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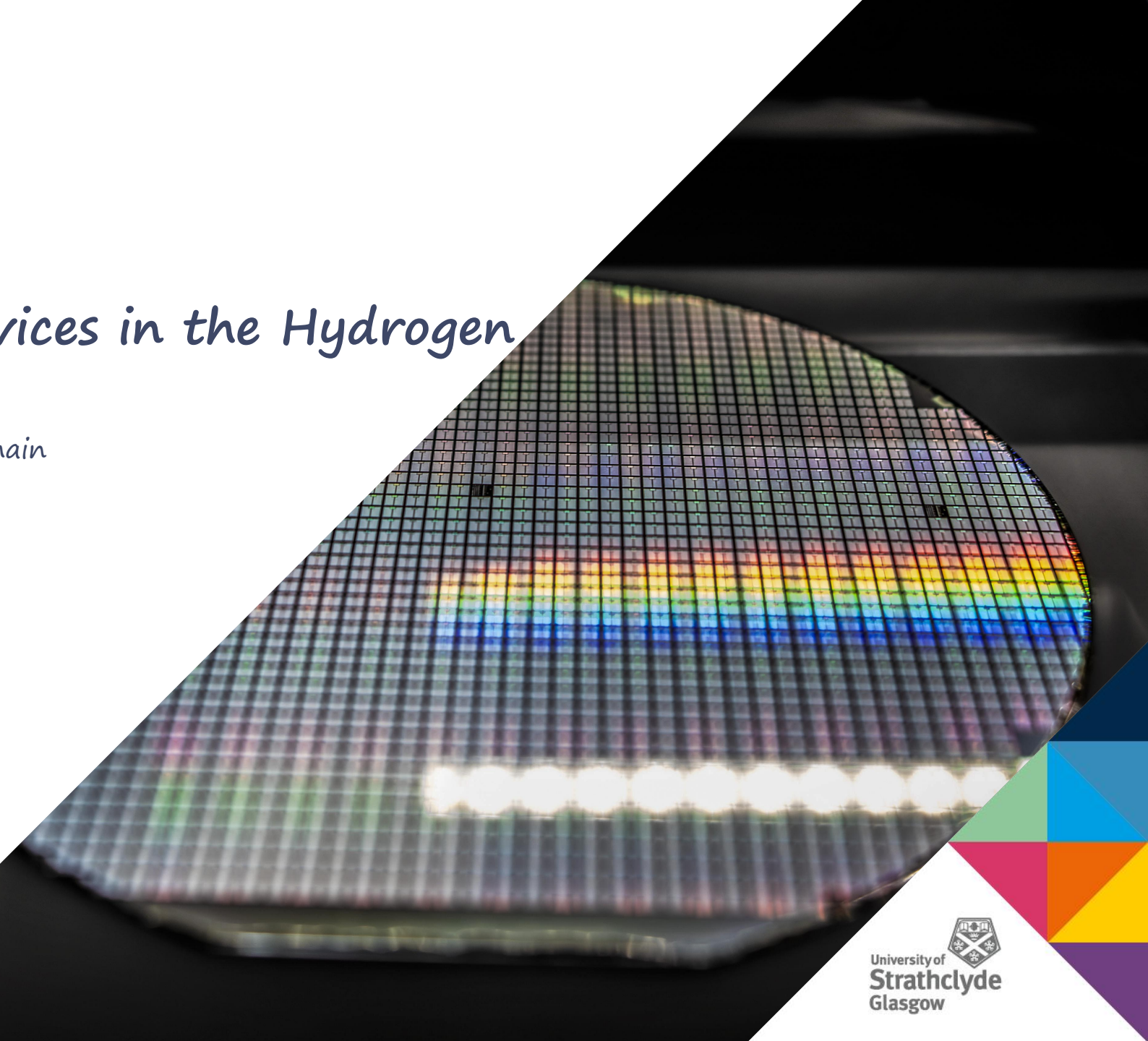
Silicon Carbide Power Devices in the Hydrogen Economy

