

Additional information on TIMES Model

The Scottish TIMES model is a high level strategic model, covering the entire Scottish energy system and containing many thousands of variables covering existing and future technologies and processes.

The model combines two different, and complementary, approaches to modelling energy: a technical engineering approach and an economic approach. The model uses this information to identify the effectiveness of carbon reduction measures in order to provide a consistent comparison of the costs of action across all sectors. The Scottish model was built by an international consortium of experts from E4TECH, E4SMA, KANORS, SYSTRA and Imperial College London and we are grateful for advice and assistance provided by the analytical team in the Department for Business, Energy and Industrial Strategy.

The aim of the model is to capture the main characteristics which effect the deployment of technologies, their costs and associated greenhouse gas emissions for Scotland as a whole given a range of policy and other constraints. This allows consideration of the strategic choices which Scotland faces as it seeks to decarbonise its energy system.

An initial version of the TIMES model was delivered to the Scottish Government in January 2016. Over the subsequent 12 months, the model has been updated to produce the model used to support the Climate Change Plan. These updates can be categorised as follows (and the key changes made for each sector, and for future fuel alternatives, are summarised in the tables below):

- **BASELINE DATA:** Incorporates the key statistics and information on the current energy system in Scotland, and the broader underlying drivers of future energy demand and supply. Over the course of the year these variables were updated in the model to reflect the publication of more timely information.
- **FUTURE TRENDS:** Reflects feedback from stakeholders and sector experts on future developments in the model's key sectors, the model's assumptions about the expected evolution and cost of new technologies and information outputted from key sector specific models that act as a point of Quality Assurance.
- **POLICY ISSUES:** Key policy and delivery assumptions in the model reflect the specific characteristics of the Scottish energy system and existing Scottish Government policies.
- **MODELLING IMPROVEMENTS:** Reflects continued refinements to the model's underlying architecture and assumptions by the contractors.

Sector	
Agriculture	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams and technical expertise at SRUC (Scotland's Rural College) to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • FUTURE TRENDS: A review of the Marginal Abatement Cost Curve for Agriculture (which measures the cost of additional reductions in emissions in the sector) identified the need to ensure measures comply with regulatory requirements, such as restrictions on GMO and Health and Safety legislation. As a result, non-energy agriculture (primarily biological) emissions were calculated off model. • BASELINE DATA: Incorporation of latest (2014) inventory information for Agriculture¹.

Sector	
Residential	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • BASELINE DATA: Benchmarked against the Scottish House Condition Survey² to determine the most appropriate residential housing archetypes to use in TIMES. Updated the share of housing archetypes that can accept conservation measures in Scotland to reflect the most recently available SHCS data at time of modelling. • FUTURE TRENDS, MODELLING IMPROVEMENTS & POLICY ISSUES: District heating data on potential schemes was revised in terms of both data and structure to make use of output from the UK National Comprehensive Assessment of District Heating and Cooling (2015), conducted by Ricardo AEA. • POLICY ISSUES: Constraints imposed on the model so that domestic gas boiler switch over from natural gas to other technologies does not occur before 2025 and is limited to a ceiling of 20% p.a. This was carried out to reflect the practical limitations on how rapidly new technological solutions could be implemented, resulting in more proven technologies, such as conservation measures, being prioritised in earlier years of forecast period.

¹ <http://www.gov.scot/Resource/0050/00503570.pdf>

² <http://www.gov.scot/Topics/Statistics/SHCS>

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Sector	
Electricity	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • BASELINE DATA: Electricity sector updated to reflect actual export/import flows from Scotland³. • BASELINE DATA & FUTURE TRENDS: Electricity sector build rates and installed capacity information was updated to reflect historical data and near-term information from the planning system. Historical information was based on data from Scottish energy statistics⁴

Sector	
Land Use	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • POLICY ISSUES & FUTURE TRENDS: Forestry planting rates adjusted to 12,000 hectares p.a. in 2020/21, increasing through a stepped approach to 15,000 hectares p.a. in 2024/25 and remaining constant thereafter. These changes resulted from consultation with sector experts in the Forestry Commission on maximum achievable planting rates. • POLICY ISSUES & FUTURE TRENDS: Peatland restoration rates set at 10,000 hectares p.a. in 2017, and increased to 20,000 thereafter. These changes resulted from consultation with sector experts.

