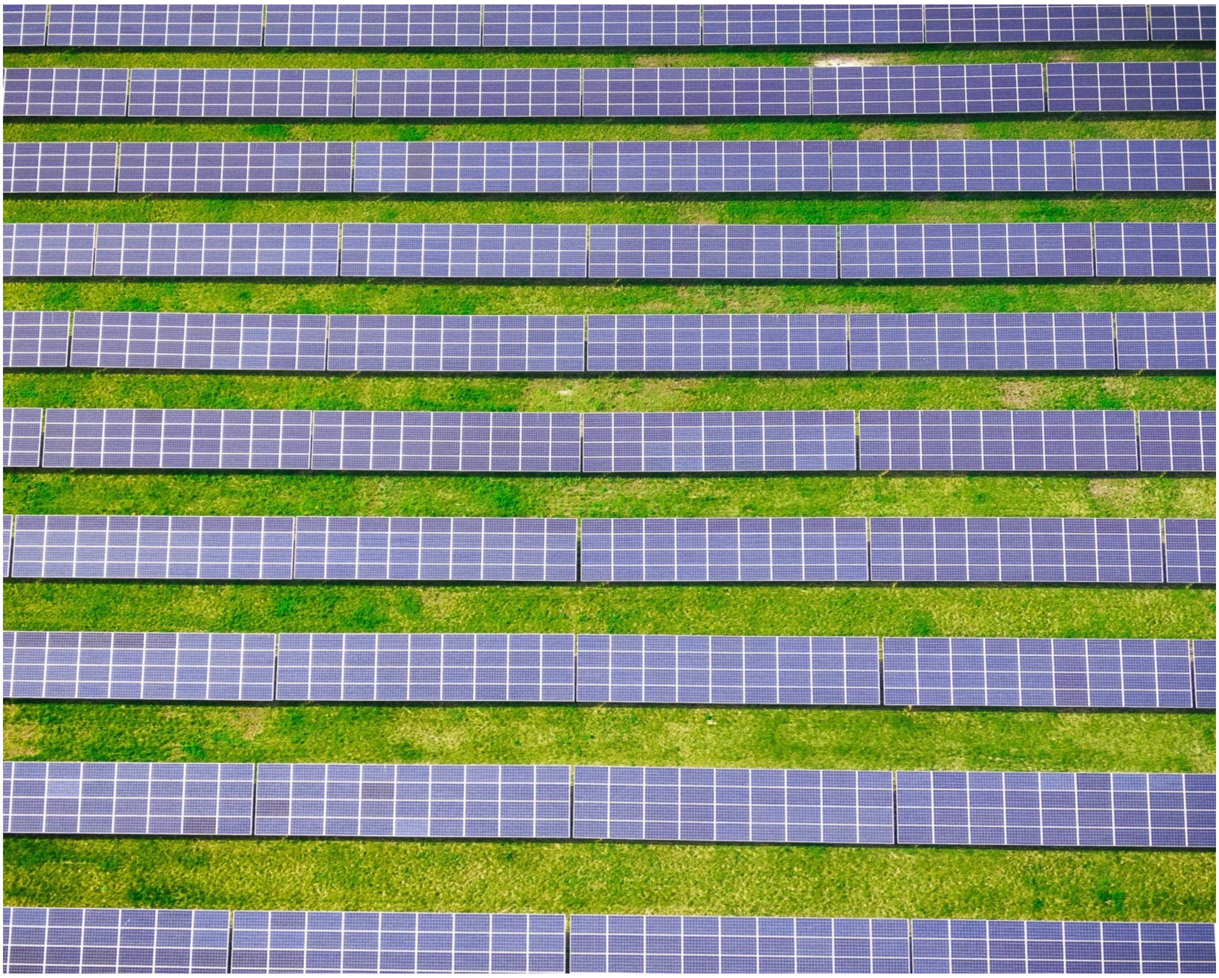
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of the Environment, Transport, Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Interim report dated 1st October 2021

Policy mix for full decarbonization by 2050



Source: https://unsplash.com/@dereksutton

Date: 1st October 2021

Location: Bern

Publisher:
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Bern
www.bfe.admin.ch

