The Coalition of Finance Ministers for Climate Action

The GreenREFORM model

Danish Research Institute for Economic Analysis and Modelling (DREAM)

A contribution to the 'Compendium of Practice from a Global Community of Ministries of Finance and Leading Organizations: Economic analysis and modeling tools to assist Ministries of Finance in driving green and resilient transitions'

Topic: Modeling tools relevant to Ministries of Finance

June 2025

Access the full Compendium at www.greenandresilienteconomics.org

This contribution was prepared at the request of, and with guidance from, the Ministry of Finance of Denmark as Lead of the Coalition's Helsinki Principle 4 initiative 'Economic Analysis for Green and Resilient Transitions' and its Steering Group, with input from its Technical Advisory Group. The views, findings, interpretations, and conclusions expressed are those of the authors. While many Coalition members and partners may support the general thrust of the arguments, findings, and recommendations made in this contribution, it does not necessarily reflect the views of the Coalition, its members, or the affiliations of the authors, nor does it represent an endorsement of any of the views expressed herein by any individual member of the Coalition.

Overview

Denmark's Ministry of Finance is taking a leading role in the coordination and design of climate policy. GreenREFORM plays an important role in this respect, as it functions as a unified framework across Central Government for the evaluation of climate and environmental policy.

Importantly for the MoF, the GreenREFORM model is aimed at evaluating the combined effects of economic and environmental policy within a unified conceptual framework, thereby facilitating an integrated assessment of a broad range of policies.

For enhanced complementarity with existing models, GreenREFORM is built on a framework familiar to the MoF, and macroeconomic projections and Government finances are calibrated against existing forecasts, except for projections of sectors and of budget posts, where GreenREFORM provides a more detailed description than existing models. Information from GreenREFORM can thus be fed back into the next round of forecasts in the yearly cycle.

The core of the GreenREFORM model is a state-of-the-art dynamic computable general equilibrium (CGE) model, featuring forward-looking behavior, overlapping generations, and various frictions to achieve credible short-run dynamics inspired by dynamic stochastic general economic (DSGE) models (Kirk, 2024). Production is divided into 52 sectors with a total of 81 products and services, including 26 types of energy. Energy demand is categorized into six tax purposes to allow for accurate representation of marginal tax rates in the model (Kirk and Stephensen, 2022). A model-consistent dynamic welfare measure has also been developed (Stephensen, 2024).

GreenREFORM has been used recently to analyze the combined effects of a complex mix of policy measures targeting agricultural emissions from livestock emissions and land use (i.e., taxes, subsidies, technology mandates, and afforestation schemes). It has proved able to provide reliable information on important metrics for political decisions:

- Detailed emission accounts in accordance with UNFCCC standards
- Accounts of land use and livestock
- Changes to the return on capital and the value of firms in each sector of the economy, and changes to the market price of agricultural land in particular
- Macroeconomic impacts (i.e., changes in production, employment, wage rates, private consumption, exports, imports, investments, etc.)
- Fiscal impacts at a high level of detail, including derivative changes to, e.g., unemployment benefits, VAT revenues.

A suite of sub-models provides for a tailored description of the production and market conditions in sectors of particular importance for the green transition. The abatement sub-model is of particular importance, as it allows a bottom-up representation of technological abatement options across sectors, akin to familiar energy system models such as TIMES/PRIMES. Finally, an innovative technical framework allows for a fully integrated models system, where all sub-models are solved simultaneously, while maintaining the ability to turn individual sub-models on/off at will.

Denmark being a small open economy, the trajectories of technology costs are exogenously determined in the model. The model framework is expandable, should it be deemed relevant to introduce endogenous path dependence of technology costs, or the effects of R&D policies, etc. The Danish Energy Agency (DEA) and the Ministry of Climate, Energy, and Utilities play a crucial role in providing information on costs and the adoption potential of future technologies.

Key strengths

The GreenREFORM model succeeds in overcoming a number of trade-offs between CGE, DSGE, and system optimization models as described above.

To elaborate, CGE models are criticized for being too rigid and for being focused on long-term structural change rather than the actual transition of the economy ahead. DSGE models are heralded for their short-term characteristics and for focusing on issues of uncertainty, but suffer from a low level of granularity, i.e., production is, for example, often only divided into a handful of sectors. System optimization models are often very granular and complex in their description of particular sectors but suffer exactly because they are sector-specific, and, by extension, do not describe general macroeconomic mechanisms as CGE and DSGE models do.

