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Report on the socio-macroeconomic impacts of the UK Labour Party's renewable and low carbon energy targets in their '*30 by 2030'* UK Energy Plan

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Abstract

The UK Labour Party’s ‘UK Energy Plan’ is aimed at achieving a 60% Renewable and Low Carbon energy mix by 2030. In order to achieve this objective, different actions are planned for the period 2019-2030, which can be split in three Parliaments: 2019-2022; 2022-2026; 2026-2030. Key actions include a building retrofit plan; development of new renewable energies infrastructures; building system heating improvements. Total investments planned over this 12 year period are £590Bn.

Researchers at the University of Leeds undertook a macroeconomic study to estimate the broader socio-macroeconomic impacts of implementing the Labour Party’s UK Energy Plan. The modelling analysis used the University of Leeds’ MARCO-UK econometric model. Key results include quantification of energy reduction and wider impacts on GDP, jobs, wages and disposable income.

Key words: Macroeconomic modelling; energy systems; thermodynamic efficiency; energy targets;

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1 Introduction

This report presents the socio-macroeconomic impact analysis of the UK Labour Party's renewable and low-carbon energy targets, contained within the *'30 by 2030'* report published in October 2019 (Bailey et al., 2019). (Hereafter called the 'UK Energy Plan' in this report). The aim of the UK Energy Plan is to achieve a 60% renewable and low carbon UK energy mix by 2030. In order for this to be achieved, different actions are planned for the period 2019-2030, which can be split over three Parliaments: 2019-2022; 2022-2026; 2026-2030. The strategy consists of four distinct actions (refer also to Table 1):

- A building retrofit plan to ensure all UK buildings save 123 TWh by 2030. 183-274 bn GBP investment depending on scenarios.
- Development of new renewable energies infrastructures, including technologies like off-shore and on-shore wind, solar, and marine power. 164 bn GBP investment.
- Investment in Carbon Capture and Storage (CCS) technologies. 4 bn GBP investment.
- Improvement of all heating and grid balancing. 149 bn GBP investment.

All these actions will require investments that will be funded mostly by the private sector. Nevertheless, public investment is committed for the energy shift to renewables and government expenditures for the building retrofit. These actions, but concretely the building retrofit and the enhancement of all heating systems would lead to final energy savings. The result would be an improvement in the energy efficiency of the UK's economy, reducing the final end-use energy requirements for households. Both capital investment and energy savings-achieved via the building retrofit, improvement of domestic heating and a demand reduction of electricity- will be gradually spread during the 2019-2030 period. As a result of these actions, high-skilled employment will be created to carry on the construction of the infrastructures and the domestic retrofit, which is accounted by this analysis. Table 1 collects the main assumptions of the UK Energy Plan and the modelling scenario(s) for each action. Later, the scenarios' definition and assumptions employed, i.e. the inputs for the modelling are described in Section 3.

Table 1. Actions of the Energy UK Plan and scenarios provision.

Category	Item	Value	Unit	Scenario
Investment	Off-shore wind	113	Billion GBP	2
Investment	On-shore wind	24	Billion GBP	2
Investment	Solar power	18	Billion GBP	2
Investment	Marine power	9	Billion GBP	2
Investment	CCS	4	Billion GBP	2
Investment	Building retrofit	183 / 274	Billion GBP	1 / 2
Investment	Grid balancing	20	Billion GBP	2
Investment	Heat systems	129	Billion GBP	2
Total Investment (2019 - 2030)		**183 / 591**	**Billion GBP**	**1 / 2**
Public. investment	Off-shore wind	11.3	Billion GBP	2
Public. investment	On-shore wind	2.4	Billion GBP	2
Public. investment	Solar power	1.8	Billion GBP	2
Public. investment	Marine power	4.6	Billion GBP	2
Public. investment	CCS	2.0	Billion GBP	2
Gov. expenditures	Building retrofit	40 / 59.8	Billion GBP	1 / 2

Category	Item	Value	Unit	Scenario
Public. investment	Grid balancing	20.0	Billion GBP	2
Gov. investment	Heat systems	48.0	Billion GBP	2
Total Public Expenditures		**40 / 150**	Billion GBP	**1 / 2**
Energy Savings	Building fabric demand reduction	91/120	TWh	1 & 2
Energy Savings	Heating system demand reduction	91.5	TWh	2
Energy Savings	Electricity demand reduction	32	TWh	1 & 2
Total Energy Savings		**123 / 243.5**	**TWh**	**1 / 2**

The total amount committed to the UK Energy Plan is 591 bn GBP (if full energy system changed), from which 150 bn GBP would be funded by the public sector. The public expenditures shown are not additive to the capital investment, but a breakdown of it, i.e. total investment (private + public) would be 183 bn GBP (only building retrofit) and 591 bn GBP (full shift of energy system) in each scenario.

This report explores the potential impact of the UK Energy Plan on the wider economy using a macro-econometric model developed at the University of Leeds. We have developed a number of scenarios taking the assumptions outlined in Table 1. The paper has the following structure:

- Section 2 describes the MARCO-UK model outlining the differences from other modelling approaches
- Section 3 provides the detailed inputs coming from the UK Energy Plan into the model scenarios
- Section 4 outlines the macro-economic impacts of the UK Energy Plan. The main modelling outputs are described here.
- Section 5 draws a number of conclusions, discusses limitations and outlines next steps.

2 MARCO-UK model

2.1 Overview of the modelling approach

2.1.1 Post-Keynesian background

MARCO-UK is a macro-econometric (ME) model based (as is common) on post-Keynesian economic theory, where agent behaviour is not based on optimisation but is instead determined from econometric equations based on historical data. The economy is conceptualised as a non-equilibrium system in the sense that markets are often not efficient and that prices and quantities do not adjust to optimal, market-clearing levels. Instead, post-Keynesians consider that prices are set by firms using some form of mark-up pricing, although it is acknowledged that the interplay of supply and demand can impact prices in some markets. It is assumed that in most circumstances not all resources are optimally used and that spare capacity exists in the economy, which allows economic growth to be demand led both in the short and long run. In the short run, production adjusts to increased demand through the increase in the utilisation of capacity, while in the long run the total capacity of the economy adjusts to demand through increased levels of investment.
As a result, economic production is not constrained by supply-side factors in the MARCO-UK model. Post-Keynesian theory recognises that supply-side factors, especially insufficient labour supply, can constrain production in unusual circumstances. Such constraints are not explicitly built into the MARCO-UK model, but we take them into account by rejecting any scenarios in which employment outstrips the available labour force.

Our model contains over 70 socio-technical-economic variables, including thermodynamic-based energy variables (primary energy, final energy, and useful exergy; thermodynamic efficiency at primary-to-final and final-to-useful conversion stages). A fuller description of the model is contained in Sakai *et al.* (2019). These energy variables are fully integrated into the model structure, as opposed to conventional soft-linking energy and economy module. An inherent weakness of ME models lie in their econometric construction: this means that they generally forecast historical trends to continue. Thus our model can struggle to study how a structural change in the economy would respond in the future. However, the model is designed to allow each variable to be exogenous. This allows the development of scenarios that break historical trends if sound evidence can be provided.

2.1.2 MARCO-UK: A thermodynamically-consistent energy-economy model

MARCO-UK is the first energy-economy-wide model to include thermodynamic efficiency. We also expand on existing macroeconometric models by including the useful stage of energy consumption (as useful exergy), as shown below in Figure 1. The inclusion of thermodynamic efficiency and useful exergy allows us to investigate their roles in economic growth. Useful exergy is the energy used at the last energy conversion stage before exchange for energy services. The final-to-useful stage is rarely studied at an economy-wide level, but as Figure 1 below illustrates, it is where most thermodynamic energy conversion losses occur. Such inclusion within modelling frameworks could thereby be important for improving the evidence base for energy efficiency policy and its effect of economic growth.

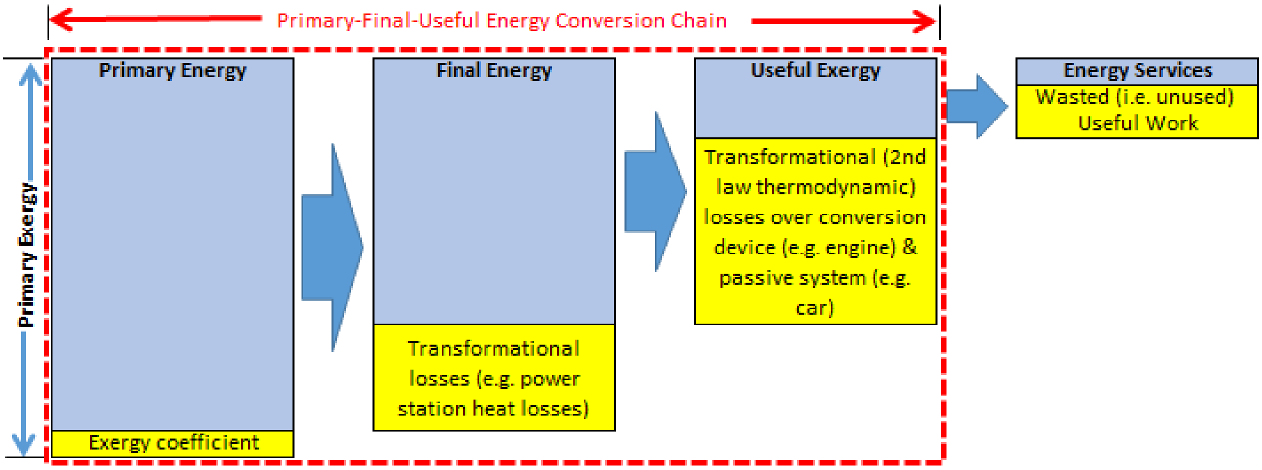

Figure 1: **MARCO-UK includes energy at primary-final-useful energy stages. (From Brockway et al. (2015))**

2.1.3 How does it compare to a general equilibrium model?

Archetypal CGE models are developed from well-specified, micro-economic theory in which behavioural relationships are derived from optimising agents and in which prices "clear" markets continuously so that resources are optimally employed (Sterman *et al.*, 2012). However, these assumptions are often relaxed in the current generation of CGE models to allow for labour market imperfections and involuntary unemployment, which implies that "equilibria" are not necessarily "optimal" in any sense. CGEs have typically been regarded as reflecting an ultra-neoclassical view of the world in which demand may not matter much (if at all) and supply influences are expected to dominate in terms of affecting the aggregate real economy. Moreover, the optimisation and aggregated production functions based on perfect substitutability of productive factors allow any combination of resources' use and total economic output, leading to unfeasible outcomes.

CGE models rely strongly on theoretical assumptions with regard to the behavioural functions and also assume that the economy as a whole is in equilibrium in the base year. On the one hand, these assumptions allow the construction of detailed models without large amounts of historical time-series data, as many parameters in the model can be derived from the calibration to a single base year (although it should be noted that some parameters in CGE models are also estimated econometrically). In addition, the stronger alignment with economic theory can provide CGEs with an advantage in terms of interpreting model results. On the other hand, CGE models have sometimes been subject to the "black box" criticism: the models are so complex that it is difficult to understand what is going on inside them.

