UCL Energy Institute

Applications of Multi-cluster Technology Learning in TIAM-UCL

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Content

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- Scenarios
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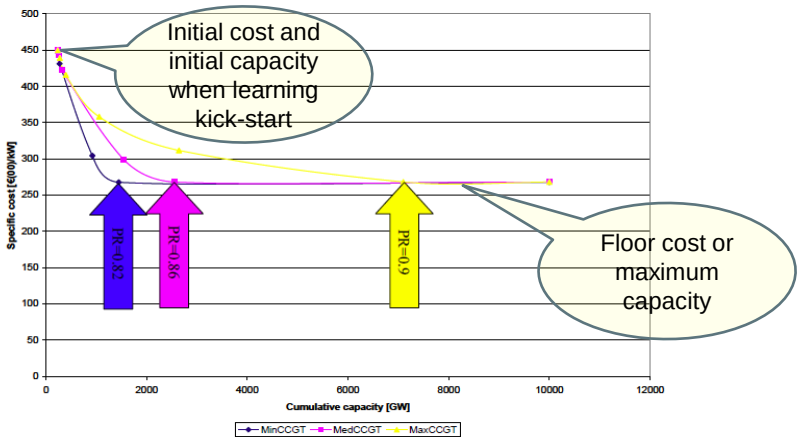
Technology learning

- Characteristics (Cost) of future technology is changing over the sequence of future periods due to *technological learning*
- Technology learning may be acquired via global or local experience, depending on the technology considered
- Technological learning can be included in modelling:
  - Exogenous: function of time
  - Endogenous: function of cumulative investment—learning by doing

Learning curve

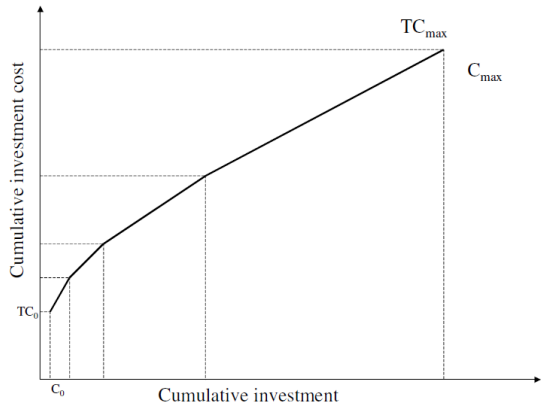
- Investment cost of the learning technology decreases with cumulative capacity
- Learning curve is defined by learning rate (progress ratio)



Mixed Integer Programming (MIP)

- Investment cost in the objective function will be represented by piecewise linear approximation of total investment cost TC_t

- Cumulative learning curve is approximated by linear segments and binary variables are used
- Mixed Integer Programming (MIP)



Learning in TIMES

- Regional learning
- Global learning
- Cluster approach
  - The case where several technologies use the same key technology (or component), itself subject to learning
  - If the fuel cell is the key technology in different transport technologies listed below, then as experience build-up for fuel cell , each of the technologies in the cluster benefits.
  - Fuel cell car, fuel cell car hybrid , fuel cell plug-in car hybrid, fuel cell light truck, fuel cell light truck hybrid, fuel cell plug-in light truck hybrid, fuel cell bus hybrid, fuel cell heavy truck hybrid

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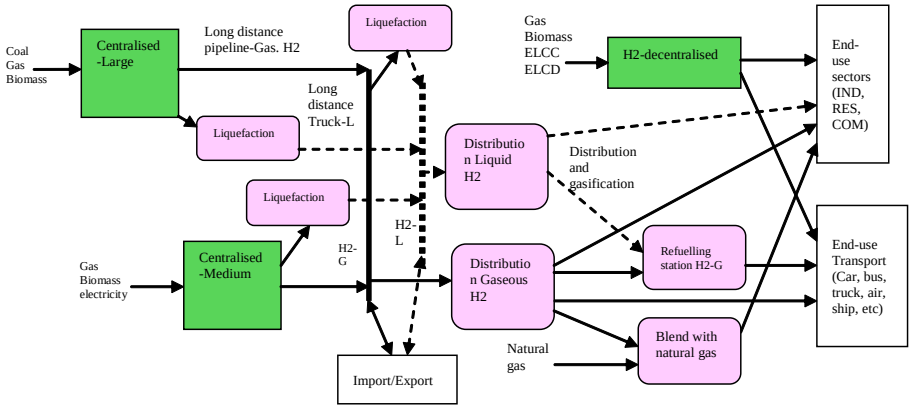
Hydrogen infrastructure in TIAM-UCL



- Production: centralised (large and decentralised)
- Long-distance transportation is modelled for centralised plant
- Transportation and distribution: liquid and gaseous H2---only gaseous H2 available to end-use technologies
- Investment cost of refuelling station includes station cost
- International trade is not enabled

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Scenarios

- Indicative results of four low carbon scenarios are presented here.
- One low carbon scenario with single cluster
  - Key technology is fuel cell
- Three low carbon scenarios with multiple cluster:
- key technologies: Electric battery, electric drive and fuel cell
  - Scenario 1: model is run till 2030 (learning rate 15%)
  - Scenario 2: model is run till 2100 (learning rate 15%)
  - Scenario 3: model is run till 2100 with lower initial capacity cost (seed value) for fuel cell

