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ECONOMICS OF HYDROGEN: Applying global technology learning in TIAM-UCL

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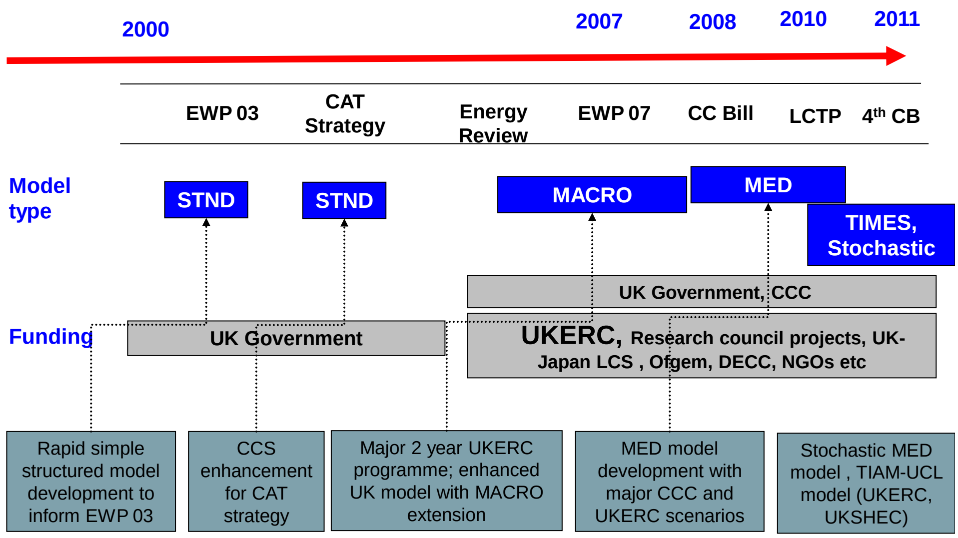
MARKAL modelling for UK policy

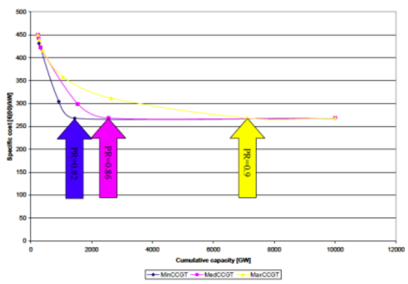


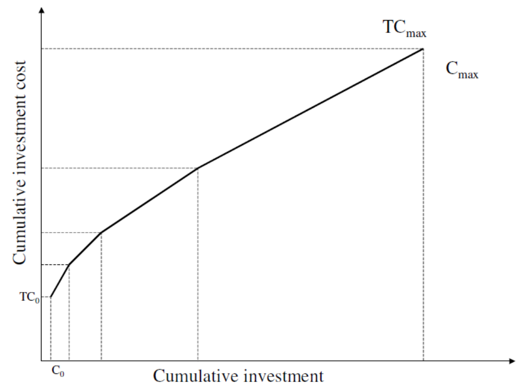
Introduction

- Cost is the single most important factor that prevents the widespread production and consumption of H_2.
- A mechanism through which the technology costs reduce is learning-by-doing
  - cumulative global deployments of hydrogen technologies lead to cost reduction is a highly uncertain but critically important aspect of the future for hydrogen technologies.
- This research apply the concept of endogenous technology learning to analyse the economics of hydrogen technologies using TIAM-UCL model

ETL in TIMES

- Objective function with VAR_INV_t will yield a non-linear expression
- Cumulative learning curve is approximated by linear segments and binary variables are used – computational burden

