

Modelling investments for the energy transition

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Abstract: The energy transition to decarbonize the economy will require mobilizing additional investment for a capital intensive low carbon energy structure. This is most obvious in the power sector with renewable energy being more capital intensive than fossil generation technologies. The electrification of other sectors (e.g. buildings or, transport) further increases the demand for electricity, requiring additional investments. Standard CGE models may not capture these dynamics and this paper argues that this can be improved by e.g. the coupling with energy models. Moreover, the additional investments also constitute a demand for sectors producing capital goods. We show the relevance of accounting for which sectors deliver capital goods for other sector's investment needs, as opposed to modelling a generic capital good.

Introduction

The global energy transition towards climate neutrality requires large-scale mobilization of investment (IEA, 2021; Keramidas et al., 2023). We here show why it is important to capture investment developments when using CGE models to assess these effects of macroeconomic relevance: they can affect the capital/labour ratio in the economy and increase the investment share in the composition of GDP, while the increase in investment has general equilibrium effects on sectors producing capital goods.

Energy models commonly project an increase in investments resulting from a shift towards low carbon or carbon free energy, e.g. from the use of renewables (European Commission, 2024; IEA, 2021; Keramidas et al., 2023). This is driven by replacing the current energy system, which has significant running costs from purchasing fuels, by one without fuel costs but higher capital costs. This change is most obvious in the power sector, which itself also plays an important role to allow other sectors to decarbonize through electrification (notably buildings and transport, but also industry under higher climate policy ambition). Similarly, energy use in other sectors of the economy can be substituted by capital through investments in energy efficiency.

In this paper, we show why it is important to account for this in CGE models, noting that a standard CGE model may have difficulties to project the strong increase in capital intensity.¹ One way to tackle this issue is to couple CGE models with energy models (Delzeit et al., 2020; Fæhn et al., 2020)², as energy models are able to better take into account the physical constraints of energy transformation. The additional investments projected by the energy models can guide CGE models, further constituting a demand for sectors producing capital goods. In addition, the GTAP database does not contain a link between investing sectors and sectors delivering capital goods, as each country has a single vector (cgds) characterized by the same shares for all sectors of activity, i.e. investment is made of the same composition. Accounting for this link could alter patterns on which sector benefits from additional investments in e.g. renewable electricity generation technologies.

Why the energy transition leads to higher investments (and why this may not be captured in CGE models)

CGE models may have difficulties to show a strong increase in investments under ambitious climate policies. Older or simpler CGE models do not differentiate various power generation technologies and thus may represent a shift to renewable electricity generation only implicitly through increases in the capital intensity in the sector (and a corresponding decrease in the share of fuel costs). Newer models capture different power generation technologies (Peters, 2016; Chepeliev, 2023) that explicitly feature different production structures with a higher reliance on capital for renewable electricity (Figure 1a). A shift towards renewables then leads (*ceteris paribus*) to a larger use of capital in the (aggregate) power sector, requiring additional investments to build up the capital stock in the power sector. This need for additional investments is even larger when one limits capital mobility across sectors, i.e. taking into account “stranded assets” from obsolete fossil generation technologies that are phased out and new investments that are required to build a new capital stock in the growing renewable electricity sectors (Figure 1b).

¹ This can also be due to model closures of savings-driven investments, which limits the scope for changes in the capital/labour ratio. However, the issue goes deeper as e.g. capital rental rates may not show the scarcity of capital in such models if the capital intensity of low carbon production is low.

² Linking energy and CGE models does not come out without own limitations. See also Delzeit et al. (2020) and Fæhn et al. (2020), for a discussion of the alternatives and challenges involved.

Energy models further project large-scale electrification of the energy system as an important driver of decarbonization (Keramidas et al., 2025), e.g. through replacing (fossil) heating systems by heat pumps and vehicles internal combustion engine vehicles by electric vehicles. This is projected to increase electricity demand in the economy. This may also hold for certain industrial processes which electrifies either directly or indirectly, e.g. though the use of hydrogen or e-fuels. These changes in energy use may be more difficult to capture in standalone CGE models, especially if the share of electricity as an input is relatively low in the benchmark. The sectoral substitution options to replace fossil fuels with electricity are more explicit in an energy model that may calculate the energy use required to a certain type of useful energy (e.g. a passenger-kilometre or ton-kilometre as transport activity or heating demand in buildings).