The technical framework of GreenREFORM, and the choice of a full model integration makes the model computationally efficient to run compared with the often-applied technique of iterating between a CGE and a system optimization model. Once a baseline is established, a standard shock simulation takes only minutes on a powerful laptop. This is a big advantage, as it makes it feasible for Government officials to use the model to support political negotiations.

GreenREFORM creates overlaps in functionality with existing sector-specific models. Advanced sector-specific models, however, still hold their own when it comes to spatial disaggregation, etc. It can be argued that such overlaps create redundancy and confusion. The experience of DREAM, however, is that it is beneficial for building a mutual understanding of complexities, and for carrying across insights from sector experts into the macroeconomic decision environment.

Limitations

Supporting all sub-models with data and establishing a baseline requires a lot of information and strong support from sector experts and institutions. Top-down commitment, planning, and stakeholder management are therefore critical factors for success when building a comprehensive model system like GreenREFORM.

The success of GreenREFORM also relies on Denmark having a strong foundation in terms of data quality and the level of sophistication of models already in use at DREAM, the MoF, the DEA, etc. In another setting, it may be advised to set the level of ambitions lower initially but to ensure the core framework will support the level of sophistication ultimately desired. The TSI project mentioned below can serve as a guideline for how to get started in a setting with less fortunate preconditions.

Relevance to Ministries of Finance

GreenREFORM functions as a unified framework across Central Government for the evaluation of climate and environmental policy, and importantly for the MoF, for evaluating the interaction with fiscal and broader economic policy objectives.

In recent political negotiations on the regulation of agricultural emissions, GreenREFORM has proved to supply all of the core metrics asked for by decision-makers.

There are a number of sector-specific expert assessments and calculations already set up in the Central Government, which are used to calculate the energy, climate, and environmental social consequences of political initiatives. The purpose of GreenREFORM is thus to coordinate these assessments and contribute to them being carried out in a mutually consistent manner. It is also intended that GreenREFORM will be able to increase the transparency and comparability of different climate policy measures.

Use in practice

GreenREFORM has been utilized by the MoF from 2022 to 2024 to support an expert group tasked with proposing various strategies to achieve climate objectives within the agriculture and land use, land use change, and forestry (LULUCF) sectors (Expert Group for a Green Tax Reform, 2024). In this

context, GreenREFORM serves as the centerpiece for analyzing combinations of taxes on agricultural emissions and Government support schemes for afforestation, food additives, biochar, and more. The work of the expert group utilizing GreenREFORM laid a solid foundation for informed political debate and paved the way for parliamentary agreement on a reform addressing agriculture and LULUCF emissions in late 2024.

The first instance of the model being used for forecasting comes from the Danish Environmental Protection Agency, which employs GreenREFORM to forecast waste generation and recycling as part of the Danish emission inventory.

Outside of Government, GreenREFORM has contributed to several published works:

1) An analysis of the importance of credible announcements of climate policy, conducted in collaboration between two Danish policy institutes (Dahl and Kirk, 2022).
2) A consultancy report prepared for the Danish Society of Engineers, where GreenREFORM was used to analyze the effects of a proposed reform of the Danish higher education system, focusing on the societal economic value of technical and scientific education (KRAKA Economics, 2024).
3) A report by DREAM for the Danish Road Directorate, which utilized GreenREFORM to analyze the net impact on domestic emissions of public investments in infrastructure, depending on the means of financing (Dalgaard and Lindstrøm-Svendsen, 2024).
4) Based on simulations from GreenREFORM, Danmarks National Bank (the central bank of Denmark) has developed a method for assessing economic and financial risks associated with the green transition. The first use case involves analyzing the impacts of a sharp increase in CO_2e taxes under a risk scenario where current emission forecasts do not hold true (Jensen et al., 2024).
5) A report for the Nordic Council of Ministers, which focuses on specific climate challenges in each of the Nordic countries; the chapter on Denmark addresses the regulation of emissions from agriculture (Nordregio, 2024).
6) A paper published in the *Journal of Agricultural Economics*, which examines the economic and environmental impacts of a Danish greenhouse gas emissions tax on livestock production (Sørensen et al., 2025).

Future work

The idea for creating the GreenREFORM model was first conceived in 2016 by Peter Birch Sørensen, Professor of Economics at the University of Copenhagen. In his role as chair of the Danish Council on Climate Change, Sørensen recognized an unresolved need for appropriate analytical tools that would facilitate the systematic integration of climate and environmental considerations into the design of economic policy. The goal was therefore to provide the Danish Government, as well as think tanks and other organizations, with a new analytical tool that would enable the integration of economic policy with climate and environmental policy.