³ <https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes>

⁴ <http://www.gov.scot/Topics/Statistics/Browse/Business/Energy>

	<ul style="list-style-type: none"> • FUTURE TRENDS: Changes to peatland restoration costs and sequestration rates based on modelling data provided by the Hutton Institute.
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Sector	
Industry	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • POLICY ISSUES: Traded sector emissions have been capped at the EU Emissions Trading Scheme cap to 2020, consistent with the methodology employed in the Scottish Government’s Greenhouse Gas Statistics. • MODELLING IMPROVEMENTS: Efficiency constraints for the refining sector updated to reflect latest available data on product mix and production efficiency. • MODELLING IMPROVEMENTS & FUTURE TRENDS: Inclusion of hydrogen producing technologies – such as natural gas steam methane reforming whereby the potential to produce hydrogen from natural gas is included, and from waste, coal, biomass and bio-oil via gasification processes. This drew on previous research by the consultants at Imperial College London. • BASELINE DATA, MODELLING IMPROVEMENTS & FUTURE TRENDS: Inputs for iron & steel, food and drink and ‘other’ industries updated using data from a study of Scottish industry performed by Parsons Brinkerhoff, and calibrated with sector emissions⁵. It was commissioned by the Scottish Government to provide a Scottish focused summary of the UK Government’s decarbonisation roadmaps for eight Energy Intensive Industries (EII): cement, ceramics, chemicals, food and drink, glass, iron and steel, paper and pulp and oil and gas refining. • MODELLING IMPROVEMENTS: Update to refinery Combined Heating & Power efficiency and availability based on data from an updated version of UK TIMES.

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⁵ <http://www.resourceefficientscotland.com/content/decarbonisation-industry-roadmaps-scotland>

Services	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • POLICY ISSUES: Constraints imposed on the model so that commercial gas boiler switch over from natural gas to other technologies does not occur before 2025 and is limited to a ceiling of 20% p.a. This was carried out to reflect the practical limitations on how rapidly other technological solutions could be implemented, resulting in more proven technologies, such as conservation measures, being prioritised in earlier years of forecast period. • FUTURE TRENDS, MODELLING IMPROVEMENTS & POLICY ISSUES: District heating data on potential schemes was revised in terms of both data and structure to make use of output from the UK National Comprehensive Assessment of District Heating and Cooling (2015), conducted by Ricardo AEA. • BASELINE DATA: The availability of district heating in services was revised for the period 2012-2015 to limit its potential uptake in earlier periods (by more accurately reflecting the actual level of deployment to date).

Sector	
Transport	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • FUTURE TRENDS, MODELLING IMPROVEMENTS & POLICY ISSUES: TIMES integrated transport model was fixed in line with Element Energy research commissioned by Transport Scotland. The TIMES model relies on a generic transport module, whereas the Element Energy and Transport Scotland work relies on detailed Scottish sector specific modelling, offering a greater degree of granularity in this area⁶. As a result: <ul style="list-style-type: none"> • The share of petrol, diesel and electric was aligned with Element Energy's view of future technologies. Consequently there are caps

⁶ <http://www.transport.gov.scot/publications-stats>

	<p>on the potential uptake of the different fuels, including the electrification of transport.</p> <ul style="list-style-type: none"> • Fuel types for all modes of transport adjusted to reflect the research findings of Element Energy • Transport emission trajectory based on Element Energy research.
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Sector	
Waste	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams concluded that the model structure should be altered to allow waste emissions to be separately identified from industrial emissions. • MODELLING IMPROVEMENTS & POLICY ISSUES: Modelled landfill emissions incorporated as an exogenous (external) input into TIMES. The use of waste for energy inputs into other processes was also restricted to reflect policies to reduce waste and increase recycling.

Sector	
Alternative Fuels	<ul style="list-style-type: none"> • BASELINE DATA: Initial review of input data with sectoral policy teams to ensure base data from UK TIMES is applicable in the Scottish context. Quality Assurance of the data inputs with modelling consultants. • MODELLING IMPROVEMENTS: Potential share of hydrogen in the existing gas grid capped at 10% of total gas through the grid. This was based on information from the HSE literature search on Injecting Hydrogen into the Gas Network⁷. • BASELINE DATA, POLICY ISSUES & MODELLING IMPROVEMENTS: Bio feedstock availability constraints tightened following discussions

⁷ <http://www.hse.gov.uk/research/rrhtm/rr1047.htm>

	<p>with sector experts. This included assumptions on consumption of both domestically-produced biomass, and the import of biomass.</p> <ul style="list-style-type: none">• MODELLING IMPROVEMENTS: Additional hydrogen technologies (i.e hydrogen transmission and distribution technologies) made available to model, in addition to potential new high-pressure hydrogen infrastructure.
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Scottish TIMES is a complex modelling framework. As a result, we are keen to draw on the expertise of the sectoral experts across the academic community, and give them the opportunity to scrutinise and use the model for their own academic work going forward. This will also help to continually develop the model, and ensure it is updated with the best available evidence. We are therefore working towards making the model available to the academic community.

The TIMES model will continue to be updated as data on emissions continues to improve. Alongside this, we have set up a formal review process with academic engineers and economists to sign off future changes to the technologies and costs in the model using our existing Technical Advisory Group on Energy and Climate Change. This will continue to improve the data and modelling capability of TIMES.

We will also continue to identify opportunities for knowledge exchange between academia and Scottish Government modelling experts. As a first step we will be seconding our lead modeller to the ClimateXChange to embed the model within the academic community.