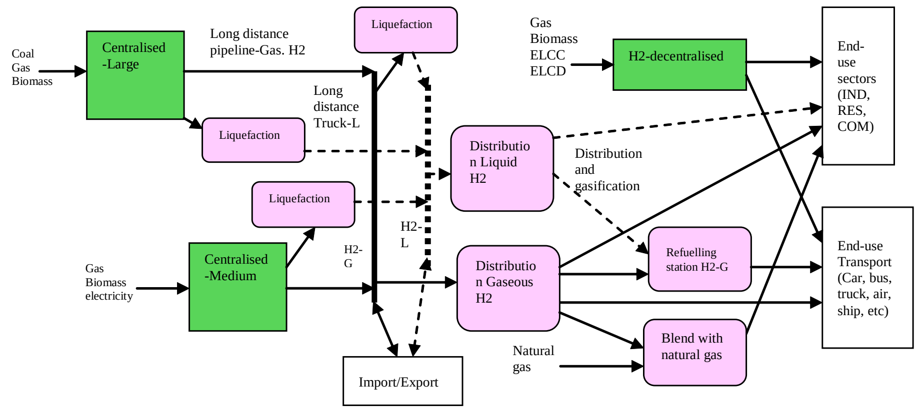




TIAM-UCL

- Breaking out the UK from WEU region from ETSAP-TIAM
- Recalibrated the base-year 2005 to the latest IEA data for all 16 regions
- GDP benchmarked against other models, and adjustments made
  - All regions show a degree of convergence across the drivers in the long term
- Added new drivers for selected energy services
- Uranium resource availability and trade modelled
- Biomass trade (energy crops and solid biomass)
- Revised/modified resource module
- Hydrogen infrastructure (revised/improved)
- Enabled endogenous technology learning
- TIAM-UCL model documentation (version 1 available)
  http://www.ukerc.ac.uk/support/tiki-index.php?page=ES_TIAM-UCL_Documentation_2010

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

ETL in TIAM-UCL

- Global learning in a multi-region model
- Cluster approach: key technology is fuel cell
- Cluster: car, light truck, heavy truck and bus
- Assumptions:
  - learning-by-doing begins when automotive firms begin a mass deployment of fuel cells, which will not occur before 2015, i.e., learning starts in the model from 2016.
  - starting capacity is 10,000 vehicles, in addition to the approximately 3700 prototype vehicles already produced, giving a total installed capacity of 1.1GW.
  - the share in 2016 of fuel cell system cost on vehicle cost is 54%, 53%, 43% and 36% for car, light truck, heavy truck and buses respectively.
  - A progress ratio of 0.85 is used for the key learning technology fuel cell.

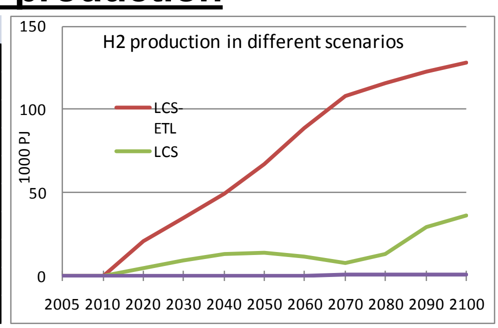
Scenarios

- Reference Scenario (REF): No climate policy
- Low Carbon Scenario (LCS): Cumulative GHG constrain of 1980 GtCO_2e -- during 2016-2105
- Learning scenario (LCS-ETL): the key technology fuel-cell which is linked to car, light truck, bus and heavy truck.
- Sensitivity scenarios: 2 sensitivity runs on the LCS-ETL with growth constraints on hydrogen production technologies

Hydrogen production

H2 production by plant type (1000 PJ)

Scenario	Plants	2020	2050	2100
	Decentralised	0.00	0.00	0.00
	Centralised	0.01	0.08	0.67
REF	Total	0.01	0.08	0.67
	Decentralised	0.00	0.00	4.50
	Centralised	4.27	14.09	32.05
LCS	Total	4.27	14.09	36.55
	Decentralised	0.02	0.07	7.03
	Centralised	20.47	64.40	120.72
LCS-ETL	Total	20.49	64.46	127.74



- In the LCS-ETL
  - Over 90% is from centralised plants (based on coal-CCS)
  - Decentralised production is based on solar and wind electricity
  - About 20% of the decentralised production is based on electricity from central grid in 2100

