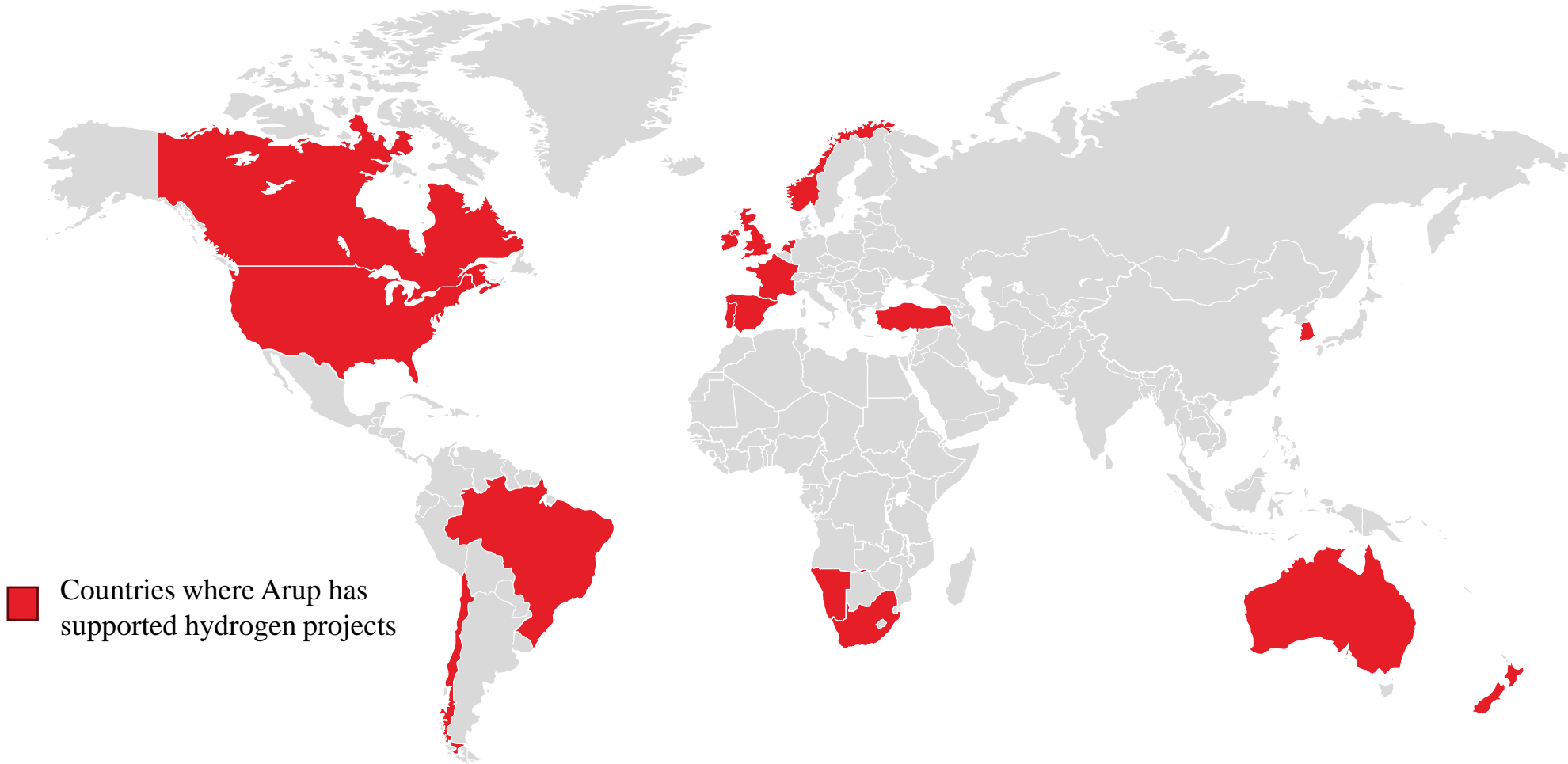


Green Hydrogen Production and Export from Scotland

Production & Transport Pathways - an international comparison

Our Global Hydrogen Experience

Global expertise, local knowledge



Select Services

Government/Policy

Developer Strategic Advice

Engineering/Design

Owner's Engineer

Consents/Environment

Safety Studies

Project Funding

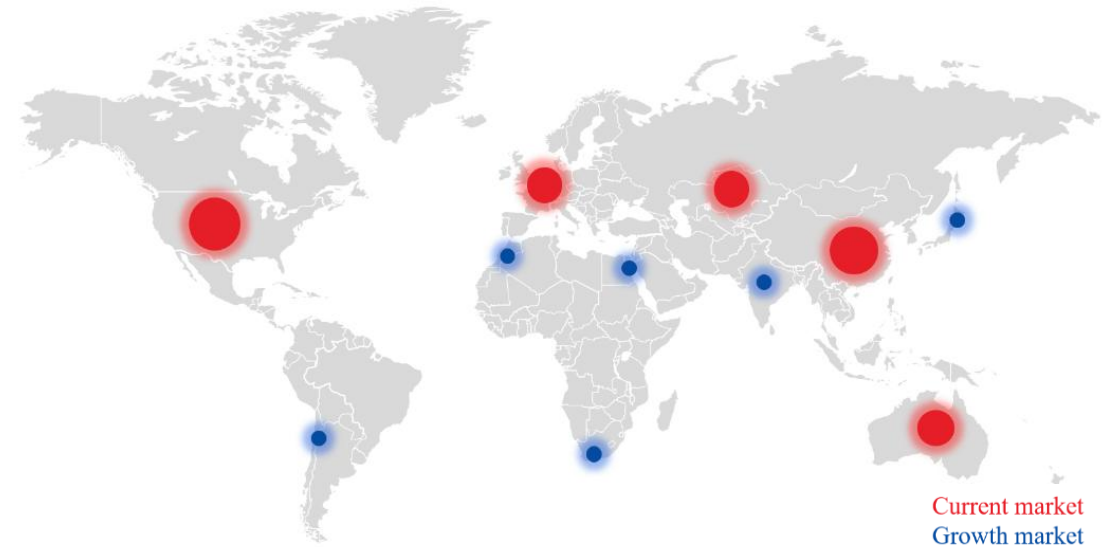
Transaction Advice

Green Hydrogen Production and Transport Costs – Pathway Comparison

Project background

Key deliverables

1. Can Scotland produce and export cost competitive hydrogen at scale to the European market?
2. How may the Scottish government support its hydrogen sector to enable it to produce and export cost competitive hydrogen at scale to the European market?



