Economic Impacts of Low-Carbon Transport Strategies for Jordan

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About us

Researchers at the Centre of Policy Studies have a 45-year history of continuous achievement in the development, application and dissemination of large-scale economic models. Our models and software are used around the world to analyse a diverse range of economic issues. CoPS' funders include: Australian federal and state government departments; private firms and universities in many parts of the world; central government agencies such as finance and trade ministries in many countries; and international development organisations. The Centre's GEMPACK software, used for solving large economic models, is used at more than 700 sites in over 95 countries.

Citation

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Abstract

Greenhouse gas emissions in Jordan come primarily from the combustion of refined oil products in transport. Hence, plans to reduce emissions focus primarily on the transport sector. These plans, often detailed from a technological point of view, seldom present reasoned economic measures of likely consequences.

This paper provides an assessment of the likely economic costs and benefits for Jordan of two typical schemes to reduce the environmental effects of transport. Both relate to the delivery of passenger services. The first is to encourage the uptake of Battery Electric Vehicles (BEVs) at the expense of Internal Combustion Vehicles (ICVs) and, to a lesser extent, hybrid vehicles. The second is to invest in new public transport infrastructure – phase 2 of the Bus Rapid Transport system - assisting to reduce the use of private vehicles principally in urban areas.

The analysis is based on scenarios to 2050 constructed using a large model of Jordan's economy, named JorGE. JorGE is calibrated to data for 2020 and has a detailed industrial classification. That classification recognizes electricity produced by several different conventional fossil fuel and renewable technologies and a number of road transport service industries. The road transport industries distinguish passenger from freight services. For passenger services there are separate industries producing public transport services and private transport services. The latter is further disaggregated into services provided by the three different passenger vehicle types – ICVs, EVs and Hybrids.

Foreword

The Centre of Policy Studies (CoPS) at Victoria University has been commissioned by the Deutsche Gesellschaft fur International Zusammenarbeit (GIZ) to undertake the following programme of work.

- Working closely with GIZ, selected political partners as well as a national expert group of modelling and transport sector researchers develop a recursive-dynamic Computable General Equilibrium (CGE) model for Jordan with detailed representation of the transport sector and energy related variables. The core CGE model is to be neo-classical in flavour while the energy module includes variables such as CO_2 emissions and energy use.
- Identify, with input from the Expert group, key policy questions regarding climate-friendly transport sector development strategies. One Business as Usual (BAU) and two policy simulations are to be run to estimate the economic costs and benefits of these future strategies. It has been agreed that the first policy simulation will be to evaluate the impact of an increase in the uptake of electric vehicles (EV) by 2050. The second simulation evaluates the increased use of public transport.
- Transfer the model, its database and software to the Jordanian government and provide preliminary training in its use.

This report describes in detail the achievements of the project with respect to the second task.

Policy Brief/Executive summary

Greenhouse gas emissions in Jordan come primarily from the combustion of refined oil products in transport. Hence, plans to reduce emissions focus primarily on the transport sector. These plans, often detailed from a technological point of view, seldom present reasoned economic measures of likely consequences.

This report provides an assessment of the likely economic costs and benefits for Jordan of two typical schemes to reduce the environmental effects of transport. Both relate to the delivery of passenger services. The first is to encourage the uptake of Battery Electric Vehicles (BEVs) at the expense of Internal Combustion Vehicles (ICVs) and, to a lesser extent, hybrid vehicles. The second is to invest in new public transport infrastructure – phase 2 of the BRT - assisting to reduce the use of private vehicles principally in urban areas.

## *Policy 1: Increased uptake of BEVs*

Battery Electric Vehicles (BEV) currently account for 5 per cent of Jordan's motor vehicle transport. This is set to increase to 60 per cent by 2050 in line with the current plans of major vehicle makers to reduce significantly the number of ICVs produced. . Over the same period the popularity of hybrid vehicles will increase from its current level and then fall to be around 10 per cent in 2050. This leaves internal combustion vehicles (ICV) accounting for just 30 per cent of motor vehicle transport by 2050.

In the first policy simulation, we examine the economic implications of increasing the BEV share to 100 per cent by 2050. In so doing we shed light on the economic costs and benefits of a 40 percentage point increase in BEV penetration. This is likely to be achieved via a mix of market and non-market measures including subsidies and taxes, regulation and moral suasion, which we model as a government subsidy on BEV services which is paid for ultimately by the household. Subsidies and taxes, in themselves have an economic cost due to their adverse impact on allocative efficiency. Our modelling takes account of this cost, and so our analysis might be regarded as conservative, with both the costs and benefits of increasing BEV penetration.

Results from this simulation are driven by two factors. The first is the different costs of operating BEVs and ICVs. The second is the size of the required subsidy.

Figure A shows percentage cost shares for operating ICVs (top) and BEVs (bottom). The cost of a unit (passenger-km) of ICV service comprises roughly equal amounts of capital cost (the annualised cost of purchasing a vehicle) and the cost of petroleum products. The remainder, or around 20 per cent, covers other running expenses such as servicing. By contrast, for BEV services capital is over 80 per cent of total cost, with electricity and servicing, etc., making up the rest. It follows, that increasing the uptake of BEVs at the expense of ICVs increases the capital intensity of the economy and reduces it reliance on petroleum and oil imports. Both effects lead to increased real GDP over time.

Figure A: Cost shares of vehicle services – ICV (top), BEV (bottom)
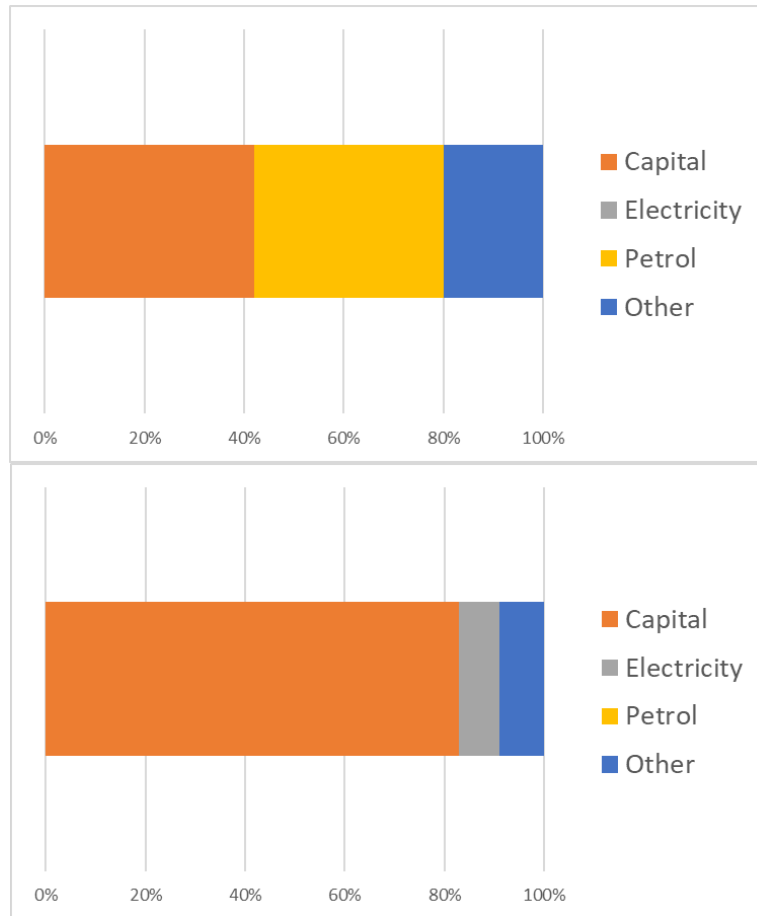
We estimate that to raise BEV's share in private passenger transport to 100 per cent will require a subsidy of around 0.9 per cent of GDP on the use of BEVs. Much of this subsidy is required to achieve the final 10 per cent increase. The last 10 per cent consist of vehicles mainly operated by people cautious about new technologies and with relatively poor access to charging facilities. By itself, the subsidy reduces real GDP because it reduces slightly the efficiency with which the economy uses its resources – capital and labour.

Overall, the shift towards BEVs is projected to increase real GDP in 2050 by 3.7 per cent relative to its level without the BEV subsidy. This is equivalent to the value of GDP created in a typical eighteen month period. However, the benefit of increased BEV uptake is not just economic. There is also a reduction in greenhouse emissions. By 2050, due to the increased BEV uptake total greenhouse gas emissions are down 13.5 per cent from 41.8 Mt of CO2-e to 36.2 Mt of CO2-e. All of the fall comes from a drop in transport-sector emissions of around 7 Mt.

The double dividend from increased BEVs – higher real GDP and lower emissions - is illustrated in Figure B. Shown are percentage changes over time in real GDP and emissions due to the progressive uptake of BEVs beyond what would otherwise occur.

Policy 2: Construction and operation of phase 2 of the BRT
This is a very different policy to the first. In terms of economy-wide impacts, it is much smaller and its impact on greenhouse gas emissions is far less. We model year-by-year the effects of BRT (Phase 2) during its construction period, 2023–2027 and operation (or production) phase, starting in 2028. The total construction cost is estimated to be JD 300 million, with JD 240 million spent on infrastructure and JD 60 million on buses and new IT systems. Operations of the Phase 2 system are assumed to

ramp-up immediately to full capacity in 2028, and to remain at full capacity through to the end of the projection period (2050). Annual operation cost of the new system is estimated to be JD 10 million.

Figure B: BEV's double dividend – more real GDP, fewer emissions
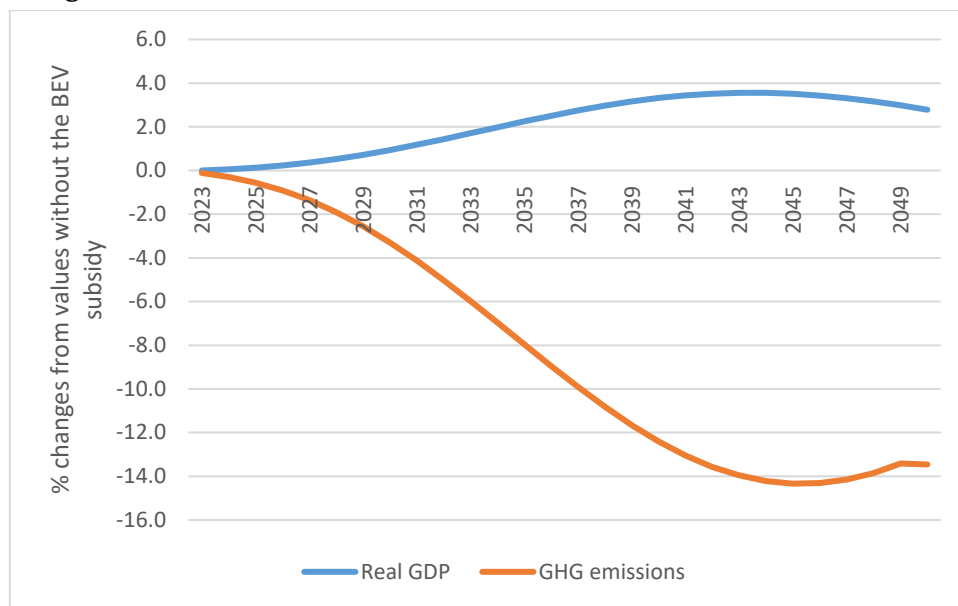
Spending an average of JD 60 billion per year during the construction phase stimulates real GDP by an average of JD 63 billion per year. This is equivalent to 0.15 per cent of GDP's baseline value.

This estimate takes account of not only the direct and indirect demand effects of the construction project, but also offsetting (i.e., crowding out) effects that arise from supply-side constraints on the economy. When investment spending in one area rises, this puts upward pressure on costs and wages faced by other industries, leading to negative effects on their competitive position. The model also captures other relative price adjustments that crowd out activity elsewhere, including changes in the real exchange rate. In this case, the investment is foreign financed. The increase in foreign investment, all else unchanged, strengthens the value of the domestic currency leading to real appreciation. Real appreciation disadvantages industries that export, and industries that compete with imports.

Following construction, the BRT (phase 2) begins operation with gross revenues of JD 10 million per year. Most of this is from businesses and households that previously used private transport services and other public transport such as private buses. Overall, there is little change in spending on passenger transport services. There is, however, a small increase in real GDP of around JD 6.5 million (or 0.07 per cent). This is due almost entirely to the economy-wide travel-cost savings associated with the new public facilities.

The impact of the BRT (phase 2) on Jordan's transport emissions is small – a reduction of around 10 kt per annum. However, it is unfair to judge the project on its ability to curb GHG emissions. Its true value lies in its ability to deal with another problem evident on the country's urban roads – that of congestion. A lack of high-quality public transport options leads many urban inhabitants to rely on private vehicle ownership. The result is frequent traffic jams that clog the main roads, take an economic toll by forcing many passengers to spend a significant amount of their time stuck in a car, and heavily affect air quality. Measurement of the benefits arising from the new BRT on congestion is outside the scope of this study, but they are almost certainly substantial.

Figure C shows percentage changes in real GDP and GHG emissions due to the building and operation of the BRT (phase 2). Nearly all of the impact occurs during construction, which raises real GDP and GHG emissions. By contrast, once operational the new infrastructure has relatively little impact on the macro-economy and emissions.

Figure C: BRT (phase 2) – Main effects on real GDP and GHG emissions mainly during construction
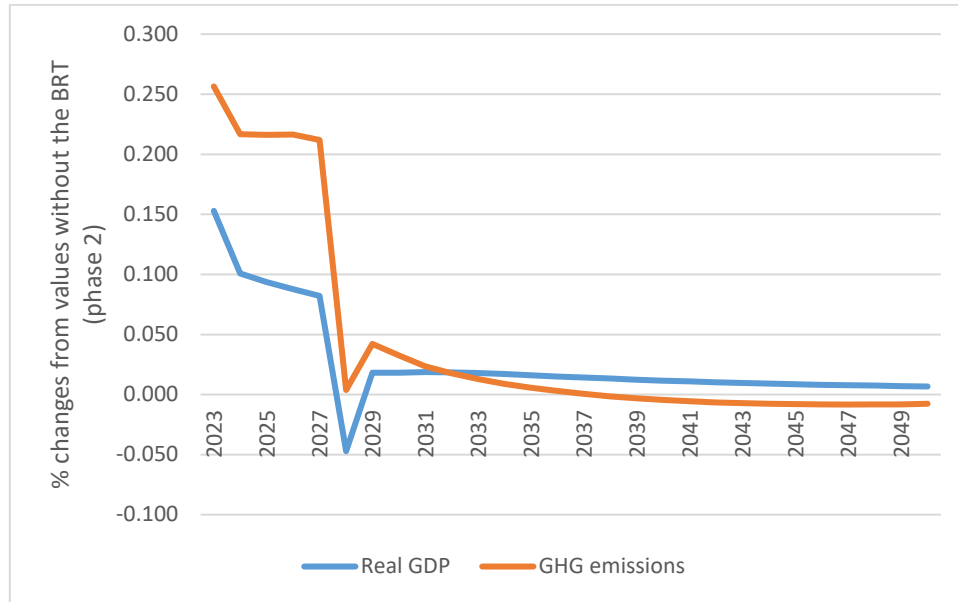
Methodological note:

The analysis is based on scenarios to 2050 constructed using a large model of Jordan's economy, named JorGE. JorGE is calibrated to data for 2020 and has a detailed industrial classification. That classification recognizes electricity produced by several different conventional fossil fuel and renewable technologies and a number of road transport service industries. The road transport industries distinguish passenger from freight services. For passenger services there are separate industries producing public transport services and private transport services. The latter is further disaggregated into services provided by the three different passenger vehicle types – ICVs, BEVs and Hybrids.

Contents

1 Introduction

Jordan is party to the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The *Agreement*, which came into force in 2016, aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to below 2°C above pre-industrial levels and pursuing efforts to limit temperature increase to 1.5°C.

In accord with the *Agreement,* Jordan has committed to prepare and communicate strategies for shaping its transformation into a low-carbon economy. In doing so, Jordan has set a target of reducing greenhouse gases (GHGs) emissions by 14 per cent by 2030.[1] In 2021, this target was updated to 31 per cent. The higher target is to be achieved *via* a combination of national policies and programmes as well as international support and finance.[2]

Transformation to low-emissions ways of transport has a key role to play in Jordan's de-carbonisation plans. According to the country's Second Biennial Update Report,[3] the transport sector was the largest energy consumer in 2018 with a share of 49 per cent, followed by households, the industrial sector, and other service sectors. Estimates that are more recent suggest 40 per cent of energy sector greenhouse gas (GHG) emissions in Jordan were generated in the transport sector.

There are a number of strategies suggested for steering Jordan onto a more sustainable development path for the transport sector. For example, the National Green Growth Plan for Jordan (2017)[4] lists a set of policy considerations as well as concrete project ideas ranging from topics such as electric vehicle charging stations and trade agreements to new Bus Rapid Transit (BRT) infrastructure.

Despite these plans and others like them, there has been relatively little in-depth assessments of their economic feasibility and implications. The purpose of this report is to shed light on the economic consequences, by using a dynamic Computable General Equilibrium (CGE) model to evaluate two strategies that are typical of those suggested.

The first involves government action to increase the uptake of Battery Electric Vehicles (BEVs).[5] Following the introduction of exemptions from customs duties for hybrid[6] and BEVs in 2015, an increasing number of such vehicles have been sold in Jordan. Most of these have been hybrids. In this report, we look at the economic implications of the government putting in place a package of policies such that by 2050 BEVs provide all private passenger vehicle services. This package effectively reduces the cost of purchasing BEV services to a point where there is no incentive to use Internal Combustion Vehicles (ICVs) or Hybrids for private passenger transport.

The second strategy investigated is a plan to increase public transport patronage through the building of phase 2 of the BRT. This has significantly smaller effects on the economy and its greenhouse gas

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[1] This target of 14 per cent is set in the 1st Nationally Determined Contributions (NDC). The unconditional outcome target is aiming to reduce GHGs by 1.5 per cent while the conditional outcome target is aimed at 12.5 per cent.