Running an off-the-shelf CGE model may thus risk underestimating electricity demand in decarbonization scenarios. One way to integrate the increased share of electricity use in sectors with important electrification trends is to make use of detailed energy modelling results, e.g. by linking or coupling those with CGE models. With the additional demand for electricity in transport or heating (both for services as well as for households), overall electricity demand then may also increase in a CGE model (Figure 1c). The link with bottom-up models thus brings a better depiction of within sector change, both in terms of energy use as well as capital requirements (Figure 1d).

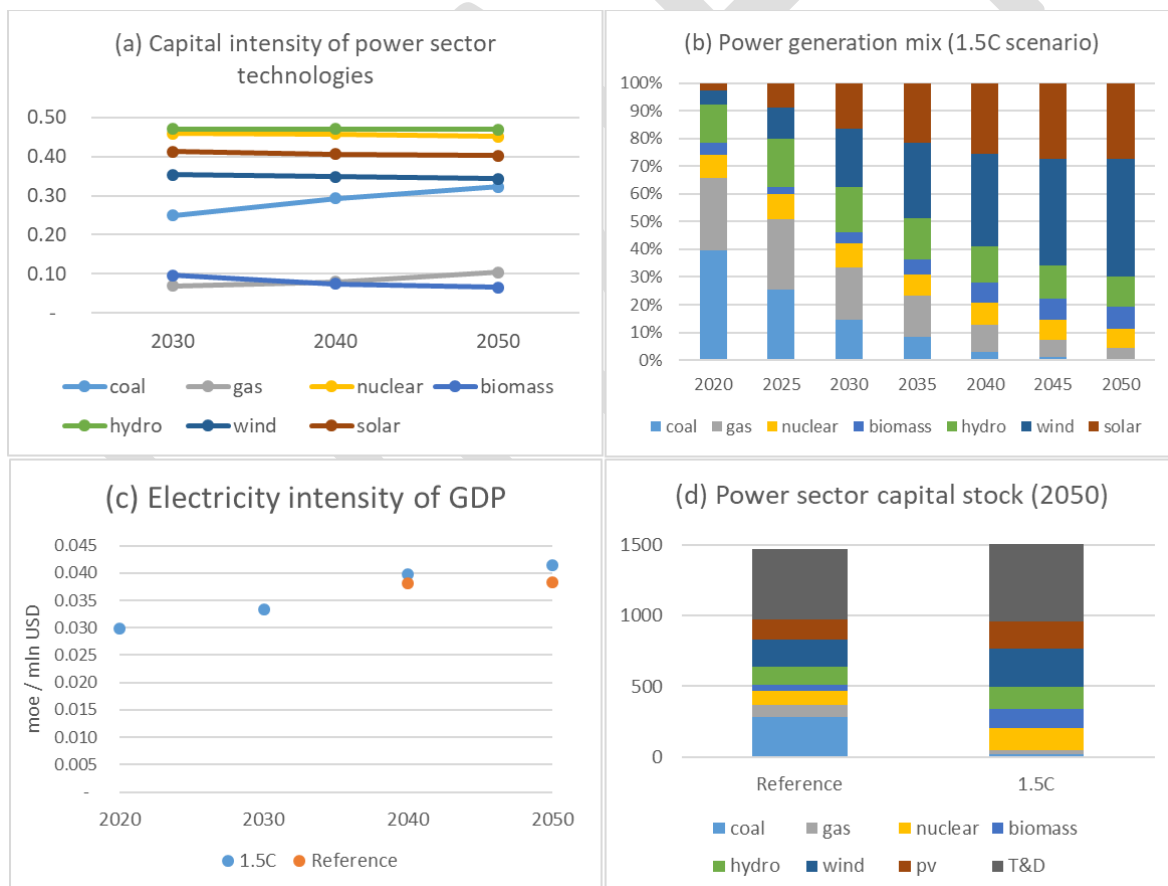


Figure 1. Capital use dynamics in the power sector and its drivers. (a) Capital intensity by electricity generation technologies, indicating the higher capital share for zero emission technologies. (b) The share of renewable electricity generation technologies rises in a decarbonization scenario. (c) Higher electricity intensity of GDP in decarbonization scenarios. (d) Capital use by power generation

technology in 2050. Based on scenarios underlying the Global Energy and Climate Outlook 2024 (Keramidas et al., 2025).

Capturing the investment drivers in a CGE model in more detail can have wider consequences on results. The shift towards more capital production technologies can lead to an overall increase in investments or at least to an increased share of investment in GDP. This is at odds to “naïve” CGE findings of reduced capital demand driven by a relocation of economic activity from sectors that are energy and capital intensive (e.g. industrial production as well as energy provision) towards less energy and capital intensive sectors (e.g. services). On the other hand, this may point to rigidities in (partial equilibrium) energy models that may overly restrict the options for economic structure.

