

An Integrated Modelling Approach to Assess the Impact of Existing Structural Policies: The Case of Switzerland's Climate and Energy Policies

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Introduction

1. Limiting climate change and achieving the objectives of the 2015 Paris Agreement requires ambitious policies to be implemented by countries around the world (D’Arcangelo et al., 2022^[2]; IPCC, 2022^[3]). While countries have made significant progress in adopting a wide set of climate mitigation policies, the challenge to optimise the combined global impact of all individual countries’ emissions reduction efforts persists. As countries continue their efforts to reach their climate mitigation targets, a key question is thus through which channels currently implemented policies affect countries’ greenhouse gas (GHG) emissions and what the associated economic outcomes are. Moreover, since government budgets become tighter under ongoing fiscal consolidation, it is also key to understand what the cost implications of the individual policies are, and where funds are spent most efficiently.

2. Many different analytical approaches have been used to assess the (cost-)effectiveness of climate mitigation policies consistently across countries, mostly grounded in a large literature on ex-post approaches. While ex-post empirical analysis is firmly grounded in observed data, econometric models are demanding in terms of data availability and identification. They require *inter alia* sufficient, consistent time series and clearly distinguishable policy impacts independent of other developments to achieve robust explanatory power and even then may lack external validity (see, for example (Stechemesser et al., 2024^[4])). These requirements may make it difficult to evaluate very recent, less intensive, or gradually implemented policies. Moreover, empirical analyses focus on only a few indicators of economic performance of different policies and cannot disentangle the respective effects of different policy tools.

3. Ex-ante economic modelling tools, such as Computable General Equilibrium (CGE) modelling - though subject to different types of uncertainties - can shed light on the likely impacts of new or evolving policies. These approaches can also explore transmission mechanisms through scenario analysis, even in situations where data availability is limited. This not only helps to understand how policies work and interact, but also to identify key levers for improving their design and effectiveness over time. Thus, modelling tools, which are mostly used as ex-ante analytical tools, lend themselves well to studying also the effectiveness of currently implemented “real world” policies.

4. Relying on ex-ante modelling tools, this study employs a novel modelling approach to systematically evaluate the efficiency of currently implemented policies across a large set of countries¹. The approach combines the breadth of a dynamic and global CGE model with the granularity of bottom-up sectoral models through a standardised soft-linking approach applied consistently across countries and policy types. By linking CGE and bottom-up models, the framework delivers highly detailed insights into technological, environmental and economic outcomes, capturing both direct and indirect policy effects. This breadth and depth enable a structured, holistic assessment of how different real-world policies affect costs through changes in technology choices, public finances, economic activity, and emissions trajectories, at both the domestic and international level, thus supporting clear and consistent information to policymakers. This framework allows for the consistent assessment of most types of current structural policies – including detailed regulatory policies affecting technology choices – rather than limiting the analysis to fiscal instruments, which can be modelled more easily with CGE models.

5. The paper describes the new harmonised and standardised modelling approach to assess the impact of currently implemented key climate mitigation policies, which was developed under the OECD’s Inclusive Forum on Carbon Mitigation Approaches (IFCMA) (OECD, 2024^[5]). But this modelling approach can also be applied for studying other policy domains, such as industrial policies or sectoral policies (Delzeit et al.,

¹ The analysis is conducted as part of the OECD’s Inclusive Forum on Carbon Mitigation Approaches (IFCMA). In addition to OECD Members and the EU, IFCMA members include Argentina, Barbados, Bulgaria, Cameroon, Croatia, Jamaica, Kazakhstan, Malta, Mauritius, Monaco, Morocco, Nigeria, Paraguay, Peru, Philippines, Romania, Singapore, South Africa, Ukraine, Uruguay and Zambia.

2020_[6]), that rely on economic structural changes and technological choices, as well as the analysis of complex mixes of fiscal instruments and regulations.

6. The paper also presents a case study conducted for Switzerland combining the sectoral JRC-EU-TIMES model², with the OECD ENV-Linkages CGE model. The Swiss case study analyses selected current policies - mostly grouped under the CO₂ act legislation - affecting the buildings, road transport and industry sectors. These key climate mitigation policies include a variety of market-based and non-market-based instruments, including carbon pricing schemes, fuel taxes and regulations in the buildings and transport sector.

7. Findings show sizable differences in the economic and environmental efficiency of the different policies. They also stress the usefulness of the novel approach, which allows to directly compare the impacts of different policy types on various economic and environmental indicators (e.g. GDP, sectoral composition of output and employment, competitiveness indicators, public finance outcomes, GHG emission reductions, energy metrics), showing that none of the selected current policy dominates the other for all the different indicators.

8. Section 2 outlines the current literature on sectoral and economy-wide modelling and connects previous modelling efforts to the IFCMA approach. Section 3 describes the IFCMA modelling approach and possible outputs. Section 4 presents the policies, modelling set-up and outcomes of the Swiss case study conducted using the IFCMA methodology. Section 5 concludes.

² The standard JRC-EU-TIMES model was further developed from the Paul Scherrer Institute PSI for the needs of this study. The version of the model used in this paper has a detailed representation of the energy system of 30 European countries.

Literature review: previous work on linking sectoral and economy-wide models

9. Sectoral models are biophysical or engineering models (e.g. an energy-system or a land-use model) that record *direct impacts* of policies on granular technology choices and input substitution options, they generally consider a partial-equilibrium framework to *ex-ante* assess of policy impacts. To be more precise, sectoral models explicitly represent numerous technical options and therefore capture finely how agents' technology choices are constrained by existing regulatory instruments. For example, power-sector models incorporate geography, grid constraints, seasonal and hourly demand patterns and plant age structures to determine optimal generation mixes - features that economy-wide models cannot represent.

10. In contrast, economy-wide models, such as Computable General Equilibrium (CGE) models, include fewer technological details (technological choices are represented by smooth non-linear production functions) but provide a comprehensive representation of economic flows, covering all economic sectors and ensuring macroeconomic consistency. These class of economy-wide models are therefore able *ex-ante* to quantify *indirect* economic effects, such as those on prices and demands for goods and sectors not directly targeted by the policies as well as income impacts, that sectoral models generally do not consider.