Global low carbon hydrogen production capacity hotspots

International Pathways

Supply of hydrogen to EU

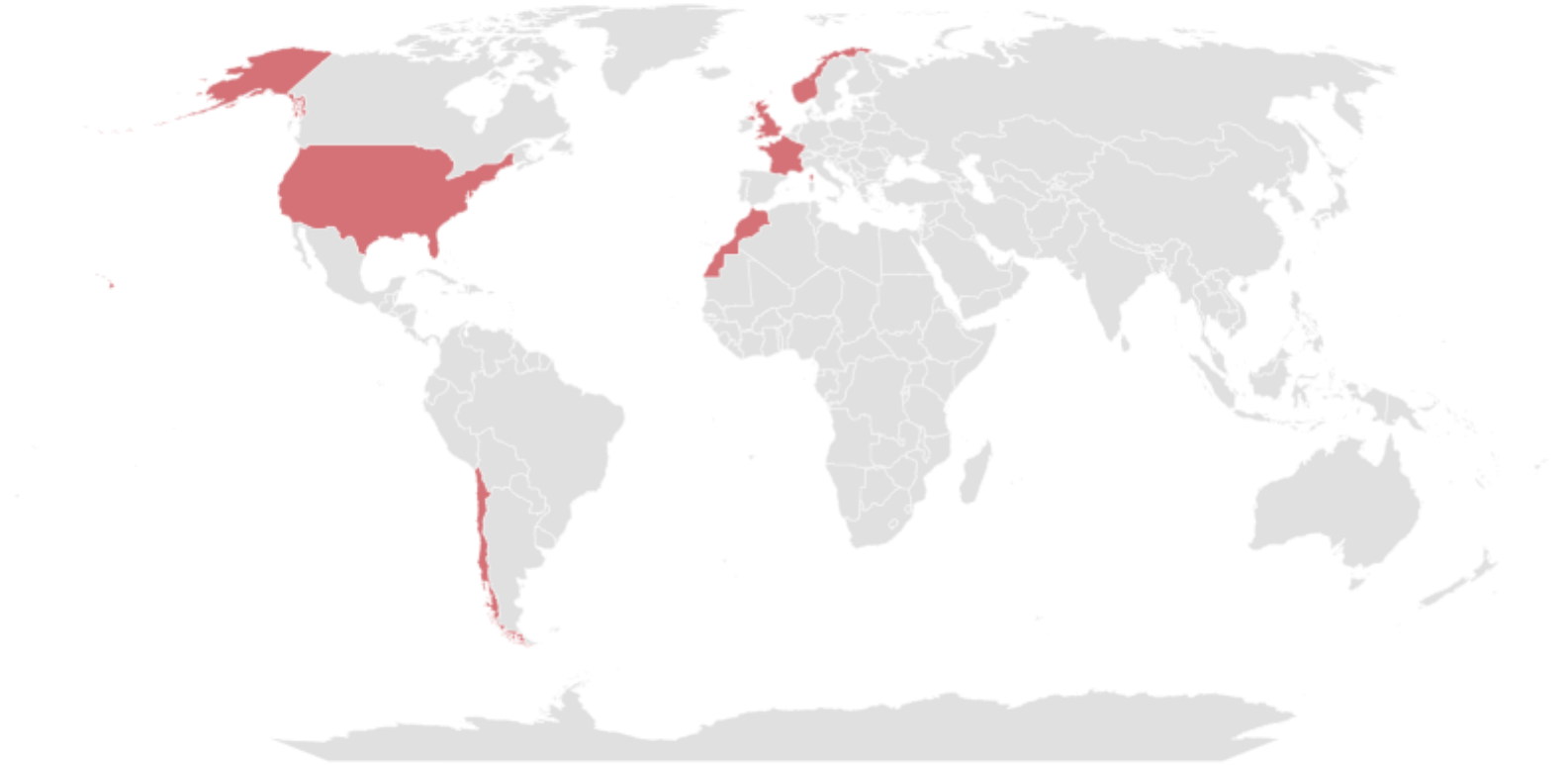


Exporting nations considered

- Scotland
- Chile
- Norway
- Morocco
- France
- USA

Transportation Pathways considered