Who is delivering the capital goods for the additional investment demand?

In addition, the increased share of investment translates into production of specific types of capital goods. The GTAP database (and thus many models based on GTAP data) only have a generic capital good, which is the same regardless of where investment demand originates from. However, if this additional investment is driven by additional investment in clean energy/electricity technologies, the provision of these technologies may have a different supply profile than the generic capital good (Figure 2). Using a sector specific investment matrix (e.g. Norman-López et al., 2023) can thus also have implications on overall projections for the output of upstream sectors delivering equipment goods or construction services.

For example, key technologies like wind and solar exhibit lower shares of services but a higher share of equipment/electric in the sector specific investment matrix compared to the generic investment matrix (dashed bar in Figure 2). This implies that certain upstream sectors producing these goods would benefit from additional investment activities for those power technologies. This is also relevant to understand socio-economic implications of the additional investment demand in the power generation sector, as it allows for an accounting of e.g. upstream jobs (Keramidas et al., 2023; Fulvimari et al., 2025) for renewable energy technologies as opposed to reporting only jobs related to operation and maintenance of these technologies.

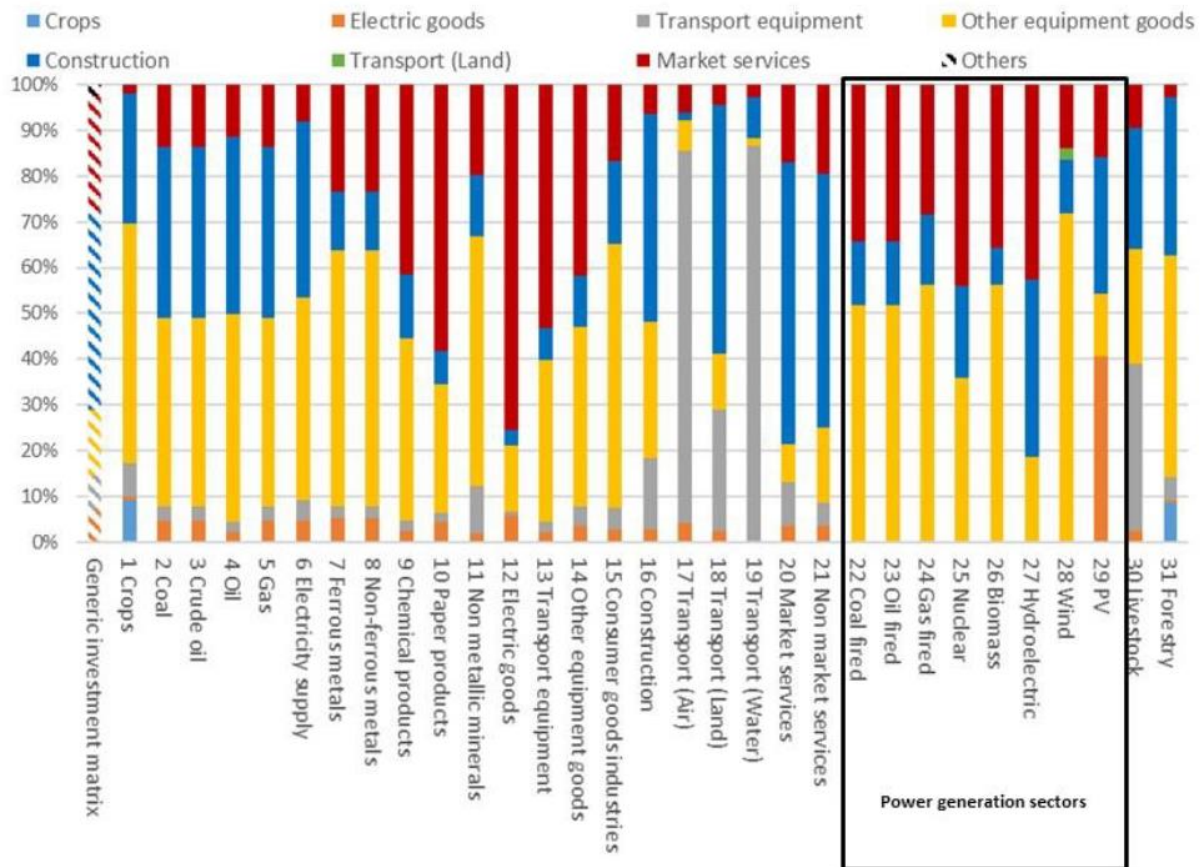


Figure 2. Sector specific investments (for the EU) as opposed to composition of a generic investment vector (dashed bar). Figure taken from Norman-López et al (2023).

