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REFEREE: Real Value of Energy Efficiency

Scenario analysis

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Partners

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Introduction and summary

This deliverable sets out the scenarios that are modelled in E3ME. These scenarios contribute to the parameterisation of the E3ME Lite model, which is a key component of the REFEREE policy decision tool.

This document addresses four key research questions;

- What is the key purpose of the scenarios, and what scenarios are to be modelled?[1]
- What are the major impacts expected to be shown in the scenarios, and what drives those outcomes? To what extent are these impacts expected to be linear vs non-linear with scale?
- What are the implications for the specification of the E3ME Lite model, and the integration of the modelling tools into the REFEREE policy decision tool?

Each are addressed in turn in separate chapters of this report.

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[1] Note that the Grant Agreement originally foresaw that this deliverable would be delivered *after* the scenarios had been modelled. However, due to the substantial expansion in the number of scenarios to be modelled (as shown in the next section), the modelling work has not yet been completed.

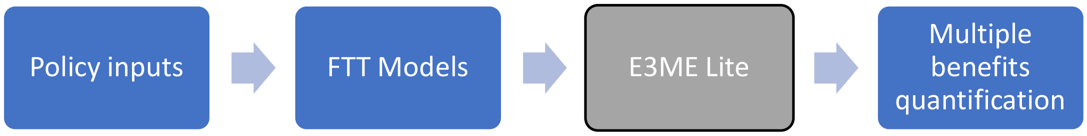
1 The scenarios to be modelled

The core purpose of the scenario modelling is to estimate parameters which are used in E3ME Lite, and ultimately the REFEREE policy decision tool.

1.1 What is E3ME lite?

The purpose of E3ME Lite is to translate the energy system outcomes from running policy scenarios through the FTT models into various socioeconomic outcomes that will feed into the REFEREE policy decision tool.

Figure 1: Modelling flow for Multiple benefits quantification



Our macro econometric model E3ME is well suited to translating the impact of FTT into economic outcomes. However, due to the scale and complexity of E3ME's modelling framework, it is not practical to integrate the full E3ME model framework into the policy assessment tool.

E3ME Lite provides a smaller modelling framework that captures the detailed macro-economic policy responses that E3ME can generate, without needing to replicate the full computation framework of the E3ME model.

A suite of parameters for all the required E3ME model outputs is generated, by carrying out various individual impact scenarios that cover each of the individual outcomes that would flow from FTT to E3ME. These parameters are used to generate economic outcomes from any FTT policy scenario that user of the tool runs.

1.2 Estimating E3ME Lite parameters

For E3ME Lite, we develop parameters to represent the various model responses from policies implemented through the FTT models. This is based on a variety of individual runs that mimic the model feedback from FTT outputs through to E3ME.

The channels through which FTT feedbacks into E3ME are:

- Fuel demand (all FTT models)
- Electricity prices (Power)
- Investment (Power and Industrial heat)
- Consumer expenditure on equipment (Heat)

The scenarios test the impact of various FTT output values across each of the fuels and fuel users and investment sectors – change in FTT output values and mimics the possible changes caused by the introduction of a wide array of policies. The estimation of parameters for each effect results from the runs performed for each individual shock element. The derived parameter is equal to the average impact on each variable relative to size of variable shock averaged over the full scenario period (2023-2050). Each impact run is ran twice – at two levels (one low and one high). This allows validation of model parameter estimates and ensures a reasonable average impact across a wide range of scales of impact that could be produced from FTT.

All impacts from FTT are modelled as additive. Thus, no interaction between impacts or recursive feedback is considered.

Parameters are estimated for each member state in isolation. This avoids induced impacts linked to trade effects from changes taking place in other Member States.

1.3 Defining the runs to derive the parameters

For E3ME Lite, we derive parameters for each direct impact from the FTT models that could feedback into E3ME. These parameters are assessed across all subcategories for each model feedback channel and for each country in EU27 + UK in isolation. Table 1 shows the total number of runs that are carried out for each individual country (levels∗subcategories).