Subsidy recipients:
École Polytechnique Fédérale de Lausanne (EPFL)
Route Cantonale, 1015 Lausanne
https://www.epfl.ch/

Haute École de Gestion Genève (HEG-Ge)
Rue de la Tambourine 17, 1227 Carouge
https://www.hesge.ch/heg/

Authors:
Fleance Cocker, EPFL, fleance.cocker@epfl.ch
Philippe Thalmann, EPFL, philippe.thalmann@epfl.ch
Marc Vielle, EPFL, marc.vielle@epfl.ch
Frank Vöhringer, EPFL, frank.voehringer@epfl.ch
Sylvain Weber, HES-SO/HEG-Ge, sylvain.weber@hesge.ch

SFOE project coordinator:
Anne-Kathrin Faust, anne-kathrin.faust@bfe.admin.ch

SFOE contract number: SI/502094-01

Zusammenfassung

Das Projekt zielt darauf ab, einen Mix aus klimapolitischen Instrumenten zu entwickeln, der es der Schweizer Wirtschaft ermöglicht, bis 2050 Klimaneutralität zu erreichen. Das Ziel wird als praktisch keine fossilen Energieimporte interpretiert und konzentriert sich daher auf die Treibhausgas-Vermeidungsbemühungen in den Sektoren Strom, Verkehr, Gebäude und Industrie. Zunächst werden die Gründe für die Kombination von Instrumenten sowie deren Eigenschaften in Bezug auf Wirksamkeit, Effizienz, Gerechtigkeit und Machbarkeit (einschließlich Akzeptanz) ermittelt. Anschließend wird eine Reihe von Dekarbonisierungsszenarien, die verschiedenen Philosophien repräsentieren und sich in Bezug auf die oben genannten Kriterien unterscheiden, in einer aktualisierten und erweiterten Version eines internationalen CGE-Modells simuliert.

Das erste Jahr des Projekts hat zu (i) einem Verständnis der Hindernisse für die Dekarbonisierung in jedem Sektor, vielversprechenden Instrumenten zur Erreichung der Klimaneutralität und der Art und Weise, wie sie zusammenwirken, geführt; (ii) der Entwicklung einer neuen Version des Modells GEMINI-E3 mit einer feineren Darstellung von Schlüsselvariablen und einer funktionalen Form, die besser geeignet ist, signifikante Faktorsubstitution zu modellieren.

Résumé

Le projet vise à définir des combinaisons d'instruments de politique climatique qui permettront à l'économie suisse d'atteindre la neutralité climatique d'ici 2050. L'objectif est interprété comme la quasi-absence d'importations d'énergie fossile et se concentre par conséquent sur les efforts de réduction des gaz à effet de serre dans les secteurs de la génération d'électricité, des transports, des bâtiments et de l'industrie. En premier lieu, les justifications pour combiner des instruments sont identifiées, ainsi que leurs propriétés en termes d'efficacité, d'efficience, d'équité et de faisabilité (y compris d'acceptabilité). Ensuite, un certain nombre de scénarios de décarbonation, représentant différentes philosophies et se classant différemment selon les critères susmentionnés, seront simulés dans une version actualisée et augmentée d'un modèle d'équilibre général calculable international.

La première année du projet a permis (i) de comprendre les obstacles à la décarbonation dans chaque secteur, les instruments prometteurs pour atteindre la neutralité climatique, et leurs interactions ; (ii) de développer une nouvelle version du modèle GEMINI-E3 avec une représentation plus fine des variables clés et une forme fonctionnelle mieux adaptée pour modéliser la substitution des facteurs de façon significative.

Summary

The project aims to design mixes of climate policy instruments that will enable the Swiss economy to achieve climate neutrality by 2050. The objective is interpreted as virtually no fossil energy imports and thus focuses on greenhouse gas (GHG) abatement efforts in the power, transport, buildings and industry sectors. To start with, justifications for combining instruments are identified, as well as their properties in terms of effectiveness, efficiency, equity and feasibility (including acceptability). Then, a number of decarbonization scenarios, which represent different philosophies and rank differently along the aforementioned criteria shall be simulated in an updated and augmented version of an international CGE model.