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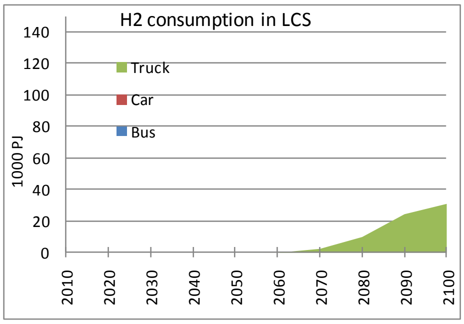
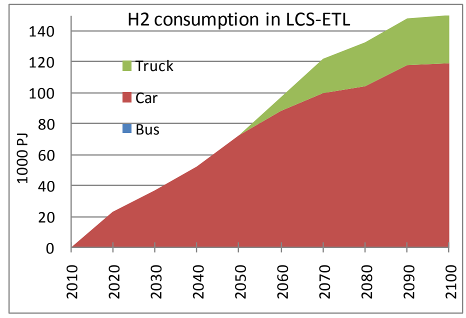
Hydrogen consumptions





- ETL increases uptake of hydrogen fuel cell trucks
- Car includes hydrogen consumption by light truck
- Bus is not selected

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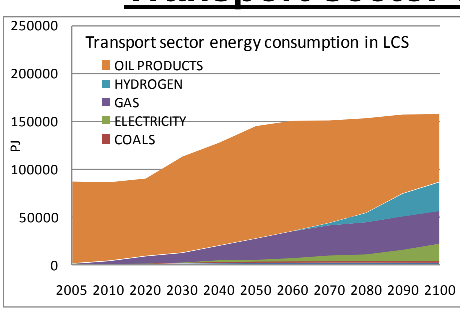
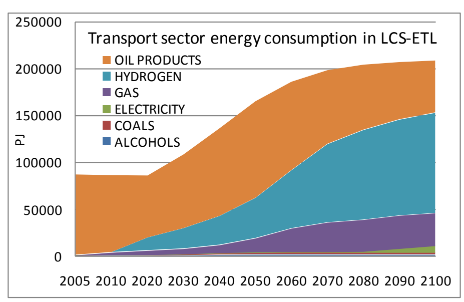
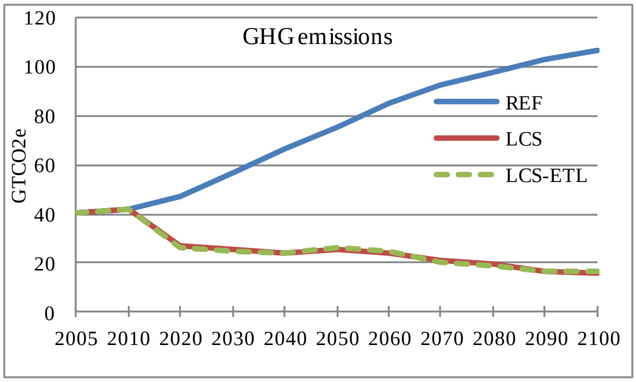
Transport sector energy consumption





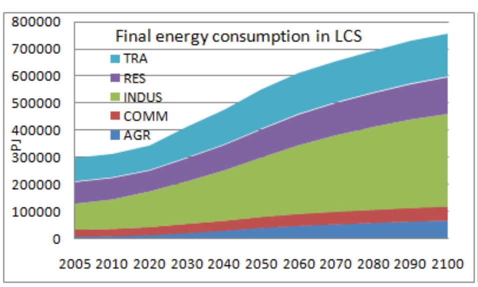
- The large uptake of hydrogen vehicles (cars) in the LCS-ETL reduces transport sector electricity consumption to less than half of that under the LCS in 2050 and thereafter.
- Transport sector energy consumption also increased in LCS-ETL

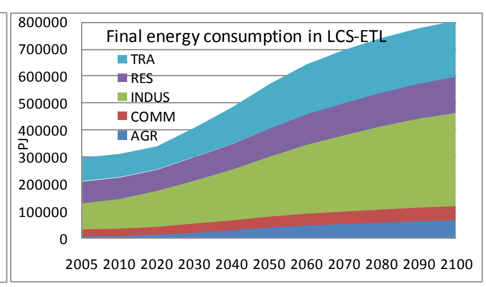
GHG emissions



- There is no notable change in the GHG emission pathways between the LCS and LCS-ETL