In contrast to the largely neoclassical-based CGE models, macroeconometric models such as MARCO-UK have a more empirically-derived construction, using timeseries data. This feature enables counterfactual simulations to be run over the model's time frame, to isolate the effects caused by changes to any variable (e.g. thermodynamic efficiency) on the whole economy. In the case of MARCO-UK, the model timeframe is 1971-2050, which allows both the study of ex-post (1971-2016) and ex-ante (2016-2050) scenarios to investigate macroeconomic effects of past or future policies/changes to the economy. For this current analysis, we conduct an ex-ante analysis (2016-2030) of Labour's proposed Energy Plan to quantify the associated socio-macroeconomic impacts on the UK. Such isolation provides an advantage over other modelling approaches, like Computable General Equilibrium (CGE) models. As a consequence of MARCO-UK model's structure, it can be considered a simulation Integrated Assessment Model. Simulation models have been identified as more realistic than optimization models due to their flexibility to capture disequilibrium, propagation of disturbances and policy effects over the system analysed (Scrieciu, Rezai and Mechler, 2013).

2.2 Model Construction

Like other ME models, MARCO-UK contains two types of equations. The first type involves definitional relationships, also known as 'identities', which represent definitions of given variables and must hold true in all time periods. The second type of equations are known as 'behavioural' or 'stochastic', which contain parameters estimated econometrically. The present version of the model contains 57 equations: 30 are identities and 27 are stochastic.

The main identities are given by the accounting definitions of gross domestic product (GDP). From the expenditure side, GDP is equal to the sum of private (C) and public (G) consumption, investment (I) and net exports (X-M). From the income side, GDP is defined by total national income (i.e. compensation of employees, profits received by firms, etc.) plus net taxes. These two identities must hold for each time period. Each of the components of GDP is estimated econometrically on an individual basis through a stochastic equation. The particular functional forms and choice of explanatory variables are empirically validated and tested using econometric techniques. Apart from GDP components, the model includes stochastic equations for other variables, such as capital, labour, prices, energy and others.

Figure 2 shows a simplified schematic of the relationships between energy and economic variables found at the core of the model, although the graph does not include all the relationships between variables.

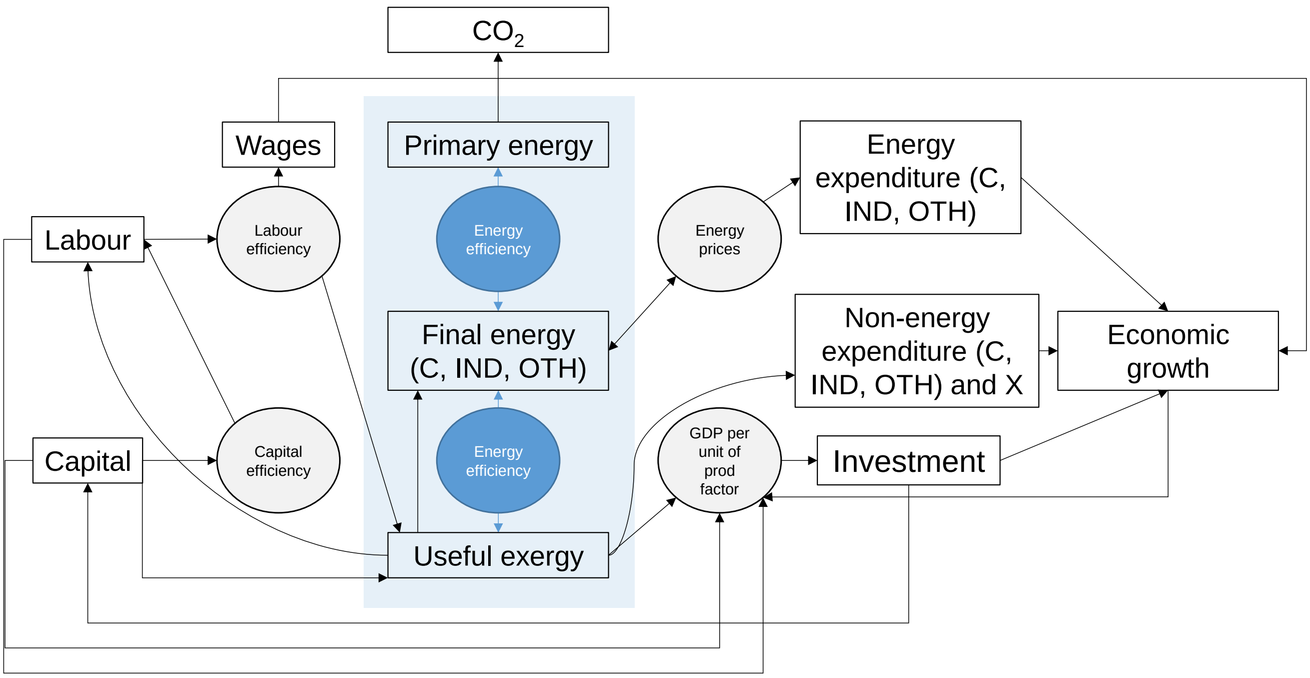

Figure 2: **Schematic MARCO-UK model structure**

3 Scenarios definition

3.1 General considerations

As mentioned before, MARCO-UK is well positioned to assess the implications of different policies and their propagation across the economy. Because MARCO-UK is an econometric model, a 'no-policies' simulation will return the *Business as usual* or *Baseline* (BL) results, representing a projection of past trends. The BL scenario is taken as the reference to which the policies' scenarios are compared in order to estimate their impacts. Once a policy target is set as an input to the model, the outcomes will define other possible paths. The more policy targets are included in the model, the more possible trajectories that can be tracked. Policy targets are normally introduced as scenarios. Scenarios can either include just one policy target – useful for exploring the isolated effect of a policy - or multiple policies to explore how they operate simultaneously. A step-by-step procedure has been conducted in order to check the strengths and weaknesses of each scenario, building up on the previous one and eventually simulating an All-policies scenario. The scenarios' structure is shown in Table 2 below.

Energy savings' input data has been converted from TWh to TJ in order to match with MARCO-UK units[1]. Because energy savings (as well as investment and government expenditures) have been gradually spread over the 2019-2030 period, the economic system demands energy while the strategy is being unfolded. Therefore, energy savings have been applied against the BL estimates, meaning that the households' final energy use is 521,584 TJ lower than BL in SCEN1 and 915,354 TJ in SCEN2 (see Figure 4). Investment has been split out between capital investment (gross fixed capital formation) and Government expenditures. According to the European System of National Accounts (ESA 2010)[2], public expenditure is defined as "*purchases by general government of goods and services produced by market producers that are supplied to households"*.

Given this, part of the building retrofit strategy ought to be regarded as government expenditures, as it is considered that the public sector will fund the retrofitting in low-income households. The System of National Accounts states that the GDP (expenditure side) is formed by (Households) Consumption, Government Expenditures, Gross Fixed Capital Formation (or investment), Trade Balance (exports-imports) and the changes in inventories. But investment can be public or private and, therefore, part of the UK Energy Plan is committed to create fixed capital despite the fact it is funded by the public sector. See in the following overview squared in red (Figure 3) the accounting categories where all the strategy's funding comes from. In order to avoid confusions, the total expenditures of the UK Energy Plan are referred as:

$$\boxed{Public\ Expenditures = Government\ Expenditures\ +\ Public\ Investment}$$

[1] The standard conversion rate used is 1 TWh=3,600 TJ.
[2] https://ec.europa.eu/eurostat/documents/3859598/5925693/KS-02-13-269-EN.PDF/44cd9d01-bc64-40e5-bd40-d17df0c69334

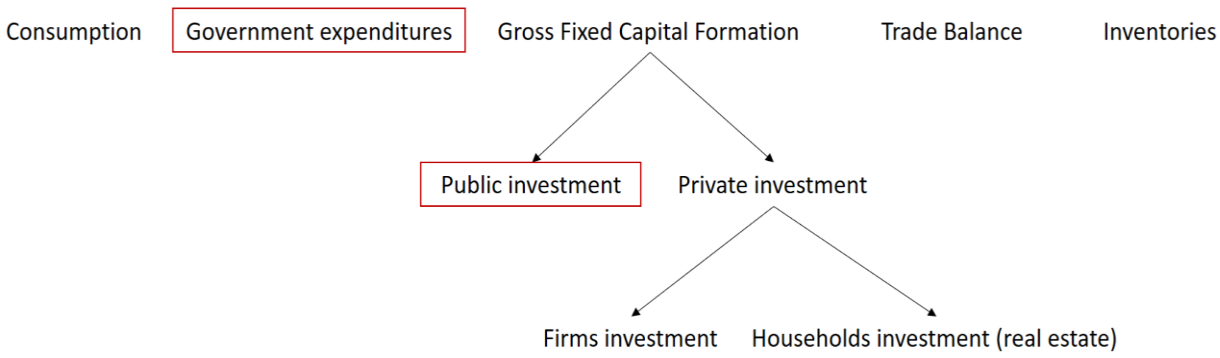

Figure 3. Expenditure-based GDP components, broken down by institutional sectors.

Therefore, 22% of the building retrofit is funded via government expenditures, meaning that 22% of SCEN1's investment is made by the public sector, whereas in SCEN2 it amounts the same quantity but it only represents 10% of the total investment (as the building retrofit is nearly 50% of total investment in this scenario). However, in SCEN, 90 bn GBP of public investment are committed to the renewable infrastructures. But, because GDP is accounted from the expenditure side, it is considered as gross fixed capital formation, regardless of the institutional sector that provides the funding.

3.2 Main inputs to MARCO-UK

As previously mentioned, Table 2 collects the main inputs used in MARCO-UK to assess the macroeconomic impacts of the UK Energy Plan. Two different energy prices options, described below, have been applied to both scenarios.

Table 2. Scenarios inputs.

	SCENARIO 1 (SCEN1)		SCENARIO 2 (SCEN2)		BASELINE (BL)
	SCEN1_A	SCEN1_B	SCEN2_A	SCEN2_B	
Actions Planned	Building Retrofit		Off-shore wind On-shore wind Solar power Marine power CCS Building retrofit Grid balancing Heat systems		No actions
Total Additional Capital Investment* (bn GBP)	143		531		Endogenous Model Estimates based on historical projections
From which: public investment (bn GBP)	0		90		
Total Government Expenditures (bn GBP)	40		60		
Total committed to the Energy Plan (bn GBP)	183		591		
Energy Savings vs BL (TJ)	-441,430		-876,628		
Energy Prices for Households (change vs BL)	Same energy prices as BL	Same Energy Bill as BL	Same energy prices as BL	Same Energy Bill as BL	

*** Together private and public investment.**

3.2.1. Energy savings

As shown in Table 1 and 2, SCEN1 assesses the impacts of an energy reduction delivered by the building retrofit, due to a decrease in building fabric (heat loss) demand and a reduction in electricity requirements. On top of that, the heating system also contributes to energy savings in SCEN2. Whereas in SCEN1 the energy savings have been applied evenly during the 2021-2030 period, in SCEN2 a three-stage approach has been conducted. During the first Parliament, 16.7% of all total energy savings are achieved. After the second, 50% of total energy savings and during the last 4 years, the 50% energy savings left are obtained. As mentioned before, the total energy savings are deducted from the BL estimates completing the total energy savings by 2030. Figure 4 shows the yearly cumulative reductions of energy use and the contribution of each action by scenarios.