The first year of the project has led to (i) an understanding of barriers to decarbonization in each sector, promising instruments to reach climate neutrality, and ways in which they interact; (ii) the development of a new version of the computable general equilibrium (CGE) model GEMINI-E3 with a finer representation of key variables and a functional form better suited to model significant factor substitution.

Contents

Abbreviations

Carbon capture and storage (CCS)

Constant Elasticity of Substitution (CES)

Computable General Equilibrium (CGE)

Electricity from Renewable Energy Sources (RES-E)

Emissions Trading Scheme (ETS)

European Union (EU)

Greenhouse Gas (GHG)

Organisation for Economic Co-operation and Development (OECD)

Photovoltaics (PV)

Swiss Energy Input Output Table (SIOT)

1 Introduction

1.1 Background information and current situation

Switzerland has committed to halve its emissions by 2030 relative to 1990 (FOEN, 2018) and attain net zero GHG emissions by 2050 (FC, 2019). Whether through a carbon tax or an emissions trading scheme (ETS), carbon pricing was long considered the ultimate solution to reducing anthropogenic GHG emissions by economists. However, the enforcement of emissions taxes and ETS around the world has either lagged or failed to put a sufficiently high price on GHG emissions to drive change to the degree required (World Bank, 2020). This may be explained by a number of political and behavioral barriers. At the same time, policy-makers have resorted to introducing multiple instruments of various sorts, thereby creating the “risk that the policy mix will degenerate into a policy mess” (Sorrell et al., 2003).

From a modelling perspective, simulating climate-neutral pathways in a CGE framework faces an important challenge, namely the difficulty to substitute inputs to significant extents (i.e. in the present case, eliminating fossil energy and replacing it with a clean input). In most instances, the literature has resorted to hybrid modelling to address this issue (Faehn et al., 2020). However, unlike many such studies, the current project would require all represented sectors of the economy to be linked to a bottom-up model, given the objective of climate neutrality at the country level. Yet “full-link” exercises have either resulted in convergence issues (e.g. Krook-Riekkola et al., 2017) or a simplification of the framework in terms of dimensionality (e.g. Helgesen and Tomasgard, 2018).

1.2 Purpose of the project

The current project aims to design coherent bundles of climate policy instruments that will allow Switzerland to achieve climate neutrality by 2050, based on a systematic analysis of their interactions and their effects on key dimensions to policy-makers. Among the latter, special attention will be given to environmental effectiveness, economic efficiency, social equity and political feasibility (including public acceptability). Such instrument mixes will then be simulated using an updated version of the CGE model GEMINI-E3 in order to determine quantitatively the required level of stringency of the various measures to achieve the net-zero objective, while taking into account feedback, income and trade effects.

1.3 Objectives

In order to successfully carry out the project, the intermediate goals described below were defined.

- WP1: review what climate policy instruments have been employed to successfully decarbonize (at least to some extent) western economies, identify their nature, the agents they affect, their strengths and weaknesses, and analyze how combinations thereof perform along the chosen criteria.
- WP2: update the underlying data of the CGE model, and choose a purposeful sectoral classification in light of key decarbonization levers, as well as a nomenclature for the international part; in parallel, extend the CGE framework to overcome the issue of “sticky value shares” associated with CES functions and hence allow for the simulation of climate neutral pathways.
- WP3: define a taxonomy of scenarios structured around a dominant philosophy and instruments which fulfil it, and perform simulations thereof using the updated CGE model.

- WP4: evaluate in a quantitative manner the effects of the various pathways on efficiency, equity and feasibility, and analyze in a qualitative manner their effects on e.g. energy security, environmental protection, industry competitiveness, and other potential risks.

2 Description of facility

See next section.

3 Procedures and methodology

WP1, tasks 1.1-1.4

The approach described hereunder was carried out on a sectoral basis, namely distinguishing between power, transport, buildings, and industry.

The methodology adopted for reviewing studies on climate policy instruments is of the narrative type, given the scope and multidimensional nature of the research question (Sovacool et al., 2018). For each of the four sectors, two strands of literature are analyzed, namely (i) that concerning the performance of instruments on an individual basis along the dimensions of effectiveness, efficiency, equity and feasibility, and (ii) when available, that concerning the performance of instrument bundles, i.e. taking into account interactions, along the same dimensions.

