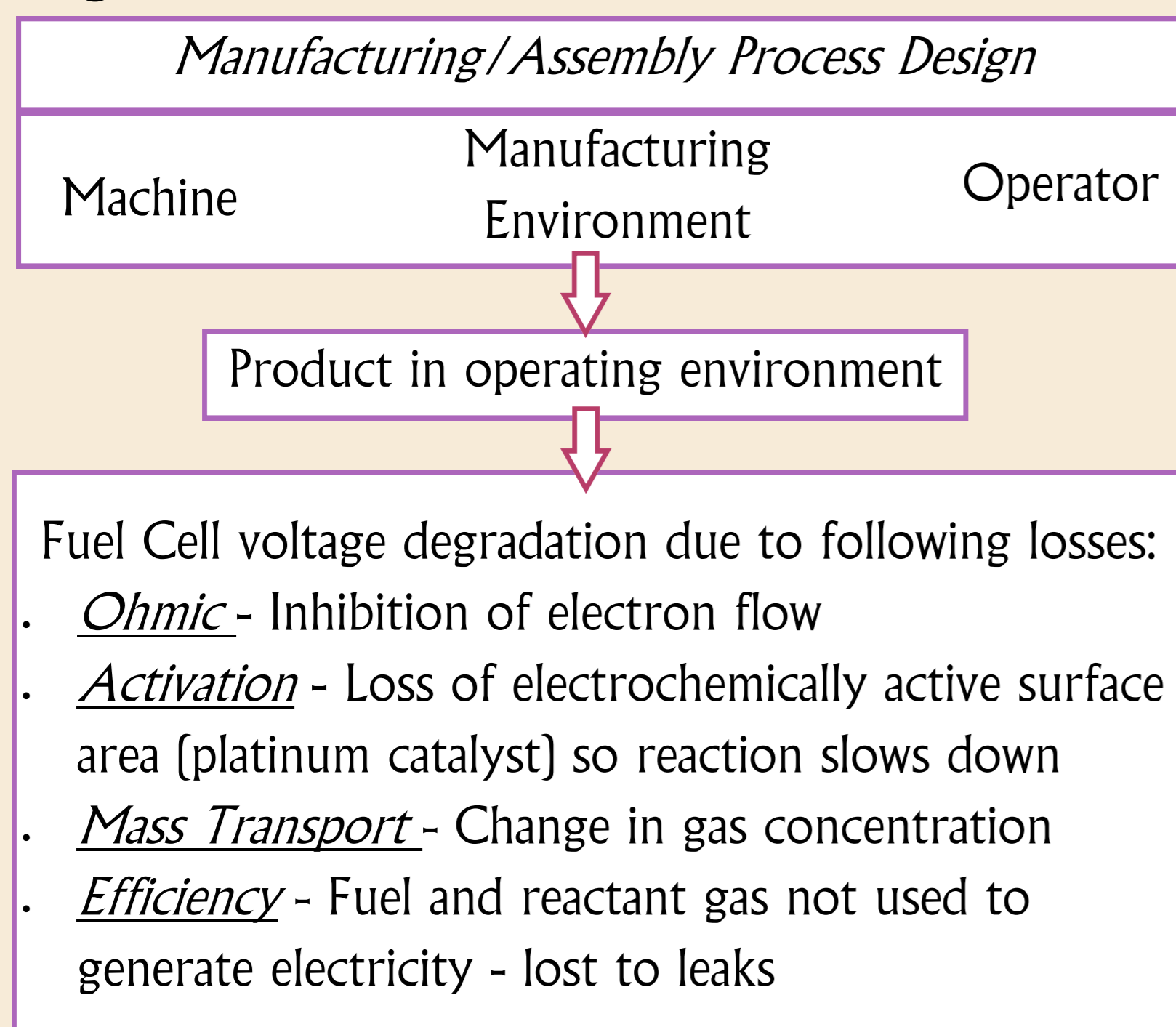50% efficiency compared to 25% of internal combustion engine

Only emission is water

[3] US Energy Information Administration. Annual energy outlook. Report no. DOE/EIA-0383, US Department of Energy, Washington, DC, 2005