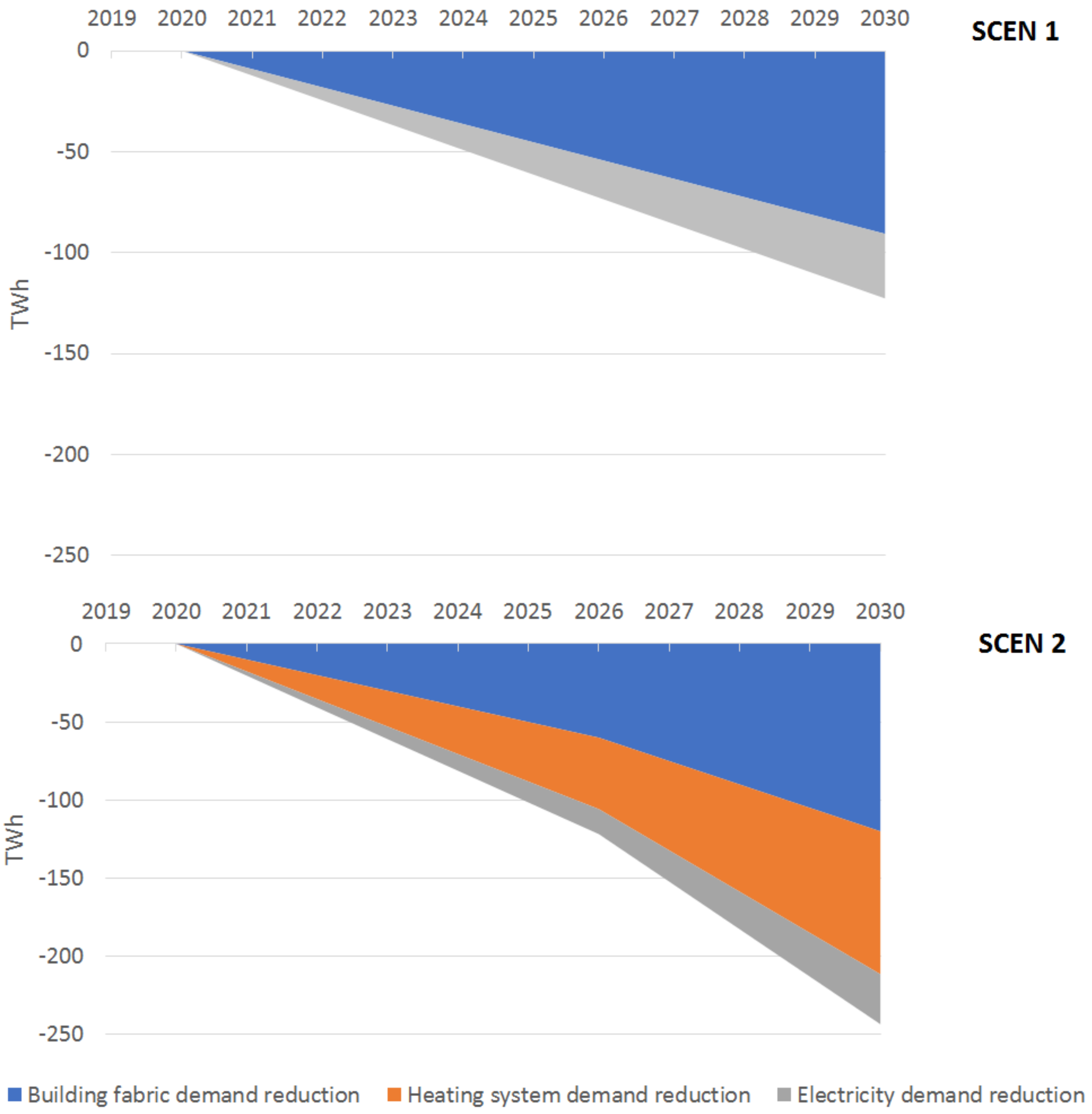

Figure 4: Yearly cumulative energy savings by action and scenarios.

Every year, this reduction is deducted from the baseline, so the gap between the households' total energy use in BL and the scenarios increases until it reaches the reduction target. As SCEN1 projects constant reductions, the growth in the energy reductions is steady, whereas in SCEN2 there is a sharper decline observed.

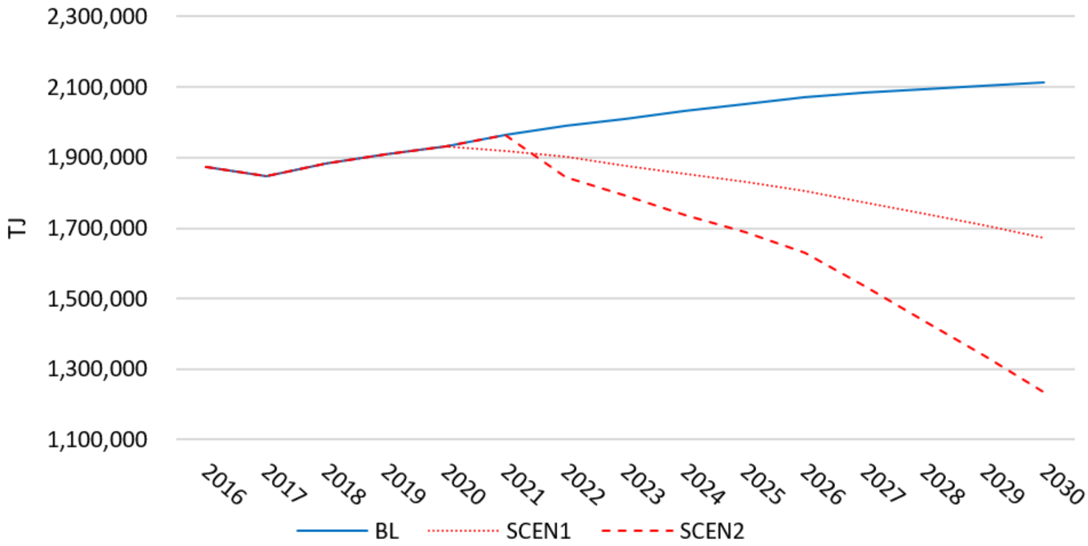

Figure 5: Households' Final Energy Use 2015-2030 by scenarios

3.2.2. Investment

Investment is aimed at funding the different UK Energy Plan's actions and it has been split between Gross Fixed Capital Formation (i.e. capital investment) and government expenditures. All government expenditures are allocated at the building retrofit strategy in order to provide funding to low-income households. SCEN1's investment is funding only the building retrofit, whereas SCEN2 funds all the actions of the plan (see Table 2). Investment has been spread through the period in three stages (Parliaments). All the investment flows are additional to the total investment that would have been made regardless of the UK Energy Plan. Therefore, additional investment has been added to the BL estimates. Figure 6 (below) shows the yearly flows of investment that are made on top of the investment in BL and the cumulative additional investment over BL reaching the overall target in 2030 (above) for scenarios 1 and 2.

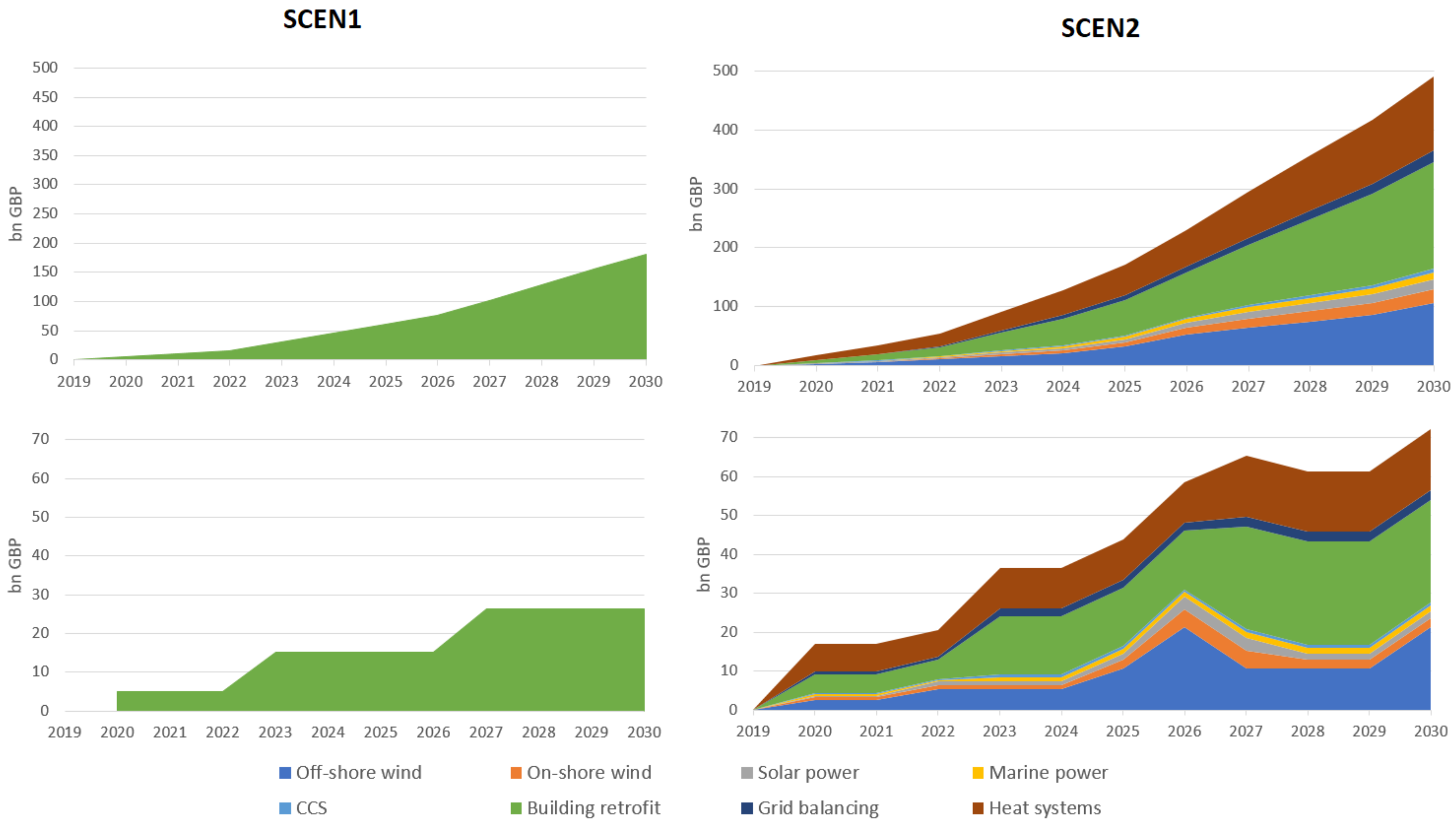

Figure 6. Additional cumulative capital investment (above) yearly flows (below) by actions in SCEN1 and SCEN2.

As a result, total investment is higher in both SCEN1 and SCEN2 compared to BL, as can be seen in Figure 7 below. Although not noticed in Figure 7 due to the stagnation of investment of the last years, the BL scenario's investment still is growing following the 1971-2016 trend.

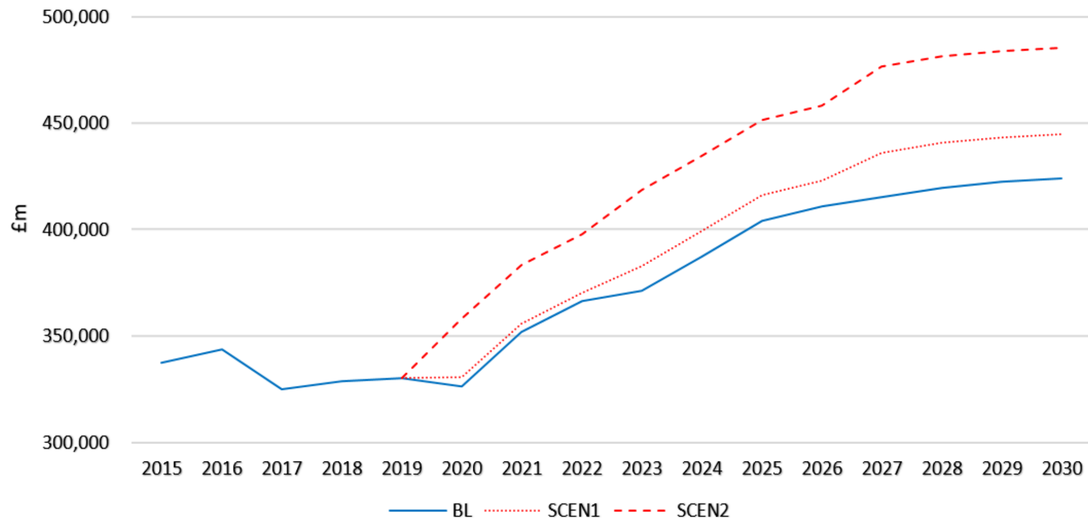

Figure 7. Total annual capital investment by scenarios versus baseline (BL).