Driving Efficiency Across the Energy Value Chain

Prof Matt Maynard



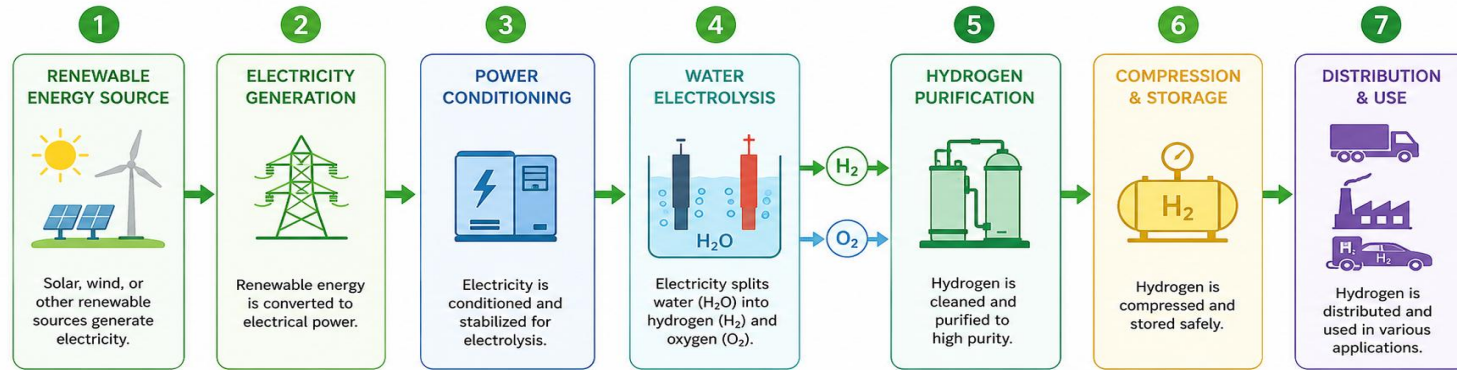
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The Hydrogen Inflection Point

- Hydrogen could supply 15% of global energy demand by 2050
- Green hydrogen is still expensive because electrolysers and conversion steps add cost
- Economics depend on low-cost renewable power and efficient conversion
- That makes system efficiency a key driver of hydrogen viability

The Importance of Efficiency in Hydrogen Production



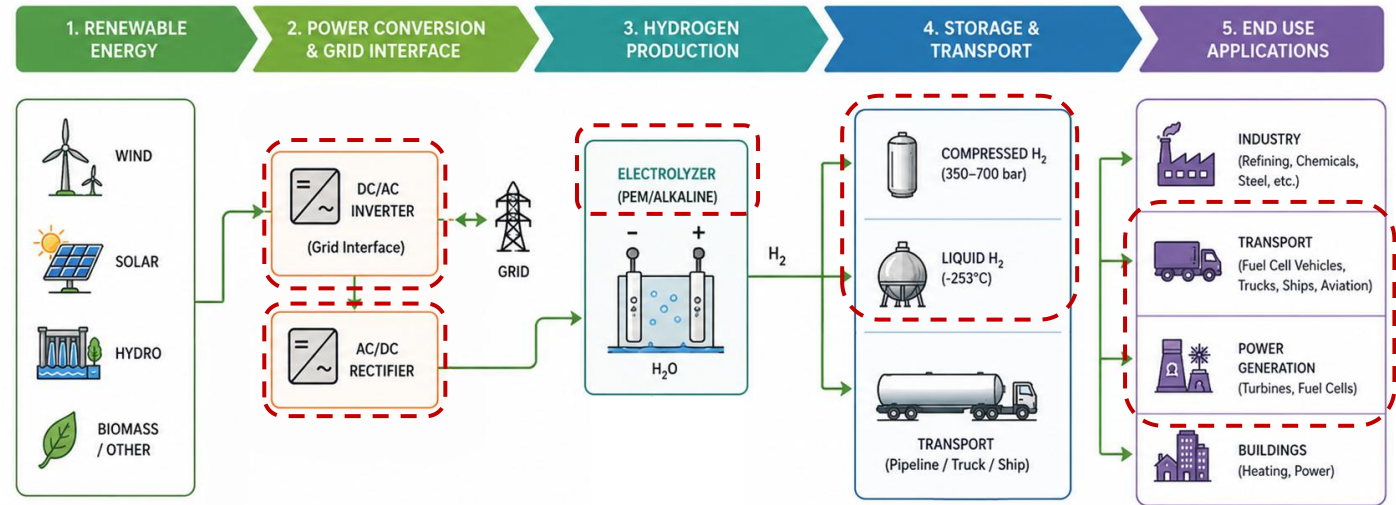
- Each energy conversion step adds losses in hydrogen production.
- Those losses directly raise the levelised cost of hydrogen (LCOH).
- Electricity remains the largest cost driver in hydrogen production.
- Hydrogen economics depend heavily on system-level efficiency