2. Research Aims

- Analyse fuel cell degradation over time due to component design and material selection to build a model which will enhance their life
- Develop a map of operational fuel cell decay, identifying specific manufacturing and assembly processes as potential root causes
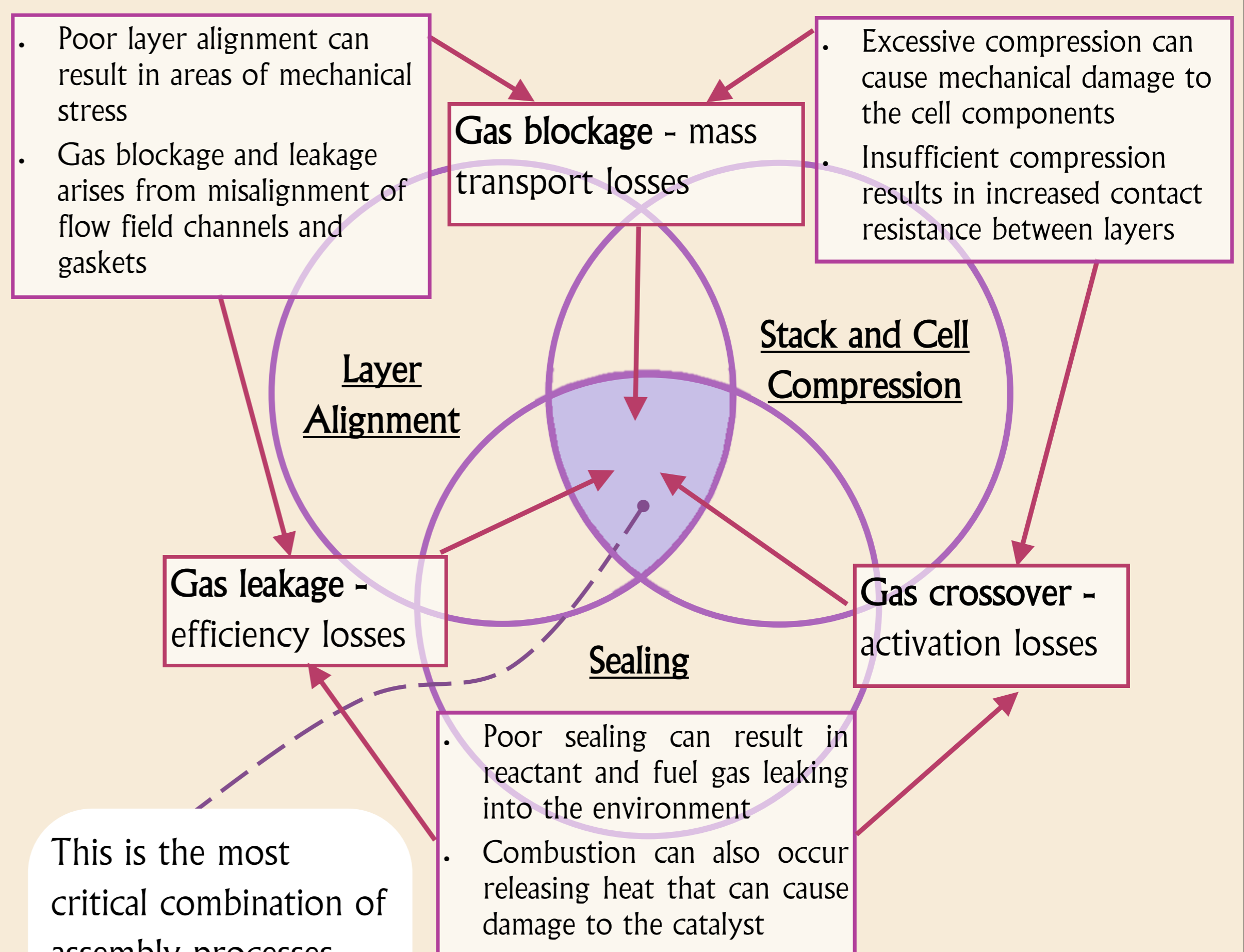
3. Manufacturing Dependent Degradation

Manufacturing/Assembly Process Design

Machine   Manufacturing Environment   Operator

Product in operating environment

Fuel Cell voltage degradation due to following losses:
- *Ohmic* - Inhibition of electron flow
- *Activation* - Loss of electrochemically active surface area (platinum catalyst) so reaction slows down
- *Mass Transport* - Change in gas concentration
- *Efficiency* - Fuel and reactant gas not used to generate electricity - lost to leaks

4. Critical Assembly Processes Identified

- Poor layer alignment can result in areas of mechanical stress
- Gas blockage and leakage arises from misalignment of flow field channels and gaskets

Gas blockage - mass transport losses

- Excessive compression can cause mechanical damage to the cell components
- Insufficient compression results in increased contact resistance between layers

Layer Alignment

Stack and Cell Compression

Gas leakage - efficiency losses

Gas crossover - activation losses

Sealing

- Poor sealing can result in reactant and fuel gas leaking into the environment
- Combustion can also occur releasing heat that can cause damage to the catalyst

This is the most critical combination of assembly processes that cause fuel cell degradation and inevitably lead to catastrophic failure during operation

5. Conclusions and Further Work

- There is currently a knowledge gap around performance degradation of fuel cells resulting from assembly operations
- The next step is to quantify the voltage decay associated with the processes to realise the most 'valuable process'
- This leads to process design optimisation using computer modelling

THE UNIVERSITY OF WARWICK

HSSMI High Speed Sustainable Manufacturing Institute

WMG Innovative Solutions

arcola energy

EPSRC Engineering and Physical Sciences Research Council