Consequences and implications for policy recommendations

Higher demand for capital in the economy also has further consequences, e.g. for distributional impacts driven by the income side. Several studies combining CGE models with microdata have argued that the decline in (aggregate) capital demand depresses capital rents, which reduces the income overproportionally for richer households with a higher share of capital income (Rausch et al., 2010; Landis et al., 2021; Mayer et al., 2021; Wallenko and Bachner, 2025). This can then render climate policy progressive despite the fact that poorer households suffer overproportionally from higher energy prices, as they spend a larger fraction of their income on energy products on the consumption side.

Within sector changes of technologies are relevant abatement options. Switching to more capital electricity generation technologies allow for decarbonization of the power sector and should either be modelled explicitly (ideally informed by energy models) or via the appropriate calibration e.g. in terms of elasticities are required. The same paradigm likely also extends to other sectors, such as the transport sector, where more capital-intensive electric vehicles are a logical abatement option. Even in industrial sectors like iron and steel, capital intensive hydrogen routes could replace blast furnaces for decarbonization.

References

- Chepeliev, M. (2023). GTAP-Power Data Base: Version 11. *Journal of Global Economic Analysis*, 8(2). <https://doi.org/10.21642/JGEA.080203AF>.
- Delzeit, R. et al. (2020). Linking global CGE models with sectoral models to generate baseline scenarios: Approaches, opportunities and pitfalls. *Journal of Global Economic Analysis* 5(1): 162-195.
- European Commission (2024). Impact Assessment Report: Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society. SWD(2024) 63.
- Fæhn, T. (2020). Capturing Key Energy and Emission Trends in CGE models: Assessment of Status and Remaining Challenges. *Journal of Global Economic Analysis*, 5(1), pp. 196–272.
- Fulvimari, A., Garaffa, R., Kunertova, L., Van Der Vorst, C. et al. (2025), Estimating labour market transitions and skills investment needs of the green transition – A new approach, Publications Office of the European Union, <https://data.europa.eu/doi/10.2767/4332366>
- IEA (2021). World Energy Outlook. <https://doi.org/10.1787/14fcb638-en>.
- Keramidas, K., Fosse, F., Diaz Rincon, A., Dowling, P., Garaffa, R., Ordonez, J., Russ, P., Schade, B., Schmitz, A., Soria Ramirez, A., Van Der Vorst, C. and Weitzel, M. (2023) Global Energy and Climate Outlook 2023: Investment needs in a decarbonised world, doi:10.2760/836798, JRC136265.
- Keramidas, K., Fosse, F., Aycart Lazo, F.J., Dowling, P., Garaffa, R., Ordonez, J., Petrovic, S., Russ, P., Schade, B., Schmitz, A., Soria Ramirez, A., van Der Vorst, C. and Weitzel, M. (2025). Global Energy and Climate Outlook 2024, JRC139986.
- Landis, F., Fredriksson, G. and Rausch, S. (2021). Between-and within-country distributional impacts from harmonizing carbon prices in the EU. *Energy Economics*, 103, p.105585.
- Mayer, J., Dugan, A., Bachner, G., Steininger, K. W. (2021). Is carbon pricing regressive? Insights from a recursive-dynamic CGE analysis with heterogeneous households for Austria. *Energy Economics*, 104, 105661.
- Norman-López, A., Tamba, M. and Weitzel, M. (2023) Data and methods for building a disaggregated EU investment matrix – with an application to the 23 non-power generation and 8 power generation sectors of the JRC-GEM-E3 model, doi:10.2760/99423, JRC134919.
- Peters, J. C. (2016). GTAP-E-Power: An Electricity-detailed Economy-wide Model, *Journal of Global Economic Analysis*, 1(2), 156–187. doi: 10.21642/JGEA.010204AF.
- Rausch, S., Metcalf, G. E., Reilly, J. M., & Paltsev, S. (2010). Distributional implications of alternative US greenhouse gas control measures. *The BE Journal of Economic Analysis & Policy*, 10(2).
- Wallenko, L., & Bachner, G. (2025). Are rural households hit hardest? Exploring the distributional effects of region-specific compensation payments in the Austrian CO2 pricing scheme. *Energy Economics*, 141, 108118.