[2] Ministry of Environment (2021). Updated submission of Jordan's first nationally determined contribution (NDC). October 2021.

[3] The Hashemite Kingdom of Jordan (2020).

[4] Ministry of Environment (2017).

[5] In this document, the term Battery Electric Vehicle covers vehicles which are fully-electric, meaning that they are solely powered by electricity and do not have a petrol, diesel or LPG engine, fuel tank or exhaust pipe. BEVs are also known as 'plug-in' EVs as they use an external electrical charging outlet to charge the battery.

[6] Plug-in hybrid electric vehicles are powered by a combination of liquid fuel and electricity. They can be charged with electricity using a plug but also contain an internal combustion engine that uses liquid fuel.

emissions than the first strategy, but it is well documented in terms of projected construction spending and operational characteristics.[7] In addition, it is a typical public-transport project, and as such, our evaluation provides a useful *indicative* perspective of the costs and benefits of similar projects involving rail, cable cars, etc.

As already mentioned, our analysis is based around scenarios constructed using a dynamic CGE model. Such models have proven to be robust and reliable tools for examining a wide range of issues (energy and non-energy related) across many countries and by many key groups such as The World Bank, OECD, the IMF and the IPCC.[8] Their strengths lie in the following.

- *Detail.* CGE models take into account the inter-dependencies between different sectors, agents and markets in the economy. CGE analysis can therefore shed light on the wider economic impact of policies including indirect or unintended effects.
- *Interpretability.* CGE models are grounded in well-established neo-classical economic theory, which allows prices to reflect costs, for most markets to clear, and for households and producers to be actively pursuing minimum cost and maximum welfare opportunities. Because of their structural nature, results can be explained using economic intuition which can be understood by decision makers without explicit understanding of the underlying model.
- *Flexibility.* Though starting from a given structure for the economy, CGE models are flexible enough to allow for significant technological changes to that structure. Such changes can include changes in multi-factor productivity, changes in the structure of demand (towards BEVs for example), changes in the cost structure of individual industries (electrification of industrial processes for example) and shifts in the way electricity is generated (increased use of renewable power for example).
- *Balance.* In contrast to partial equilibrium models, which focus on one section of the economy only, CGE models capture the entire economy and take into account the interactions and knock-on effects between its different segments. Unlike input-output models, which capture only the demand side and assume there are no capacity constraints, CGE models incorporate the supply side and an active price mechanism. Compared to macro-econometric forecasting models, CGE models have a stronger foundation in economic theory. Macro-econometric forecasting models tend to be more data-driven, combining time series data with economic theory and often omit the detailed industrial data provided in CGE models. Whilst sharing many features with CGE models, Dynamic Stochastic General Equilibrium models (DSGE) aim to capture business cycle fluctuations and thus have a stronger focus on the shorter-term impacts. Unlike many CGE models, these types of models are less disaggregated and allow random variation to account for uncertainty.

    Because the CGE structure is more general than other model alternatives, it provides a more *balanced* appraisal of the costs and benefits of an economic shock. That appraisal includes the crowding out of activity when supply- or demand-side expansions occur elsewhere.

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[7] We use two sources of information. The first is a confidential in-progress report from the World Bank titled *Amman bus rapid transit phase II Preliminary technical assessment and financing options*. No statistical data are used from this report. The second is Dalala *et al.* (2020).

[8] Robson *et al.* (2018) provides a brief review of the use of CGE models for modelling transport issues and their application to economic appraisal. Papers using CGE models to examine energy and transport issues in Australia and elsewhere are included in the listing of CoPS working papers which can be downloaded at https://www.copsmodels.com/elecpapr.htm

- *Practicality.* CGE models are used for applied research which seeks to solve a specific problem or provide innovative solutions to issues affecting an individual, group or society as a whole. Accordingly, their theoretical structure is populated by real world data which provides a statistical picture of what an economy looks like at a particular point of historical time. In most cases, CGE models are also dynamic which allows them to project from the historical year of record (in Jordan's case 2016) to the present year (2022) and into the future (out to 2050 in this study). A wide range of external information can be incorporated into these projections, including when constructing the Base scenario forecasts from expert macroeconomic forecasting groups and projected changes in energy supply and transport use from groups that specialise in those areas

The model used in this study is called (with very little imagination) the Jordan General Equilibrium model (JorGE). It is built in the *ORANI/MONASH* tradition and is solved using GEMPACK software.[9]

The remainder of this report is divided into four sections. JorGE is described briefly in Section 2, with a focus mainly on the changes incorporated into the model to facilitate the modelling of energy and greenhouse emission issues. The economic impacts of increased EV uptake and expanded public transport infrastructure are calculated as deviations away from a baseline scenario to 2050. The baseline incorporates business-as-usual trends in population, technology, world trading conditions and key macroeconomic variables. It also includes known trends and policies that encourage the take up of renewable forms of electricity generation and the replacement of ICVs with BEVs and Hybrid vehicles. The modelling of the baseline is described in Section 3. Deviations from the baseline due to the policy shocks are explained in Section 4. Section 5 contains concluding remarks.

2   JorGE and energy-related enhancements

In this section we provide a brief overview of JorGE and of the enhancements added for this study to examine energy related issues. More details are available in a separate document explaining fully the model's theory and computational coding. The detailed document is available on request by contacting Louise Roos at the address shown in the front of this document.

The theoretical structure of JorGE is essentially a system of simultaneous equations, which can be classified into several inter-related blocks covering industry and final demands (for locally produced and imported products), industry production (for local markets and export), pricing, market clearing, dynamics (linking of investment in one year to productive capital in the next year, etc.) and reporting.

The model recognizes 104 industries producing 104 goods and services. Of the 104 industries, three produce primary fuels (coal (zero production), oil and gas), one produces refined oil (petroleum products, another industry produces hydrogen (with zero production but can be triggered in the future), five generate electricity and one supplies electricity to final customers. The *Petroleum products* industry produces gasoline (including gasoline-based biofuel blends), diesel (including diesel-based biofuel blends), LPG, aviation fuel, and other refinery products (mainly heating oil).The five generation industries are defined according to primary source of fuel: *Electricity-gas* includes all plants using turbines, cogeneration and combined cycle technologies driven by burning gas; *Electricity-hydro* covers hydro generation; *Electricity-solar* covers generation from photovoltaic systems; *Electricity-*

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[9] ORANI/MONASH models are large CGE models solved in percentage changes. Their origins lie in the work of Peter Dixon – see Dixon *et al.* (1977) and Dixon and Rimmer (2002). GEMPACK (General Equilibrium Modelling PACKage) is a suite of economic modelling software described fully in Horridge *et al.* (2018). It is especially suitable for CGE models, but can handle a wide range of economic behaviour.

wind covers renewable wind generation; and *Electricity-other* produces electricity from other sources (including the potential of nuclear in the future).

2.1   General equilibrium core

2.1.1   The nature of markets

JorGE determines supplies and demands of commodities through optimizing behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply is determined by demographic factors, while capital supply responds to rates of return.

The assumption of competitive markets implies equality between the basic price (i.e., the price received by the producer) and marginal cost in each sector. Demand is assumed to equal supply in all markets other than the labour market (where excess-supply conditions can hold). The government intervenes in markets by imposing *ad valorem* sales taxes on commodities. This places wedges between the prices paid by purchasers and the basic prices received by producers. The model recognizes margin commodities (e.g., retail trade and road transport) which are required for the movement of a commodities from producers to the purchasers. The costs of the margins are included in purchasers' prices of goods and services.

2.1.2   Demands for inputs to be used in the production of commodities

JorGE recognizes two broad categories of inputs: intermediate inputs and primary factors. Firms are assumed to choose the mix of inputs that minimises the costs of production for their levels of output. They are constrained in their choices by a three-level nested production technology. At the first level, intermediate-input bundles and a primary-factor bundle are used in fixed proportions to output.[10] These bundles are formed at the second level. Intermediate-input bundles are combinations of domestic goods and goods imported from overseas. The primary-factor bundle is a combination of labour, capital and land. At the third level, the input of labour is formed as a combination of inputs from nine occupational categories.

2.1.3   Domestic final demand: household, investment and government

A single representative household buys bundles of goods to maximise a utility function subject to an expenditure constraint. The bundles are combinations of imported and domestic goods. A consumption function is usually used to determine aggregate household expenditure as a function of household disposable income.

Capital creators for each industry combine inputs to form units of capital. In choosing these inputs, they minimise costs subject to a technology similar to that used for current production, with the main difference being that they do not use primary factors directly.

The national government demand commodities. In JorGE, there are several ways of handling these government demands, including: (i) by a rule such as moving government expenditures with aggregate household expenditure, domestic absorption or GDP; or (ii) as an instrument to accommodate an exogenously determined target such as a required level of government budget deficit.

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[10] A miscellaneous input category, *Other costs*, is also included and required in fixed proportion to output. In the current database, other costs are set with zero production but can be triggered in the future.

2.1.4   Foreign demand (international exports)

JorGE assumes that each export-oriented sector faces its own downward-sloping foreign demand curve. Thus, a shock that reduces the unit costs of an export sector will increase the quantity exported, but reduce the foreign-currency price. By assuming that the foreign demand schedules are specific to product, the model allows for differential movements in foreign-currency prices received by domestic producers.

2.1.5   Physical capital accumulation

Investment undertaken in year *t* is assumed to become operational at the start of year *t*+1. Under this assumption, capital in industry *i* accumulates according to:

$$K_i(t+1) = (1 - DEP_i) \times K_i(t) + Y_i(t) \tag{1}$$

where:

$K_i(t)$ is the quantity of capital available in industry *i* at the start of year *t*;

$Y_i(t)$ is the quantity of new capital created in industry *i* during year *t*; and

DEP_i is the rate of depreciation for industry *i*.

Given a starting value for capital in *t*=0, and with a mechanism for explaining investment, equation (1) traces out the time paths of industries' capital stocks. The explanation of investment for the is based on a non-linear positive relationship between investment and expected rate of return. It is assumed that *t* investors take account only of current rentals and asset prices when forming expectations about rates of return (static expectations).

2.1.6   Lagged adjustment process in the labour market

JorGE models the labour market where wages are sticky in the short run and flexible in the long run. Thus, it is assumed that if employment deviates from the baseline level, then the deviation between years in the real wage will move from its baseline level. Typically, a positive (negative) labour market outcome manifests in the short run as an increase (decrease) in employment away from the baseline, while real wages remain sluggish. In the long run, positive (negative) outcome manifests as an increase (decrease) in the real wage away from the baseline while employment moves towards baseline.

2.2   Energy-related enhancements

In this sub-section, the key enhancements of JorGE to facilitate the simulations in this study are described. These are:

- quantity-specific carbon taxes or prices;
- inter-fuel substitution in the generation of electricity;
- a new treatment of demand and supply for different types of private passenger motor vehicles;
- allowance for substitution between public and private passenger transport; and
- an accounting module for energy and greenhouse-gas emissions that covers each emitting agent and source of emissions recognized in the model.

2.2.1 Carbon taxes and prices (not implemented for this project)

JorGE treats a carbon tax or an Emissions Trading Scheme (ETS) price on emissions as a specific tax on emissions of CO2-e. On emissions from fuel combustion, the tax is imposed as a sales tax on the use of fuel. On *Activity* emissions, it is imposed as a tax on production of the relevant industries.

In JorGE, sales taxes are generally assumed ad *valorem*, levied on the basic value of the underlying flow. Carbon taxes, however, are specific, levied on the quantity (CO2-e) emitted by the associated flow. Hence, equations are required to translate a carbon tax, expressed per unit of C02-e, into *ad valorem* taxes, expressed as percentages of basic values. The C02-e taxes are specific but coupled to a single price index (typically the national price of consumption) to preserve the nominal homogeneity of the system.

2.2.2 Inter-fuel substitution in generation of electricity

For most industries, there is no price-responsive substitution between composite units of commodities, or between composite commodities and the composite of primary factors.[11] The one exception is electricity, where inter-fuel substitution is allowed using the "technology bundle" approach.

As noted at the start of Section 2, electricity-generating industries are distinguished based on the type of fuel used. There is also an end-use supplier (or distributor). The end-use supplier can substitute between the different generation technologies in response to changes in generation costs. Such substitution is price-induced, with the elasticity of substitution between the technologies typically set at around 5.

Final demand for electricity is determined within the CGE-core of the model in the same manner as demand for all other goods and services. That demand is satisfied entirely by supply from the single distributor.

2.2.3 Enhanced treatment of demand and supply for different types of private passenger motor vehicles

Without enhancement, the model would have only one type of private passenger vehicle sold to households and businesses, with demand for vehicle services being determined *separately* from the demand for fuel (petroleum and electricity).[12] Thus, vehicle usage might move in a different direction to fuel used. This is inadequate, especially for the purposes of this project.

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[11] Composite commodities are aggregations of domestic and imported products with the same name. The composite of primary factors is an aggregation of labour, capital and land inputs.

[12] The input/output statistics to which JorGE is initially calibrated has a single vehicle industry called Motor Vehicle and Parts (MVPs). The product of this industry (along with imported MVPs) is sold to other industries as an inputs to current production and investment, and to the household. Two other industries produce electricity and petroleum. Electricity and petroleum (domestically produced and imported) are sold to industries as inputs to current production, and to the household.
In the enhanced version of the model, for the household we assume that all of the petroleum, a very small portion of electricity and all of the MVPs initially purchased are for passenger transport. For industries other than the freight and public transport sectors, we assume that a proportion of petroleum, a negligible (but non-zero) amount of electricity and all of the MVPs initially purchased are for passenger transport. We assume that the remaining petroleum initially purchased is for the running of light and heavy commercial vehicles, or for use in stationary motors and large relatively immobile agricultural, mining and construction equipment. More detail of these assumptions and associated changes to the model's input/output database is given in a separate

In the enhanced version of the model we distinguish three vehicle types used for private passenger transport: BEVs, Hybrid vehicles and ICVs. All are imported. These vehicles are purchased *initially* by three new *dummy* transport service sectors:

- the BEV services sector uses capital (the stock of BEVs), electricity and inputs required for the day-to-day running of electric vehicles (such as repairs and servicing);
- the Hybrid services industry uses inputs of capital (the stock of Hybrid vehicles), petroleum and electricity, and other inputs required for day-to-day operation; and
- the ICV services sector uses capital (the stock of passenger ICVs), petroleum and other day-to-day inputs.

For each industry, capital (i.e., vehicle stock) accumulates in line with new investment (the purchase of used and unused vehicles, nationally from overseas). The three industries sell directly to the representative household and to businesses that use *passenger* transport services. Note that we do not distinguish different vehicle types within each of the three broad categories. In other words, there is no explicit modelling of age, fuel efficiency or quality profiles. Depreciation rates are set such that vehicles are replaced on average every ten years. Finally, note that the enhanced treatment of vehicles applies only to the use by businesses and the household of *passenger* vehicles. It does not apply to the use of commercial vehicles (light and heavy) by businesses.

With the three new passenger-vehicle service industries in place, the household and businesses no longer *directly* purchase passenger vehicles, passenger-vehicle fuel and passenger-vehicle service inputs, etc. Instead, they purchase vehicle services that cover the full cost of using each passenger-vehicle type.

Including these new industries improves the model's treatment of price-induced energy substitution for passenger vehicle use, and its treatment of the relationship between energy (electricity and petroleum) and vehicles. For example, without these new industries, if the price of petroleum were to fall relative to the price of electricity, then petroleum would be simply substituted for other commodities, including cars. Nevertheless, with the new industries in place, a change in the price of petroleum induces substitution only through its effect on the price of Hybrid-vehicle and ICV services. If the change in petroleum price reduces the price of ICV and Hybrid services, then these services (including the associated capital and energy) will be substituted for BEV services.

We finish this sub-section with a stylised demand equation that explains to a good approximation demand for private vehicle services of each type in the enhanced model. The equation will prove useful later when understanding the baseline and policy deviations.

Let $xveh_i$ be the percentage change in use of private passenger vehicle service type i (i = BEV, Hybrid vehicle, ICV), and $xvehave$ be the percentage change in use of private passenger vehicle services generally. Then, to a good approximation, the percentage change in ratio of vehicle service type i to total private passenger vehicle services is given by:

$$xveh_i - xvehave = -\sigma(pveh_i - pvehave) + aveh_i \qquad \text{(i = BEV, Hybrid, ICV)   (2),}$$

where:

σ is the elasticity of substitution across vehicle service types (set to a high value of 12);

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document explaining fully JorGE's database. This is available on request by writing to Louise Roos at the address given at the start of this document.

$pveh_i$ is the percentage change in price of vehicle service type i;

$pvehave$ is the percentage change in average price of vehicle services; and

$aveh_i$ is an exogenously given taste change term.

On the right hand side of (2) is the percentage change in price of vehicle service type i relative to the average price of vehicle services with an allowance for changes in taste. In this context, taste can be considered as any factor that leads to a change in the share of vehicle type i other than a change in relative price. All else unchanged, an increase in $aveh_i$ increases the share of vehicle type i in total vehicle services used. Note that the percentage changes in price are determined elsewhere in the model through the interaction of supply and demand and the taste variables are generally exogenous. The change in overall use of private passenger vehicle services is determined by a separate decision explained in Section 2.2.4.

The percentage change in average price is a share weighted sum of percentage changes in price of each vehicle type, i.e.,

$$pvehave = \sum_i Sveh_i \times pveh_i \tag{3},$$

where

$Sveh_i$ is the share of vehicle type i in the total purchase cost of private vehicle services.

Provided the taste changes are cost neutral, i.e.,

$$\sum_i Sveh_i \times aveh_i = 0$$

then equations (2) and (3) imply that the percentage change in quantity of vehicle services is a weighted sum of percentage changes in quantity of each vehicle type, i.e.,

$$xvehave = \sum_i Sveh_i \times xveh_i \tag{4}.$$

2.2.4   Allowing for substitution between public and private passenger transport

In the enhanced version of JorGE, households and businesses not only decide how much of each type of private passenger vehicle service to use (Section 2.2.3), they also decide the overall mix of private and public passenger transport services to buy.[13] This public/private transport decision is made separately from the decision about which type of private vehicle service to use.