As mentioned above, government expenditures have been allocated to the building retrofit, according to Washan *et al.*(2014). This increases public expenditure, which also has a positive effect on GDP. Figure 8 shows the additional government expenditures (i.e. disregarding public investment, already accounted within capital investment) by scenarios, which is the same in SCEN1 and SCEN2 a both include the building retrofit action. In scenarios with no additional government expenditures, we keep government expenditure at the same long-term historical percentage versus GDP (19%). For the scenario analysis – i.e. when the additional government expenditure shown in Figure 8 is added - this increases government expenditure as a percentage of GDP by around 1%, i.e. from 19% to 20% of GDP (19.8%-20.2% depending on the year).

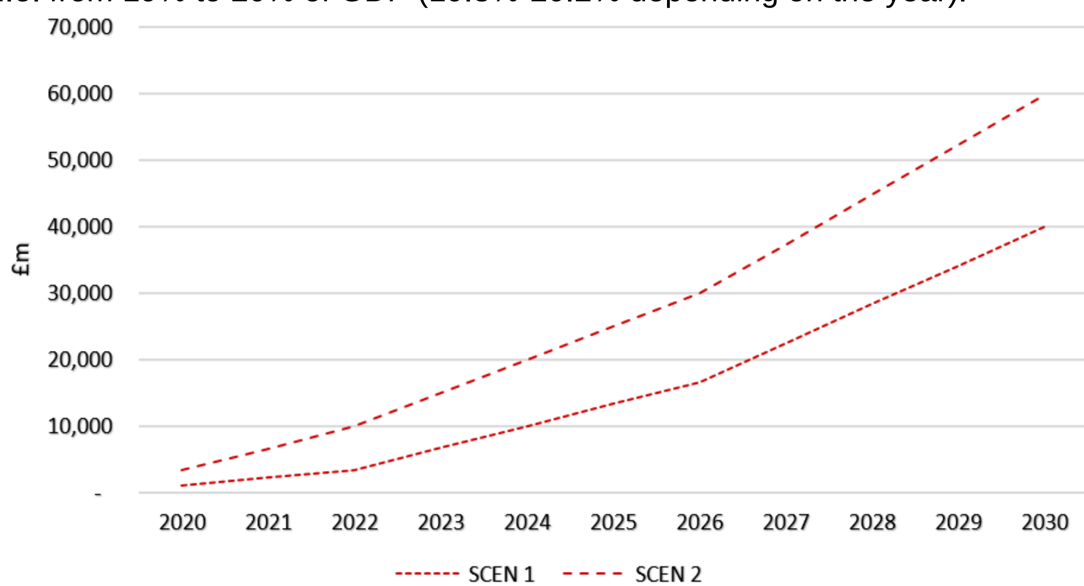

Figure 8: Total cumulative additional government expenditures in BL versus Scenarios.

3.2.3. Energy Prices for Households

Despite the economy demanding more energy (driven by the acceleration of economic growth) energy use in the MARCO-UK model is being exogenously reduced, leading to tensions in the determination of energy prices. In normal circumstances, this constraint would result in an endogenous elevation of energy prices. Therefore, in order to prevent an undesired rise in energy prices for households, it has been assumed that prices would be kept under control in two additional options. The implications of this approach are discussed in section 4.6 and briefly in the Conclusions.

Both SCEN1 and SCEN2 have been estimated with these two energy prices options (see Table 2). Option (A) implies keeping prices as high as in BL. On the other hand, option (B) keeps energy bills equal to BL. Option A is the same for SCEN1 and SCEN2 with the same energy prices as in BL, whereas it changes for option B. This is due to the way these sub-scenarios were built. Because energy bills are equal to energy prices times the final energy use, the method to obtain the new exogenous energy prices is straightforward once we get the BL's energy bills. Therefore, by dividing the BL's energy bills by the final energy use we obtain the exogenous energy prices that are required to maintain energy bills equal to BL. Provided that the final energy use is different in SCEN1 and SCEN2, the energy prices are different in option (B) regarding the scenario. As a consequence, we have three different energy prices trajectories that are shown in Figure 9:

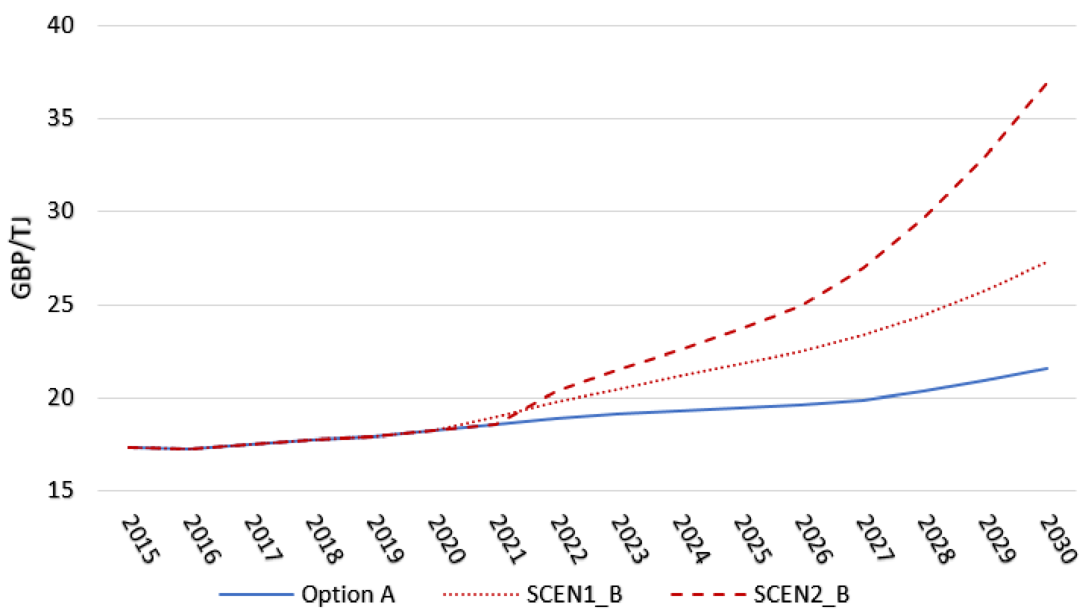

Figure 9: Households' energy prices by scenarios and sub-scenarios.

4 Socio-macroeconomic impacts of the UK Energy Plan

A set of energy and macroeconomic variables have been selected to represent the potential impacts of the UK Energy Plan according to the MARCO-UK analysis. Different formats of the results are displayed in this section depending on what is more convenient for each variable. First, plots of the variables from 2015 to 2030 with the numbers in levels are shown for energy variables, because the changes are much larger (than for other variables). Most of the other results, conversely, are depicted with bar graphs showing the cumulative additional flows during the period. This makes sense, for instance, for GDP or disposable income, but not for jobs, that cannot be accumulated in a stock. Rather, the model provides the total employment for every year. So, the difference from the employment in the scenarios to the Baseline would be the net effect of the strategy. The outputs that are presented from this analysis are the following:

- Section 4.1: GDP and Cost-Benefit results
  - Gross Domestic Product (Y).
  - Ratio Costs/Y.
  - Ratio Additional Government Income/Additional Government Expenditure.
- Section 4.2: Jobs and unemployment
  - Jobs (L).
  - Unemployment Rate (UR).
- Section 4.3: Wages, profits and disposable income
  - Total wages (W).
  - Wages per hour (W_HOUR).
  - Disposable Income (Y_D).
- Section 4.4: Energy results
  - Total Final Energy use (FEN_T).
  - Total exergy efficiency (EXEFF_FU2).
  - Final energy intensity (FEN_T/Y).
- Section 4.5: Summary detailed tables - the 17 key variables in three formats:
  - Absolute values in 2030;
  - % change 2016-2030;
  - % change in 2030 versus baseline

Lastly, in Section 4.6 we discuss the implications of the results.

4.1 GDP and Cost-Benefit results

To start, Figure 10 shows the GDP results:

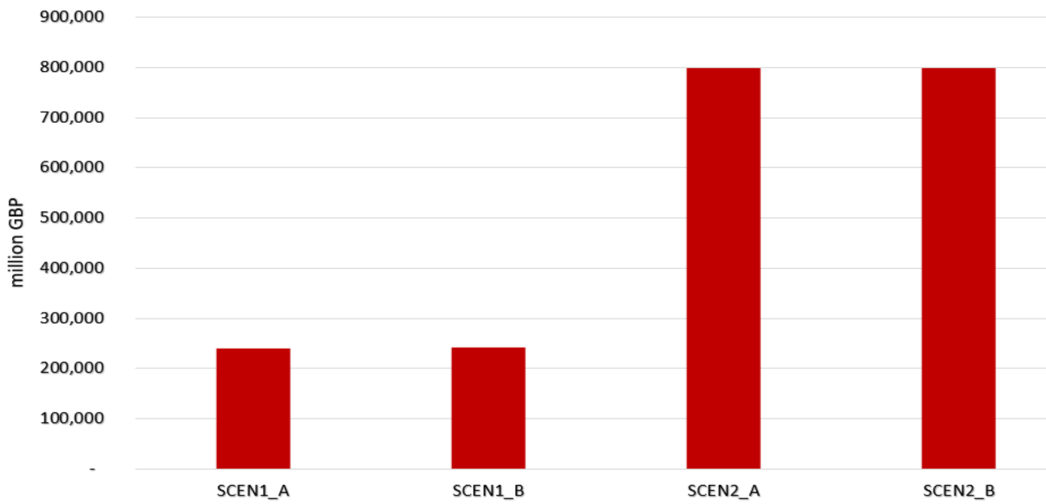

Figure 10. Cumulative additional GDP vs Baseline (2020-2030).