11. Recent advances in policy modelling increasingly combine top-down CGE models with bottom-up sectoral models to evaluate the effects of structural real-world policies that target specific sectors or agents. Such approaches have been applied widely to energy, transport and agriculture sectors (see the list of representative studies reported in Table 1). This growing literature recognizes that while CGE models excel at capturing economy-wide feedback effects, price adjustments, and cross-sector interactions, they often lack the technological details which is needed to assess technology-based mitigation options (e.g. regulations) or very granular policy intervention (like subsidies to a specific type of vehicles for example).

12. To overcome this, a common way is to link sectoral and economy wide models. Linking models means to use the outcomes of one model to feed the other model. The type of variables that are exchanged across models is determined by the modelling purpose of each model. For example, CGE models generally inform other models about structural changes (i.e. changes in sectoral composition of the economy) or about the full structure of relative prices, macro-economic models would provide information about monetary and financial variables, while an energy system model will provide to other model changes in energy mix, fuel prices and energy-related technology. There is no unique way to link models, a variety of model linking approaches have been developed, characterized by a taxonomy that distinguishes models by their methodological structure, most notably: 'soft-linking' versus 'hard-linking', and in the direction of information flow, 'one-way' versus 'two-way' coupling or 'complete integration' of models, as discussed by Delzeit et al., (2020^[6]). The paper by Faehn et al., (2020^[7]) propose a literature review, that survey 17 state-of-the-art CGE models (including ENV-Linkages), of methods frequently used to couple CGE model with energy informations/models.

13. Building on this taxonomy, OECD (2024)^[2] developed a framework to orient modellers in selecting model linking designs for evaluating the direct and indirect impacts of climate and energy policies. The framework distinguishes approaches along several key dimensions, like level of sectoral and technological detail, extent of coverage of economic interactions, degree of harmonisation, and scalability. Each dimension involves distinct trade-offs between analytical depth, consistency, and resource intensity. These design choices, together with differences in how information is exchanged between models, shape the degree of coupling across modelling initiatives (the main features of common linking configurations are summarised in Table 1). Overall, no single strategy prevails across all criteria, as each balances flexibility and consistency differently depending on modelling scope and available resources.

Table 1. Overview of model linking configurations

Degree of coupling	Information flow	Key strengths	Typical limitations	Representative studies	Implementation approach
Soft-link	One or Two-way linking	Flexibility; Modularity; Practical implementation; Preserves model autonomy	Resource intensive; Iterative convergence challenges	Labriet et al., (2015 ^[8]); Vandyck et al., (2016 ^[9]); Hasegawa et al., (2017 ^[10]); Krook-Riekkola et al., (2017 ^[11]); Zhang et al., (2018 ^[12]); Andersen et al., (2019 ^[13]); Gebremeskel (2023 ^[14]); Weitzel et al., (2023 ^[15]); Nishiura et al., (2024 ^[16]); Fujimori et al., (2024 ^[17]); Schreiber et al. (2025 ^[18]);	Independent models exchange selected variables through a one-way or iterative exchange
Hard-link	Two-way linking	Enhanced internal consistency; Simultaneous equilibrium solution; Full feedback effects	Resource and computationally intensive; Complex calibration; Reduced modularity	Arndt et al., (2016 ^[19]); Helgesen et al. (2018 ^[20]); Durand-Lasserve et al., (2023 ^[21])	Models are coupled and solved simultaneously
Fully-integrated linking	Unified system (no separate linking)	Full consistency; No iterative exchanges; Streamlined computation; Shared database	Requires design from scratch; Less flexible; Limited sectoral detail vs. specialized models	Böhringer & Rutherford, (2008 ^[22]); Helgesen & Tomasgard (2018 ^[23])	All components are integrated into a single modelling system with a common database and codebase

Source: Authors, adapted from OECD (2024) and selected literature.

14. Model linking is also needed for a better estimation of the magnitude of impacts of a policy. Many linked modelling studies find that considering indirect/general equilibrium effects may reinforce or offset the magnitude of the partial equilibrium effects of sectoral models. The necessity of adopting a model-linking framework to provide a better estimation of policy costs is demonstrated by Schreiber et al., (2025^[18]). Their study estimates the general equilibrium social costs of a US regulation in the electricity sector to be 29% above the partial equilibrium costs (due to demand responses and tax interaction effects). Others demonstrated that the linked approach reveals faster renewable energy transitions compared to standalone CGE approaches (Fujimori et al., 2024^[17]) and enables earlier emission reductions yielding 98 Gt CO₂ of additional cumulative abatement by 2050 in the simulated mitigation scenario consistent with a temperature rise below 2°C (Nishiura et al., 2024^[16]).

15. While soft-linking approaches enable detailed policy analysis and are valued for their practicality and transparency, facilitating a clearer understanding of each model's contribution to the analysis, the exchange between models will never be complete, and thus limit the degree of convergence between the two types of models to some extent. This has motivated researchers to explore hard-linking configurations (Arndt et al., (2016^[19]); Helgesen et al. (2018^[20]); Durand-Lasserve et al., (2023^[21]). The trade-off lies in the fact that hard-link integration enhances internal model consistency, while requiring intensive computation and more stringent calibration processes than soft-linking approaches.

16. Pushing integration even further, some studies adopt fully integrated frameworks. Böhringer and Rutherford (2008^[22]) were the first to illustrate the evolution toward integrated models with their Mixed Complementarity Problem (MCP) formulation, which simultaneously solves for the energy system and the economy-wide model. Their study provides evidence on how energy-policy shocks induce welfare effects and electricity-mix changes that would not emerge in less integrated modelling frameworks. Similarly, Helgesen and Tomasgard (2018^[23]) designed CGE and sectoral components as a single modelling system from the outset, sharing databases and solving simultaneously. This configuration eliminates the singular or iterative exchanges of soft-linking and the computational intensity of hard-linking, providing a streamlined yet

internally consistent representation of the economy-sectoral nexus. Their findings indicate that even though iterative hard-linking and integrated models produce comparable outcomes, a fully unified formulation can better capture cross-sectoral feedback and agents' anticipatory behavioural responses, suggesting that complete integration offers analytical depth that linked approaches cannot easily replicate. Yet, because such designs are complex to implement and restrict flexibility, most applied studies still rely on soft-linking frameworks.