Where Power Electronics Losses Occur

- Power electronics losses occur across the hydrogen value chain

- Key loss points include:

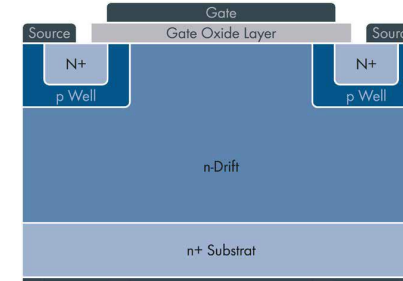
- **Grid interfaces (AC to DC)**
- **Power supplies**
- **Motor drives**
- **DC/DC and DC/AC conversion**







- Each conversion stage introduces energy losses

What is SiC and Why It Matters

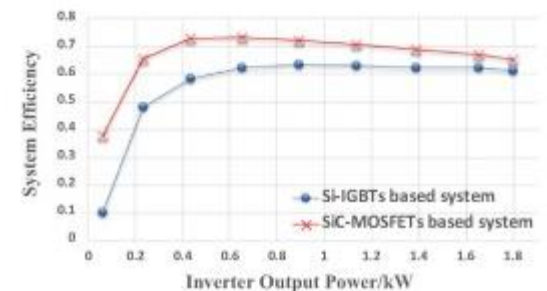
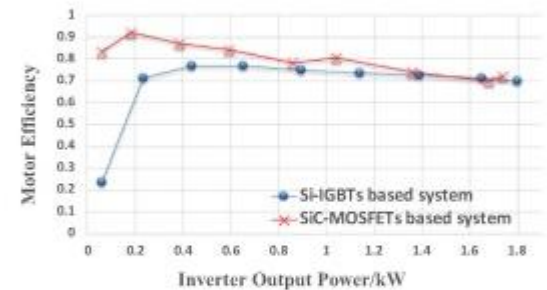
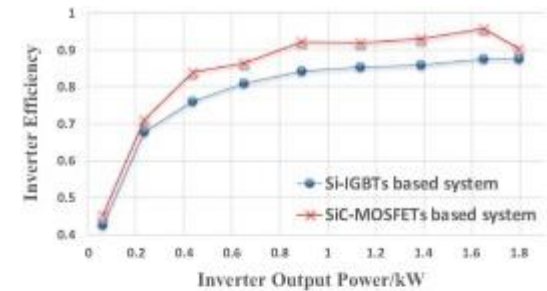
- SiC is a wide-bandgap semiconductor with much higher voltage capability than silicon
- It is used in EVs, solar, grid converters, and industrial power systems
- It enables faster, lower-loss switching for **higher efficiency**
- It improves thermal performance and power density for **more compact systems**



SiC (Silicon Carbide)		Silicon (Si)
Very fast		Slower
Up to ~200°C		Up to ~150°C
650 V – 3300 V+		Usually up to ~1200 V
Lower losses		Higher losses