Table 1. Runs required to estimate parameters for each feedback channel

FTT Feedback channel	Subcategories of impacts	Total runs
FTT demand	6 fuels & 10 fuel users	2∗60 runs = 120 runs
Electricity prices	None	2∗1 run = 2 runs
Investments	10 fuel users	2∗10 runs =20 runs
Consumer expenditure for heating technologies	None	2∗1 run = 2 runs

Below is the breakdown of the individual subcategories to be run.

6 fuels:

- Coal,
- Gas,
- Oil,
- Middle distillates,
- Electricity
- Biomass

10 Fuel Users

- Power
- Households
- Road transport (Passenger)
- Road transport (Freight)
- Industry heat users groups
    - Chemicals
    - Non-metallic minerals
    - Food drink & tobacco
    - Non-ferrous metals, machinery, and transport equipment
    - Other industries

When we consider all permutations of impacts plus the running of the model in isolation for each member state + UK, we obtain a total of 4,033 runs. This includes a baseline run for reference. At 10-15 minutes per run (run to 2050), we obtain a total computing time of 600 – 1000. Alternatively, if the model is only ran to 2030, individual run time is reduced to 4-5 minutes. Overall computation time becomes ~300 hours.

To speed up the process of preparing these runs, we run the model in parallel over several machines.

Following the completion of the runs, we implement an extensive checking process. The purpose of the checks is to review the modelled runs and check for notable outliers in terms of the key output variables. Parameters are generated from the validated runs.

2 The impacts demonstrated in the scenarios

The IEA's original handbook on the benefits of energy efficiency [ref] highlighted a range of impacts from relevant policy. Through subsequent analysis, that list has been extended, and within the REFEREE project we have identified a number of quantitative indicators that will be used to assess the impacts of energy efficiency policy. In Table 2 below, we summarise the mechanism through which these policies can be expected to influence the specific outcome indicators, and highlight differences between the different policies (whether in terms of type of policy, or sector coverage).

Impact indicator	Relationship between energy efficiency and impact indicator[2]	Mechanism through which this impact indicator is affected
Gross Value added	Positive	First, the stimulus impact of investment in energy efficiency can be expected to increase output, through the manufacture and installation of measures. This generates additional output and in turn additional value added. Furthermore, a reduction in energy demand per unit of output is expected to increase the value added generated for a given level of gross output, as more of the final value can be retained as value added (and/or prices can be lowered, leading to higher demand and therefore output elsewhere across the economy).
Energy intensity	Uncertain, although initial direct impact is positive	Lower energy demand in industries can reduce the proportion of energy required for production. The net effect on energy intensity depends on how much value

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[2] A positive value indicates that higher energy efficiency may result in a higher value of the impact indicator. A negative value indicates that higher energy efficiency may result in a lower value of the impact indicators. An uncertain value indicates that higher energy efficiency may result to a lower or higher value, subject to country socioeconomic characteristics, the effective policy mix and the policy scope/design.

		added increases compared to energy consumption (i.e. how large the rebound effect on energy demand is).
Energy cost impact	Uncertain	Net effect on energy cost impact depends on how much the gross value added increases compared to energy costs.
International competitiveness	Positive	Reducing the costs of energy inputs to production can result in a capacity to charge a lower price for products consumed domestically and abroad. Competitiveness effects are most evident in sectors exposed to international trade. A large home market allows more scope for benefitting from economies of scale.
Labour productivity	Positive	Investment can lead to higher employment in the targeted sectors, in order to meet increased demand for output. Changes in employment and gross value added affect labour productivity. The final outcome depends on how much value added increases compared to employment, and precisely which sectors economic activity is being created in; for example, creating additional economic activity in construction (which has a relatively low level of productivity) is likely to reduce economy-wide productivity, even as total economic activity increases.
Gross Domestic Product	Positive	Gross Domestic Product (GDP) is affected through the same channels as Gross Value Added – the key difference is that GDP also