- Pipeline
- Ship - Ammonia
- Ship - Compressed hydrogen



Hydrogen production costs

Key conclusions

Hydrogen Production Costs

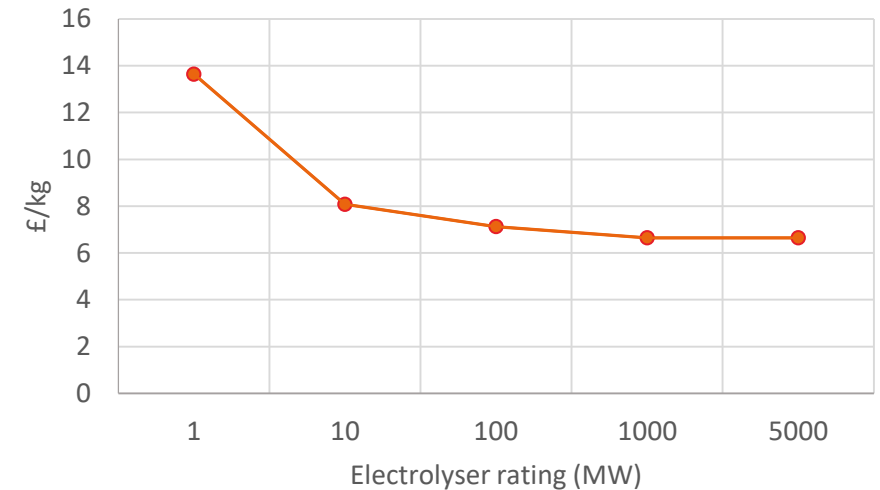
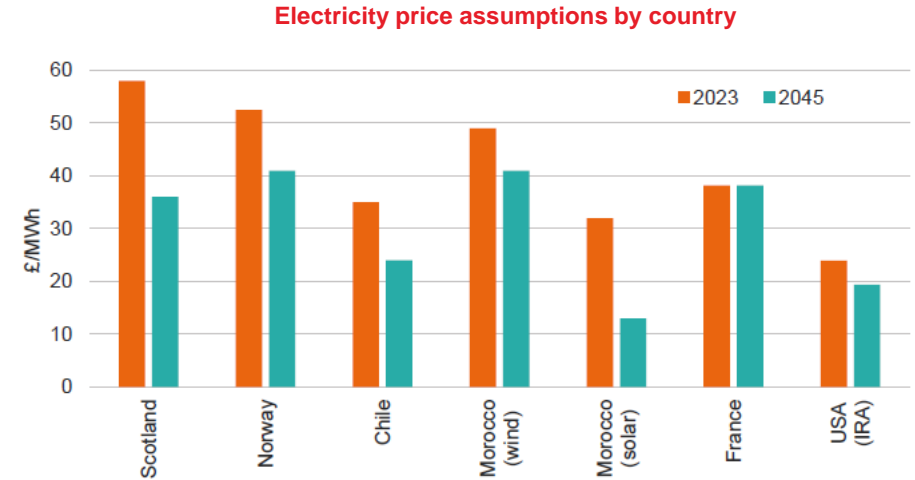
Hydrogen production cost key contributors:

- Electricity – Levelised cost of energy (LCOE)
- Capacity factor
- Capital costs

Economies of Scale

- Economies of scale enable cost reductions – *to a point*
- Stack size limitations
- Efficiencies in Balance of Plant (BoP)

Future cost reductions assumed due CAPEX, O&M, innovations



Effect of economies of scale on LCOH

Hydrogen Transport costs

Key conclusions

Pipeline

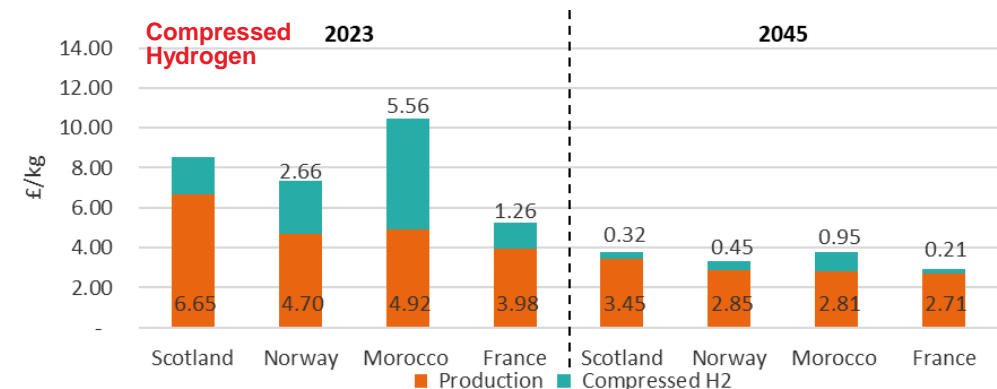
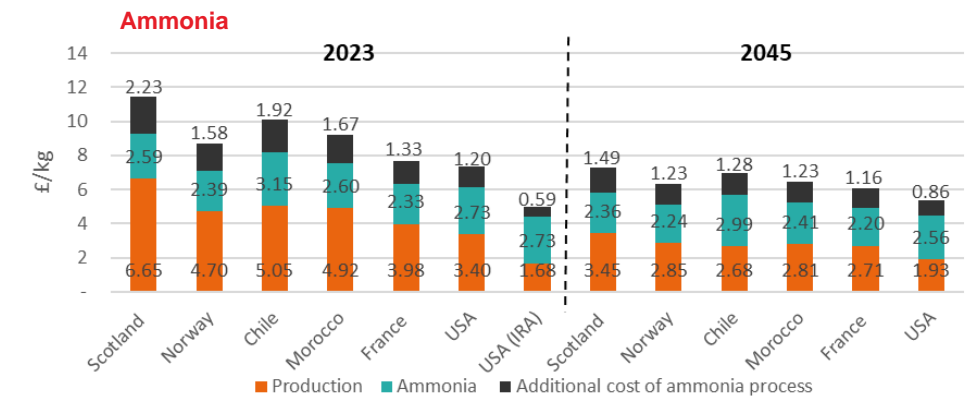
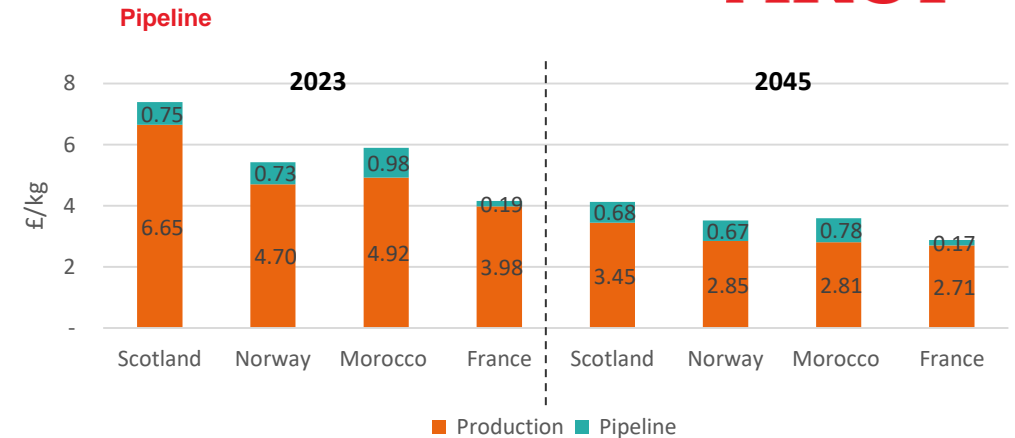
- Pipelines provide lowest LCOT to move hydrogen
- Repurposed pipelines CAPEX saving
- Shared, large-scale pipeline provides economies of scale
- Scotland competitive, France benefits proximity