The policies applied by the UK Energy Plan would allow the GDP growing above the BL projections in both SCEN1 and SCEN2. This is largely stimulated by the increase in capital investment and public expenditures, leading to higher GDP growth. The improvement of economy-wide energy efficiency also drives further expansion of the economy during the analysed period. The average annual GDP growth rate would be 4.5%-11.3% higher compared to BL in SCEN1-2 respectively. The additional GDP compared to BL grows over time and, cumulatively, means 240,000 and 800,000 million GBP more by 2030 compared to BL (SCEN1 and SCEN2). Figure 11 shows the ratio between the costs of the strategy and its returns in terms of additional GDP:

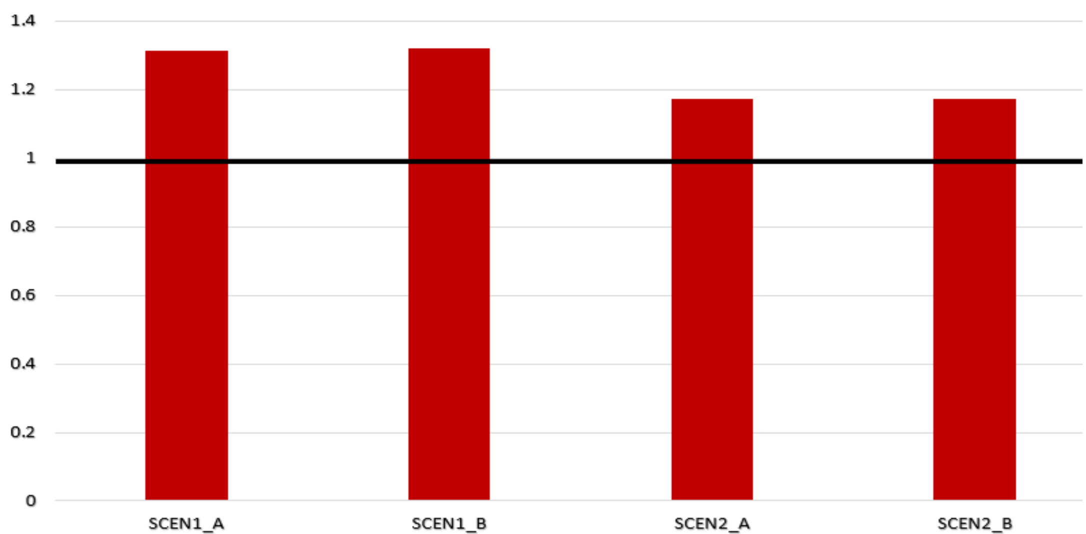

Figure 11. Additional Investment vs Additional GDP ratio

All scenarios create more GDP versus investment by the UK Energy Plan. Concretely, this means that the strategy would yield a GDP return-on-investment of 31% in SCEN1 and 17% in SCEN2.

Considering all the public funding, both government expenditures and public investment (embedded in capital investment), we can balance it with the additional government income that the strategy would yield. Whereas the government income can be endogenously estimated in-model assuming that it stays constant at its near past levels (37% of GDP), additional public expenditure is already known: 40,000 and 150,000 million GBP in SCEN1 and SCEN2. Along the 10 years' period (2020-2030), the additional government income generated reaches around 89,000 million GBP in SCEN1 and 295,000 million GBP in SCEN2.

The ratio between additional government expenditure and additional government income is shown in Figure 12. It is 2.22-2.24 for SCEN1 and 1.97 for SCEN2. This means that the additional revenue for the public sector would be 122%-124% higher in SCEN1 and 197% in SCEN2. A multiplicative effect emerges out of the public expenditure implemented by the UK Energy Plan, which would therefore have additional monetary benefits on top of the environmental ones.

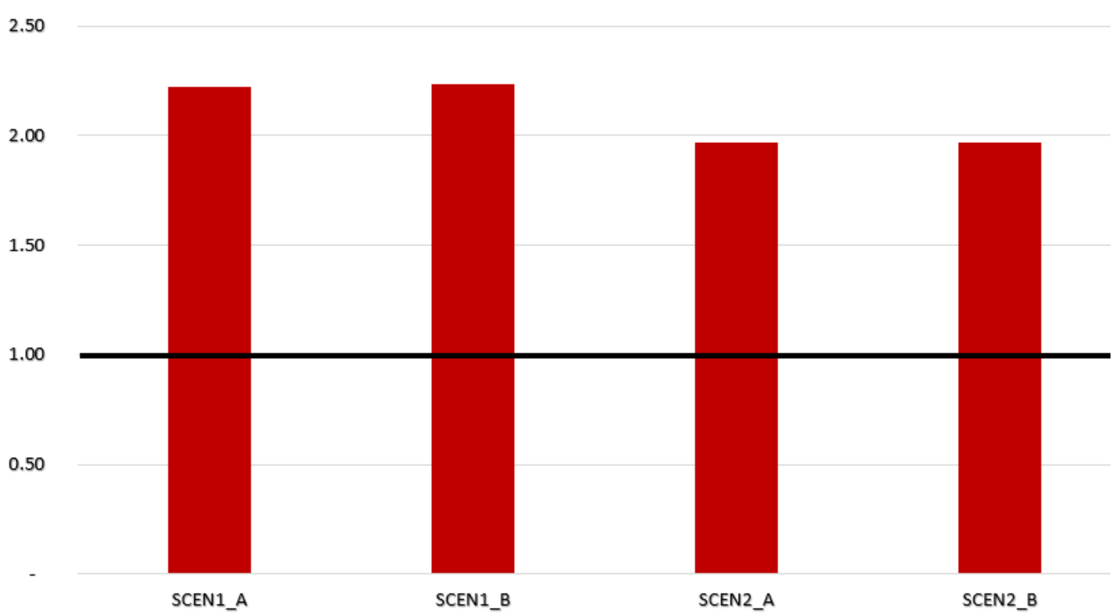

Figure 12. Ratio between additional government income and additional public expenditures due to the UK Energy Plan

4.2 Jobs and unemployment

As mentioned previously, the investment and public expenditures create jobs as shown in Figure 13. It shows the additional net jobs created by the UK Energy Plan measured as the difference between total employment in each scenario against baseline for every year. From 2019 (the first year where policies are applied is 2020) to 2030, the number cumulative annual jobs increases by 3.73-3.91 million over the period 2020-2030, depending on the scenario (see Table 3). As can be seen in Figure 13, SCEN2 is the scenario which is able to deliver a higher level of employment for a longer period of time.

However, the potential to create jobs declines over time, starting to lose momentum in 2025 (in SCEN2) after reaching its maximum in 2024 (around 467,000-473,000 additional annual jobs vs Baseline, see Table 3). Investment creates new job opportunities but, at the same time, it feeds and increases the capital stock. This capital accumulation eventually leads to an increase in wages –via labour productivity as described in the following section- and to a reduction in capital costs. This rapid increase in the capital stock is built by workers, some of them no longer required after the construction process. That is the reason why jobs creation declines during the last years of the analysed period. Moreover, the much higher capital investment in SCEN2 explains why this effect is more intense in this scenario.

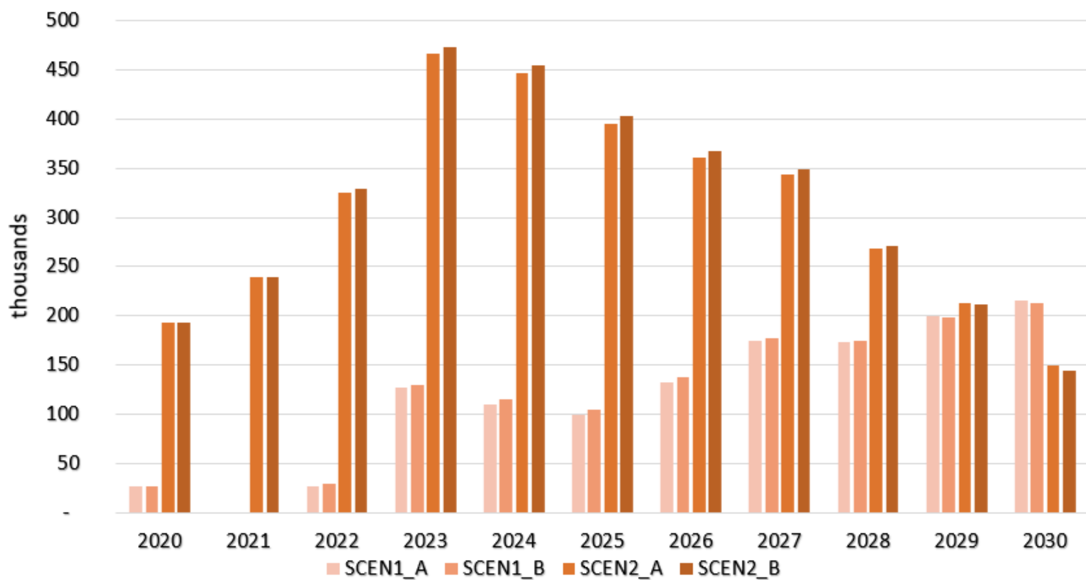

Figure 13: Additional annual jobs vs Baseline.

Whereas capital investment feeds a stock of capital, jobs cannot be accumulated. Every year, a number of the labour force is required for the productive process. If this number is higher than the amount required in the BL scenario, we can state that these jobs were created by means of the UK Energy Plan. According to Table 3, the average 2020-2030 difference from scenarios to BL is 115-117 thousand annual jobs in SCEN1 and 274-277 thousand annual jobs in SCEN2.

Nevertheless, the maximum increase in people working in a year compared to BL is 250-252 thousand in SCEN1 and 309-312 thousand in SCEN2. Nevertheless, as mentioned before, the strategy is able to create 400-473 thousand jobs by 2023-2025. Then, employment is still growing but slower than BL due to the abovementioned capital stock feedback effect. In addition, these figures should be assessed along with the unemployment rates that are reached on each scenario.

As shown in Table 3 and Figure 14, unemployment is lower in the UK Energy Plan scenarios and more than 2 points lower than 2020. Flattening the capital investment inflows to the economy or committing further government expenditures would potentially increase the employment figures (since the ambiguous effect of the increasing capital stock would be offset).

Table 2: Employment in different UK Energy Plan scenarios and Baseline.

	Employment by 2030 (thousands)	Avg. Diff. vs BL (thousands)	Max Diff. vs BL (thousands)	Unemployment Rate (avg. 2020-2030)
BL	35,562	0	0	5.38
SCEN1_A	35,778	115	216	5.14
SCEN1_B	35,775	117	213	5.13
SCEN2_A	35,712	309	467	4.80
SCEN2_B	35,706	312	473	4.79

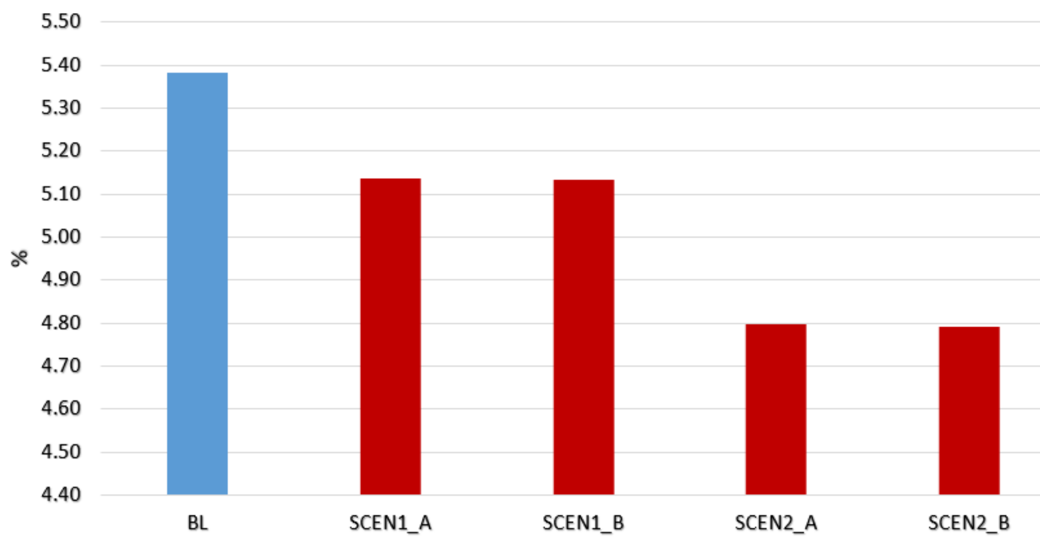

Figure 14: Unemployment Rate (Average 2020-2030).