While the core development of the model is by and large completed, and the supply of data has been systematized, there is still scope for future development. Attention is currently focused on supporting the implementation of the model in the MoF and in other Government Agencies. Courses are being run to build capacity to use the model, a common server has been set up, and each Agency is making plans on how to make best use of respective relevant sub-models.

At the same time, DREAM is engaged in a project sponsored by the EU Commission Technical Support Instrument (TSI) program, to develop a "'work horse"' version of GreenREFORM for institutions in four EU countries. This will enhance their ability to identify, assess, and select the most efficient and effective policies and investments for the green transition. It will also enable them to forecast energy balances and emissions. This project can also serve as a blueprint for other countries to develop their

own customized models based on their specific data and needs. Building models on a common framework can offer significant advantages.

In the long term, the "'work horse"' models can be expanded to include additional sector-specific sub-models and more detailed descriptions of national regulations, similar to the approach taken in Denmark. However, it is important to note that these extensions will add complexity to the model and require additional data. Therefore, they should only be implemented once users are familiar with the model and a solid data foundation has been established.

Lessons and challenges

The primary challenge for the original team of researchers was how to reformulate existing power market and energy system models into a continuous problem space, to enable seamless integration with the macroeconomic model. This was achieved by the development of novel modeling techniques, which allow full integration between a dynamic CGE model and several detailed sector-specific models.

The Danish MoF got involved in 2019 and provided finance for a dedicated team of modelers set up at the Research Institute, DREAM. Since then, the model team has been working in close collaboration with the MoF and other Ministries, to make sure the model serves their particular needs. From the point of view of the model team, it has been challenging to get the various Ministries to engage in full during the development phase, the lesson being that top-down commitment and enforcement is critical when developing and introducing a new complicated tool across institutions.

With increasing international interest in the project, the experiences and insights gained from the development of GreenREFORM have been documented in a dedicated paper (Kirk, 2024). The content is based on numerous presentations and discussions with individuals from the global policy and modeling community.

Conclusions

The development of GreenREFORM started in 2017 as a university research project, based on an apparent unresolved need for appropriate analytical tools that would facilitate the systematic integration of climate and environmental considerations into the design of economic policy. Seven years on, the project objective has been met, and the model is being used in active support for political negotiations by the MoF, as well as by external institutions, with the aim of informing the domestic political debate about current climate policy.

Close collaboration between a dedicated model team, university researchers, sector experts and the end users of the model throughout the development has been key for its success.

The current EU-funded project to develop a '"work horse"' version of GreenREFORM can serve as a blueprint for other countries to develop their own customized models based on their specific data and needs. Such a model can be maintained by a small, dedicated team, to be expanded over time, when a solid data foundation and wider support has been established.

References

Dahl, G. E., and Kirk, J. S. (2022) *Analyse af CO2-afgift – Beregninger udført for CONCITO og KRAKA*.

Dalgaard, T. N., and Lindstrøm-Svendsen, M. (2024) *Infrastruktur og drivhusgasudledninger*. DREAM.

Danish Society of Engineers (2024) *Den samfundsøkonomiske værdi af de tekniske og naturvidenskabelige uddannelser*.

Expert Group for a Green Taxreform (2024) *Green Tax Reform*: Final Report.

Henriksen, J. S., and Kirk, J. S. (2022) *Macroeconomic Effects of a 350DKK Uniform Carbon Tax*.

Jensen, S. S., Deis-Bach, J., Ingholt, M. M., and Oksbjerg, M. (2024) *Ny metode til at vurdere økonomiske og finansielle risici ved den grønne omstilling. Danmarks Nationalbank*.

Kirk, J. S. (2024) *Development of the GreenREFORM Model*.

Kirk, J. S., and Stephensen, P. (2022) *Modelling Marginal Tax Rates in GreenREFORM*.

KRAKA Economics (2024) *Den samfundsøkonomiske værdi af de tekniske og naturvidenskabelige uddannelser*.

Nordregio (2024) *Regional Economic Effects of the Green Transition in the Nordic Region*.

Sørensen, P. B., Beck, U. R., Kirk, J. S., Berg, A. K., Stewart, L. B., and Stephensen, P. P. (2025) The effects of unilateral climate policy towards agriculture: A case study of Denmark. *Journal of Agricultural Economics* 76, 3–23. https://doi.org/10.1111/1477-9552.12624

Stephensen, P. (2024) *Velfærdsmål i GrønREFORM*.