17. The approach followed in the present paper stands out compared to most studies discussed previously in a few ways. Most notably this approach has a focus on the effectiveness of currently implemented policies, instead of studying impacts of future policies. Therefore, this novel modelling approach considers real-world and not stylized policies – an approach which has previously not been developed in the literature in a cross-country setting. Also, in contrast to the tools used in many studies, the ENV-Linkages model used in the IFCMA modelling approach is global, which ultimately allows for comparing effectiveness of policies across different countries, which helps to provide insights on where there might be differences in the conditions for successful policies. Lastly, the present approach does not focus on one single policy but aims to evaluate various policies and policy packages.

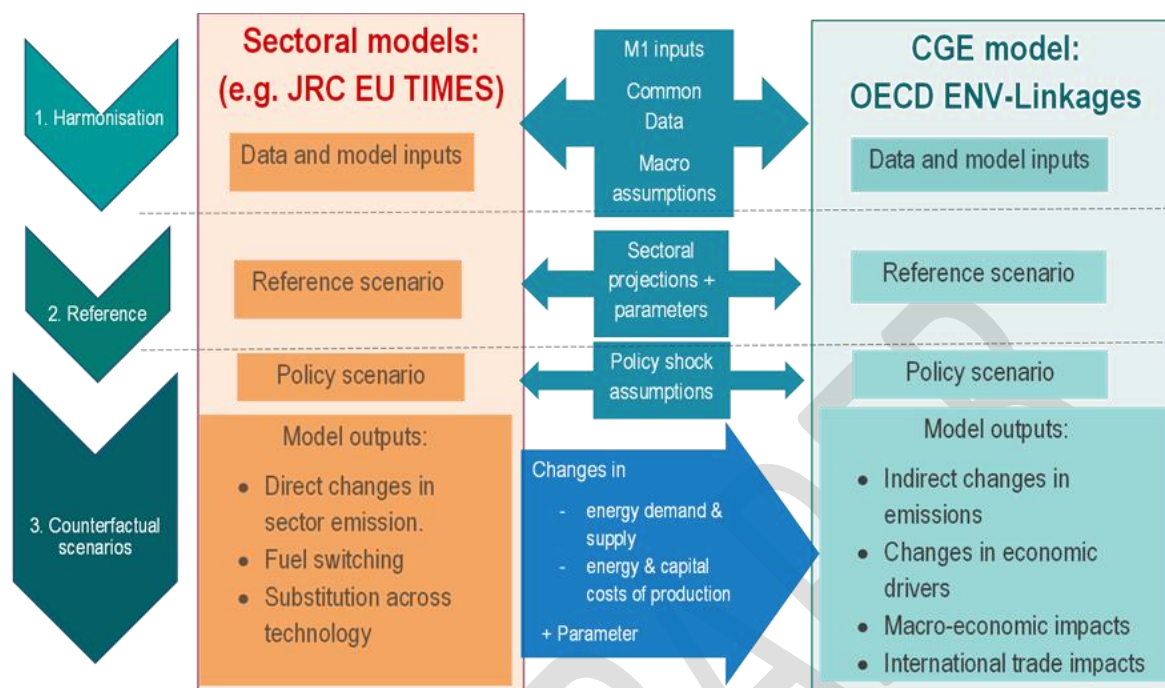
The IFCMA modelling methodology: soft-linking sectoral bottom-up models with an economy-wide model

18. Considering the benefits and trade-offs of different approaches outlined in section 2, the harmonised model linking approach used in this analysis combines detailed sectoral models (such as the JRC-EU-TIMES model used for Switzerland) with the OECD's economy-wide model ENV-Linkages (Château, Dellink and Lanzi, 2014^[24]). The model linking is conducted through a one-way soft-link following very closely the methodology described by Schreiber et al., (2025^[18]). More details about ENV-Linkages and the JRC-EU-TIMES model used for the Swiss case study are provided in Annexes A.1 and A.2.

The three steps of the model linking methodology

19. The one-way soft-linking configuration was chosen for its ability to preserve sectoral technological detail while maintaining macroeconomic consistency, its scalability across diverse national contexts and to avoid the computationally intensity of hard-linking or fully integrated approaches. Unlike iterative soft-linking frameworks that exchange information bidirectionally until convergence (see Table 1), the IFCMA approach prioritizes resource efficiency through a systematic sequential information flow from sectoral models to the CGE framework, making it particularly well-suited for consistent multi-country climate policy assessment.

Figure 1. Schematic of IFCMA modelling approach



Source: Authors, adapted from (OECD, 2024^[5]).

20. The IFCMA modelling approach consists of several steps, which are schematized in Figure 1. While the exercise is conducted as a soft-linking exercise, meaning information from the sectoral model feeds into the CGE model, the harmonisation of data and reference scenario includes two-way information flows between both models. These exchanges and calibrations ensure that the reference scenario in both models starts from a consistent, policy-informed foundation for the subsequent policy analysis.

21. The first step of the IFCMA modelling methodology entails the harmonisation of inputs across both models, including a stocktake of existing implemented or legislated policies based on the IFCMA's novel Climate Policy Database (OECD, 2025^[25]), and selection of a common set of macroeconomic projections for the main aggregate variables. A wide range of data must be harmonised across both models, starting with historical greenhouse gas emissions, which can be drawn from national UNFCCC submissions but often require supplementary data from international datasets such as EDGAR, CEDS, EPA, or IEA to address data gaps (see more details about the database used for model calibration in Annex A).

22. The second step involves building a common reference scenario for both models, with the same macro-economic trends, the same sectoral economic and energy historical projections and the same current and legislated policies (their historical trends as well as assumptions about their future evolution). In practice, because both kind of models treat endogenous and exogenous variables differently, sectoral models often take macro variables as given, whereas CGE models are calibrated to match external macroeconomic projections. Information can flow both ways: the sectoral models can provide detailed energy or agriculture trends to refine the CGE baseline, while the CGE can provide projections of broader variables (such as sectoral value-added shares or trade flows) that sectoral models cannot generate internally.