In a first step, the individual instruments are classified according to the targeted agents (producers, consumers), their nature (prescriptive, financial, other), and, when possible, their performance along the dimensions of feasibility, efficiency, equity, feasibility in a qualitative manner. In a second step, rationales for combining instruments in a given sector are identified, and promising instrument mixes are designed and later evaluated in a qualitative manner based on existing studies or gained insights of similar combinations.

WP2, task 2.1

The model is calibrated on two main sources: (i) the Swiss Energy Input Output Table (SIOT) 2014 (Nathani et al., 2019) and (ii) the GTAP 10 Database (Aguiar et al., 2019). The new base year of the model is 2014. The database is completed by other sources like Inventories of GHG emissions, marginal abatement cost curves for non-GHG emissions, demographic scenarios, etc. The model benefits from its participation into the H2020 Paris-Reinforce project[1] where a procedure was implemented for sharing and harmonizing in a transparent way socio-economic and technological assumptions and climate policies database (this work is detailed in Giarola et al., 2021; Nikas et al., 2021).

The industrial classification of the model is revised with the aim to better describe the energy carriers that could potentially increase their contribution to Swiss energy supply (like biofuels, wood and waste). This new classification also takes into account the exiting design of the climate policies, i.e. sectors that are part of the ETS are represented (through six sectors). Another aim is to detail specificities of energy demand, therefore transport is disaggregated into six sectors.

[1] see https://paris-reinforce.eu/

WP2, task 2.2

In addition to the above refinements, a greater level of detail was given to the representation of energy carriers, types of energy usages, and power generation technologies. An appropriate regional classification was devised based on similarity of economic fundamentals and intended climate policies.

At the same time, an alternative functional form to the CES was developed in order to allow for full substitution of fossil energy, as required by climate-neutral pathways. It is inspired by the specification first proposed by Rivers and Jaccard (2005). The current approach bears a number of advantages over other methodologies such as hybrid modelling, namely the fact that it may be easily calibrated and implemented in a CGE model, keeps the framework tractable and avoids issues related to data compatibility and convergence. Specifically, the suggested solution builds on the insight that with the novel function, the diffusion rate of an input's market share does not decrease by a factor proportional to its price as in the CES case. Hence, although both options require an input's price to converge to infinity for the input's demand to reach zero in the limit, the convergence speed is far greater under the novel specification. These properties are desirable both from a technical (smoothness) and conceptual (substitution) point of view. A straightforward calibration procedure is proposed to replicate the CES demands in the reference year, and emulate their behavior around the equilibrium for marginal changes in input prices.

4 Activities and results

The main outcomes at the end of the first year of the project are described hereunder.

WP1, tasks 1.1-1.4

The performed literature review has led to a number of important findings.

First, no instrument is superior across all dimensions. There exist inherent tradeoffs between effectiveness, efficiency, equity and feasibility. For instance, strict prescriptive measures (e.g. bans) are very effective but highly inefficient, inequitable and unpopular, while voluntary programs and information campaigns tend to have limited environmental effectiveness, but are efficient, fair and enjoy way more support. Furthermore, specific design characteristics play a critical role in the performance of instruments along the various dimensions. For instance, electric vehicle subsidies that are not contingent on a scrappage scheme, may result in wealthy households buying an additional car rather than in the replacement of internal combustion engines. Similarly, the inclusion of a capacity cap in feed-in tariffs still provides certainty to investors but ensures the government keeps control on expenses.

Second, each of the four sectors faces a number of market failures or barriers, which may render the achievement of climate neutrality challenging. While some are general in nature, e.g. technological lock-in or cost barriers, other are particularly relevant for specific sectors. They consist for instance of innovation spillovers, deployment spillovers and financing restrictions in the power sector; trust in novel technologies, myopia, social status and infrastructure availability in the transport sector; split incentives between the landlord and tenant, imperfect information and bounded rationality in the buildings sector; or stranded assets and leakage in the industry sector.