We assume for each user of public and private passenger transport services that their optimal private/public is a function of their overall need for road passenger transport services with allowance for changes in the relative price of public to private transport. If the price of public transport rises relative to the price of private transport (a weighted average of the price of BEV, Hybrid vehicle and ICV services), then the user will reduce the share of public transport in its overall use of road passenger transport services. Note that for each user, the overall need for road passenger services (private and

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[13] For the purpose of this study, public transport (also known as public transportation, public transit, mass transit, or simply transit) is defined as a system of transport for passengers by group travel systems available for use by the public. Unlike private transport, public transport is typically managed on a schedule, operated on established routes, and with a charged fee for each trip.

public) is determined elsewhere. For the household, the overall need for road passenger services is determined as part of its general budget allocation decision. For industries (businesses), the overall amount of road transport services used is a fixed proportion of their level of production.

In the enhanced version of JorGE there are seven transport service industries, whereas previously there were four. The seven industries are listed below, with the first three being unaffected by the enhancements documented here and in Section 2.2.3).

1. Road freight (used as a margin to facilitate the movements of goods and services by road) – provides commercial transport services only;
2. Air and rail freight (used as a margin to facilitate the movement of goods and services by air and rail) – provides commercial transport services only;
3. Air and rail passenger transport (sells air and rail transport services only);
4. Public passenger transport;
5. Private BEVs (sells private passenger transport using BEVs to households and businesses);
6. Private Hybrid vehicles (sells private passenger transport services using Hybrid vehicles to households and businesses); and
7. Private ICVs (sells private passenger transport using ICVs to households and businesses).

2.2.5 Energy and emissions accounting

JorGE tracks emissions of greenhouse gases according to emitting agent (104 industries and the household sector) and emitting activity (4). The first three emitting activities are the burning of fuels (coal, natural gas and petroleum products). A residual category, named *Activity*, covers non-combustion emissions such as emissions from mines and agricultural emissions not arising from fuel burning. *Activity* emissions are assumed to be proportional to the level of activity in the relevant industries (animal-related agriculture, gas mining, cement manufacture, etc.).

The resulting 104×4 array of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon-dioxide equivalents, CO2-e. Table 1a summarizes JorGE's emission data for 2016 in terms of broad emission categories of the type used for reporting under the Kyoto protocol. Table 1b provides more detail, with a breakdown of emissions across the four sources for 21 aggregated industry sectors + residential, with some additional detail for specific electricity and transport sectors.[14]

According to Table 1a, Jordan released around 31 Mt of CO2-e emissions in 2016. The largest emitting category was the energy industry sector (mainly electricity generation) with 28.8 per cent of the total, followed closely by transport which contributed 28.2 per cent. The rest, about 45 per cent, came from non-combustion sources, principally industry processes and waste disposal.

The data in Table 1b was assembled, in part, by spreading the information in Table 1a across user and source in line with basic value data from the model's 2016 input/output data base. Thus, for example, the control total for Transport emissions shown in Table 1a was allocated to the transport-related

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[14] We show emissions for the two main components of the electricity sector, namely fossil fuel generation and renewable generation. Excluded from the more detailed breakdown is emissions associated with transmission and distribution services.
We also provide more detail for the Transport services sector, focussing on emissions from industries that produce passenger services from private and public road transport. We do not show separately information for the other main components of the transport sector that produce freight services and rail and air services.

industries in line with their Input/output shares in petroleum use.[15] An explanation of the four road passenger transport industries distinguished in Table 1b is given in Sections 2.2.3 and 2.2.4. As shown in Table 1b, most emissions from the use of petroleum in transport is due to the use of ICVs for private passenger transport.[16] The remainder comes from the use of public transport, and from the use of road freight and air and rail services (not shown separately).

3   The Baseline

The baseline is the control projection against which policy scenarios are compared (see Section 4). For this project, considerable importance is placed on establishing a baseline with credible projections for electricity generation by technology type and for the use of vehicles for private passenger transport. There are two reasons for this. The first is that the effects of increasing the uptake of BEVs depends critically on the underlying level of baseline usage. The second is that acceptance of the policy modelling is reliant on the credibility of the baseline.

In building the baseline for this study, the simulation period was divided into two parts. The first, covering the years 2016 to 2021, should be viewed as the period where the database is updated to the most recent year. Considerable statistical information is available for this period. The second part, covering 2022 to 2050, incorporates forecasts mainly from the World Economic Outlook (IMF, 2022), along with assumptions for key variables such as productivity, changes in electricity generation shares and changes in the mix of private transport vehicles.

To accommodate the extraneous information supplied to the model, numerous naturally endogenous variables in the model are made exogenous.[17] To allow the naturally endogenous variables to be exogenous, an equal number of naturally exogenous variables are made endogenous. For example, to accommodate exogenous settings of the aggregate terms of trade, an all-commodity shift variable, naturally exogenous in the model but endogenous in the baseline simulation, imparts changes in the positions of foreign demand curves necessary to achieve the terms-of-trade target. Another example relates to Gross Domestic Product (GDP). In the baseline, real GDP (a naturally endogenous variable) is set exogenously by allowing economy-wide technology to adjust endogenously.

Subsections 3.1 to 3.5 contain baseline projections for macroeconomic variables, industry output, electricity generation, private and public road passenger transport use, and greenhouse gas emissions. Other results are available on request

3.1   Macroeconomic variables

Table 2 summarises the baseline projections for real GDP and its income and expenditure components, employment, population and other key macroeconomic variables. For 2016 to 2021, GDP data was

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[15] More details are available in a separate document explaining fully the model's database and its derivation.

[16] For the purposes of this paper, we do not distinguish between personal and business use of vehicle services. In the model and its database we do make such a distinctions, with industries (businesses) buying passenger vehicle services as well as the household.

[17] We use the term exogenous to mean user-determined. The term endogenous means model-determined. In each simulation, every variable is classified as either exogenous or endogenous, with the number of endogenous variables equal to the number of equations in the model. A feature of JorGE and all other models solved using the GEMPACK software is that users are allowed to choose which variables are exogenous and which are endogenous, provided that the choice is economically sensible.

sourced from the Department of Statistics on-line data facility (DOS, 2022a, 2022b). The data is also presented in the annual Statistical Yearbook.

Real GDP, employment and population

For 2022 to 2027, we adopt the GDP forecast from the World Economic Outlook (WEO) Database (IMF, 2022). From 2028 onwards, no forecast data are available and therefore we assume a constant growth rate in line with the medium trend shown in the WEO data. As shown in the final column of Table 2, across the entire period (2016 to 2050), we project GDP growth on average of 3.0 per cent per annum

Employment data for 2016 to 2020 was sourced from the Department of Statistics on-line data facility (DOS, 2022b). From 2021 onwards, no forecast data are available. For the forecast years, we impose the historical average growth rate between 2012 and 2019. Population data was sourced from the Department of Statistics (DOS, 2016; 2020b). For the period to 2050, we adopt the medium population projection. To avoid any large differences in growth rates, we impose an annual average growth rate in population growth between 2016 and 2050. As shown in the final column of Table 2, these assumptions imply average annual growth in employment (persons) of 1.9 per cent for the full projection period, which is in line with projected growth in population and the economy's labour force. It follows that in the baseline we are projecting little change in Jordan's unemployment rate between now and 2050.

Capital, economy-wide productivity (TFP) and the real wage rate

Growth in the economy's capital stock is determined largely by initial conditions for the ratio of investment to capital and by the economy's ongoing needs for new and replacement capital. With real GDP growth exogenously imposed at 3.0 per cent per annum, there is considerable scope for capital to grow. Accordingly, to our modelling, over the entire period capital growth is likely to average around 2.6 per cent per annum. With employment, growth of 1.9 per cent and capital growth of 2.6 per cent, all factor productivity (TFP) must improve to achieve 3.0 per cent GDP growth. As shown in row 5 of Table 2, productivity is expected to grow at an average annual rate of 0.6 per cent, which is roughly in line with historical norms for countries at the same stage of development as Jordan.

Growth in the real wage rate (line 6) is relatively strong at 1.6 per cent per year across the entire period. This is allowed for, in part, by growth in productivity which in our modelling is biased towards labour. Another positive factor for wages is the projected shift in the economy toward industries (particularly in the service sectors) in which wage rates are relatively high.

As a final point, note that the average annual growth rates reported in Table 2 for the income components of real GDP mask considerable year-to-year variations in the early years. These can be seen in Figure 1 which shows the annual pattern of growth in the different components. While the latter years are bland, the early years show considerable disruption largely due to the COVID pandemic and associated containment policies in Jordan and elsewhere.

Expenditure components of real GDP

In its standard configuration, the model assumes that private consumption is determined via a function that links consumption spending to household disposable income (HDI), with a fixed coefficient of proportionality – the Average Propensity to Consume (APC). Through the forecast period, we assume that the APC remains unchanged allowing the model to determine the growth in private consumption. Accordingly, as shown in row 7 of Table 2, growth in private consumption follows closely growth in real GDP – a good proxy for real income accruing to Jordanian citizens.

The model does not have a formal theory that explains changes in government consumption. Typically, the division of consumption into private and public is governed by an assumption of a constant ratio

of real public to real private consumption. Thus, in the baseline growth in public consumption matches growth in private consumption (compare rows 7 and 8 in Table 2).

Row 9 in Table 2 shows real investment growth of 3.0 per cent per annum on average across the entire period. This is slightly higher than the growth rate of capital, reflecting, in part, replacement needs for retired capital. Note that in each year, the model determines industry-specific investment based on initial investment to capital ratios and a mechanism that allows those ratios to change in line with changes in actual rates of return. However, there are exceptions for some very small industries, for which the model projects very large and unrealistic growth/falls in investment. For these industries, we simply assume that investment is unchanged through time.[18]

In the forecast simulation, we allow the model to determine the growth in exports and imports. In aggregate terms, with real GDP (Y) assumed to grow at 3.0 per cent, and growth in real Gross National Expenditure ($C + I + G$) at 2.9 per cent per year, there is little scope for the net volume of trade ($X - M$) to change.[19] Import growth is projected to be 2.5 per cent per annum. This is a little below growth in final domestic demand (real Gross National Expenditure), reflecting in part compositional changes in the economy against import-intensive forms of expenditure. With ($X - M$) largely unchanged, and with imports growing at 2.6 per cent, exports are forced to follow a similar path, with projected average annual growth of 2.5 per cent.

Figure 2 shows the annual pattern of growth in the different expenditure-side components of real GDP. Similar to the income-side pattern shown in Figure 1, the latter years are bland, but the early years show considerable disruption largely due to the COVID pandemic and associated containment measures.

Other macroeconomic variables
In the absence of expansion in foreign demand for Jordanian products, export growth would need to be accompanied by a decline in export price to encourage foreign purchases of Jordanian goods and services. In the baseline, we assume that as Jordan expands, foreign markets for Jordanian commodities will be found such that there is no change required in the price of exports and hence no change in Jordan's terms of trade (row 13 of Table 2).

The real exchange rate is the mechanism *via* which the economy achieves the required growth in exports of 2.6 per cent per annum. As shown in Table 2, across the entire projection period little change is required in the real exchange rate. Note that real appreciation signals a deterioration in the competitiveness of Jordanian producers versus foreign producers. Real depreciation signals an improvement in competitiveness.

The final variable in Table 2 is total greenhouse gas emissions. More detail is given in Section 3.5, but it is relevant to note here that the economy is projected to reduce its greenhouse intensity, measured as emissions per unit of GDP. With GDP growth of 3.0 per cent, and emissions growth of 0.9 per cent, we are projecting a fall in emissions intensity at an average rate of 2.1 per cent. As discussed below,

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[18] An example of a very small industry is the Stone and Sand sector. This sector does not produce any output and imports the entire commodity for domestic use. Stone and Sand imports accounts for less than 0.008 per cent of total imports.

[19] Recall the basic real GDP definition: real GDP (Y) = real private consumption (C) + real public consumption (G) + real investment (I) + the net volume of trade ($X - M$).

much of this is due to baseline trends towards use of renewable generation for electricity and towards BEVs for passenger transport.

3.2   Industry production

Table 3 shows projected growth rates in production of aggregated industry sectors, with additional detail for electricity and transport.[20] As with the macroeconomic variables, we provide six columns of numbers, with the final column showing in average annual percentage terms total growth across the period 2016 to 2050.

For the period 2016 to 2021, we adopt for the major industries annual percentage growth rates in economic activity based on constant-price activity data in DOS (2022a). For the years after 2021, with a few exceptions the growth rates are model determined. The exceptions relate to fossil fuel and renewable generation, which are part of aggregated sector 4, and to the private and public road passenger transport sectors, which are part of aggregated sector 9. The exogenously imposed settings for these industries are discussed in Sections 3.3 and 3.4. In the remainder of this section, we discuss the baseline growth projections for industries not exogenously tied down.

The aggregated sector with the best overall growth prospects is Sector 11: Financial and insurance services, with projected average annual growth of 3.9 per cent, compared to overall real GDP growth of 3.0 per cent. This sector benefits from strong initial capital growth, reflecting historical shifts in industry technologies and household tastes towards the provision of financial services. In our baseline modelling, this strong growth rate continues through the forecast period, facilitated by favourable price substitution particularly in the household sector.

The aggregated sector with the poorest growth prospects is Sector 2: Mining. This small sector largely provides material used by the construction industries (gravel, etc.). While growth in construction activity (Sector 5) is relatively strong, growth in demand for mining products is weak because much of the construction spending is on building which is less intensive in its use of mining material compared to, say, civil construction projects. Mining also suffers from a lack of growth in its natural resource – in our baseline we assume no new mining discoveries.

Agriculture (Sector 1) also has comparatively poor growth prospects, partly due to no growth in arable land and partly due to comparatively weak growth in household demand which increasingly favours imported food and drink products.

Sector 18 produces arts and recreation services which are sold equally to local residents and foreign tourists. Its overall growth of 1.9 per cent per annum is relatively poor. In this case, the main reason is COVID lockdown which caused the sector to contract in the first part of the projection period. For the years thereafter growth returns to normal rates, but the level of activity remains subdued compared to the levels that would have been in place without COVID lockdown.

Sector 12: Rental is another sector with relatively poor growth prospects, with average annual growth of 1.5 per cent over the full period. This sector comprises a single industry which leases and rents passenger vehicles to businesses and individuals. It suffers in the early years from COVID containment policies that severely limit transportation use.

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[20] The model formally recognises 104 industries, including the dummy transport service industries described in Section 2.2.3. The sectors shown in Table 3 are aggregations of the 104. For example, aggregated sector 1 – Agriculture, forestry and fishing is a composite of the 11 agricultural, forestry and fishing industries in the 104 classification.

Prospects for the remaining industries are close to average, especially in the later years of the projection period. This signals that in areas outside of electricity and passenger transport services the baseline story is of balanced growth with no industry in decline and most industries growing at around the economy-wide average.

3.3 Electricity generation

We impose what we regard as a plausible view on the generation of electricity from fossil fuels and renewable sources (hydro, solar and wind). Based on expert knowledge and suggestions by the expert group, we assume continuation of the current trend towards renewables. In 2021, renewable energy accounted for 27 per cent of Jordan's generation, up from less than ten per cent a decade earlier. Continuation of this trend means that 45 per cent of electricity will be generated from renewable sources in 2030 and 70 per cent in 2050.

Table 3 and Figure 3 provide further numerical detail. On average over the period 2016–2050, fossil-fuel (natural gas) generation falls at an average rate of 2.1 per cent, while renewable generation increases at an average rate of 5.1 per cent. Fossil-fuel generation remains the main source of electricity through to the middle of 2035, at which point the level of renewable generation becomes the dominant source of power.

The increase in renewable generation relative to fossil-fuel generation has two important implications for the uptake of BEVs in the baseline (see Section 3.4) and for the increased uptake of BEVs in the first policy simulation (Section 4). First, it justifies policies to encourage electric vehicle use because of their environmental benefits. If electricity vehicles were not free to use renewable power, then it is unclear whether they have any environmental benefit, at least in terms of lowering greenhouse gas emissions.

The second implication of increased renewable generation is that it forces up the baseline price of electricity, and hence the running cost of BEVs. While it is true that the cost of renewable generation has declined significantly over the past ten years or so, it is also true that more renewables has led to increases in the retail electricity price in most countries including Jordan.[21] The retail prices paid by final customers reflect the full cost of delivering electricity. Generation, though the largest component, accounts for less than 50 per cent of the total cost of electricity. The other main costs affected by renewables integration are transmission and distribution costs to take electricity from many different locations (where wind and solar are generated) to its point of use, reliability costs to maintain stable voltage and increased maintenance needed to keep the system continuously running with many renewable sources of supply entering and leaving the system.

We introduce this price paradox into the baseline by assuming that the real retail price of electricity increases in line with the increase in renewable share.[22] More specifically, based on subjective judgement used in Adams (2021), we assume that for every 1 percentage point increase in renewable generation share, there is a 0.25 per cent increase in the real retail price of electricity. Figure 4 shows the index-level of the real retail electricity price through the projection period. For later convenience, we also show the baseline projection for the real price of petroleum products. As shown, the real retail

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[21] Most recent analyses in the US (and Australia) show that over the last decade the *levelised* cost per unit of electricity from new on- and off-shore wind and solar plants has dropped about 70 and 90 percent, respectively (see for example Graham *et al.* (2020). Indeed, according to the World Bank in many places, the cost of new renewable generation is at or below that of existing conventional sources like natural gas, coal and nuclear.

[22] By real retail price, we mean the price relative to the CPI.

price of electricity at the end of the period is around 40 per cent higher than at the start of the period. By contrast, the real price of petroleum products remains virtually unchanged.

3.4   Private and public road passenger transport use

In the standard set up of the model, the shares of private and public passenger vehicles and the shares of each type of private passenger vehicle are determined endogenously. In the baseline, we impose on the model views on each of these shares used by households and industries. To accommodate these views, we allow household preferences and industry technologies to adjust endogenously.