23. After that, in the third step some counterfactual policy scenarios (see next subsection) are first run for the sectoral bottom-up model only. Then the soft linking is conducted, meaning the same counterfactual policy scenarios are now run in the OECD ENV-Linkages model, but the CGE model is also using information about policy impacts, from the sectoral model, with the objective of aligning the direct impacts of policies in both models. The direct impacts of policies from the sectoral model that are targeted in the CGE are mainly

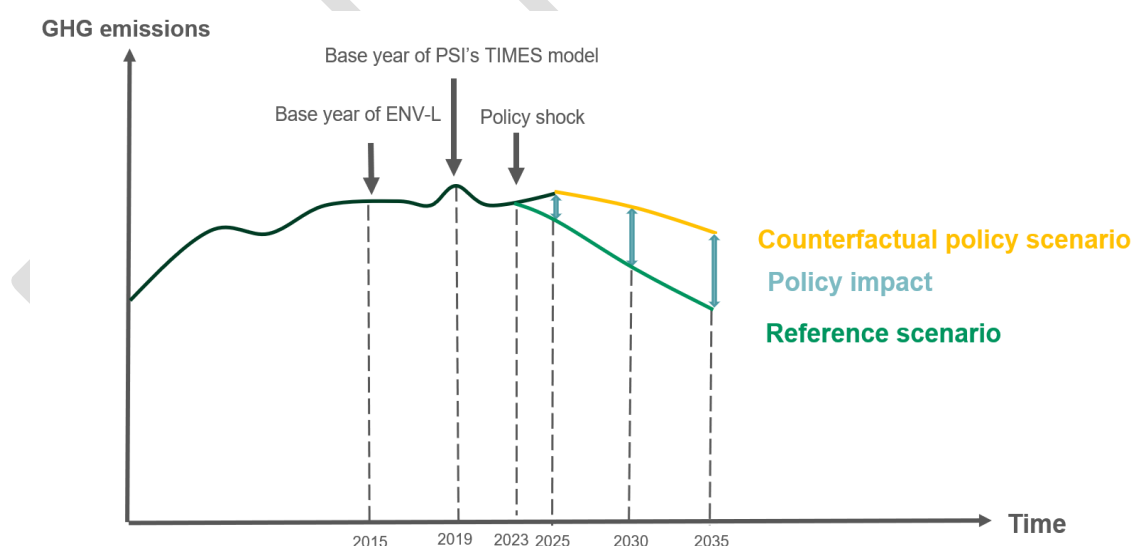
the changes about technology choices and about input/fuel substitutions (e.g. capital costs or energy expenditures). Given that CGE models are more aggregated, aligning their results with the outputs of sectoral models requires adjusting key structural parameters (such as substitution elasticities, demand and supply elasticities) and technology-related efficiency parameters as in (Schreiber et al., 2025^[18]). Following (Château, Magné and Cozzi, 2014^[26]) some other sectoral outputs are directly imposed in the CGE model, like the changes in power-technology mix, because these technological details are also represented in the ENV-Linkages model. Real-world sectoral policies are generally more granular than the level of sectoral aggregation proposed in the CGE model. They must be translated into the CGE model's broader commodity and technology categories, with information flows tailored to the type of instrument³.

The design of policy scenarios as counterfactual

24. For the IFCMA modelling exercise, all policies are implemented in the reference scenario of both models and subsequently removed in counterfactual policy scenarios, to assess their economic and environmental impacts. Figure 2 shows the design of the counterfactual policy scenarios with the example of JRC-EU-TIMES model as a sectoral bottom-up model: current selected policies are, first, all implemented in the reference scenario, after which they are removed one by one.

25. The core novelty of the IFCMA modelling framework lies in this counterfactual design. Because the reference scenario already includes all existing policies considered in the exercise, the assessment of ex-post economic and emissions impacts relies on explicitly constructed “as-if” scenarios in which individual policies are assumed to have never been implemented. This systematic removal allows the isolated contribution of each policy to be assessed over time, against a reference pathway that embeds the full policy mix. This approach departs from conventional policy analysis by reversing the usual logic of policy addition and instead quantifying impacts through policy removal, thereby providing a consistent and transparent basis for evaluating the effectiveness of current climate and energy policies.

Figure 2. Building counterfactual policy scenarios in the IFCMA framework



Source: Authors.

³ For example, price-based measures require aggregated effective tax rates; technology-support policies require data on induced investment, production cost changes, and supply-chain effects; and regulatory measures require detailed changes in service demand and technology adoption.

26. To conclude, thanks to the linkage of two types of models, the IFCMA modelling framework can produce comprehensive outputs for technological, environmental, macroeconomic and fiscal outcomes, accounting for both *direct* impacts of policies on the energy system and *indirect* economy-wide impacts. Sectoral models capture technology choices in detail — including physical constraints such as geography, grid structure, demand patterns, and asset vintages — allowing for a granular assessment of how policies affect investment and operational decisions. Complementing this, the ENV-Linkages dynamic CGE model provides economy-wide, global insights into fiscal, macroeconomic, competitiveness, and cross-sector spillover effects, as well as detailed emissions outcomes across gases and sectors, enabling a comprehensive evaluation of policy impacts. Drawing on the diverse outputs generated by the IFCMA modelling framework, policymakers can conduct a comprehensive cost-benefit analysis that integrates fiscal, economic and technological dimensions of policy interventions.

27. This modelling framework does not integrate climate hazards and damages (like OECD (2026_[27])) and therefore the analysis will not assess feedback impacts on economy through changes in climate damages (as in a former OECD (2015_[28]) analysis conducted with ENV-Linkages). But, given the temporal horizon of the current study (2015-2035), not much difference can be expected between the reference and the scenarios in terms of climate feedback, and this should thus not be considered as a serious limitation of the analysis. Another type of mechanisms that are out-of-scope for the modelling framework applied for the Swiss case study (next) is that technological progress is defined exogenously in JRC-EU-TIMES to facilitate model resolution under the assumption of intertemporal optimisation (see Annex A for more information about both models). This means that innovation - from for example learning-by-doing - is not influenced by the projected energy system pathways. This assumption of exogenous technological trends seems valid for our case study, given the current analysis is focused on ex-post evaluation of policies implemented in the past. Finally, the modelling framework also does not account for micro-economic behavioural changes from households, like anticipation impacts from a (signalling value) which might come from policies like regulations for building energy efficiency or a market-instrument like a carbon tax. More research or meta-analysis would be needed to arrive at robust estimates for such impacts before they could be integrated in a regional or global modelling framework.