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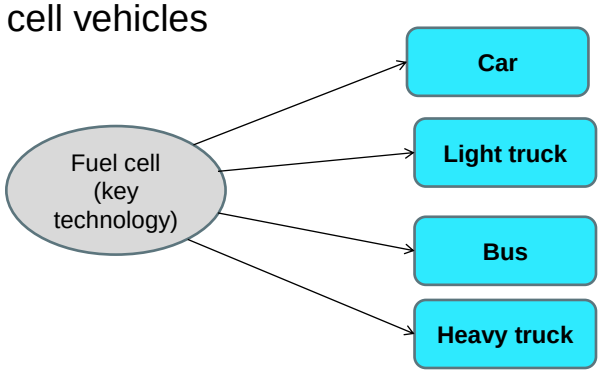
Indicative Results: Single cluster approach

- Single cluster
- Fuel cell is the key technology in the cluster of fuel cell vehicles



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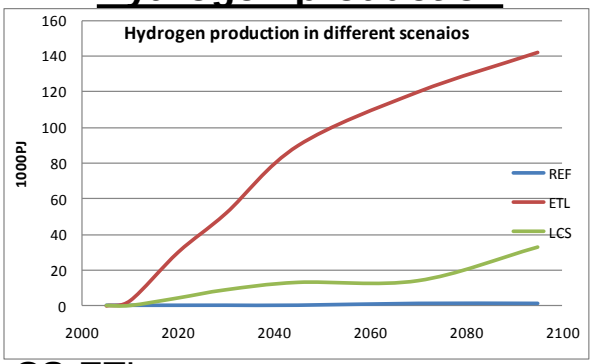
Hydrogen production



- In the LCS-ETL
  - Over 90% is from centralised plants (based on coal-CCS)
  - Decentralised production is based on solar and wind electricity
  - About 60% of the decentralised production is based on electricity from central grid in 2100

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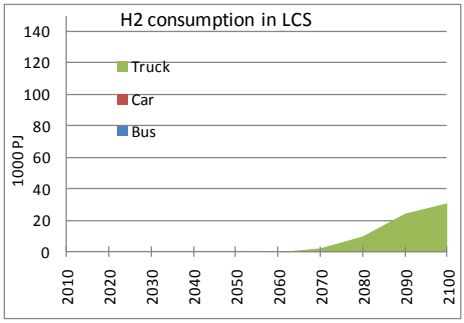
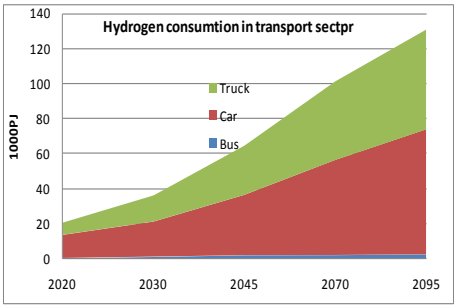
Hydrogen consumption





- ETL increases uptake of hydrogen fuel cell trucks
- Bus is selected but not significant

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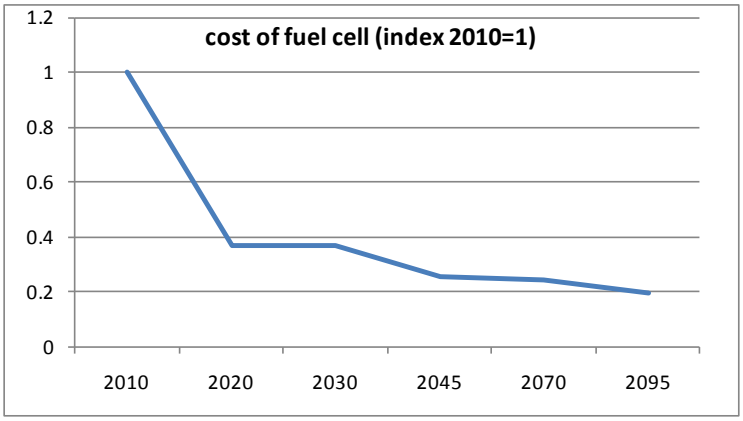
Fuel cell cost decreases with deployment



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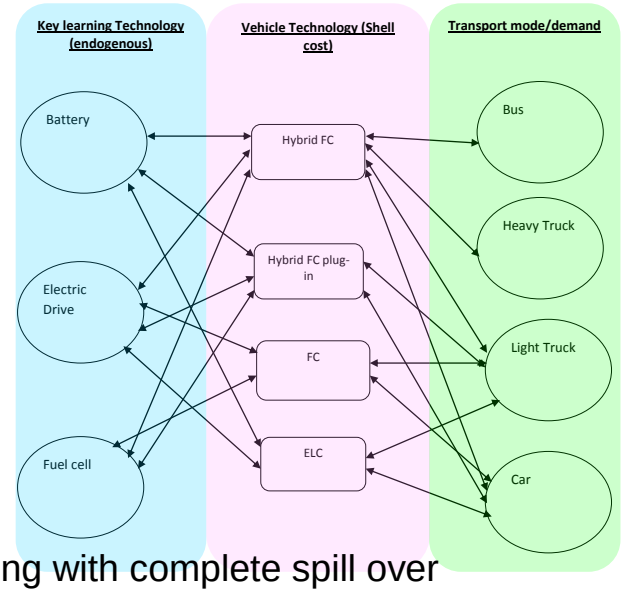
Indicative Results: Multi-cluster approach