		includes a measure of taxes and subsidies. So the precise nature of the policies introduced (if they include fiscal measures) can lead to a difference between GDP and GVA outcomes – however the direction of the impact will be the same.
Employment	Positive	Jobs will be both created and destroyed in energy supply sectors, although the net positive impacts on GDP are likely to lead to net job creation through indirect and induced effects generated through supply chains and changes in aggregate wages paid across the economy.
Public budget	Uncertain	Energy efficiency measures applied across any sector will have an impact on the public budget, due to the cost of financing energy efficiency programmes, tax revenues from changes in economic activity, increased labour participation and consumption, and the lower cost of unemployment and social welfare programmes. These will be counteracted to some extent by the higher levels of economic activity across the economy, which lead to additional tax revenues (from those activities). The net impact will depend upon the balance between these two effects.
Energy poverty and vulnerable groups	Positive	By improving energy efficiency, and therefore reducing energy demand across low income groups, their spending on energy can be reduced leading to positive

		impacts on these groups – although net impacts are subject to policy choices which could incur public budget costs that need to be reclaimed from the population via higher tax rates.
Demand for skills	Uncertain	Employment in sectors implementing the policy, e.g. construction and manufacturing, is expected in increase, while after the full adoption of the energy efficiency, lower demand for energy is expected to impact negatively employment in the power sector. This has implications for the demand for different occupations and skills, although the impact on 'average' skill requirements in the labour market are unclear (because it is likely that a combination of both low- and high-skilled jobs will be required).
Value of assets	Positive	Energy efficiency improvements in buildings are expected to improve the financial value attributed to the asset.
Air pollution and emissions	Negative	Energy demand reductions, including a shift away from fossil fuel-reliant generation, will reduce the creation and release of air pollutants and GHG emissions through requiring less fossil fuel to be burnt.
Air pollution damages	Negative	Switching away from fossil fuel use, whether to alternatives or through demand reductions, can reduce the release of particulates and therefore improve the quality of outdoor air. Lower levels of air

		pollution lead to reduced risk of respiratory and cardiovascular diseases, thereby reducing associated damages.
Fossil fuel consumption	Negative	Reductions in energy demand, or switching the low carbon alternatives, will reduce both direct fossil fuel use and it's use in electricity generation.
Energy independence	Positive	Lower overall energy demand, coupled with increased levels of electrification from the switch to more energy efficiency technologies, will reduce reliance on imported fossil fuels and therefore improve energy independence.
Water use in electricity generation	Negative	The chief use of water in electricity generation is for cooling of combustion processes, and reduced demand for electricity overall will reduce water use accordingly.
Material consumption	Uncertain	Fuel switching and reduced energy demand will reduce demand for European fossil fuels – although much of the reduction in fossil fuel demand will reduce material consumption elsewhere in the world, where the majority of the fossil fuels used in Europe are produced. Conversely, increased economic activity is likely to lead to increased demand for materials for other purposes (e.g. construction materials), with a higher proportion extracted within Europe.

3 Implications for the model design

The FTT models are designed to account for key non-linear responses of consumers/businesses to policy change. The use of S-shaped technology diffusion curves is one of the central features of the model. This incorporate the existence of tipping points in technology adoption within a given population, which reflect the presence of a plethora of technology adoption profiles ranging from early to late adopters. As a greater share of population adopts the new technology, the adoption speed increases.

Through the use of behavioural technology adoption formulas and consumption/investment response functions that solve by relying on past data, rather than an equilibrium-based model, the modelling framework delivers an apt account of the adoption of more energy efficient technologies and explicit reductions in energy demand. This framework is directly called by the REFEREE policy design tool.

Most of the resultant impacts, in terms of Productivity, Socioeconomic development, Wellbeing and Environment & Climate are expected to be largely linear in terms of how they scale as the scale of the change in technology deployment or energy demand changes. As such, there are no suggested changes to the design of the modelling framework as a result of this analysis.

3.1 Next steps

The key outstanding actions in developing the modelling framework are;

- Carry out the 2,017 model scenario runs as outlined in Chapter 1 – to be completed by end of 2022.
- Connect the interface prepared by MCRIT with E3ME Lite. This involves the introduction of the user inputs (policy mix) collected by the interface to the E3M3 Lite modelling framework, and the communication of the quantified energy efficiency impacts back to the interface responsible for the presentation of the results to the user.
- Work with MCRIT and other WP4 partners to ensure that the models (FTT, E3ME Lite) can be smoothly integrated into the REFEREE policy decision tool – by early 2023.