Case study of Switzerland

28. This section describes the case study for Switzerland, including the modelled policies, the set-up and models used as well as the key results and lessons for policy making. It was conducted in collaboration with the Paul Scherrer Institute (PSI), which runs the JRC EU-TIMES model (Nijs and Ruiz, 2019_[29]), the sectoral bottom-up model used in this study. National experts were involved closely in the process, including when designing the policy simulation and in validating the data used for model calibration, to ensure the accuracy of the modelling exercise.

Modelled current policies and application of the soft-linking procedure

29. The policies covered in this study are impacting the industry, the road transport and the residential and commercial buildings. These sectors combined account for more than three-quarters of the GHG emissions in the country. As Switzerland has a nearly carbon-free electricity system, the remaining one-quarter of GHG emissions mainly come from the agriculture sector. The policy types were selected to have a good balance between economic and regulatory instruments, as well as to be able to be quantified by the two models, JRC-EU-TIMES and ENV-Linkages. Some of these policies are legislated under the Swiss CO₂ Act as a policy package targeting energy sectors or energy and climate targets. The assessed policies are described in the Table 2. More detail about the characteristics of these policies and on their modelling implementation features can be found in Annex B.

Table 2. Modelled Swiss Climate and Energy Policies

Policy name	Implementation date	Instrument type and sector targeted	Policy level (tax rate or standard)	Tax base and economic incidence
Swiss Emissions Trading System (ETS) [#]	Implemented in its current form in 2013; linked to the EU ETS since 2020	Market-based instrument, Cap-and-trade system – Industry (including power and heat generation and intra-zone aviation)	Economy-wide emissions cap covering the most CO ₂ -intensive sectors; design and targets aligned with the EU ETS while operating as a separate scheme	Applies to covered installations and operators; economic incidence borne by regulated firms through allowance obligations and carbon pricing
CO ₂ Levy [#]	Introduced in 2008; current rate in place since 2022	Market-based instrument, Carbon tax on stationary sources Industry and buildings not covered by ETS.	CHF 120 per tonne of CO ₂ applied to thermal fossil fuels used in stationary installations not covered by the ETS (e.g. heating oil and natural gas);	Levied on thermal fossil fuels; economic incidence on fuel users, with two-thirds of revenues redistributed to households and firms and one-third to finance the Buildings Programme
CO ₂ Emission Regulation for Newly Registered Vehicles [#]	Introduced in 2015; revised targets from 2025 onwards	Non-market-based instrument, Regulatory standards Transport (passenger cars and light commercial vehicles)	Fleet-average CO ₂ emission limits: 118 g CO ₂ /km (passenger cars) and 186 g CO ₂ /km (LCVs) in 2021; 93.6 g and 153.9 g for 2025–2029; 49.5 g and 90.6 g from 2030 onwards	Applies to newly registered vehicles; economic incidence borne by vehicle manufacturers and purchasers
Mineral Oil Tax	Implemented in 1996	Market-based instrument, Excise tax Transport (also levied on heating fuels)	Differentiated rates by fuel type and use (automotive vs. stationary); tax reductions for biofuels and light heating oil;	Levied on liquid and gaseous fossil fuels; economic incidence falls predominantly on the road transport sector
Motor Vehicle Tax	In place across all Cantons by 2005	Market-based instrument, Annual vehicle tax Transport	Primarily weight-based levy, with rates and exemptions determined at the cantonal level; in some Cantons, motor power and CO ₂ emissions are also considered	Applies to vehicle ownership; economic incidence borne by vehicle owners, with cantonal differentiation
Federal and Cantonal Buildings Programme [#]	Enacted in 2010	Non-market-based instrument, Financial incentives Buildings	Subsidies for energy-efficient renovations, deployment of renewable heating technologies and improvements in building services technology; implementation at the cantonal level	Applies to residential and non-residential buildings; economic incidence on building owners through investment incentives, with cantonal discretion in programme design
Building Codes [#] (MoPEC/MuKE ⁿ)	Developed in 2014; revised in 2018	Non-market-based instrument, Regulatory standards Buildings	Mandatory requirements limiting energy consumption for space heating, hot water, cooling and ventilation; adoption varies across Cantons	Applies to building construction and renovation; economic incidence on building owners and developers through compliance with energy performance requirements

Note: [#]these policies are part of the Swiss CO₂ Act.

Source: Authors.

30. As described above, the modelling strategy consists of a one-way soft linking exercise with a sectoral model, the JRC EU-TIMES model (Nijs and Ruiz, 2019^[29]), managed and further developed by the Paul Scherrer Institute (PSI), with the OECD's economy-wide model, ENV-Linkages (Château, Dellink and Lanzi, 2014^[24]). Consistent with the modelling strategy and the type of energy and climate policy to be assessed, the JRC-EU-TIMES model proposes a very granular representation of close to a thousand energy technology options to capture fuel switching and shifts in choice of energy technologies, while OECD ENV-Linkages focuses on the responsiveness of demand and supply to price-adjustments in over 40 sectors which clear markets for all goods and factors, and on ensuring a coherent national and global accounting framework. Annex A provides an overview of the two models while Annex B describes in detail the specific linking between the two models for the Swiss case study following the three steps described in section 3. A more detailed picture of historic and reference energy consumption and economic is presented in Annex A.

Key results

31. This subsection analyses the key outputs provided by the modelling analysis for Switzerland. It starts by showing the changes in the energy system when each of the policy considered above are removed (with respect to the reference scenario)⁴. These results mostly build on the JRC-EU-TIMES model outputs. Then it discusses the corresponding changes in CO₂ emissions. Subsequently, the analysis relies on OECD ENV-Linkages outputs about economic impacts of removing each policy, starting with macroeconomic and sectoral impacts. Furthermore, impacts on households and government budgets are shown, followed by impacts on trade with a focus on competitiveness and energy security. Lastly, the outcomes from the modelling analysis are used to formulate policy insights.