- **Key technologies:** battery, electric drive and fuel cell
- **Transport modes:** car, light truck, bus and heavy truck
- **Vehicles:** fuel cell, hybrid fuel cell, plug-in hybrid fuel cell and electric battery vehicles



Global learning with complete spill over

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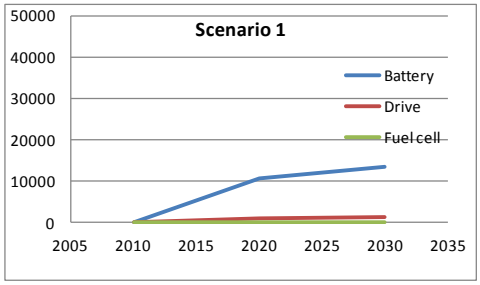
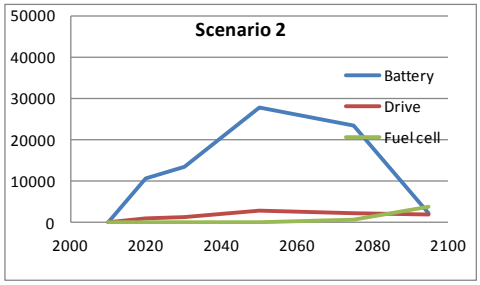
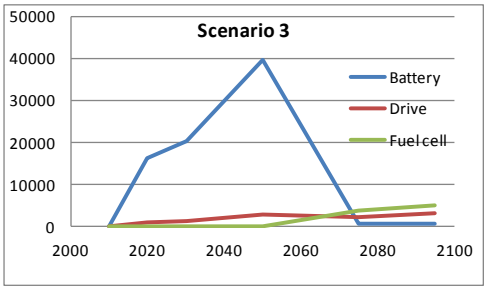
Capacity of key technologies





- Fuel cell cost effective from 2075 in Scenario 2 and 2050 in Scenario 3



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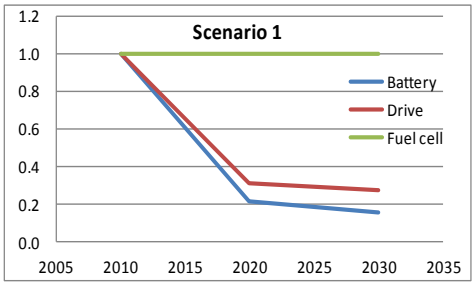
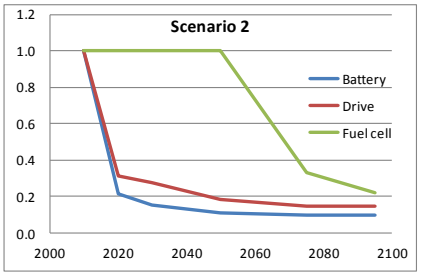
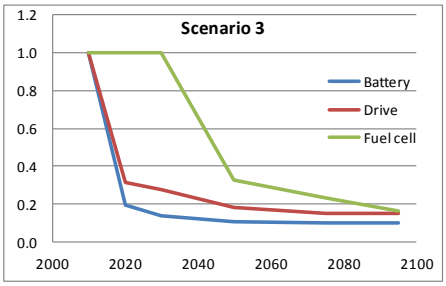
Unit cost of key technologies





- Cost reduction due to technology learning can reduce demand reduction under ETL scenarios



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Sensitivity/uncertainty

- Input parameters: progress ratio, initial cost, initial capacity (seed value), maximum capacity

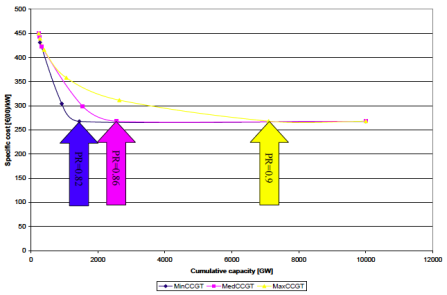
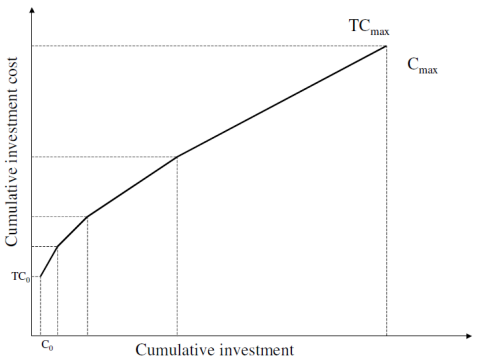


Figure 3-6: Specific cost development from learning curve



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Thank you