Public and private road passenger transport services

In the baseline we impose a view on the share of public transport used by households relative to the use of private vehicles. No data are available on how the share of public transport use will change over time. However, based on expert knowledge and suggestions by the expert group, we assume that the share of public transport increases over time, but at a slow rate. In 2021, the share of public transport in total transport use is 14 per cent. This share progressively increases such that by 2050 20 per cent of the economy's requirement for passenger transport services is provided by public transportation.

Figure 5 shows the baseline shares of private and public transport use. As indicated above, the share of public transport is assumed to rise slowly to reach 20 per cent by 2050. These changes are imposed *via* a mix of endogenous changes in technology (for industries) and tastes (for the household).

Shares of private passenger vehicle type in overall private transport use

It is clear based on current manufacturer plans and Jordan's commitment to environmentally sustainable growth that the share of BEVs in the country's stock of private passenger vehicles will increase from now on. However, it is unclear how this increase will evolve. Based on the views and advice from various Ministries, the World Bank and discussions with the expert group, we impose on our baseline the following view.

For 2016 to 2021, we use data on the observed number of ICV and BEV and hybrid vehicles given in Ministry of Transport (2022). The data suggests that (for the household and businesses):

1.   the share of ICV use falls from approximately 90 per cent in 2016 to 80 percent in 2021;

2.   the share of hybrid vehicles increases from 10.5 per cent in 2016 to 18 per cent in 2021; and

3.   the share of EV increases from a negligible level in 2016 to 2 per cent in 2021.

From 2022 to 2050, we impose the following assumptions:

1.   The share of ICV used by households and businesses continues to fall at a rate which implies that by 2050, the share of ICV in total private vehicle use is 20 per cent. This implies an annual fall in ICV of 4.6 per cent.

2.   The share of BEV progressively increases over time reaching 60 per cent by 2050.

3.   The share of hybrid vehicles used as private vehicles increases over time and reaches a maximum point in the late 2030s. Thereafter the share falls as BEVs become predominant in the market.

Table 3 shows baseline growth in BEV passenger services of nearly 18 per cent per year on average between 2016 and 2050. The use of hybrid vehicle services is projected to grow by 4.5 per cent, with all of the growth occurring before 2040. From 2040 onwards, the use of Hybrid services is projected to fall at an average annual rate of 1.4 per cent. Consistent with the increases overall in BEV and Hybrid

services, personal use of ICV passenger services is forecast to fall, but not in every year. Between 2021 and 2040, little change is expected in the use of ICVs, with a decline in use after 2040.

Figure 6 shows the changes in the shares of BEV, Hybrid vehicle and ICV vehicle services in total private passenger vehicle services imposed in the baseline. The ICV share is projected to be in constant decline, from an initial level of around 92 per cent to 30 per cent by 2050. In contrast, the BEV share rises from a negligible level in 2016 to 60 per cent at the end of the period. The share of Hybrid vehicle services rises initially and peaks in 2035 at just over 18 per cent. Thereafter it declines to 10 per cent by 2050.

Equation (2) sheds some light on the forces necessary to achieve the assumed changes in vehicle shares. Recall that the change in share has two parts: that due to changes in the relative prices; and that due to exogenous shifts in taste and/or technology.

In terms of price, Figure 7 shows in index level form baseline projections for the real prices of each type of private passenger vehicle services. Perhaps surprisingly, there is little change in relative prices over the projection period, with the price of each type of vehicle service falling at roughly the same rate. Due to the increase in electricity price relative to petroleum price (Figure 6), we might have expected the price of BEVs to rise relative to the price of ICVs. However, the price of fuel is only part of the story. For BEV services, electricity makes up around 12 per cent of the annualised running cost, with 80 per cent due to capital cost. For ICV services, the cost of petroleum makes up around 30 per cent of total annual cost, with the cost of capital making up 40 per cent.[23] So what keeps the prices of vehicle services together? Ultimately, it is market competition. In our modelling, we assume a high substitution elasticity in demand for the different types of vehicle services. Thus, producers of the different vehicle services are forced to adjust their profit margins to keep output price more-or-less in line with those of their competitors.

If there is little movement in relative prices, then the taste variable in equation (2) does most of the adjustment to accommodate the exogenously imposed changes in vehicle shares. At this point we can only speculate on the non-price factors that might lead to the rapid adoption of BEVs assumed for the baseline. These factors are likely include some of the following.

- Reductions in *range anxiety.* One of the more common reasons drivers avoid BEVs is the fear that the battery will run out of charge before reaching their destination.
- Increases in the number of publically available charging stations. This is an important factor in countries such as Australia where long-distance driving is common.
- Reductions in charging time, fear of too few charging stations, long charge times, etc.
- Improved range of models and car types as global manufactures shift to BEV production.
- Reductions in upfront vehicle costs. In Jordan, the share of Hybrids in the stock of private passenger vehicles is high relative to world standards. Most of these vehicles are used Chinese made cars, which are available at a price similar to similar ICVs. However, more high-end new BEVs from Japan and Europe are still relatively high. Over time, not only will more such vehicles be available, but also their cost will be fall into line with similar ICV prices.

3.5   Greenhouse gas emissions

Figure 8 shows the level of greenhouse emissions expressed as kt of CO_2-e in five-year intervals in the baseline. For each of the years, we show a total with a breakdown into the key Kyoto categories. Noted

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[23] Currently, to the best of our knowledge in Jordan he cost of the electricity required to charge an EV is around 40% less than the cost to use petrol for a similar sized vehicle driving the same distance.

already is the relatively slow growth in overall emissions (see the final row of Table 2). In 2016, emissions total around 31 Mt (see Table 1). This falls to 28 Mt in 2020, before slowly rising to reach 41.7 Mt in 2050. From 2020 onwards, emissions in all categories continue to grow, but general improvements in energy efficiency, a shift towards renewable generation and increased use of BEVs means that the rate of growth across the full period in each category is weak.

4 Policy Effects

JorGE is a versatile and flexible comprehensive analytical framework that explicitly traces each variable through time at annual intervals. As illustrated in Figure 9, policy analysis using JorGE requires two simulations. The first is the *baseline* forecast (see Section 3). This simulation models the growth of the economy over time in the absence of the policy change under consideration. The second simulation is the *policy* simulation. This simulation generates a second forecast that incorporates all of the exogenous features of the baseline forecast, plus policy-related shocks reflecting the details of the policy under consideration.

The impacts of a policy are typically reported through changes (percentage or absolute) away from the baseline forecast. These changes measure the gap (C-B) shown in Figure 9 for *each* year of the projection period.

4.1 Policy 1: Increased uptake of BEVs

4.1.1 Simulation design

Figure 10a shows for the years 2023 to 2050 the shares of private passenger vehicle services provided by each vehicle type in the baseline and policy simulations. Dashed lines show baseline shares (see also Figure 6). As discussed in Section 3.4, in the baseline the BEV share rises to 60 per cent by 2050. Over the same period, the hybrid share rises and then falls to be around 10 per cent in 2050, while the ICV share declines progressively to around 30 per cent.

In the policy simulation, we ask of the model 'what are the economic implications of increasing the BEV share to 100 per cent by 2050?' The solid blue line in Figure 10a shows the specific adjustment path. As indicated by the shape of the curve, we think that annual increases in BEV share will slow as the level of the share moves to 100. This reflects the idea that some vehicle owners will be more reluctant to change vehicle type than others will and so going from 90 per cent share to 100 per cent will take longer than going from 60 to 70 per cent. Over the period, we assume that the Hybrid and ICV shares are forced to fall to zero as shown by the red and green solid lines. The annual percentage point increase in BEV share in the policy simulation compared to baseline simulation is shown in Figure 10b.

The purpose of this policy simulation is to shed light on the economic costs and benefits of increasing BEV uptake beyond baseline levels. A 40-percentage point improvement in BEV penetration represents the maximum additional uptake possible in the context of our baseline. Most policies will seek to achieve something less. Though JorGE is non-linear, the results for a 40-percentage point increase will at least be qualitatively suggestive of outcomes for a less ambitious target.

For our modelling, we choose not to speculate on what package of policies will achieve the outcome shown in Figure 10b. Most likely, it would be a mix of market and non-market measures including subsidies and taxes, regulation and moral suasion. We simply assume that the targeted increase in BEV's is achieved *via* a government subsidy on BEV services which is paid for ultimately by the

household.[24] Subsidies and taxes in themselves have an economic cost due to their adverse impact on allocative efficiency. Our modelling takes account of this cost, and so our analysis might be regarded as conservative, with both the costs and benefits of increasing BEV numbers relative to baseline being considered.

The following assumptions are made for key aspects of the macro economy in the policy simulation.

Labour markets

At the national level, lagged adjustment of the real-wage rate to changes in employment is assumed. Increasing BEV use can cause national employment to deviate from its baseline value initially, but thereafter, real wage adjustment steadily eliminates the short-run employment consequences. In the end, the effects of using more BEVs are realised almost entirely as a change in the national real wage rate, rather than as a change in national employment.

This labour-market assumption reflects the idea that, in the long run, national employment is determined by demographic factors, which are unaffected by anything to do with the amount or type of passenger motor vehicles.

Private consumption and investment

Private consumption expenditure is determined by a consumption function that links nominal consumption to household disposable income (HDI). HDI includes the lump-sum payments from or to the government necessary to maintain a fixed budget balance. This includes annual payments to the government to fund the subsidy on BEV passenger vehicle services.

In both policy simulations, the average propensity to consume (APC – see Section 3.1) is an endogenous variable that moves to ensure that the balance on current account in the balance of payments as a share of GDP remains at its baseline level. Thus, any change in aggregate investment brought about by the shift towards BEV services is accommodated by a change in domestic saving, leaving Jordan's call on foreign savings unchanged.

Investment in all but a few industries is allowed to deviate from its baseline value in line with deviations in expected rates of return on the industries' capital stocks. In the policy scenarios, JorGE allows for short-run divergences in rates of return from their baseline levels. These cause divergences in investment and hence capital stocks that gradually erode the initial divergences in rates of return. Provided there are no further shocks, rates of return revert to their baseline levels in the long run.

The most important exceptions to this industry investment rule is for industries producing vehicle services in the increased BEV uptake simulation. For stability purposes, we adopt a simple rule that allows investment to increase by half the percentage increase in capital. Thus if the model requires, say, BEV services to increase by 1 per cent, then investment in that industry will go up by 0.5 per cent.

Government consumption and fiscal balances

JorGE contains no theory to explain changes in real public consumption. In these simulations, public consumption is simply indexed to private consumption. The government's budget balance is fixed at baseline values. Endogenous movements in lump-sum payments to households accommodate budget-balance constraints.

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[24] Most policies, market or non-market, can be approximated via the introduction of a tax or subsidy for the purposes of economic analysis. Thus, our modelling of a simple subsidy on BEVs, though not specific to a prescribed set of government decisions, will show results indicative of analyses of policies specified in detail.

JorGE contains many variables to allow for shifts in technology and household preferences. In the policy scenario, most of these variables are exogenous and have the same values as in the baseline.

The rest of this section contains a discussion of deviations from baseline values in the increased BEV simulation. Macroeconomic impacts are dealt with first, followed by results for industry output and variables associated with energy usage and greenhouse gas emissions.

4.1.2   Results

Figure 11 shows the value of the subsidy required to produce the increased uptake of BEVs shown in Figure 10a, expressed as a percentage share of GDP. The subsidy progressively rises, reaching around 0.9 per cent of GDP in 2043. Thereafter, growth in the subsidy falls to a rate similar to the growth rate of GDP. The deceleration is due to the task of increasing the BEV share relative to baseline being a little easier. As can be seen by comparing the solid blue line with the dashed blue line in Figure 10a, *relative to its baseline value*, the BEV share in the policy scenario reaches a peak in 2043, before slowly declining through the remaining years to 2050.

Macroeconomic variables

The shift towards BEV services and away from other vehicle services has the following twin effects that requires significant macroeconomic adjustment.

(1) *Economy-wide capital deepening*. BEV services are capital intensive relative to the vehicle services that they replace. Hence, all else unchanged, the shift towards BCV services leads to economy-wide capital deepening.

(2) *Reduced allocative efficiency of factor of production.* The introduction of a large subsidy on the flow of BEV services has a negative impact on real GDP because it lowers real GDP per unit of labour and capital input.

The macroeconomic adjustment arising from these effects, and related but less important effects, are explained below. A series of charts provide time profiles of the deviations for key variables. In the discussion below, which focuses mainly on the final year (2050), italicized headings outline the main features of the results.

Increasing the uptake of BEV services leads to an economy-wide increase in capital

The explanation of macro effects begins with the impacts on factor inputs – capital and labour. Figure 12 shows percentage deviations in the national capital stock, employment and the real wage rate. The real wage is defined as the ratio of the nominal wage rate to the price of consumption.

As noted above and discussed earlier, BEV services are capital intensive relative to Hybrid vehicle and ICV services. Nearly 80 per cent of the cost of BEV services is the cost of capital, while the capital costs for Hybrids and ICVs are around 40 per cent of their annual cost. It follows that when BEV services replace other vehicle services, this will cause the use of capital in the economy to rise.

According to our projections shown in Figure 12, increasing the uptake of BEV services leads to an increase in capital throughout the projection period. The increase peaks in 2043, with capital in that year almost 9 per cent above its baseline level. Thereafter, the increase falls a little such that by 2050 capital is 7.8 per cent above its baseline value.

The increase in capital leads to capital deepening – a rise in capital per worker in the economy, and is accompanied by an increase in the real wage rate.

Despite increased capital, there is comparatively little change in persons and hours employed. As shown in Figure 12, initially there is some upward movement in employment such that, by around 2035, employment has expanded by 0.7 per cent compared to its baseline value. After 2035, however, the number of jobs created progressively returns to base.

The change in employment is restrained by an increase in the real wage rate. According to the labour-market specification in JorGE (subsection 4.1.1), the real wage rate adjusts over time to eliminate any deviations in employment. Figure 12 clearly shows this mechanism at work, with the labour market implications of the shift towards BEV services being revealed as an increase in real wage rather than an increase in employment. In 2050, the real wage has risen by around 5.0 per cent relative to baseline levels. At that point, as noted above, the employment consequences have been completely suppressed by the increased cost of employing.

Overall, in 2050, the capital-stock deviation is 7.6 per cent and the increase in employment is 0.0 per cent, implying an increase in the ratio of capital to labour of around 7.6 per cent.

A point worth noting is that even though the increase in overall employment is small, this does not mean that employment at the individual industry or regional level remains close to baseline values. In some industries, there might be significant permanent employment responses to the expansion in BEV services, compounding or defusing existing (baseline) pressures for long-term change.

With little change in employment and no change in TFP, the increase in capital leads to an increase in real GDP at factor cost.

Real GDP *at factor cost* is a measure of economy-wide production based on the use of labour and capital without hindrance due to *distortions* arising from commodity taxes and subsidies. In our modelling, the percentage change in real GDP at factor cost is a share-weighted average of the percentage changes in quantities of factor inputs (labour, capital), with allowance for changes in Total Factor Productivity (TFP).

Figure 13 shows the projected effects on real GDP at factor cost arising from increased uptake of BEV services. In the peak years 2043, real factor-cost GDP is 5.3 per cent above its baseline value. By the end of the period, the increase has fallen to 4.3 per cent.

The BEV subsidy introduces an allocative inefficiency (or distortion) which subdues the size of the eventual increase in real GDP.

Real GDP *at market prices* is the headline measure of real GDP. In nominal levels, it equals the value of GDP at factor cost plus the collection of commodity taxes net of subsidies. The percentage change in real GDP at market prices equals the percentage change in real GDP at factor cost plus any change to the efficiency with which resources are used due to commodity taxes and subsidies.[25]

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[25] The change in allocative efficiency due to taxes and subsidies is measured by the value of the commodity tax base times the proportional change in the quantity of the underlying tax flow. For example, if a subsidy of JD100 million is imposed on BEV services which results in the quantity of BEV service increasing by 10 per cent, then there is an efficiency loss equal to JD10 million (= JD100 million × 10/100). All else unchanged, this reduces real GDP by JD10 million.

As shown in Figure 13, the loss of allocative efficiency due to the introduction of the BEV subsidy is large. In the peak year of 2043, real GDP at market prices is 3.7 per cent above its baseline value, compared with an increase of 5.3 per cent in real GDP at factor cost, meaning the loss of efficiency is worth 1.6 per cent of GDP. In 2050, market price real GDP is 2.8 per cent above base, compared to 4.3 per cent for real factor-cost GDP, implying a 1.5 per cent efficiency loss.

Real gross national expenditure (C + I + G) increases relative to real GDP (Y) leading to a mild deterioration in the net volume of trade (X − M).

Figure 14 shows percentage deviations from baseline values for real consumption – public and private (*C* + *G*), real investment (*I*), real exports (*X*) and real imports (*M*). As already explained in Section 4.1.1, in these simulations we index public consumption to private consumption, meaning that deviations in *G* equal deviations in *C*.

The shift towards BEV services increases the real income accruing to Jordanian residents (i.e., Household Disposable Income, HDI)). Much of that increase comes from increased real income from labour and capital, reflecting the increase in real GDP at factor cost. However, real HDI does not rise by the full amount of the increase in factor-cost GDP, with part of the income that would otherwise go to consumers being returned to the government to cover the cost of the BEV subsidy. Ultimately, real HDI rises roughly in line with real GDP at market prices.

Recall from Section 4.1.1 that the Average Propensity to Consume is an endogenous variable, moving to ensure that the national balance on current account as a share of GDP remains at its baseline value. To maintain an unchanged balance on current account, domestic savings (private plus public) must change to accommodate changes in aggregate investment. In this simulation, the change in APC is negligible, leaving consumption to move in line with real HDI.

Investment (*I*) is stimulated by the switch to BEV services. In the peak year, real investment is 4.5 per cent above its baseline value, with the gap falling to 2.8 per cent in the final year. The increase in investment reflects what is required to provide for additional capital and, over time, to cover the additional replacement needs of the increased capital stock.