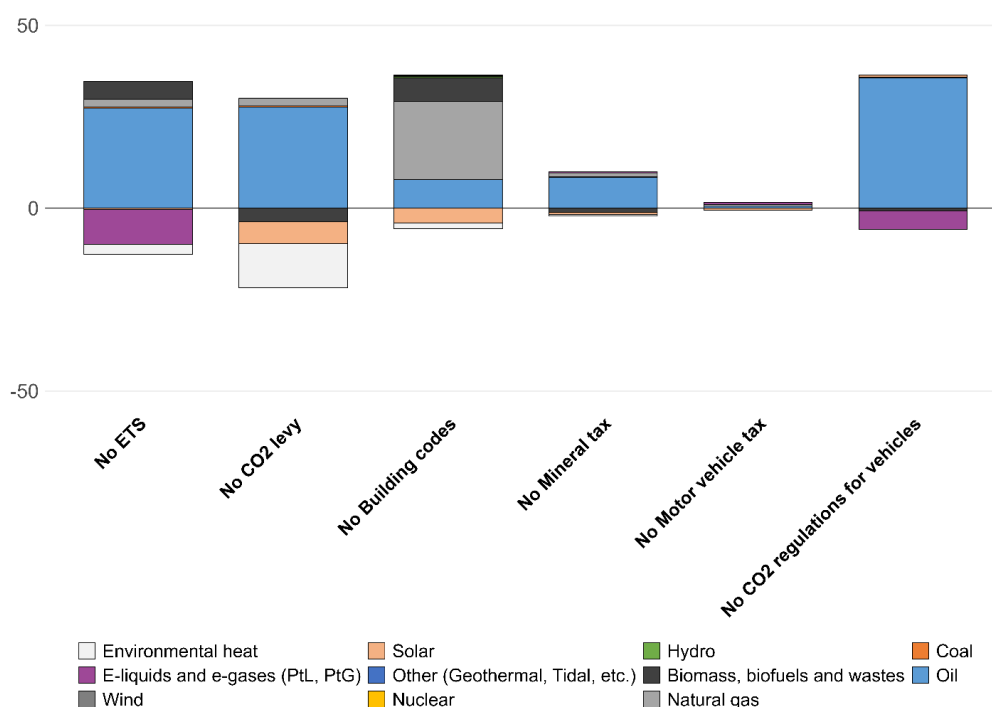
Changes in energy system, and environmental benefits

32. The selected policies affect total energy demand and the energy mix in different ways (Figure 3, see also Annex A.4 for an overview of Reference scenario developments). From a general point of view, three main channels for how policies affect energy use are at play: 1) fuel switching, 2) energy savings and efficiency improvements, and 3) changes in the fundamental drivers of energy demand. The first channel involves switching between fuels through technological changes to provide a given energy service. For example, the CO₂ emission regulations for new vehicles encourages a shift from oil powered internal combustion engine vehicles (ICEs) to electric vehicles (EVs). The second channel consists of energy savings resulting from higher efficiency. For instance, improved building insulation, resulting from the Building Codes, reduces heating and cooling needs while maintaining the same indoor temperature. The third channel operates through changes in economic structures, either change of a firm's output, or changes in households' consumption patterns, driven by prices and income effects, which affect the fundamental drivers of demand for energy services (e.g., space heating, km per passenger for personal transport). In the current modelling framework, the first two channels are primarily assessed in the JRC-EU-TIMES model (and then passed to the CGE model), while a part of the second channel and most of the third channel are assessed in the ENV-Linkages model.

Figure 3. Swiss primary energy consumption mix in 2035, by policy scenario

Differences in energy use between the no-policy scenario and the reference, Petajoule

⁴ For sake of simplicity the discussion of results will focus on isolated policies, but in order to analyse policy interactions or to decompose policy impact, more policy runs have been performed including (i) removing all policies together; (ii) removing both carbon price policies, (iii) removing together the three transport policy, (iv) isolating mineral oil surtax from rest of mineral oil tax; (v) removing Building codes and Building programmes together, (vi) removing the EU-ETS for all countries.



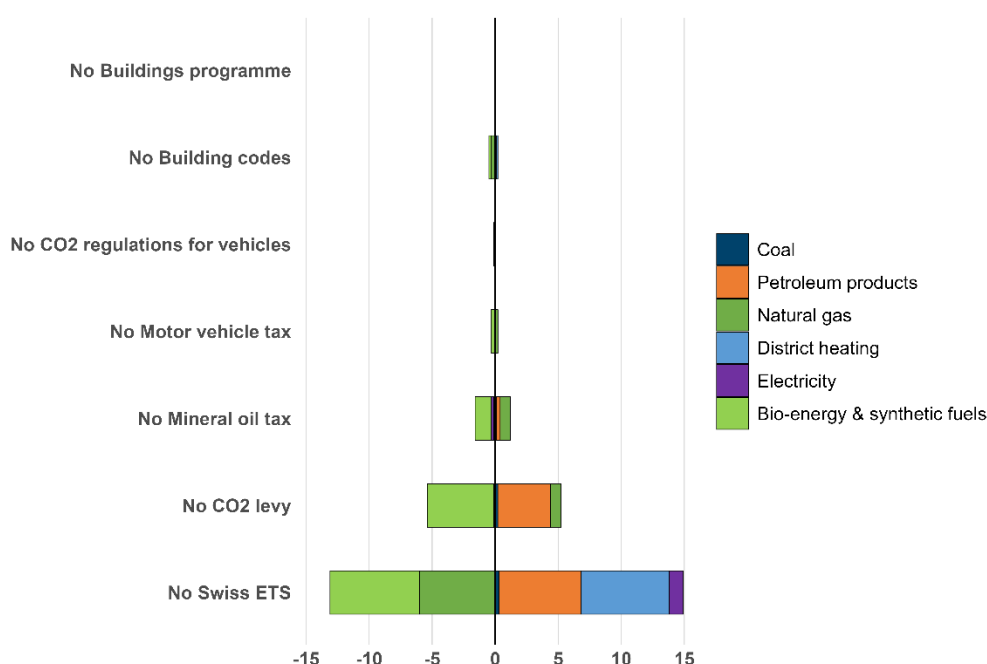
Note: * Primary energy for nuclear energy is accounted with a conversion rate to electricity of 4:1; ** Hydro and wind energy is accounted with a conversion rate to electricity of 1:1; *** Solar energy consists by majority of solar power, a minor part is solar thermal. Solar power is accounted with a conversion rate to electricity of 1:1.