Third, the combined effect of instruments is seldom equal to their individual effect on the dimensions of interest. Indeed, interactions may be mitigating, neutral or reinforcing. For instance, combining support for RES-E with an ETS will not increase effectiveness (unless the cap is set by taking into account the former target) and will have an adverse effect on efficiency, yet will increase feasibility. In the buildings sector, combining information campaigns and retrofit subsidies is more effective than either instrument on its own, while also increasing efficiency.

WP2, task 2.1

Table 1 describes the sectoral classification adopted for the current project.

Table 1: Sectoral classification of the Swiss version of the GEMINI-E3 model

Sector number	Sector name	Sector number	Sector name
01	Coal	11	Other Energy Intensive industries (ETS)
02	Crude Oil	12	Construction
03	Natural gas	13	Other Industries
04	Refined oil	14	Passenger Rail & Land transport
05	Electricity	15	Freight rail Transport & Pipeline
06	District heating	16	Freight road Transport
07	Agriculture & Fishing	17	Water Transport
08	Forestry	18	Air Domestic Transport
09	Mineral	19	Air International Transport
10	Pharmaceutical & Chemical products	20	Services

The table deserves two important clarifications:

- It was necessary to disaggregate two sectors represented in the SIOT. The sector "Product of mining and quarrying" (NOGA 05-09) was disaggregated into four subsectors: "Coal", "Crude Petroleum", "Natural Gas" and "Metal Ores & Other Mining & Quarrying". In the same manner, the sector "Air Transport Services" (NOGA 51) was divided into "Domestic Air Transport Services" and "International Air Transport Services".
- The GTAP classification does not provide the same level of detail as the SIOT. Therefore, some sectors are more aggregated. Sectors 14, 15, and 16 are aggregated into "Land Transport". Sector 18 and 19 into a single "Air Transport" sector. Finally, "District Heating" and "Electricity" are aggregated together.

WP2, task 2.2

Several improvements were implemented with respect to the previous Swiss GEMINI-E3 model[2]. The number of energy carriers was extended to 10 and now include coal, crude oil, natural gas, refined oil, electricity, district heating, biofuel, biogas, wood, waste. In addition, for households and every sector, the model distinguishes energy uses according to three categories: transport purposes, other energy consumption (heating, heat in industrial process), non-energy uses i.e. the use of energy as a raw material (feedstock), e.g., crude oil for making plastics. The electricity generation sector describes 13 types of power plants: oil (with or without CCS), coal (with or without CCS), natural gas (with or without CCS), bioenergy (with CCS or without CCS), wind, solar (only PV), nuclear, other types (all other power plants not described elsewhere). Finally, the regional classification describes five countries/regions: Switzerland, The European Union (in its 28 Member-State configuration), rest of OECD countries, China, rest of the world (consisting of all remaining countries).

[2] The previous version is described in Thalmann and Vielle (2019).

In parallel to updating the GEMINI-E3 model as described above, the novel specification developed to replace the CES function was implemented in a previous version of GEMINI-E3 for the energy nest (taking fossil energy and electricity as inputs) of the Energy-Intensive Industry (EII) sector. The outputs of the standard CES function and the alternative functional form were then compared under various carbon tax schedules in terms of scope (uniform, sector-specific) and stringency (targeted reduction in GHG emissions relative to the baseline). Table 2 shows the results for an EII-specific carbon tax that yields a 90% reduction in emitted tCO2eq relative to the baseline in the year 2050.

Table 2: Energy-Intensive Industry sector, 2050 (90% reduction in GHG emissions)

Specification	Factors	Quantity (mCHF)	Price (normalized)
CES	Energy	521	3.34
	Fossil energy	49	19.57
	Electricity	941	0.83
Alternative	Energy	1,522	0.94
	Fossil energy	47	4.24
	Electricity	1,475	0.83

Note: carbon taxes in 2050 are 4,328 CHF/tCO2eq (CES) and 716 CHF/tCO2eq (alternative).

As expected, a given reduction expressed in terms of emitted tCO2eq is achieved with a much lower carbon price under the novel functional form than the CES function when the level of decarbonization is deep. More generally, less fossil energy is used under the alternative specification than the CES for given price increases, and this differential increases the more ambitious the abatement target. Convergence in the model is also achieved with stricter emission targets, suggesting the proposed function is technically well-suited for the task at hand.