What SiC Delivers in Practice

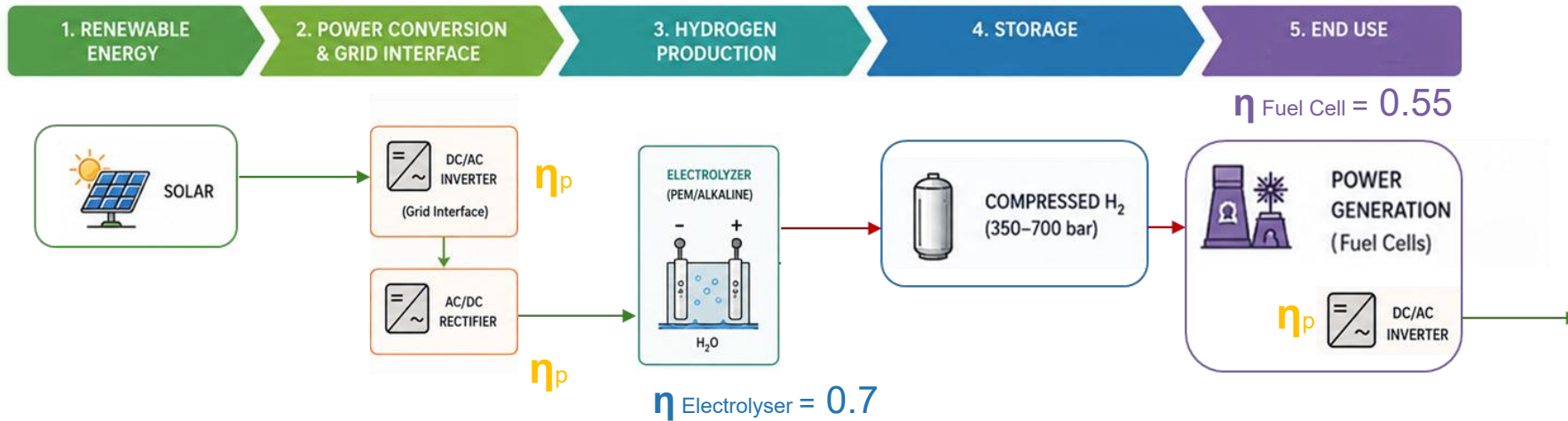
- SiC based converters deliver an absolute efficiency gain of 1–3% per conversion stage versus Si based alternatives.
- Lower cooling losses allow SiC to support demanding industrial applications while reducing cooling-system requirements.
- Higher switching frequencies enabled by SiC allow for smaller passive components
- Power converters based on SiC technology can achieve efficiency rates of up to 99.2%.



Comprehensive comparison between silicon carbide MOSFETs and silicon IGBTs - Xiaofeng Ding et al 2018 Applied Energy, Elsevier, vol. 194(C)