End-use sectors final consumption





- Final consumption increased in LCS-ETL due to increased consumption in transport sector
- No notable change in electricity consumption and generation mix other than a small reduction in coal-CCS, which is offset by solar and wind generations

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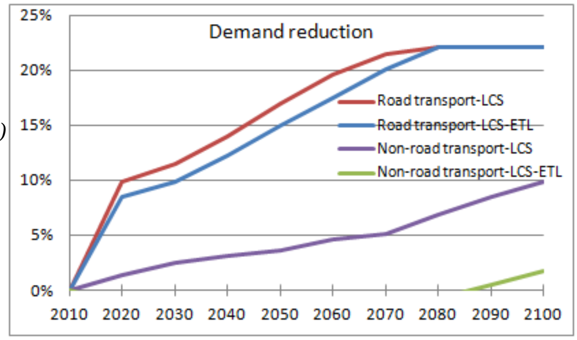
Demand reduction/GHG values

Marginal GHG values (US$/tCO2e)

SCENARIO	2020	2050	2070	2100
LCS	79	220	438	1229
LCS-ETL	70	197	391	1098



- The major impact of ETL is that it brings down the supply price of low-carbon transport, enabling the model to meet carbon targets with less acute demand reductions
- Social welfare gain under the LCS-ETL is about 30 trillion US$ compared to the LCS

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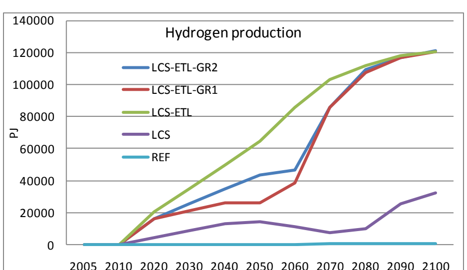
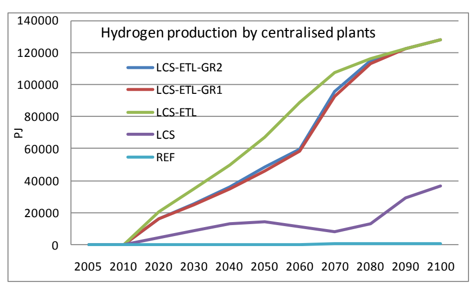
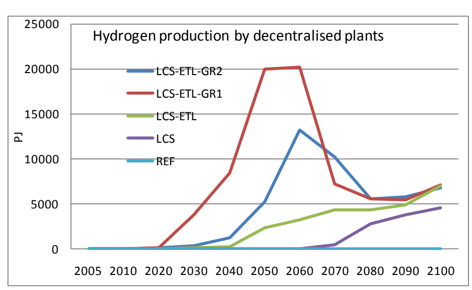
Sensitivity scenarios

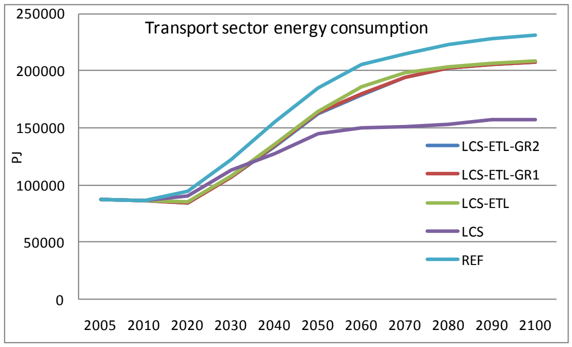




- LCS-ETL-GR1: applying a growth constraint of 15% to centralised production technologies
- LCS-ETL-GR2: applying growth constraint to both centralised and decentralised production



Sensitivity scenarios



- The growth constraints reduces hydrogen consumption and increases demand reduction as compared to a non-constraint scenario

Next

- Creating more cluster technologies such as battery is the key technology for electric and fuel cell cars, etc.
- Partial spill over of learning for some regions
- Many sensitivity scenarios

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Thank you