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

33. The selected policies accelerate the policy-independent techno-economic developments (see the description of the projected reference scenario in Annex A) but also create new opportunities for emission reduction. As shown in Figure 4 these policy impacts are different by policy and by sector. The manufacturing sectors are mainly affected by the ETS, and to a slightly lesser extent by the CO₂ Levy and the Mineral oil tax. In manufacturing, the suppression of the policies analysed drives a shift in fuel use away from biomass and biogas towards oil and district heating. District heating is subject to the ETS, and partially relies on the use of natural gas, besides solid biomass. Consequently, if the Swiss ETS is removed, it is no more needed to purchase emission allowances to cover heating emissions, and therefore the demand for district heating would increase (the 'blue' bar in figure).

Figure 4. Swiss industry final energy use in 2035, by policy scenario and by energy carrier

Differences in energy uses between the no-policy scenario and the reference, Petajoule

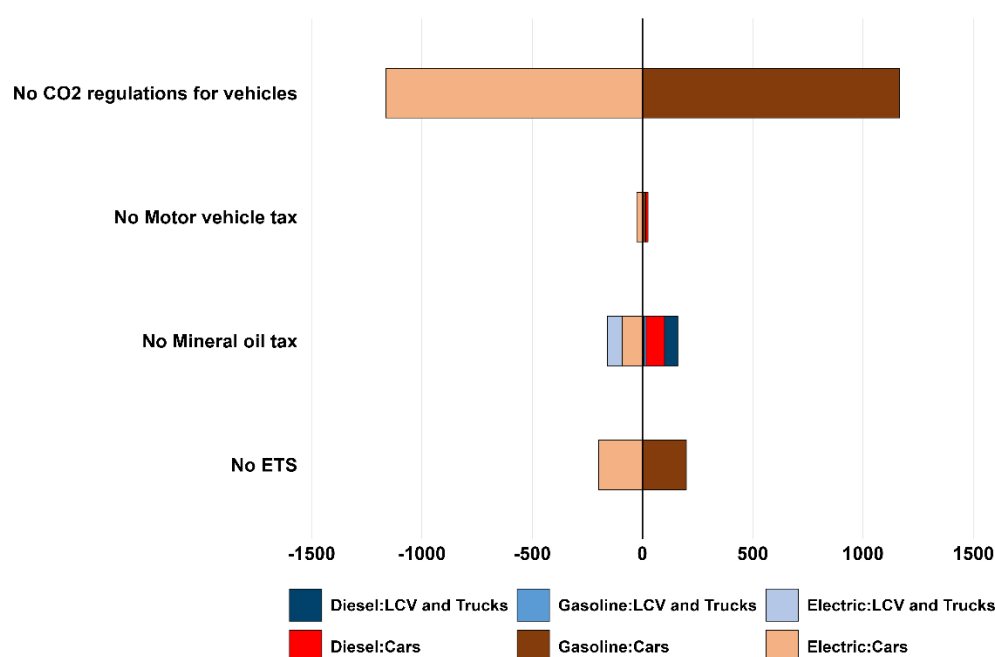


Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

34. The transport sector is affected mainly by the Mineral Oil Tax and the CO₂ regulation for vehicles. Each policy drives, in its own way, a push to further car electrification, which is mainly the result of the CO₂ regulation but reinforced by the Mineral Oil Tax. Therefore, removing these policies will imply a shift towards internal combustion engine vehicles (see Figure 5). A policy side-effect takes place when the ETS drives an increase in the use of bioenergy in industry and in power & heat supply, thereby making biofuels more expensive for the transport sector. If the ETS policy is removed, this reduces the cost of biofuels, which drives a small additional decrease in the use of electric vehicles (also shown in Figure 5). The Swiss ETS has furthermore a direct impact on intra-EEA country aviation, therefore another consequence of the ETS removal (not reported here) is to reduce the substitution away from less efficient airplanes.

Figure 5. Swiss vehicle stock in 2035, by policy scenario and by broad category of vehicles

Differences between the no-policy scenarios and the reference, thousands of vehicles



Note: The policies not reported on the chart like building policies have no impact on the mix of vehicles by type of engine.