On balance, real gross national expenditure (*C* + *I* + *G*) increases in line with real GDP, implying a mild deterioration in the net volume of trade (*X* − *M*). As shown in Figure 14, the volume of exports falls by around 2.4 per cent compared to its baseline value before recovering a little to finish 2.0 per cent below baseline in 2050. By contrast, the volume of imports remains relatively unchanged, finishing the period 0.1 per cent above its baseline level.

To achieve the necessary change in net trade volumes, mild appreciation of the real exchange rate is necessary, as shown in Figure 15. This lowers the competitiveness of export industries on foreign markets and the competitiveness of import-competing industries on local markets. Lowering the competiveness of Jordanian exporters results in higher a slightly higher price being paid for Jordanian exports. Thus, as shown in Figure 15, there is a small improvement in the country's terms of trade (the ratio of export to import price).

Industry production
Table 4 gives percentage deviations from baseline production levels for aggregate sectors and a few individual industries at five yearly intervals between 2025 and 2050.

Production in most industries increases relative to baseline, while production in some industries falls.

The centre of Table 4 is where all the action occurs. There we see directly the consequences of the changes in vehicle shares in the production of private transport services. In 2050, production of BEV passenger services is up 78.3 per cent relative to its baseline level, while the production of passenger services from Hybrid vehicles and ICVs has fallen to zero.

Interestingly, we see an increase in public transport use of 3.1 per cent relative to baseline. A small part of this is due to slippage from private transport services as not all of the increase in BEV services absorbs the decline in services previously supplied by ICVs and hybrid vehicles. Most of the increase in public transport, though, is due to an increase in size of the economy which translates into greater demand for both public and private transport services.

Three key factors largely explain the output changes of other industries.

- Input/output linkages;
- Connections to international trade; and
- Connections to domestic final demand

Input/output linkages explain production declines for Sector 7: Retail trade (output down 5.2 per cent relative to baseline in 2050) and Sector 12: Rental (down 7.0 per cent in 2050). Demand for retail trade tends to move with consumption expenditure, the total of which rises. However, this positive influence is more than offset by the contraction in output of industries selling ICV retail services such as petroleum stations and ICV repair and maintenance facilities. Overall, there is far less upkeep associated with BEVs. As noted previously, the Rental sector provides mainly rental and leased vehicles for private passenger transport. In our database, this sector uses ICV and Hybrid vehicles more intensively than it does BEVs. Hence the contraction in its output.

The petroleum refining industry, which is part of Sector 3: Manufacturing, is projected to experience an 84 per cent fall in output by 2050 relative to baseline levels. This is the main reason why output of the composite manufacturing group falls by 1.0 per cent.

Trade exposed industries tend to do poorly due to the mild contraction in exports brought about by real appreciation. Good examples are industries in Sector 8: Accommodation and food services and Sector 18: Arts and recreation. Both composite sectors are projected to experience a fall in output due to a fall in exports which in some cases is compounded by an increase in import penetration on local markets.

Connections to domestic final demand, which grows relatively strongly, explains the output response of most of the remaining composite sectors, nearly all of which produce services. Good examples are Sector 10: Communication sectors (production up 2.5 per cent relative to baseline in 2050), Sector 11: Financial and insurance services (production up 1.7 per cent) and Sector 21: Dwelling services (3.1 per cent).

It is a little surprising that most of the remaining service industries do not experience larger increases in production, given the overall expansion in consumption and investment spending. Good examples are Sector 16: Education and training and Sector 17: Health care and social assistance. Both sell primarily to private consumption, but expand production by less than half of the expansion in consumption. These industries lose consumption share because the price of their products increases relative to the CPI inducing adverse substitution effects in household demand. At this stage, it is unclear why this happens and is subject to further investigation.

Figure 16 shows changes away from baseline levels in greenhouse gas emissions (kt of CO2-e) for each of the major Kyoto categories.

The increase in uptake of BEV services leads to a significant reduction in greenhouse gas emissions.

By 2050, total greenhouse gas emissions are down 13.5 per cent from 41.8 Mt of CO2-e to 36.2 Mt of CO2-e. All of the fall comes from a drop in transport-sector emissions – 7.1 Mt in the peak year of 2043 and 6.4 Mt in the final year.

Otherwise, small increase are recorded in the other categories, especially electricity generation. Due to an increase in electricity supplied to the vehicle sector which is supplied in small part by fossil-fuel generation, emissions from the electricity sector are up by almost 1 Mt in 2043, and by 0.8 Mt in 2050.

4.2   Construction and operation of the BRT (Phase 2).

The Bus Rapid Transport (BRT) system is a bus-based public transport system designed to have more capacity and reliability features than a conventional bus system. Typically, a BRT system includes roadways dedicated to buses and gives priority to buses at intersections. BRT systems aim to combine the capacity and speed of a light rail or a metro system with the flexibility, simplicity and affordability of a bus system. The Amman BRT project is owned by the Greater Amman Municipality (GAM) and aims to provide affordable public transport services to the Amman community.

Construction of the BRT system in Jordan started in 2010 but was suspended shortly after due to feasibility concerns. BRT construction was revived in 2015. The BRT has two phases: Phase 1 consists of two corridors. The first corridor is within Greater Amman and is under the responsibility of the GAM. This corridor includes a line from al Mahatta terminal to Sweileh and a line from Sports City to Al Muhajereen terminal. A "soft operation" has been operating between Sweileh Terminal and the Jordan Museum Terminal since July 2021 and a further line between Sweileh Terminal and the Tareq Interchange Terminal was opened in August 2022. The second corridor is the Amman-Zarqa BRT corridor which is under the responsibility of the Ministry of Transport. Currently this corridor is still under construction. The two corridors will be operated under one integrated service.

Phase 2 of the BRT focuses on the Southern part of Amman and will be connected to Phase 1. It is expected that the infrastructure development will commence in 2023 and be completed in 2027, with the operational phase of BRT 2 to commence in 2028. Total construction cost is approximately 240 million JOD over the period with additional costs of 60 million JOD for buses and the ITS system.

Phase 2 includes three additional lines with an additional 41.5 km and 38 additional bus stops. In considering fares for the BRT Phase 2 system, the approach currently adopted by GAM is to introduce two fares: one for "short hop" (any single trip up to 3 kms in length) and a flat fare for all other trips.[26] The service plan considers a combined fleet of 18-metre and 12-metre long articulated buses. The fleet may include a combination of diesel and battery electric buses.

The demand for the BRT system is estimated at close to 240,000 trips per day and 10,000 passengers per hour. It is estimated that the demand for BRT services will increase by 4.4 per cent annually.

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[26] For the study by the World Bank (2022), their analysis selected for 2022 a fare of JD 0.350OD for "short hop" and 0.65 JOD for other trips. This is in-line with the current range of bus fares in Amman. A reasonable assumption is to increase the fares with the rate of inflation.

Introducing the BRT system and improving public transport in general can reduce GHG emission from the transport sector.

4.2.1   Simulation design

Using JorGE we project year-by-year the effects of BRT (Phase 2) during its construction period, 2023–2027 and operation (or production) phase, 2028–. As noted above, total construction cost is estimated to be JD 300 million, with JD 240 million spent on infrastructure and JD 60 million on buses and new IT systems. In the absence of additional information, we spread the total across the build-years in equal JD 60 million instalments. The initial construction spending is allocated to the JorGE industry *Public transport.*

For modelling purposes, operation of the BRT (Phase 2) is assumed to ramp-up immediately to full capacity in 2028 and to remain at full capacity through to the end of the projection period (2050). Annual operation cost of the new system is assumed to be JD 10 million. In the context of the model, all of the new production is attributed to production of *Public transport*. However we assume that some (15 per cent) of the new services replace existing public transport services provided largely by privately run buses. Hence, annual output of *Public transport* expands by less than JD 10 million.

A final, critical assumption, relates to ownership – who funds the investment and how are profits, if any, distributed? For the initial simulations reported here, we assume that largely foreign interests fund Phase 2. Thus, all after-tax profit goes overseas.

As with the first policy simulation, the impacts of the new BRT are reported as changes (percentage or absolute) relative to the baseline forecast described in Section 3. With one exception, the same assumptions are made for key aspects of the macro economy as were made for the first policy simulation (see Section 4.1.1). The exception relates to the treatment of the APC. In the first simulation, the APC moves endogenously so that changes in investment are matched by changes in domestic saving, leaving the balance on current account fixed at its baseline level. This assumption does not apply in this simulation since foreign savings finance the direct BRT investment. Thus, the domestic APC is exogenously fixed at its baseline level and the balance on current account is endogenously determined.

Exogenous shocks are applied to investment, production and the production structure of the Passenger *transport* industry, along with a small economy-wide shock to productivity. The shock to production structure is necessary to ensure that all of the new production is powered by electricity, rather than petroleum. The economy-wide shock represents the economy-wide productivity benefits of the new project which arise through less congestion. These arise through reduced time-costs of passenger and freight road transport in urban areas. We assume that the new BRT infrastructure reduces costs in the economy by JD 5 million per year.[27]

4.2.2   Results

Note that results for only two macroeconomic variables (real GDP and employment) are reported, along with results for aggregated industry output, the mix of private and public consumption, and greenhouse gas emissions. Results for all other variables are available on request.

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[27] Work undertaken in Australia by CoPS analysing transport infrastructure projects suggest that economy-wide cost savings from new and improved roads and rail roughly equal the operating revenue of the new project. For the BRT (phase 2), we guess conservatively that the ratio of cost saving to operational revenue is 0.5.

Macroeconomic variables

Figure 17 show changes from baseline values in real GDP due to the construction and operation of BRT (phase 2). Results are expressed in two ways: as percentage deviations from baseline values and as absolute deviations in JD million at constant 2022 prices.

During the construction phase (2023 to 2027), investment spending on the new project amounts to JD 60 million per year. During that period, the spending stimulates real GDP by a little more – on average JD 63 billion per annum. This is equivalent to 0.15 per cent of GDP's baseline value.

A GDP to final spending ratio of a little more than one might surprise people more used to seeing Input/Output (IO) multipliers of at least 2. CGE models like JorGE take account of not only the direct and indirect demand effects that IO modelling captures, but also offsetting (i.e., crowding out) effects that arise from supply-side constraints on the economy. When investment spending in one area rises, this puts upward pressure on costs and wages faced by other industries for both investment purposes and current production. Increased costs have adverse competitive effects that increase import penetration on local markets and reduce sales of exports on foreign markets. The model also captures other relative price adjustments that crowd out activity elsewhere, including changes in the real exchange rate. In this case, the investment is foreign financed. The increase in foreign investment, all else unchanged, strengthens the value of the domestic currency leading to real appreciation. Real appreciation can have adverse effects on traded goods industries, leading to further crowding-out of activity.

Following construction, the BRT (phase 2) begins operation with gross revenues of JD 10 million per year. Most of this is from businesses and households that previously used private transport services and other public transport such as private buses. There is thus little change overall in spending on passenger transport services. During the operational phase, as shown in Figure 17 there is a small increase in real GDP of around JD 6.5 million. This is due almost entirely to the economy-wide travel-cost savings assumed for the modelling.

The aggregate employment consequences of building and operating the BRT (phase 2) are shown in Figure 18. Again, we express the effects as changes away from baseline values in percentage and absolute terms. The latter are measured in the number of annual jobs.

Through the five years of the construction period, around 1,600 new jobs are created in the economy. This represents around 0.25 per cent of annual baseline employment. When building finishes, the employment stimulus also stops. In a typical operational year, there is a gain in total employment of around 20 people (barely statistically significant). The employment gain is negligible partly because new employment on BRT services is offset by reduced employment in other transport areas, and partly because the overall time-cost savings for the economy supresses slightly annual needs to employ more people (essentially there are slightly more work hours available from a given pool of employed persons).

Industry output

Table 5 shows changes in industry production (% and JD million) for a typical year in the construction period (2025) and a typical year in the operational phase (2035).

Not surprisingly, in the typical construction year the industries with the largest changes in output are construction related. These are Sector 5: Construction, for which production is projected to rise by 1.8 per cent or JD 22.6 million relative to baseline values, and Sector 2: Mining, which produces low grade product such as gravel used in larger civil construction style projects. Other sectors gain output because of indirect demand effects. A good example is Sector 15: Public administration, for which

demand expands simply because the economy has become larger and there is increased need for public-government services.

In the production phase, the industry story is mainly about the change in provision of transport services (Sector 9) away from private transport (industries 9a – 9c) and toward the production of public passenger services (9d). The last mentioned is projected to experience an increase in output of 0.6 per cent (JD 11.2 million) relative to baseline values in the typical operational year.

Greenhouse gas emissions

The final set of results relate to the effects of BRT (phase 2) on greenhouse gas emissions as shown in Figure 19. Stimulus to the economy during the construction phase leads to an increase in emissions in a typical construction year of around 70 kt. Most of the additional emissions are transport related and come from a mix of emission-intensive construction activity associated with the use of IC motors and general expansion effects, which increase the need for transport services and hence petroleum products.

In the operational years, there are small annual reductions in emissions in the order of 10 kt. This is brought about by substitution in public transport towards electricity-powered BRT vehicles and away from conventional buses which even in the later years are powered by IC motors.

5   Concluding remarks

Greenhouse gas emissions in Jordan come primarily from the combustion of refined oil products in transport. Hence, plans to reduce emissions focus primarily on the transport sector. These plans are often detailed from a technological point of view, but seldom present economic assessments of likely consequences.

In this report, we provide a summary of the likely economic costs and benefits for Jordan of two typical schemes to reduce the environmental effects of transport. Both relate to the delivery of passenger services. The first is to encourage the uptake of BEVs at the expense of ICVs and, to a lesser extent, hybrid vehicles. The second is to invest in new public transport infrastructure – phase 2 of the BRT - assisting to reduce the use of private vehicles principally in urban areas.

The analysis is based on scenarios to 2050 constructed using a dynamic CGE model of Jordan, named JorGE. JorGE is calibrated to data for 2020 and has a detailed industrial classification. That classification recognizes electricity produced by several different conventional fossil fuel and renewable technologies and a number of road transport service industries. The road transport industries distinguish passenger from freight services. For passenger services there are separate industries producing public transport services and private transport services. The latter is further disaggregated into services provided by the three different passenger vehicle types – ICVs, EVs and Hybrids.

Results are reported as changes away from baseline values over time due to increased BEV uptake and the construction and operation of the BRT (phase 2). Key features of the results are as follows.

Policy 1: Increased uptake of BEVs

In the baseline, the BEV share rises from its present level of around 5 per cent to 60 per cent. Over the same period, the hybrid share rises and then falls to be around 10 per cent in 2050, while the ICV share declines progressively to around 30 per cent. These changes, which are projected to occur without specific government action, reflects the current projected plans of major vehicle makers to reduce significantly the number of ICVs produced by 2050.

In the policy simulation, we ask what are the economic implications of increasing the BEV share to 100 per cent by 2050? In so doing we shed light on the economic costs and benefits of a 40 percentage point increase in BEV penetration. We choose not to speculate on what package of policies will achieve this outcome. Most likely, it would be a mix of market and non-market measures including subsidies and taxes, regulation and moral suasion. Instead, we simply assume that the targeted increase in BEV's is achieved via a government subsidy on BEV services which is paid for ultimately by the household. Subsidies and taxes, in themselves have an economic cost due to their adverse impact on allocative efficiency. Our modelling takes account of this cost, and so our analysis might be regarded as conservative, with both the costs and benefits of increasing BEV numbers relative to baseline being considered.

Results from the first simulation are driven by two factors. The first is the different cost shares of services (kms travelled per year per person) produced by BEVs and ICVs. The second is the size of the required subsidy.

The figure below shows percentage cost shares for annual vehicle services provided by ICVs (top) and BEVs (bottom). The cost of a unit of ICV service comprises roughly equal amounts of capital (vehicles) and petroleum products. The remainder, or around 20 per cent of total cost, comprises other running expenses such as servicing. By contrast, for BEV services capital is over 80 per cent of total cost, with electricity and servicing, etc., making up the rest. It follows, that increasing the uptake of BEVs at the expense of ICVs increases the capital intensity of the economy and reduces it reliance on petroleum and oil imports. Both effects lead to increased real GDP in the long run.

We estimate that to raise BEV's share in private passenger transport to 100 per cent will require a subsidy of around 0.9 per cent of GDP on the use of BEVs. Much of this subsidy is required to achieve the final 10 per cent uptake. The last 10 per cent consist of vehicles mainly operated by people cautious about new technologies and with relatively poor access to charging facilities. By itself, the subsidy reduces real GDP because it reduces slightly the efficiency with which the economy uses its resources – capital and labour.

Overall, the shift towards BEVs is projected to increase real GDP (relative to its baseline value) by 2.8 per cent in 2050. This is equivalent to the value of GDP created in a typical eighteen month period. However, the benefit of increased BEV uptake is not just economic. There are obvious beneficial environmental effects as well, especially a reduction in greenhouse emissions. By 2050, total greenhouse gas emissions are down 13.5 per cent from 41.8 Mt of CO_2-e to 36.2 Mt of CO_2-e. All of the fall comes from a drop in transport-sector emissions of around 7 Mt.