Finally, as already mentioned, Unemployment Rate goes down in all the UK Energy Plan scenarios. It is important to note that the Unemployment Rate (UR) reduction is achieved together with an increase in hourly wages –actually, also boosted by the reduction of UR as well- disposable income and the energy services obtained by the UK households. So this is not only an improvement in employment creation regardless of the quality of the jobs. The UK Energy Plan would actually imply an enhancement of welfare.

4.3 Wages, profits and disposable income

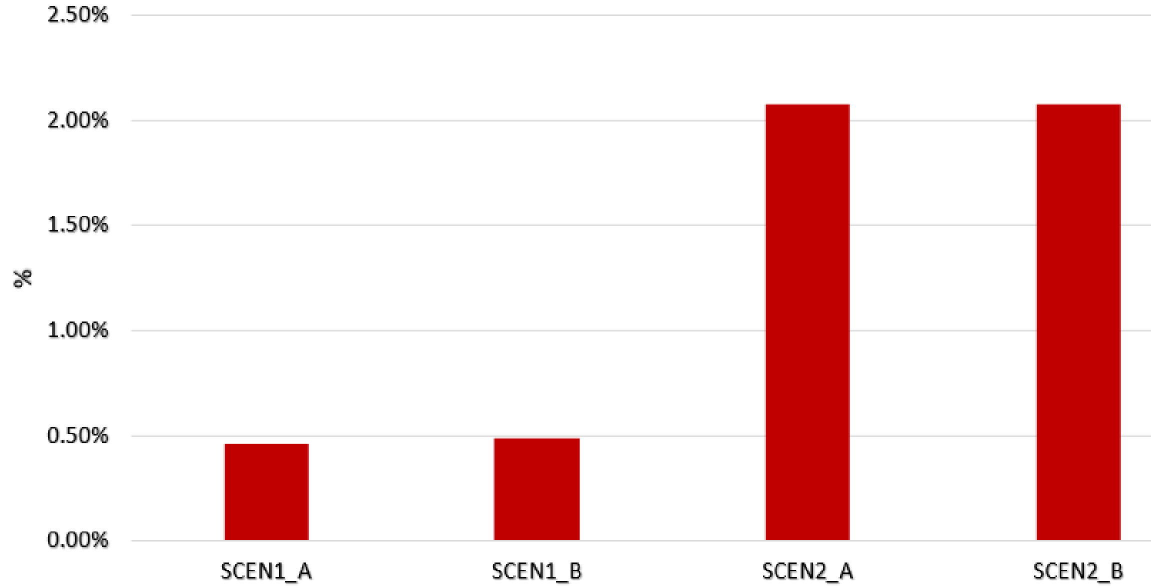

Figure 15: Increase (%) in hourly wages vs BL from 2019 to 2030.

Not only wages would increase after the UK Energy Plan, but also the firms' profits, as can be seen in Figure 16.

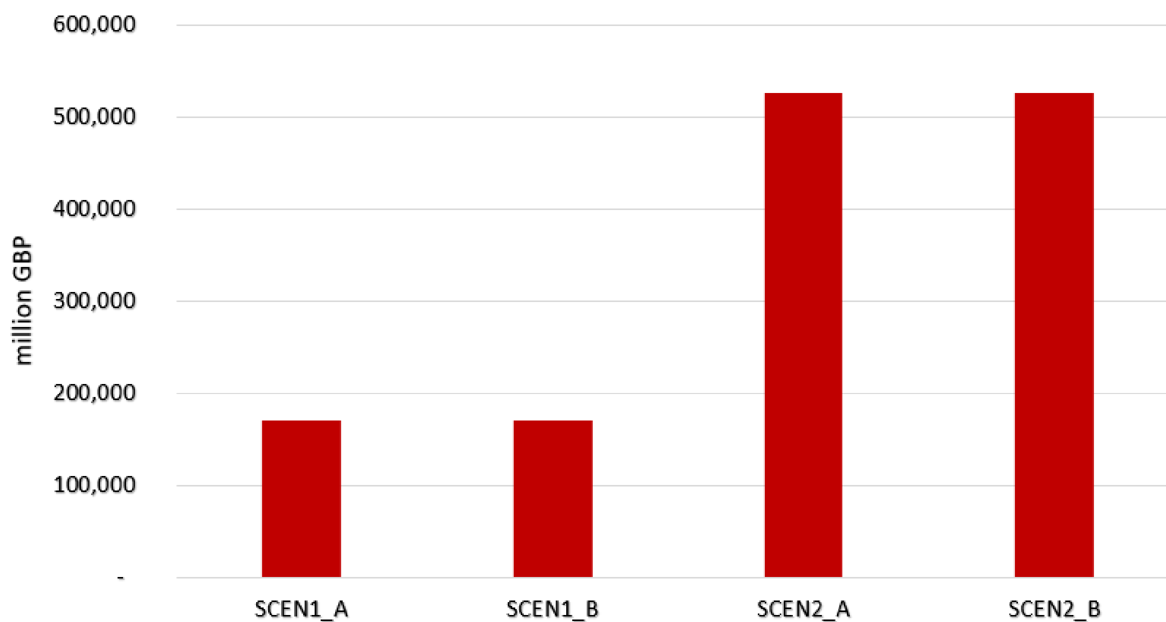

Figure 16. Additional cumulative profits (2020-2030).

Next, we show the results of disposable income in Figure 17:

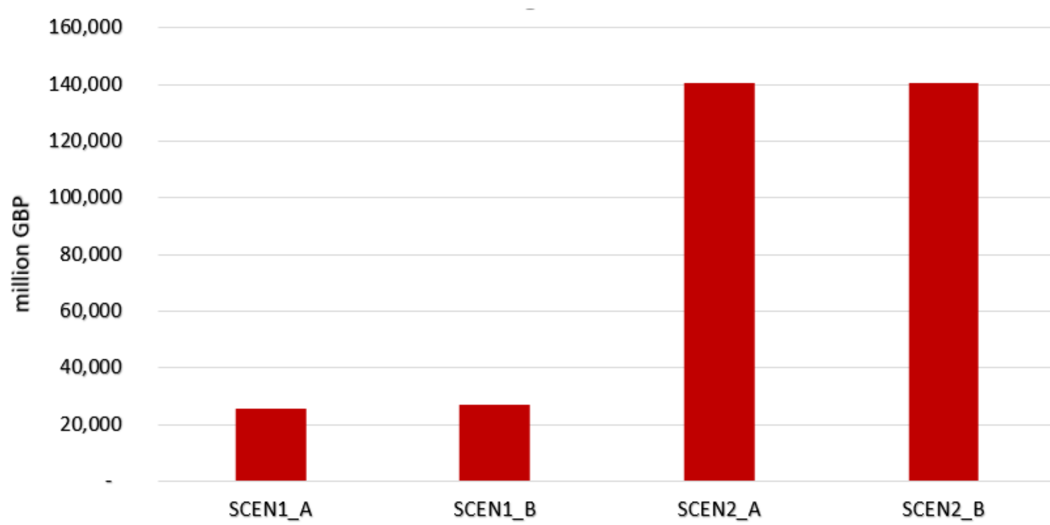

Figure 17: Additional cumulative disposable income (2020-2030).

A significant increase in both salaries and disposable income would come out of the UK Energy Plan. Figure 15 shows the hourly wages increase vs baseline, which would reach more than 2% by 2030 in SCEN2. The lower capital and government expenditure leaves SCEN1 with a relatively poorer performance in this regard, though. The increase in wages is eventually triggered by the enhanced energy efficiency and GDP growth rates. Moreover, wages are also boosted as a reaction to the growing energy prices, in order to maintain the households' purchase power. However, the main driver of this change is not the reaction to prices, but the improvement of labour productivity (GDP/People employed).

Labour productivity, in turn, has been encouraged by the demand-side measures of the Energy UK Plan, since the additional capital investment and government expenditures increased the economy's capability to hire new workers beyond its initial status. As a consequence of the growth in salaries, disposable income is also expanded (Figure 17). Disposable income would rise by 0.40%-1.35% after the UK Energy Plan is implemented, similarly to hourly wages (see Table 6).

4.4. Energy results

First, we see the effects on final energy consumption in Figure 18:

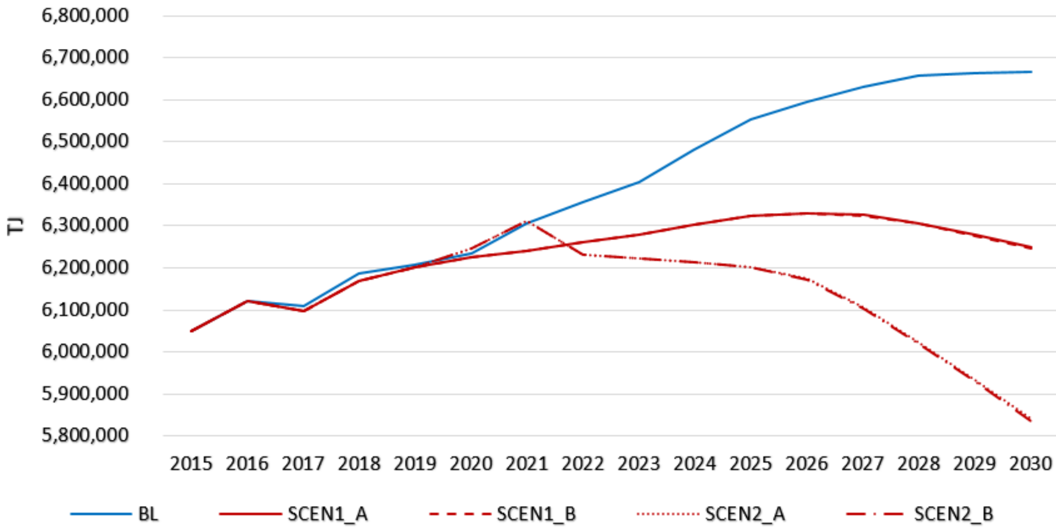

Figure 18: Total Final energy use (fen_t) under baseline and scenarios 1 & 2

Next, we see the impacts on final-to-useful thermodynamic efficiency, a key variable in our model:

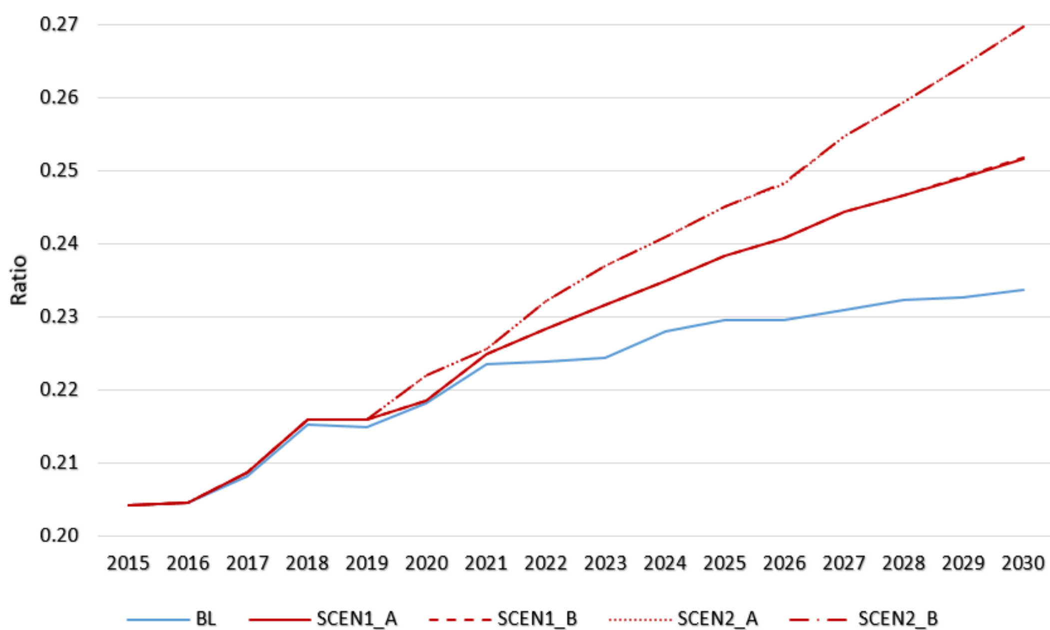

Figure 19: Final to Useful Energy Efficiency (exeff2_fu) under baseline and scenarios 1 & 2