5 Evaluation of results to date

Most tasks of WP1 have been fulfilled, since instruments and combinations thereof for three sectors (power, transport, buildings) were studied based on both theoretical and empirical papers, allowing for key lessons to be drawn. However, at the time of writing, less attention was given to instruments targeting the fourth sector (industry), and as such, remains to be analyzed in depth. No significant delay should be incurred given that the literature is not as vast as the one covering each of the three other sectors.

All tasks of WP2 have been successfully completed within the defined timeframe, as GEMINI-E3 has been updated, augmented with a novel functional form and is ready to be run. Some aspects will nonetheless be explored further, namely ways to include the production of hydrogen in the model thanks to inputs from the Paris-Reinforce project, as well as alternative procedures to calibrate the novel functional form and deducing the overarching class of production or consumption it is consistent with.

6 Next steps

The next steps to be undertaken in the second year of the project are described hereunder.

WP3, task 3.1

Simulate the baseline scenario (i) using assumptions on GDP, population and energy prices from the Energy Perspectives 2050+ (Prognos, 2021) for Switzerland, and the World Energy Outlook (IEA, 2020) for the international part of the model; and (ii) taking into account the currently implemented climate policies based on those in the Energy Perspectives 2050+ (Prognos, 2021) for Switzerland, and based on those included in the Paris-Reinforce project for other countries.

WP3, task 3.2

Simulate decarbonization pathways reaching climate neutrality in 2050 solely based on carbon pricing. Specifically, the four considered scenarios are described below.

- Uniform tax: a uniform carbon tax covers all sectors of the Swiss economy.
- EU ETS & uniform tax: sectors currently subject to the EU ETS face a price determined thereby, while the remaining sectors face a uniform tax.
- EU ETS & differentiated tax: sectors currently subject to the EU ETS face a price determined thereby, while the remaining sectors face a differentiated tax.
- Extended EU ETS & uniform tax: some sectors currently not subject to the EU ETS join the scheme and face a price determined thereby, while the remaining sectors face a uniform tax.

WP3, task 3.3

Develop a taxonomy of decarbonization philosophies, such as e.g. “polluter pays” or “rewards for socially desirable behavior”, associating dominating instruments to them (e.g. carbon taxation under “polluter pays”, subsidies under “rewards”) and complementing the mix with instruments that address specific issues related to effectiveness, efficiency, equity and feasibility on a sectoral basis. Simulate decarbonization pathways towards climate neutrality in 2050 based on the above instrument mixes, by setting the right price incentives at the correct time period and ensuring non-price instruments are modelled appropriately and their effects calibrated to those found in the relevant literature.

WP3, task 3.4

Integrate the policy targets implied by the simulation outputs from GEMINI-E3 into the Energyscope model by defining the corresponding ambition levers (e.g. 80% of electric vehicles in the car fleet).

WP4, tasks 4.1 & 4.2

Perform a quantitative analysis on the effects of each pathway on (i) efficiency, which shall be measured through welfare changes directly in the CGE model, and (ii) equity, which shall be measured through impacts of prices and transfers on the budgets of relevant household types defined using FSO HBS data.

7 National and international cooperation

The project benefits from the participation of our lab to the H2020 Paris-Reinforce project. We have access to several databases and the work done within this international project will help us to validate our model and design the scenarios especially regarding the international part.

Two versions of the model are registered to the IPCC scenario submission portal platform (https://data.ene.iiasa.ac.at/ar6-scenario-submission/#/workspaces), therefore the scenarios developed within this project could potentially be uploaded to the IPCC portal and be part of the future IPCC Assessment Reports.

8 Communication

Not applicable.

9 Publications

None at the time of writing.

10 References

Aguiar, A., Chepeliev, M., Corong, E., McDougall, R., and van der Mensbrugghe, D. (2019). The GTAP Database: Version 10. *Journal of Global Economic Analysis*, 4(1):1–27.