Cost shares of vehicle services – ICV (top), BEV (bottom)
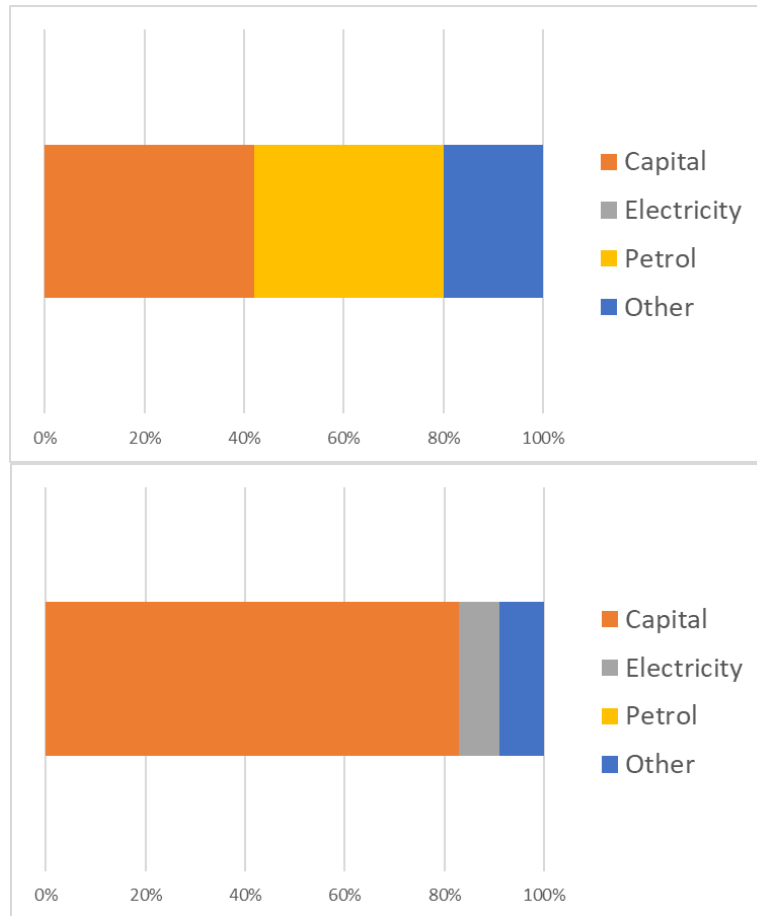
Policy 2: Construction and operation of phase 2 of the BRT

This is a very different policy to the first. In terms of economy-wide impacts, it is much smaller and its impact on greenhouse gas emissions is far less. Using JorGE we project year-by-year the effects of BRT (Phase 2) during its construction period, 2023–2027 and operation (or production) phase, 2028–. The total construction cost is estimated to be JD 300 million, with JD 240 million spent on infrastructure and JD 60 million on buses and new IT systems. Operations of the Phase 2 system are assumed to ramp-up immediately to full capacity in 2028, and to remain at full capacity through to the end of the projection period (2050). Annual operation cost of the new system is assumed to be JD 10 million.

During construction, the additional spending stimulates real GDP by an average of JD 63 billion per year. This is equivalent to 0.15 per cent of GDP's baseline value.

A GDP to final spending ratio of a little more than one might surprise people more used to seeing Input/Output (IO) multipliers of at least two. CGE models like JorGE take account of not only the direct and indirect demand effects that IO modelling captures, but also offsetting (i.e., crowding out) effects that arise from supply-side constraints on the economy. When investment spending in one area rises, this puts upward pressure on costs and wages faced by other industries which has adverse competitive effects on their production. The model also captures other relative price adjustments that crowd out activity elsewhere, including changes in the real exchange rate. In this case, the investment is foreign financed. The increase in foreign investment, all else unchanged, strengthens the value of the domestic currency leading to real appreciation. Real appreciation can have adverse effects on traded goods industries, leading to further crowding-out of activity.

Following construction, the BRT (phase 2) begins operation with gross revenues of JD 10 million per year. Most of this is from businesses and households that previously used private transport services and other public transport such as private buses. Overall, there is little change in spending on passenger transport services. There is, however, a small increase in real GDP of around JD 6.5 million. This is due almost entirely to the economy-wide travel-cost savings associated with the new public facilities.

The impact of the BRT (phase 2) on Jordan's transport emissions is small – a reduction of around 10 kt per annum. However, it is unfair to judge the project on its ability to curb emissions. Its true value lies in its ability to deal with another problem evident on the country's urban roads – that of congestion. A lack of high-quality public transport options leads many urban inhabitants to rely on private vehicle ownership. The result is frequent traffic jams that clog the main roads, take an economic toll by forcing many passengers to spend a significant amount of their time stuck in a car, and heavily affect air quality. Measurement of the benefits arising from the new BRT on congestion is outside the scope of this study, but they are almost certainly substantial.

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Table 1a: Summary of emissions data by broad emission category, 2016

Category	Kt of CO2-e	% of total
Energy sector	23,649	76.1
Fuel combustion	23,033	74.1
Energy industries (mainly electricity)	8,956	28.8
Manufacturing and construction	2,432	7.8
Transport	8,609	27.7
Other sectors	3,035	9.8
Fugitive emissions	22	0.1
Industrial processes	3,177	10.2
Agriculture	429	1.4
Waste	3,808	12.3
Total	*31,063*	*100.0*

Table 1b: Summary of emissions data by aggregated sector and source, 2016 (Kt of CO2-e)

Aggregated sector (and some components)	Burning of coal	Burning of gas	Combustion of refined oil	*Activity*	*Total*
Sector 1 - Agriculture, forestry and fishing	0	0	300	429	729
Sector 2 – Mining	0	0	0	401	401
Sector 3 – Manufacturing	632	0	1,474	3,177	5,283
Sector 4 – Electricity and gas distribution	0	8,713	256	0	8,970
4a Fossil fuel electricity services	0	8,713	256	0	8,970
4b Renewable electricity services	0	0		0	
Sector 5 – Construction	0	0	335	0	335
Sector 6 - Wholesale trade	0	0	0	0	0
Sector 7 - Retail trade	0	0	0	0	0
Sector 8 - Accommodation & food services	9	0	178	0	188
Sector 9 - Transport, postal and warehousing	0	0	8,782	0	8,782
9a BEV passenger services	0	0	0	0	0
9b Hybrid vehicle passenger services)	0	0	408	0	408
9c ICV passenger services	0	0	7,800	0	7,800
9d Public passenger transport services	0	0	226	0	226
Sector 10 - Communication services	0	0	159	0	159
Sector 11 - Financial & insurance services	0	0	24	0	24
Sector 12 - Rental	0	0	11	0	11
Sector 13 - Professional services	0	0	180	0	180
Sector 14 - Administrative services	0	0	94	0	94
Sector 15 - Public administration and safety	0	0	1,221	0	1,221
Sector 16 - Education and training	0	0	421	0	421
Sector 17 - Health care and social assistance	0	0	214	0	214
Sector 18 - Arts and Recreation	0	0	39	0	39
Sector 19 - Other services	0	0	104	0	104
Sector 20 – Waste disposal	0	0	38	3,808	3,846
Sector 21 - Ownership of dwellings	0	0	0	0	0
Residential	62	0	0	0	62

Table 2. Macroeconomic variables in the baseline (average annual growth rates, %)

	2016-2021	2021-2025	2025-2030	2030-2040	2040-2050	2016-2050
A Income components of GDP						
1. Real GDP	1.3	3.1	3.3	3.3	3.3	3.0
2. Capital stock	1.8	2.0	2.6	3.0	3.1	2.7
3. Employment, persons	1.2	1.8	2.1	2.1	2.1	1.9
4. Employment, wage-bill weighted	1.1	1.8	2.1	2.1	2.1	1.9
5. Total factor productivity (TFP)	-0.1	1.1	0.9	0.7	0.7	0.6
6. Real wage (CPI deflated)	1.1	1.2	1.5	1.8	1.8	1.6
B. Expenditure components of GDP						
7. Real private consumption	1.2	3.0	3.2	3.2	3.2	2.9
8. Real public consumption	1.2	3.0	3.2	3.2	3.2	2.9
9. Real investment	0.6	4.0	3.8	3.3	3.3	3.0
10. Export volumes	0.6	1.9	2.7	3.1	3.1	2.5
11. Import volumes	0.3	2.8	3.0	3.0	3.0	2.6
C. Other macro indicators						
12. Real exchange rate (+ = appreciation)	0.2	-0.2	-0.2	-0.1	0.0	-0.1
13. Terms of trade	0.0	0.0	0.0	0.0	0.0	0.0
D. Other variables						
14. Greenhouse gas emissions	-2.0	1.3	1.6	1.5	1.2	0.9

Table 3: Output by aggregated sector in the baseline (average annual growth rates, %)

Aggregated sector (and some components)	2016-2021	2021-2025	2025-2030	2030-2040	2040-2050	2016-2050
Sector 1 - Agriculture, forestry and fishing	3.0	2.3	2.1	1.9	1.6	2.0
Sector 2 – Mining	-0.4	0.4	0.4	0.4	0.3	0.3
Sector 3 – Manufacturing	2.2	2.5	2.9	3.0	2.9	2.8
Sector 4 – Electricity and gas distribution	1.2	4.1	4.4	4.3	4.5	3.9
4a Fossil fuel electricity services	-9.0	-1.9	-0.9	-0.8	-0.5	-2.1
4b Renewable electricity services	6.0	5.6	5.2	4.8	4.7	5.1
Sector 5 – Construction	1.6	4.1	3.9	3.4	3.2	3.2
Sector 6 - Wholesale trade	1.7	2.8	3.1	3.2	3.1	2.9
Sector 7 - Retail trade	0.8	2.3	2.4	2.4	2.3	2.1
Sector 8 - Accommodation & food services	2.1	1.8	2.7	2.9	2.6	2.5
Sector 9 - Transport, postal and warehousing	0.2	3.6	4.0	4.2	4.5	3.6
9a BEV passenger services	32.5	36.0	18.6	12.2	9.5	17.7
9b Hybrid vehicle passenger services	8.7	13.5	7.9	3.7	-1.6	4.5
9c ICV passenger services	-2.1	1.0	0.8	0.1	-1.4	-0.4
9d Public passenger transport services	0.7	3.0	3.7	4.4	4.9	3.7
Sector 10 - Communication services	0.0	2.8	3.2	3.4	3.5	2.8
Sector 11 - Financial & insurance services	5.7	3.6	3.7	3.6	3.5	3.9
Sector 12 - Rental	-1.7	0.2	0.5	1.9	3.7	1.5
Sector 13 - Professional services	0.2	2.8	3.2	3.2	3.2	2.7
Sector 14 - Administrative services	0.9	3.1	3.3	3.2	3.1	2.8
Sector 15 - Public administration and safety	0.9	3.0	3.1	3.1	3.1	2.8
Sector 16 - Education and training	-0.5	2.8	3.0	2.9	2.8	2.4
Sector 17 - Health care and social assistance	0.2	2.7	3.0	3.1	3.1	2.6
Sector 18 - Arts and Recreation	-1.7	2.9	3.0	2.4	2.2	1.9
Sector 19 - Other services	0.1	3.4	3.5	3.1	3.0	2.7
Sector 20 – Waste disposal	1.3	3.1	3.3	3.3	3.3	3.0
Sector 21 - Ownership of dwellings	5.1	3.6	3.8	3.9	4.0	4.1

Table 4: Output by aggregated sector: percentage changes in policy simulation 1 away from baseline values (% deviations in five yearly intervals, 2023 to 2050)

Aggregated sector (and some components)	2025	2030	2035	2040	2045	2050
Sector 1 - Agriculture, forestry and fishing	0.0	0.0	0.1	0.2	0.2	0.2
Sector 2 – Mining	0.0	-0.2	-0.9	-2.0	-3.2	-4.2
Sector 3 – Manufacturing	0.0	-0.3	-0.6	-0.8	-0.9	-1.0
Sector 4 – Electricity and gas distribution	0.6	4.9	11.3	16.1	16.5	13.3
4a Fossil fuel electricity services	0.8	5.9	13.6	19.3	19.8	15.6
4b Renewable electricity services	0.8	6.0	13.5	18.8	19.0	15.0
Sector 5 – Construction	0.2	1.4	3.0	4.0	3.6	2.0
Sector 6 - Wholesale trade	0.0	0.2	0.5	0.8	0.8	0.5
Sector 7 - Retail trade	-0.1	-0.6	-1.9	-3.5	-4.8	-5.2
Sector 8 - Accommodation & food services	0.0	-0.4	-1.4	-2.7	-3.7	-3.9
Sector 9 - Transport, postal and warehousing	0.9	6.6	15.4	22.3	23.3	18.8
9a BEV passenger services	25.3	96.5	147.9	154.6	124.0	79.0
9b Hybrid vehicle passenger services	-2.6	-16.4	-40.1	-66.0	-85.8	-100.0
9c ICV passenger services	-1.5	-12.7	-34.3	-58.5	-76.3	-100.0
9d Public passenger transport services	0.0	0.2	0.7	1.5	2.4	3.1
Sector 10 - Communication services	0.0	0.3	1.0	1.9	2.5	2.5
Sector 11 - Financial & insurance services	0.0	0.3	1.0	1.6	1.9	1.7
Sector 12 - Rental	-0.1	-1.1	-3.6	-6.7	-8.3	-7.0
Sector 13 - Professional services	0.0	0.2	0.7	1.1	1.2	0.9
Sector 14 - Administrative services	0.0	0.4	0.8	1.1	1.0	0.5
Sector 15 - Public administration and safety	0.1	0.6	1.6	2.6	2.9	2.4
Sector 16 - Education and training	0.0	0.3	0.8	1.2	1.2	0.7
Sector 17 - Health care and social assistance	0.0	0.3	0.8	1.3	1.3	0.9
Sector 18 - Arts and Recreation	-0.1	-0.7	-2.1	-3.7	-4.8	-4.9
Sector 19 - Other services	0.0	0.5	1.2	1.6	1.4	0.6
Sector 20 – Waste disposal	0.0	0.3	0.9	1.6	1.9	1.7
Sector 21 - Ownership of dwellings	0.0	0.2	0.8	1.8	2.7	3.1