Ammonia

- Significant recovery cracker CAPEX & OPEX burden
- Ammonia as an end-product therefore beneficial

Compressed Hydrogen

- Nascent market results in large uncertainties in LCOT
- Vessels size relatively small, logistical challenges
- Scotland's proximity to EU ports advantageous



Summary

Key conclusions

Hydrogen Production

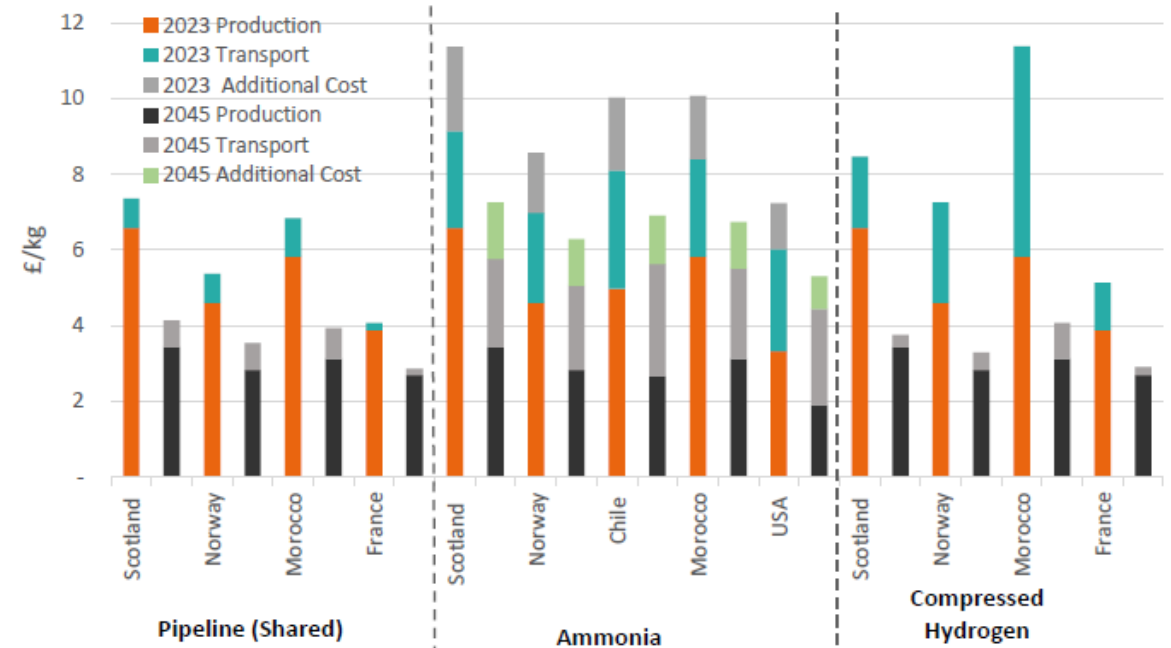
- Scotland has highest cost of production in assessment
- Low-carbon electricity cost the dominant factor

Transport Pathways

- Repurposed pipeline is most cost-effective pathway
- Ammonia option for distant producers such as Chile and USA, especially if ammonia is the end-product
- Compressed hydrogen shipping market uncertainties

Outlook

- Proximity to NW Europe enables multiple pathways
- Demand will not be met by lowest cost exporters alone
- Low-carbon electricity cost reduction is required
- Support for scale-up of offshore wind and hydrogen





Contact

Craig McCafferty

craig.mccafferty@arup.com

Associate Director – Energy Advisory



The Report:

CxC – Cost Reduction Pathways of Green Hydrogen Production in Scotland – total costs and international comparisons

ARUP