Faehn, T., Bachner, G., Beach, R., Chateau, J., Fujimori, S., Ghosh, M., … and Steininger, K. (2020). Capturing key energy and emission trends in cge models: Assessment of status and remaining challenges. *Journal of Global Economic Analysis*, 5(1), 196–272.

FC. (2019). Federal Council aims for a climate-neutral Switzerland by 2050. *Federal Council*. Retrieved (15.08.2021), from https://www.admin.ch/gov/en/start/documentation/ media-releases.msg-id-76206.html

FOEN. (2018). The Paris Agreement. *Federal Office for the Environment*. Retrieved (15.08.2021), from https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/ climate--international-affairs/the-paris-agreement.html

FSO. (2016). Revenus et dépenses des ménages (ensemble des tableaux des années 2012-2014). *Federal Statistical Office*. Retrieved from https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/income-consumption-wealth/household-budget.html

FSO. (2019). Revenus et dépenses des ménages (ensemble des tableaux des années 2015-2017). *Federal Statistical Office*. Retrieved from https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/income-consumption-wealth/household-budget.html

Giarola, S., Mittal, S., Vielle, M., Perdana, S., Campagnolo, L., Delpiazzo, E., Bui, H., Anger Kraavi, A., Kolpakov, A., Sognnaes, I., Peters, G., Hawkes, A., Köberle, A. C., Grant, N., Gambhir, A., Nikas, A., Doukas, H., Moreno, J., and van de Ven, D.-J. (2021). Challenges in the harmonisation of global integrated assessment models: A comprehensive methodology to reduce model response heterogeneity. *Science of The Total Environment*, 783:146861.

Helgesen, P. I., and Tomasgard, A. (2018). From linking to integration of energy system models and computational general equilibrium models e effects on equilibria and convergence. *Energy*, 159, 1218-1233.

IEA. (2020). World Energy Outlook. International Energy Agency. Paris.

Krook-Riekkola, A., Berg, C., Ahlgren, E. O., and Söderholm, P. (2017). Challenges in top-down and bottom-up soft-linking: Lessons from linking a Swedish energy system model with a cge model. *Energy*, 141, 803-817.

Nathani, C., Zandonella, R., van Nieuwkoop, R., Brandes, J., Schwehr, T., Killer, M., Sutter, D. (2019). Energiebezogene Differenzierung der Schweizerischen Input-Output-Tabelle 2014. Schlussbericht an das Bundesamt für Energie. Rüschlikon/Zürich/Thun.

Nikas, A., A. Elia, B. Boitier, K. Koasidis, H. Doukas, G. Cassetti, A. Anger-Kraavi, H. Bui, L. Campagnolo, R. De Miglio, E. Delpiazzo, A. Fougeyrollas, A. Gambhir, M. Gargiulo, S. Giarola, N. Grant, A. Hawkes, A. Herbst, A. C. Köberle, A. Kolpakov, P. Le Mouël, B. McWilliams, S. Mittal, J. Moreno, F. Neuner, S. Perdana, G. P. Peters, P. Plötz, J. Rogelj, I. Sognnæs, D.-Jan Van de Ven, M. Vielle, G. Zachmann, P. Zagamé, A. Chiodi. (2021). Where is the EU headed given its current climate policy? A stakeholder-driven model inter-comparison, *Science of The Total Environment*, Volume 793.

Prognos. (2021). Energy perspectives 2050+. Prognos, INFRAS, TEP Energy, Ecoplan for the Swiss Federal Office of Energy.

Rivers, N., and Jaccard, M. (2005). Combining top-down and bottom-up approaches to energy-economy modeling using discrete choice methods. *The Energy Journal*, 26(1), 83–106.

Sorrell, S., Smith, A., Betz, R., Walz, R., Boemare, C., Quirion, P., ... and Pilinis, C. (2003). Interaction in EU climate policy. Final report. *Science and Technology Policy Research*.

Sovacool, B. K., Axsen, J., and Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research & Social Science*, 45, 12-42.

Thalmann, P., and Vielle, M. (2019). Lowering CO_2 emissions in the Swiss transport sector, *Swiss Journal of Economics and Statistics*, 155:10.

World Bank. (2020). State and trends of carbon pricing 2020. World Bank, Washington, DC.