Finally, we see the overall impact on (final) energy intensity (final energy / GDP) in Figure 20:

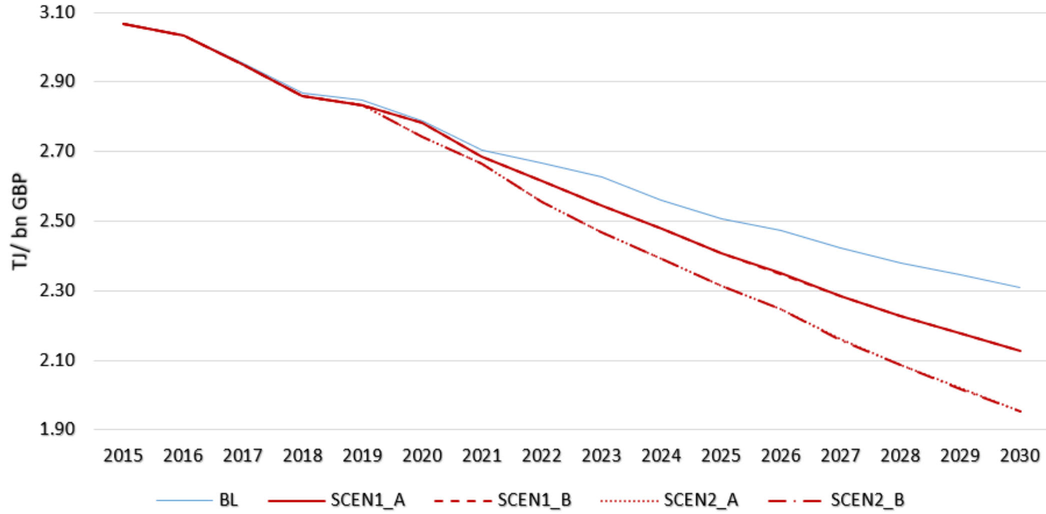

Figure 20: Final Energy Intensity (Total Final Energy use/GDP)

Largely through reductions in domestic energy use, overall economy-wide final energy use also declines. Industry's energy use also decreases, whereas a slight rebound appears in other sectors (services, government, etc.). This rebound effect has been measured to be around 5% on scenarios. This means that the total final energy reduction is 95% of the energy savings initially planned. Nevertheless, this rebound effect could be underestimated, as the households' energy used is fixed at the exogenous values. Moreover, the rebound is higher in the scenarios with lower households' energy prices, i.e. option A.

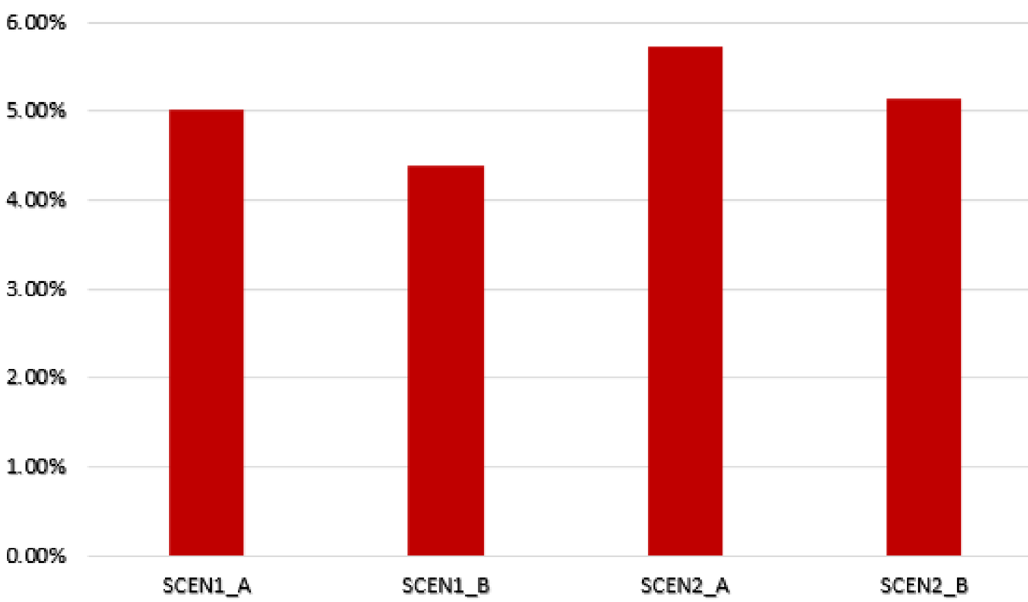

Figure 21. Rebound effect in the UK Energy Plan scenarios. % of energy non reduced versus planned reduction.

However, overall as can be seen in Figure 18, total final energy use declines by 2030 in both SCEN1 and 2. The efficiency to transform final energy to useful exergy (EXEFF_FU) is simply a ratio between total useful exergy (UEX_TOT) and total final energy (FEN_T). The more energy services (heat, lighting, cooking, etc.) that we can obtain with the same amount of final energy, the higher final to useful exergy efficiency.

Thus, an increase in this variable allows increasing welfare with lower environmental impacts –i.e. energy use. The investments that the UK Energy Plan would provide higher useful exergy per unit of final energy use. Also, the final energy use required to produce one unit of output (GDP), or final energy intensity, is lower after the investment program (Figure 20). As a consequence, energy carriers of the UK's economy decrease and, simultaneously, enable a better performance of the economy.

4.5 Summary detailed tables

More detailed data of the modelling outcomes can be seen in Table 4-6 below.

Table 3: Scenarios outcomes. Absolute values in 2030

Variable	Units	Symbol	BL	SCEN1_A	SCEN1_B	SCEN2_A	SCEN2_B
GDP	£m	Y	2,888,443	2,936,415	2,935,695	2,989,645	2,989,645
Investment	£m	I	416,427	444,698	444,698	485,485	485,485
CPI	Index (100=2016)	CPI	138.30	138.28	138.97	138.63	139.82
Energy prices	Index (100=2016)	CPI_E	126.72	126.20	126.70	126.82	127.67
Unemployment rate	%	UR	4.93	4.51	4.52	4.96	4.98
Employment	000's	L	35,562	35,778	35,775	35,712	35,706
Wages	£m	W	1,432,127	1,442,602	1,442,915	1,457,092	1,457,581
Wages per hour	£/hour	WH	25.23	25.34	25.35	25.75	25.75
Disposable income	£m	YD	1,897,754	1,905,514	1,905,847	1,923,304	1,923,304
Energy use by households	TJ	FEN_C	2,116,891	1,670,876	1,670,876	1,235,678	1,235,678
Energy costs for households	£m	FEN_C_COST	45,637,702	36,100	45,637	26,697	45,637
Energy use by industry sectors	TJ	FEN_IND	813,060	815,342	815,775	817,534	818,314
Energy use by non-industry sectors	TJ	FEN_OTH	3,737,588	3,762,057	3,758,801	3,787,997	3,781,983
Total final energy consumption	TJ	FEN_T	6,667,539	6,248,275	6,245,452	5,841,209	5,835,975
Final to Useful Energy Efficiency	Ratio	EXEFF2_FU	0.234	0.252	0.252	0.270	0.270
Final energy intensity	TJ/£m	FEN_T/GDP	2.31	2.13	2.13	1.95	1.952
Total useful exergy consumption	TJ	UEX_TOT	1,557,851	1,572,701	1,572,245	1,575,424	1,574,593

Table 4: Scenarios outcomes. Change (%) 2030 vs 2018

Variable	Units	Symbol	BL	SCEN1_A	SCEN1_B	SCEN2_A	SCEN2_B
GDP	£m	Y	33.92%	36.14%	36.11%	38.61%	38.61%
Investment	£m	I	26.63%	35.23%	35.23%	47.64%	47.64%
CPI	Index (100=2016)	CPI	37.86%	37.85%	38.53%	38.19%	39.38%
Energy prices	Index (100=2016)	CPI_E	22.69%	22.19%	22.67%	22.79%	23.60%
Unemployment rate	% points	UR	-1.38	-1.79	-1.79	-1.35	-1.33
Employment	000's	L	12.22%	12.90%	12.89%	12.69%	12.68%
Wages	£m	W	41.92%	42.96%	42.99%	44.39%	44.44%
Wages per hour	£/hour	WH	31.62%	32.22%	32.25%	34.35%	34.35%
Disposable income	£m	YD	41.42%	42.00%	42.02%	43.32%	43.32%
Energy use by households	TJ	FEN_C	11.42%	-11.31%	-11.31%	-34.41%	-34.41%
Energy costs for households	£M	FEN_C_COST	36.61%	5.49%	33.38%	-21.98%	33.38%
Energy use by industry sectors	TJ	FEN_IND	-17.26%	-17.03%	-16.99%	-16.81%	-16.73%
Energy use by non-industry sectors	TJ	FEN_OTH	13.16%	13.90%	13.80%	14.68%	14.50%
Total final energy consumption	TJ	FEN_T	7.79%	1.28%	1.23%	-5.32%	-5.41%
Final to Useful Energy Efficiency	Ratio	EXEFF2_FU	8.53%	16.61%	16.63%	24.95%	25.00%
Final energy intensity	TJ/£m	FEN_T/GDP	-19.51%	-25.61%	-25.63%	-31.69%	-31.76%
Total useful exergy consumption	TJ	UEX_TOT	16.99%	18.10%	18.06%	18.30%	18.24%

Table 5: Scenarios outcomes. Change (%) against Baseline in 2030

Variable	Units	Symbol	SCEN1_A	SCEN1_B	SCEN2_A	SCEN2_B
GDP	£m	Y	1.66%	1.64%	3.50%	3.50%
Investment	£m	I	6.79%	6.79%	16.58%	16.58%
CPI	Index (100=2016)	CPI	-0.01%	0.48%	0.24%	1.10%
Energy prices	Index (100=2016)	CPI_E	-0.41%	-0.02%	0.08%	0.74%
Unemployment rate	Percentage points	UR	-0.41	0.01	0.44	0.02
Employment	000's	L	0.07%	0.07%	-0.37%	-0.38%
Wages	£m	W	0.73%	0.75%	1.74%	1.78%
Wages per hour	£/hour	WH	0.46%	0.48%	2.08%	2.08%
Disposable income	£m	YD	0.41%	0.43%	1.35%	1.35%
Energy use by households	TJ	FEN_C	-21.07%	-21.07%	-41.63%	-41.63%
Energy costs for households	£M	FEN_C_COST	-20.90%	0.00%	-41.50%	0.00%
Energy use by industry sectors	TJ	FEN_IND	0.28%	0.33%	0.55%	0.65%
Energy use by non-industry sectors	TJ	FEN_OTH	0.65%	0.57%	1.35%	1.19%
Total final energy consumption	TJ	FEN_T	-6.29%	-6.33%	-12.39%	-12.47%
Final to Useful Energy Efficiency	Ratio	EXEFF2_FU	7.73%	7.74%	15.43%	15.48%
Final energy intensity	TJ/£m	FEN_T/GDP	-7.82%	-7.84%	-15.36%	-15.43%
Total useful exergy consumption	TJ	UEX_TOT	0.95%	0.92%	1.13%	1.07%