Figure 1: GDP, employment, capital and productivity improvement in the baseline (2017-2050) (year-on-year % change)
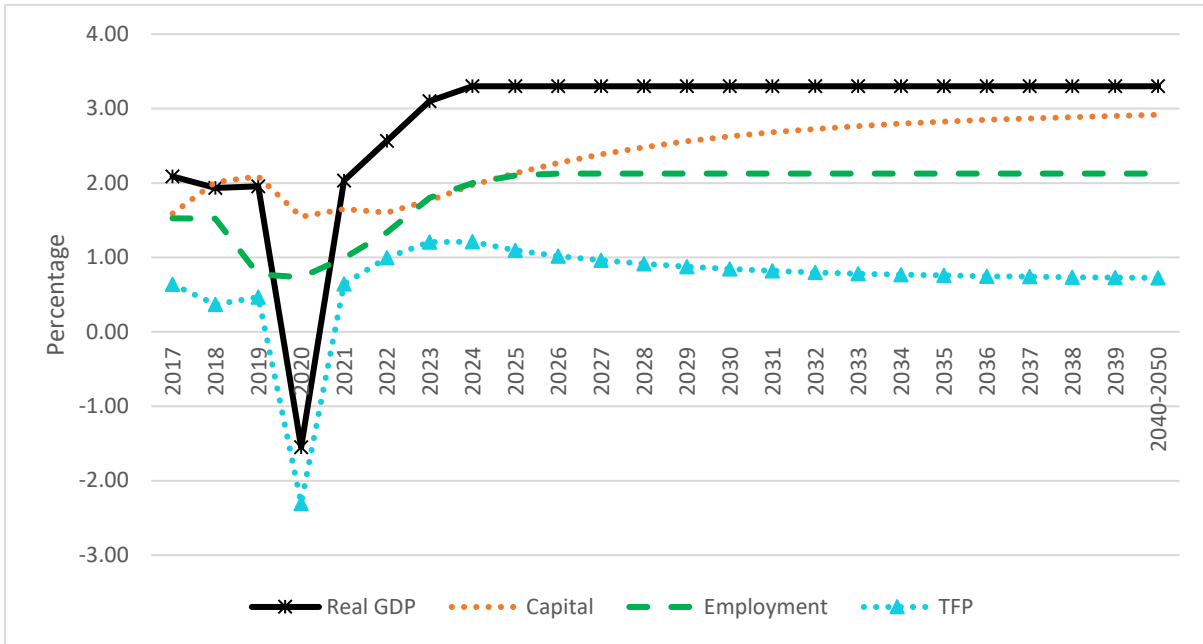
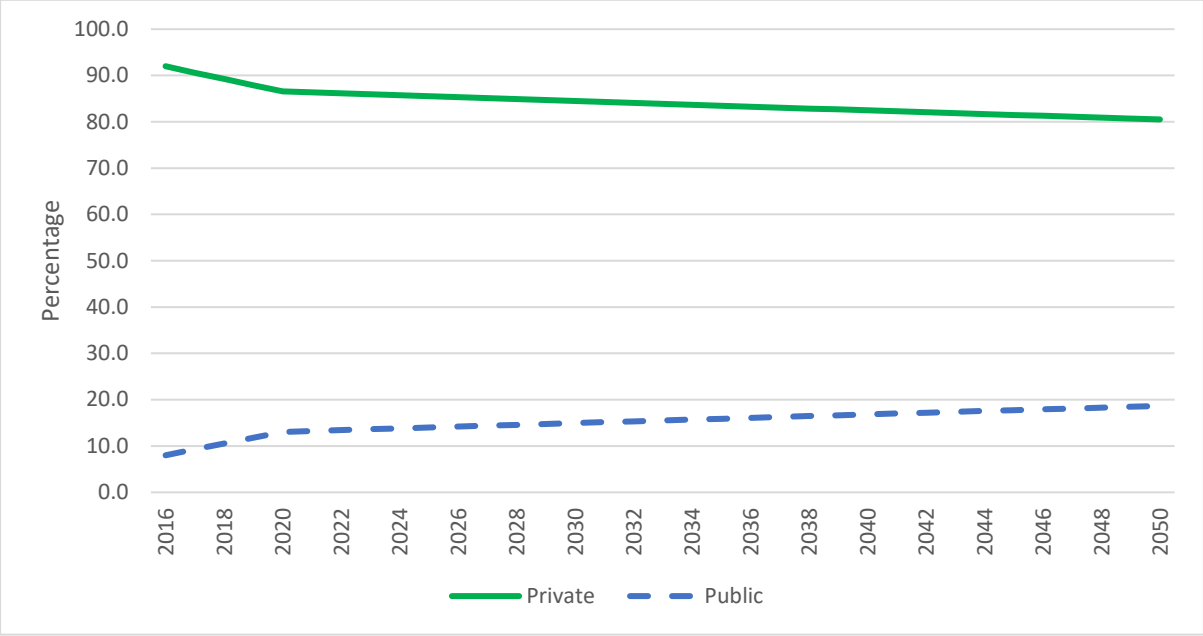## Figure 2: Real GDP and its expenditure-side components in the baseline (2016-2050) (year-on-year % change)
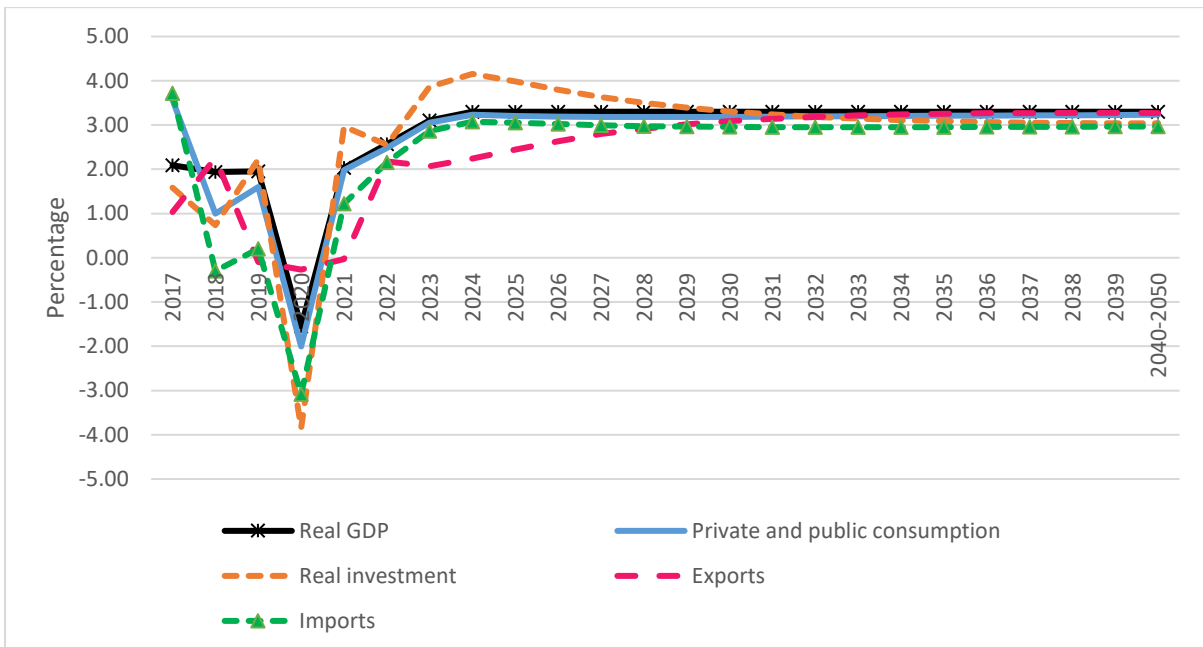
**Figure 3: Shares of electricity generated from renewable and fossil fuels, baseline (%, 2016 – 2050)**
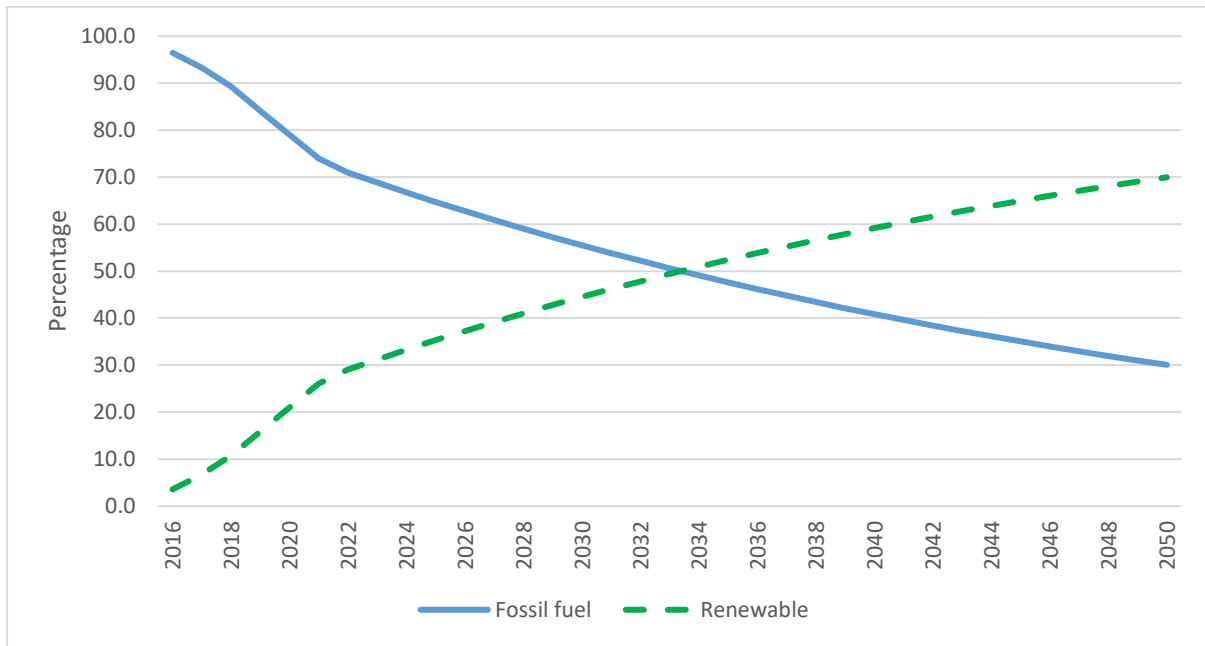
Figure 4: Real retail prices of electricity and petroleum, baseline (index levels (2020 = 100), 2020-2050)
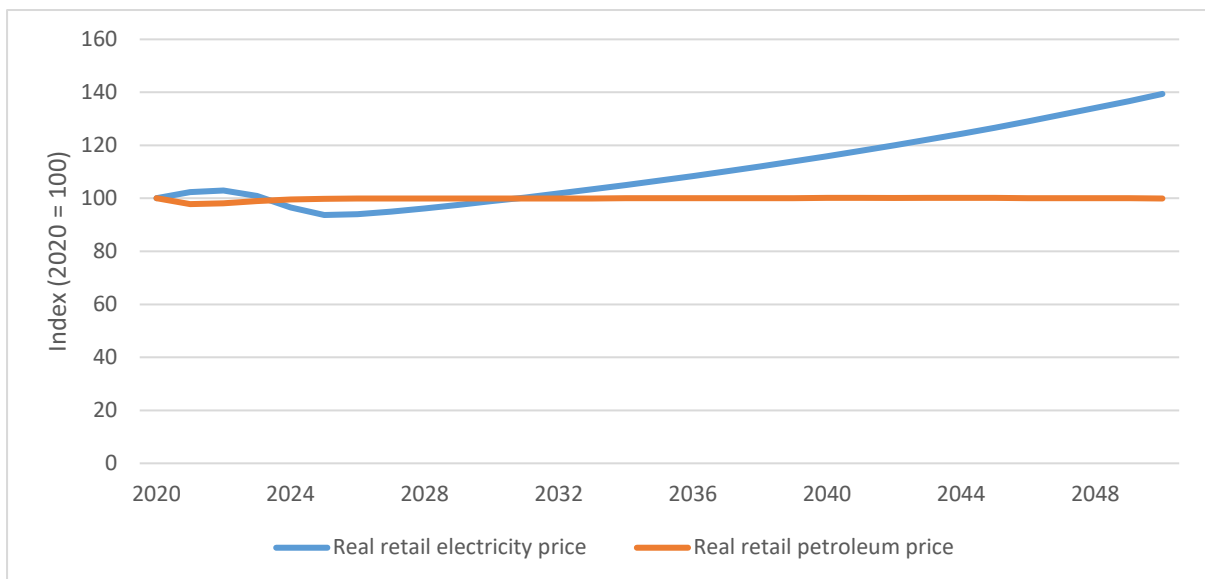
Figure 5: Share of public and private transport baseline (%, 2016 – 2050)