System- Level Efficiency: Why Small Gains Matter

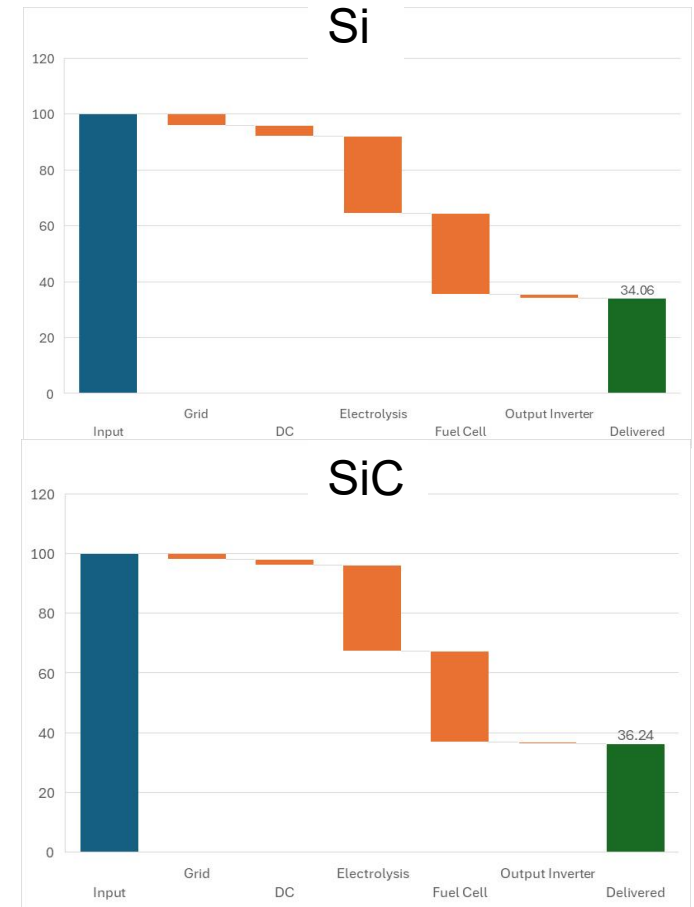
Illustrative Hydrogen Energy Pathway



- Hydrogen pathway includes three major power electronics stages, each with stage efficiency of η_p
 - Silicon (Si) baseline: $\eta_p=96\%$ per stage
 - Silicon carbide (SiC) case: $\eta_p=98\%$ per stage
- PE block efficiency improves from Si $\approx 88.5\%$; SiC $\approx 94.1\%$

The Economic Lever: System-Level Efficiency

- Multiple conversion stages compound efficiency gains across the full system.
- **~2% per stage** improvement lifts system efficiency from **34% to 36%**.
- SiC system can deliver about **6% more** usable output.
- a **6% efficiency** gain translates to an equivalent **6% reduction** in LCOH
- At scale, a 100 MW system saves MWs of power
- GW systems can therefore unlock large annual savings.



Based on industry rectifier efficiencies (Si: 96.2%, SiC: 98.9%) and typical PEM stack + BOP data

Why Efficiency Changes Hydrogen Economics

- **Lower OPEX:** SiC power electronics reduce losses and cut renewable electricity requirements.
- **Lower CAPEX:** Higher switching frequencies and SiC enable smaller, simpler power systems
- **Higher reliability:** More durable components reduce maintenance, downtime, and lifecycle risk.
- **System improvements:** Combined gains across energy sources and equipment can reduce energy cost by about 6%.
- **Economic impact:** When captured system-wide, efficiency gains directly reduce LCOH.

SiC Market Position

Maturity

Commercial SiC is proven in the field, but still early in industrial-scale expansion

Current Uses

Adopted where system-level efficiency and power density justify a premium cost

- EV traction inverters
- Industrial motor drives
- Renewable and grid converters

Current Costs

Relative position

- Higher upfront cost than silicon (Si) devices
- Cost competitiveness remains application dependent

Higher device cost offset by lower losses and smaller cooling and passive systems

Future Trends

Technology trajectory

- Wafer scaling
- Device architectures
- Advanced packaging

- Market direction
- Grid infrastructure
- Hydrogen systems
- Heavy-industry electrification

SiC is advancing from a component upgrade to a system-level enabler

- SiC is now scaling through cost reduction and system-level integration

Challenges and Research Needs

- Manufacturing process: Reduce upfront manufacturing cost with lower lifetime cost potential.
- Environmental Factors: evaluating long-term exposure to hydrogen-rich atmospheres and potential effects on threshold voltage and transconductance.
- Packaging Requirements: Advanced electrical and thermal packaging remains essential to fully capture SiC's high-power capability.



Conclusion: A Critical Enabler

- Hydrogen could supply roughly 15% of global energy demand by 2050, so efficiency gains matter at scale.
- Better system efficiency helps lower **levelised cost of hydrogen** across the value chain.
- Higher efficiency reduces losses, boosts **higher throughput** and enables **faster scaling**.
- SiC power electronics are a **key enabler** for scaling the hydrogen economy economically.