4.6 Implications of the overall results

Figure 22 shows the percentage change in 2030 (except L and UR, using the 2020-2030 average instead) versus Baseline in SCEN2_B. It can be noticed that changes in energy-related variables are way higher than the macroeconomic ones, except UR. Final energy intensity reduction (FEN_T/Y) is equivalent to the thermodynamic efficiency gains because the latter basically adapts, representing the efficiency required to achieve these macroeconomic outcomes. The exogenous scenarios designed to assess the UK Energy Plan have implied the imposition of a reduced energy use. As a consequence, energy efficiency adapts in order to deliver the energy services that GDP growth demands. Nevertheless, there is no guarantee that the additional investment applied to the economy will produce the energy efficiency gains that are needed to reach the socioeconomic outcomes reported. Special attention should be payed to rebound effects –i.e. overall increases in energy demand after an increase in the energy efficiency due to the energy cheapening- if the energy savings objectives want to be met. Moreover, thermodynamic efficiency has been flat during the last decades, suggesting an increasing difficulty from the socioeconomic system to improve it, despite energy use was reduced from 2008 to 2014. Demand-side policies could contribute to enhance thermodynamic efficiency, such as car-sharing, telecommuting, etc.

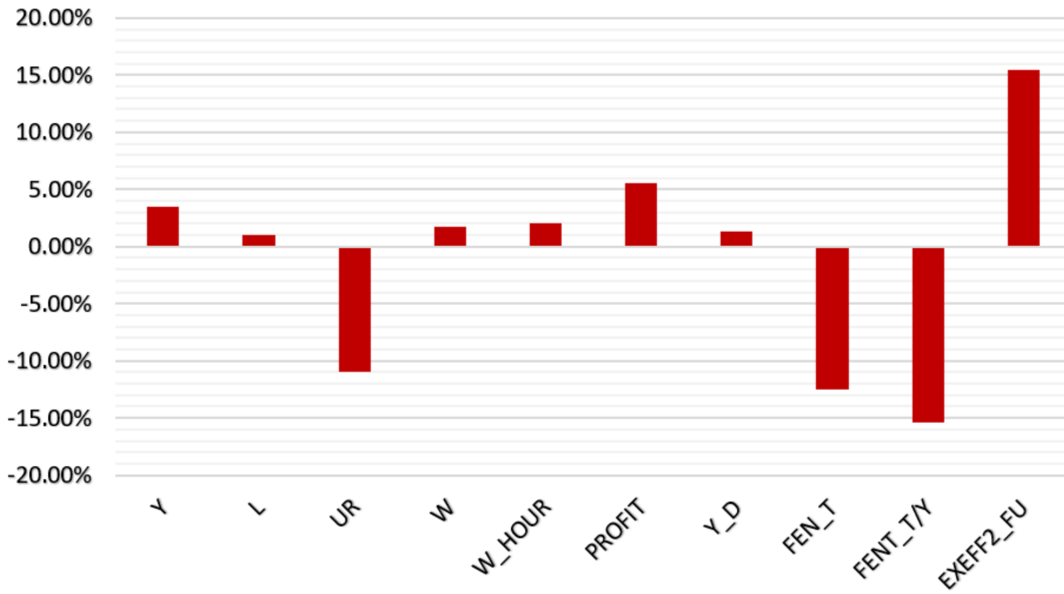

Figure 22. Overall results. % Change against Baseline

As mentioned before, should the government not take action, energy prices may go up. Although there is a high energy efficiency increase and energy use by households reduction, the capital investment and government expenditures committed by the Energy Plan lead to an expansion of the economy. As a result, a rebound effect is triggered, pushing up energy use in other sectors and eventually increasing energy prices. So, besides what it is mentioned in the previous paragraph, given that the efficiency gains do not balance out the increase in the energy unit cost, the containment of energy prices may require public funding in order to allow households to afford the increased energy bills. A higher increase of energy prices would potentially harm the households' purchase power and hence, reduce consumption and eventually GDP growth and jobs creation.

Therefore, additional government expenditures might be required in order to meet this objective. Our model estimates that the potential expenditure required to keep energy prices stable would range between 2.6-3.7 bn GBP for option B (keeping energy bills) and 10.6-14.6 bn GBP for option A (keeping energy prices). It has been considered in this analysis that this funding is embedded within the total government expenditures, so Figure 12 would be different should we consider this as expenditures associated to the Energy Plan and shown in Figure 21 below. This would not imply a big change, though, lowering the ratios from 2.22-2.24 for SCEN1 and 1.97 for SCEN2 to 1.76-2.10 and 1.79-1.92. The impact would be higher in option A, since the effort would be greater than in option B, but overall the cost-benefit analysis would result in 76%-110% returns depending on the scenario.

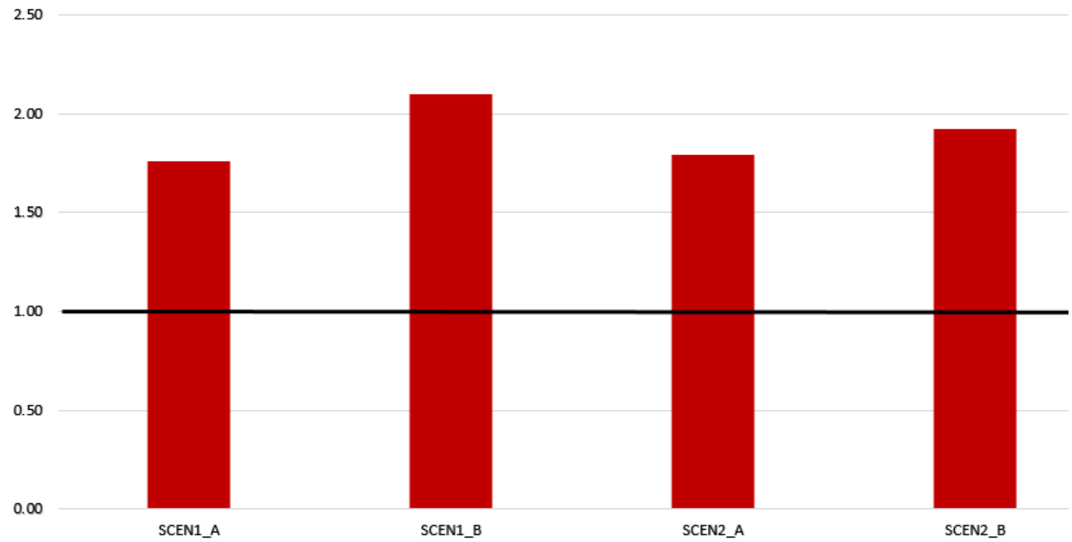

Figure 23. Modified Figure 12 if maintaining energy prices taken into consideration.

In fact, the intense capital investment – regardless of whether it is made by the private or public sector – leads to a rapid increase in the capital stock, that together with the increase in salaries (see section 4.2) can potentially harm the jobs creation in the medium-term. In addition, in the medium to long-term, the rate of profit may be affected by the excess of capital and the increasing difficulties to make it profitable. Also, capital investment increases the medium/long-term economy's employment potential, but at an early stage, infrastructures development creates job opportunities that do not necessarily go beyond the investment period. Take, for instance, a wind mill: it takes labour to build it and also to operate it, fix it, etc. After the building period, only the latter are strictly required. Therefore, more policies may be needed to maintain the job creation strength after 2028. Although the jobs creation decline happens both in SCEN1 and SCEN2, is in SCEN2 where the effect is more intense, due to the increased additional investment.

Jobs are not a stock that can be accumulated –as capital is- and for that reason, the number of jobs in each year is the most relevant variable. Of course, everything else constant, only the additional jobs compared to baseline can be attributed exclusively to the strategy. For instance, SCEN2 reaches its maximum extra jobs compared to baseline by 2024 (467,000-473,000 jobs more than baseline). Then it declines to 150,000-144,000 extra jobs compared to baseline by 2030.

Potential mechanisms to improve jobs creation would be the following. Firstly, turning part of the capital investment into government expenditures. Government expenditures are directly spent on the economy and do not accumulate capital stock, avoiding the abovementioned effect. After splitting part of the investment and considering part of the building retrofit as funded by government expenditures – which is consistent with the European System of National Accounts – the jobs creation improved. Moreover, a delay on time of the additional investment flows as well as flattening of its path, also contributes to avoid this contradictory effect.

5 Conclusions

<u>Summary headlines: Analysis outputs</u>

1- *The UK Energy Plan would reduce the households' energy use by **41%** relative to Baseline and **34%** in absolute terms (versus 2019). Total final energy use would **be 5% lower** in absolute terms (versus 2019) in SCEN2.*

2- *The UK Energy Plan would increase government income **by 88/295 billion GBP** (SCEN1/SCEN2) in 2030, outpacing additional government expenditures **by a factor of 2.22-1.97** respectively.*

3- *The plan would be able to create up **to more than 460,000 annual new total jobs** (maximum) and **200,000 additional annual jobs** as a 2019-2030 average. This would also reduce the average unemployment rate by 0.59 percentage points (relative to baseline).*

4- *Further, the plan would improve incomes, with **a 2% increase in hourly wages** across the economy in 2030 (relative to baseline).*

5- *GDP would be increased by **800 billion GBP** if full energy system changed (SCEN2) in 2030 (relative to baseline).*

6- *The benefits in terms of GDP well exceed the upfront costs, with **a 31% return on investment** in **SCEN1 and 17% in SCEN2.***

Labour's UK Energy Plan combines at least three objectives: shift towards a renewable energy mix; energy efficiency improvements; and demand-side energy reductions. In order to achieve these objectives, a set of actions is to be implemented. These actions require investments intended to be funded mainly by the private sector, although supported by public expenditures. Increasing the share of public expenditures on the total transition's investment, would contribute to ease the negative pressure on employment and wages during the last years of the strategy. These actions are aimed at achieving net zero emissions as the energy mix shifts towards renewables. However, the transition and investments to green technologies should carry on during the next decades and stronger energy reductions should be undertaken.

Finally, whilst the UK Energy Plan has overall positive socio-macroeconomic effects, including GDP, disposable income, wages and jobs, it is worth taking into consideration the following modelling assumptions/limitations:

1- A 20-22% increase in thermodynamic efficiency and 26-30% increase in final energy efficiency would be necessary by 2030 to obtain the predicted GDP growth.

2- Energy prices (£ per kWh) might substantially increase if no measures are undertaken to prevent it.
3- During the first stage of the energy transition, the investments required to deploy the green energy infrastructures, could still rely on fossil fuels. Moreover, these investments can induce rebound effects that offset the energy reduction efforts.
4- A quick capital accumulation can harm the economy's capability to maintain jobs creation.

Further policies are required to overcome these limitations such as promoting car-sharing, telecommuting, etc. (1); demand management policies to reduce energy use requirements and avoiding rebound effects (2); funding energy bills to low-income households to avert energy poverty (3) or creating and funding long-term jobs on top of those created by the infrastructures deployment, mostly in low-energy demand sectors (4).

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