Figure 6. Shares of ICV, EV and hybrid vehicle services in private passenger services, baseline (%. 2016 – 2050)
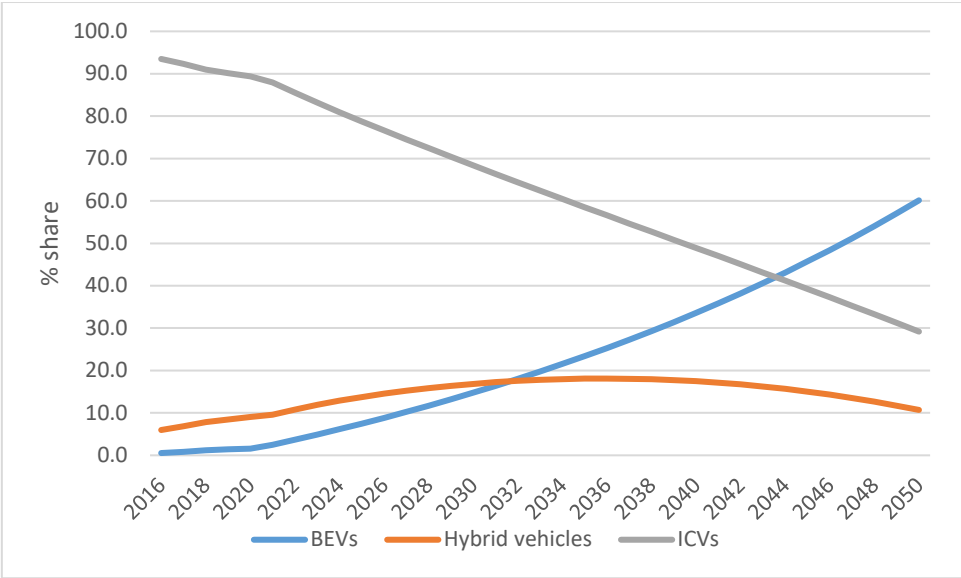
Figure 7: Real retail prices of vehicle services for private road transport, baseline (index levels (2020 = 100), 2020-2050)
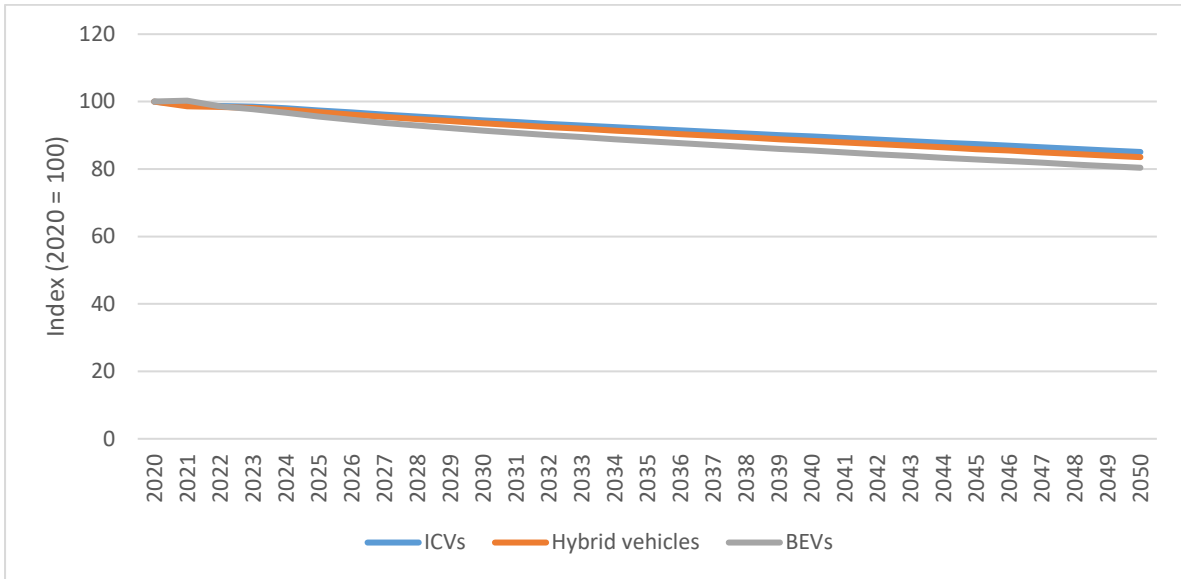
Figure 8: Greenhouse gas emissions by major Kyoto category, baseline (kt of CO2-e)
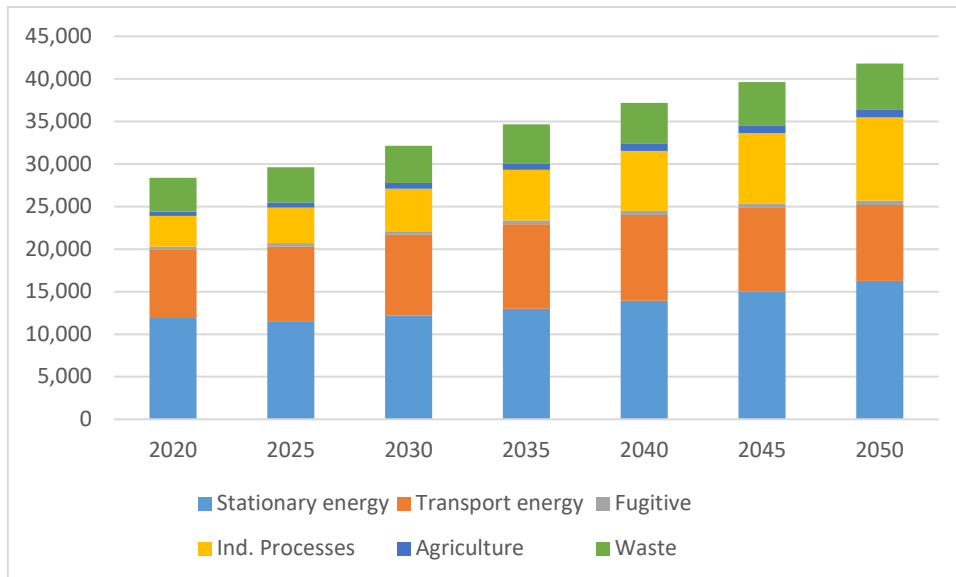
Figure 9. Policy analysis with JorGE
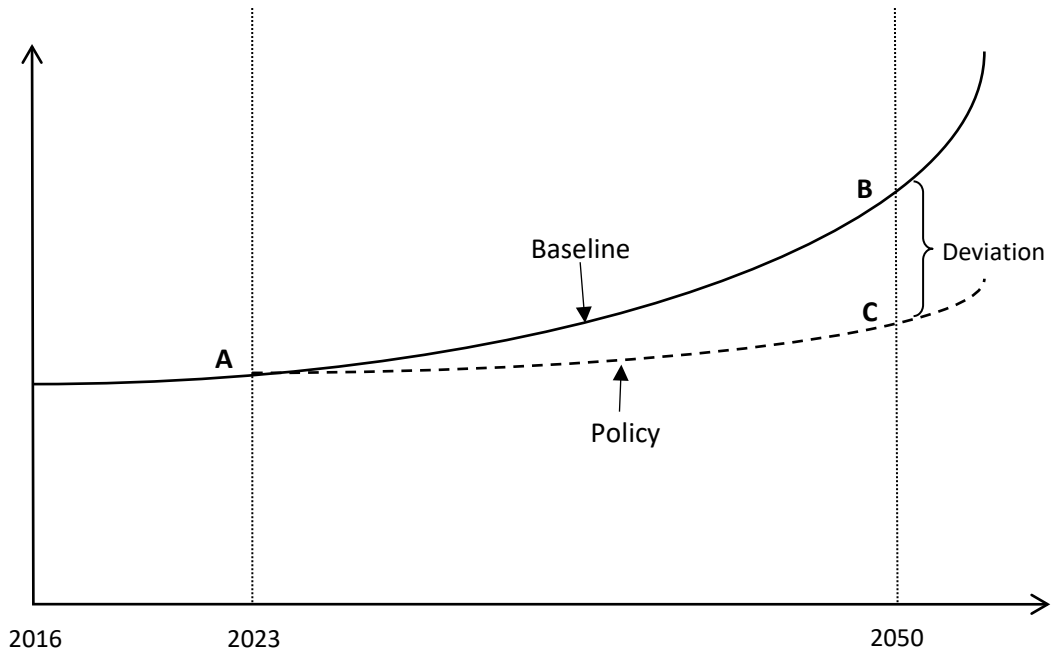
Figure 10a. Baseline and policy shares of ICV, EV and hybrid vehicle services in total private passenger services (%, 2023 – 2050)
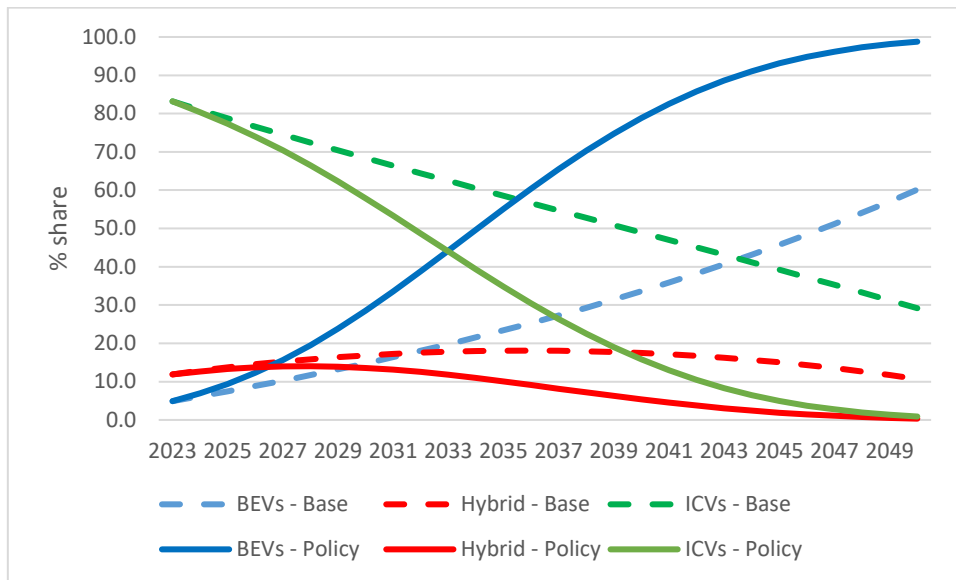
Figure 10b. Percentage point increase in BEV share of passenger transport services, policy simulation relative to baseline simulation (%, 2023 – 2050)
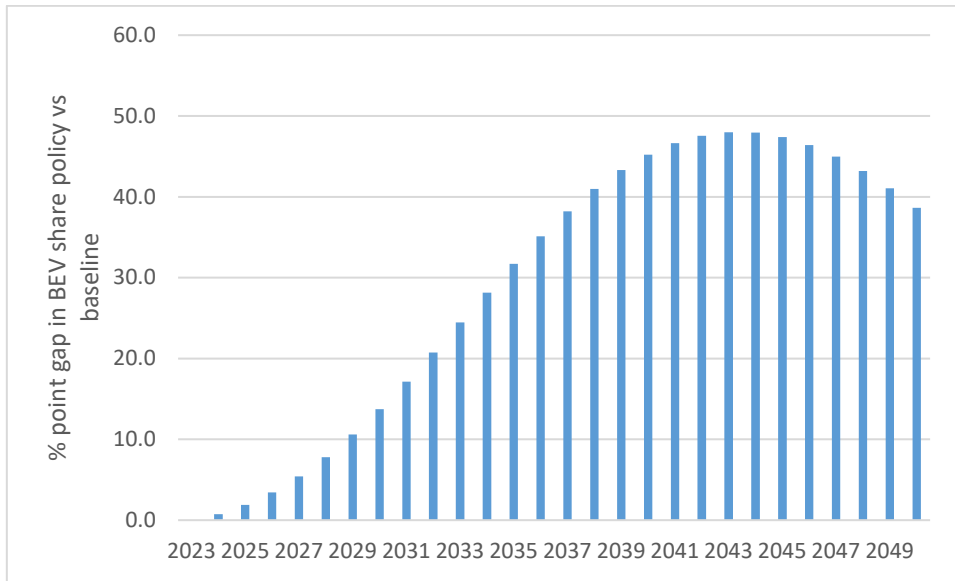
Figure 11: Subsidy on BEV services as a share of GDP (%, 2023 – 2050)
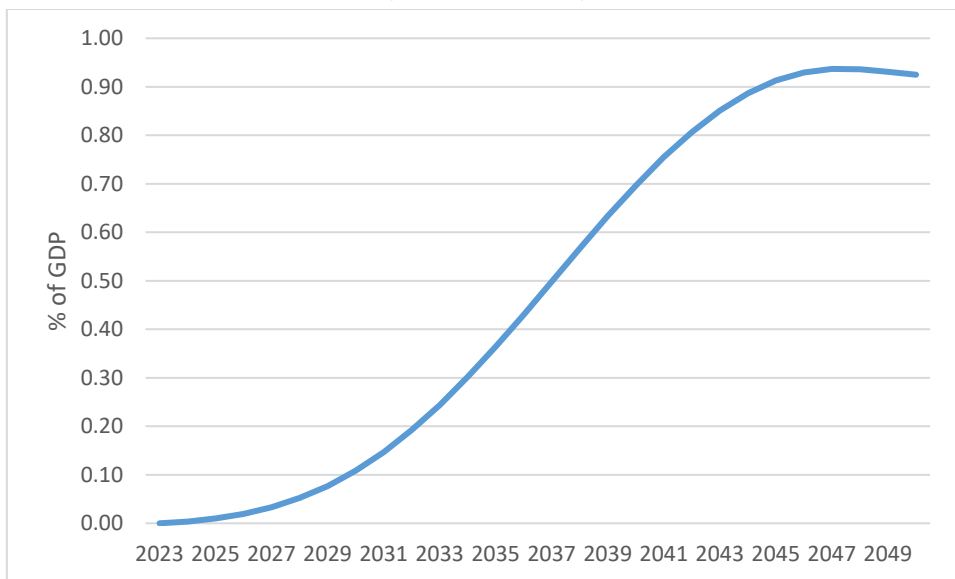
Figure 12: Deviations in capital, employment and the real wage rate, policy simulation 1 (% deviations, 2023 to 2050)
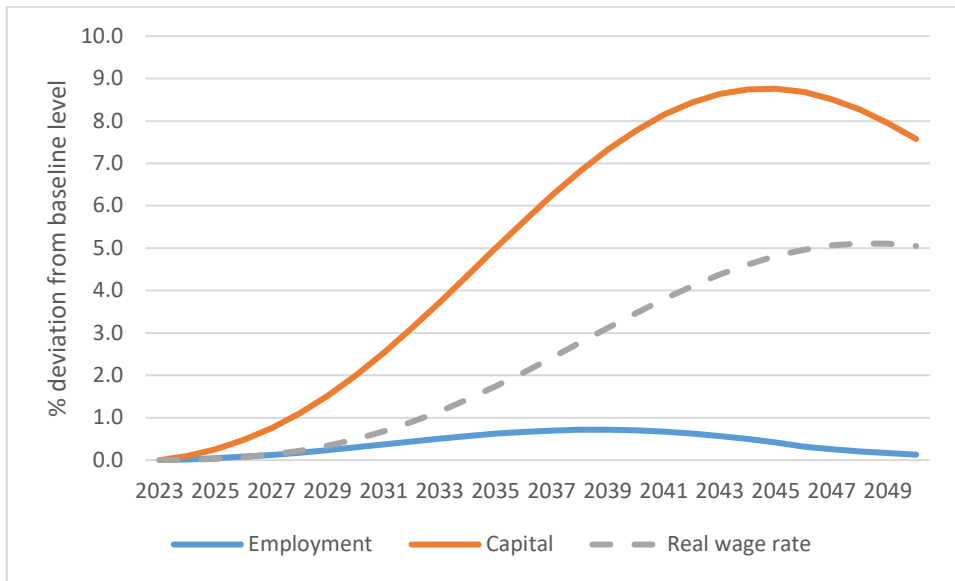
Figure 13: Deviations in real GDP at factor cost and real GDP at market prices policy simulation 1 (% deviations, 2023 to 2050)
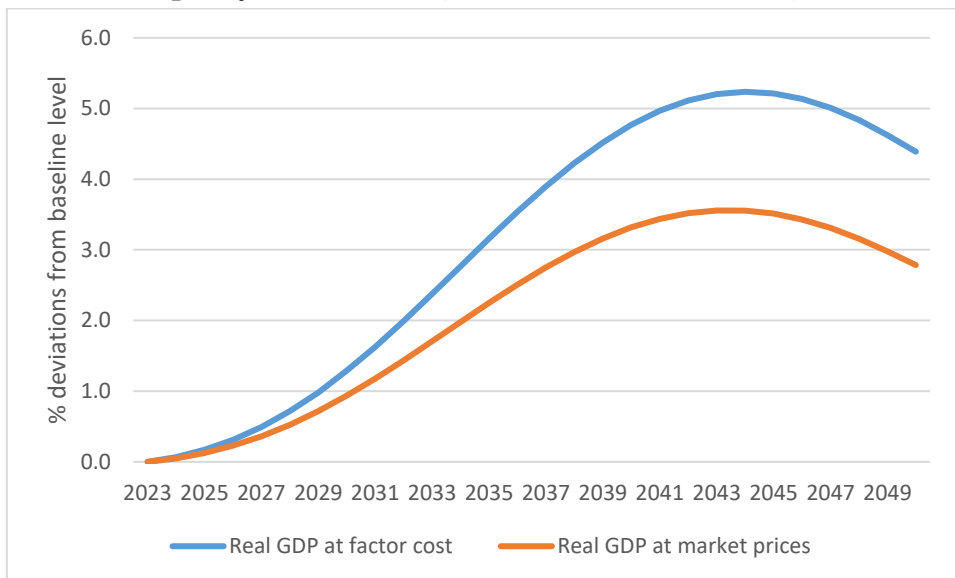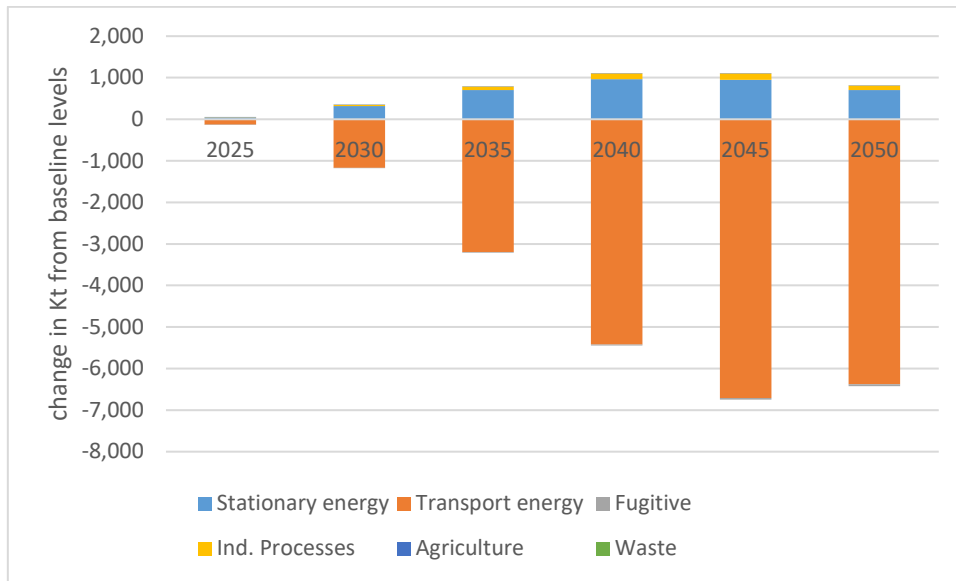
Figure 14: Deviations in expenditure components of real GDP policy simulation 1 (% deviations, 2023 to 2050)
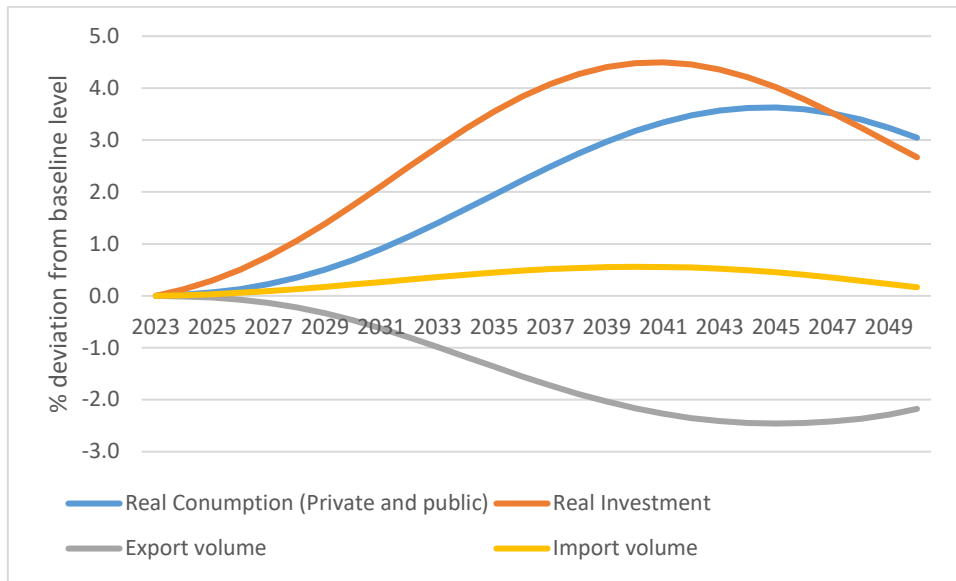

Figure 15: Deviations in the real exchange rate and economy-wide term of trade policy simulation 1 (% deviations, 2023 to 2050)
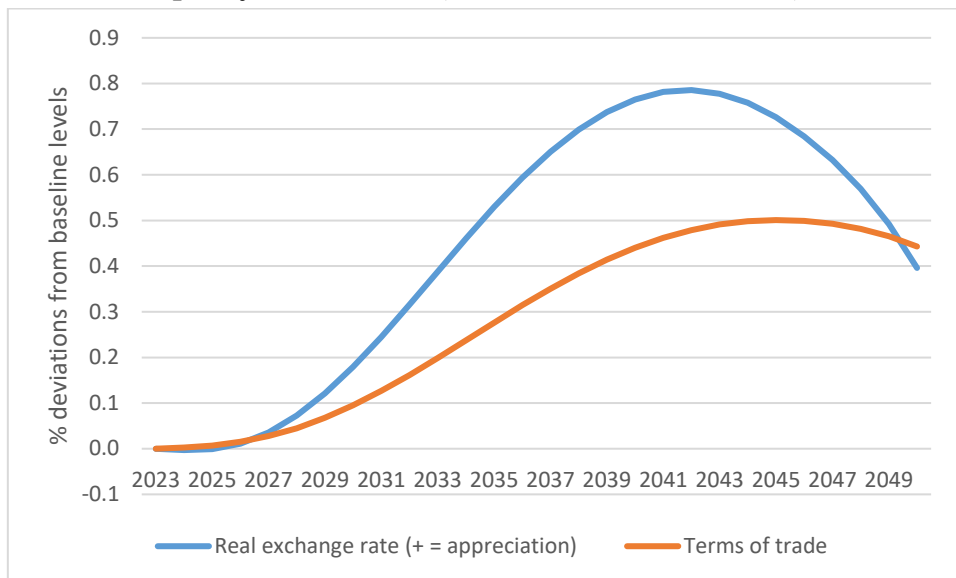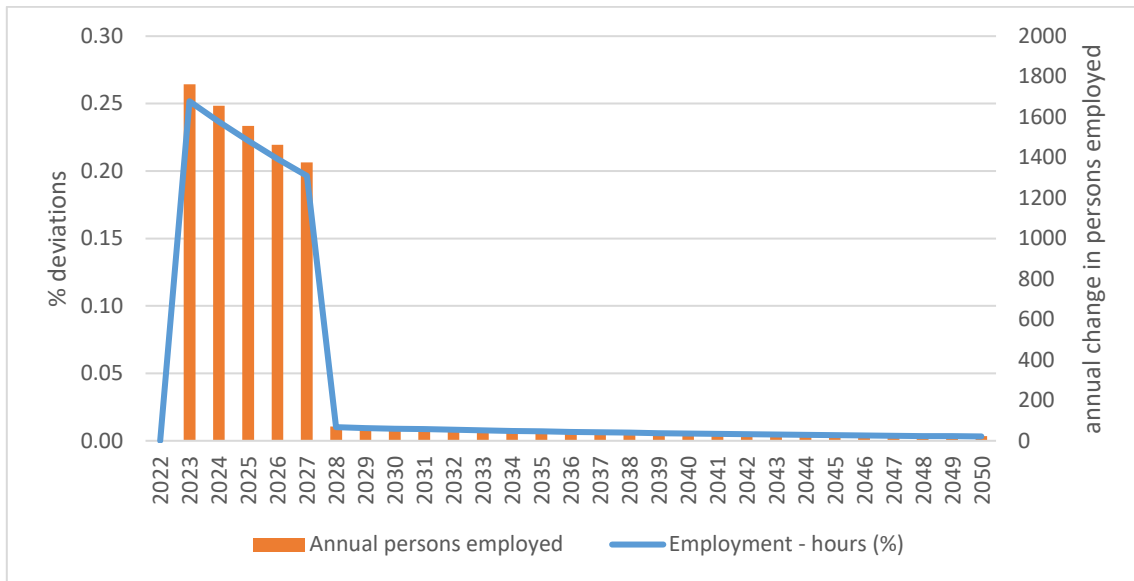
Figure 16: Changes in greenhouse gas emissions by major Kyoto category, policy simulation 1 (kt of CO2-e changes from baseline values)

Figure 17: Changes in real GDP due to building and operation of BRT (phase 2) relative to baseline values (% and JD million)
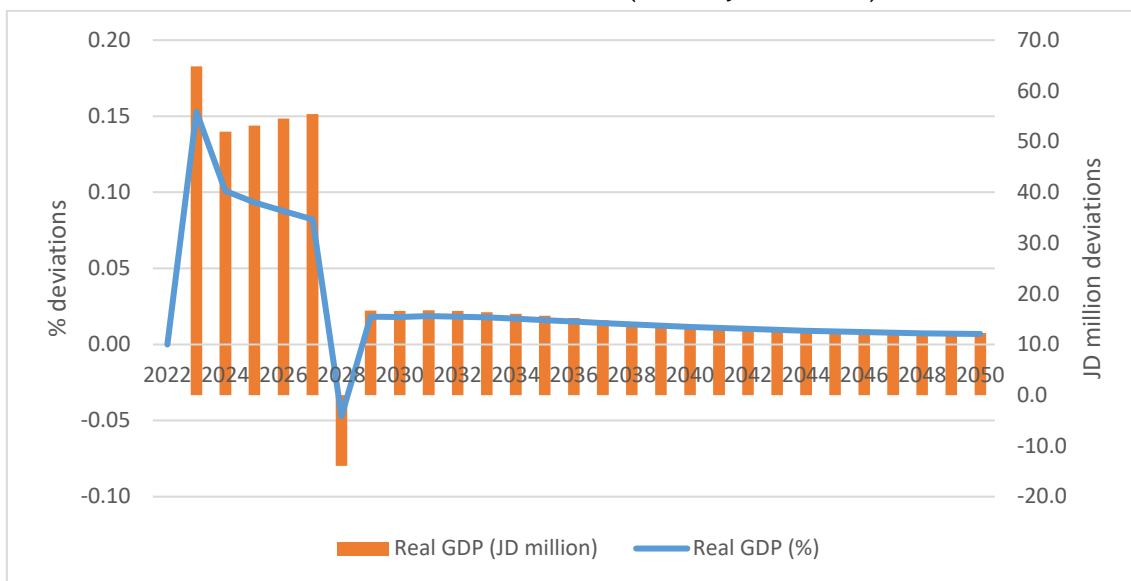
Figure 18: Changes in employment due to building and operation of BRT (phase 2) relative to baseline values (% and annual persons employed)

Figure 19: Changes greenhouse gas emissions by major Kyoto category due to building and operation of BRT (phase 2) (kt of CO2-e)