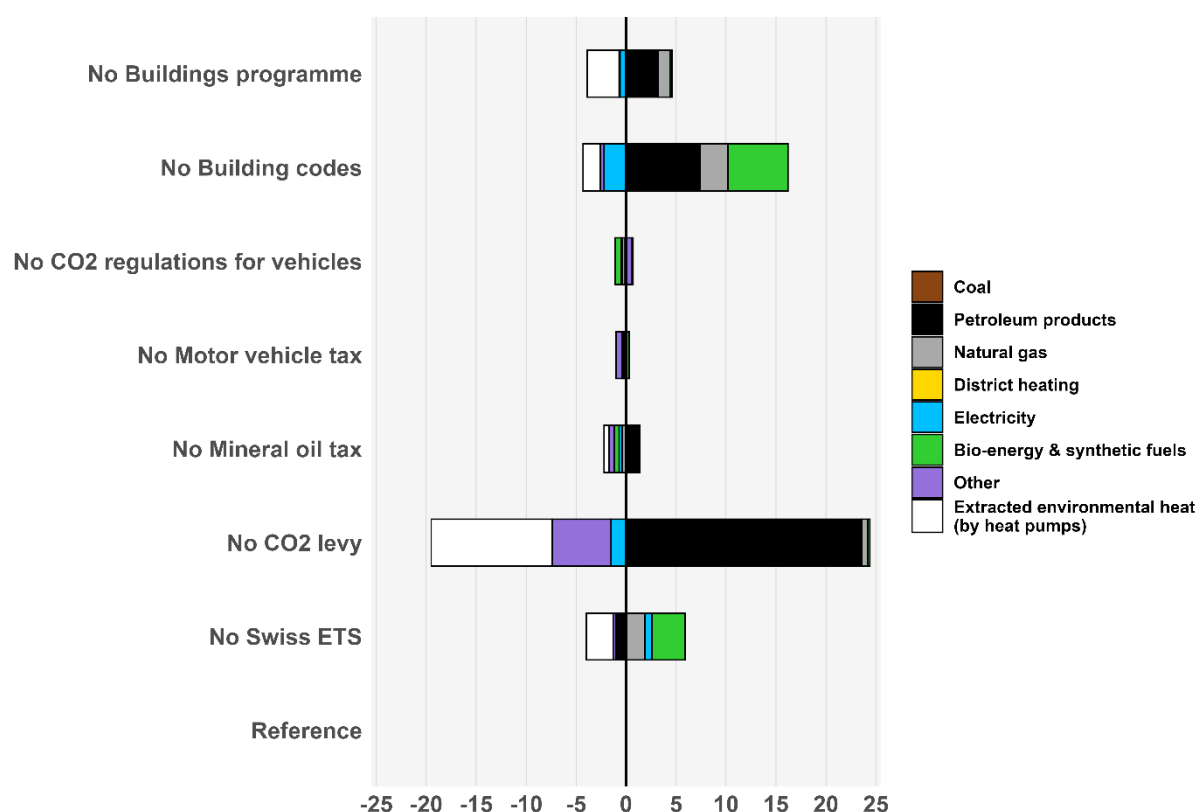
Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

35. The choice of the energy mix in the buildings sector is mainly affected by the CO₂ Levy, the Building Energy Codes, and the Buildings Programme (Figure 6). The impacts are different for each of the policies: removing the CO₂ Levy limits the fuel shift from oil-based heating to electricity-using heat pumps. Removing the Building Energy Codes slows the development of energy efficiency measures in buildings and keeps oil boiler heating systems in use, both of which would imply higher total energy demand.⁵ Finally, the Buildings Programme has similar impacts as the Building Energy Codes, but to a lesser extent, due to the smaller scale at which the Buildings Programme operates, compared to the Building Energy Codes. The former depends on voluntary applications for Building Renovations, while the latter imposes standards for all newly built structures.

⁵ In bigger buildings, oil boilers have solid biomass fuelled back-up systems, which explains a large part of the reduction in biomass use under the Building Energy Codes.

Figure 6. Swiss final energy consumption in Residential, Services and Agriculture sectors in 2035, by policy scenario and by energy carrier

Differences in energy use between the no-policy scenarios and the reference, Petajoule

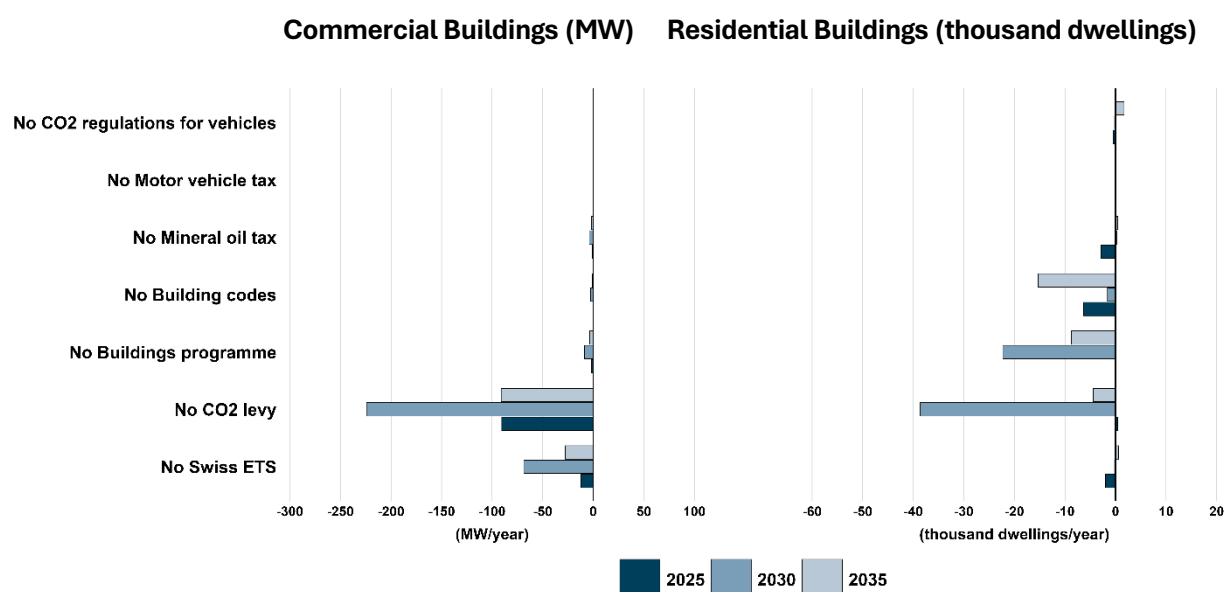


Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

36. Heat pumps are a key technology to decarbonise heat supply in buildings. The figures below show the estimated impact of the selected policies on heat pump installations for services and residential sectors' buildings if the policy would have been removed (Figure 7). In the commercial sector, a pricing measure like the carbon levy turns out to be the main driver of heat pump installations, while the Swiss ETS is observed to have a side-effect, driving further electrification and efficiency gains in electric heating in the services sector as well. Note that the impacts are sizeable: the CO₂ levy motivates 44% of reference commercial heat pump capacity additions in 2035. In the residential sector, the levy is also responsible for most heat pump additions, closely followed by the Buildings Programme, and the Building Codes. Impacts of individual policies are relatively small in this sector, which can be related to policies overlapping and thus sharing responsibility in electrification of heat supply. For example, in 2030, the Carbon Levy motivates around 12% of reference heat pump additions. The other policies (i.e. CO₂ regulations for vehicles, the Mineral Oil Tax, and the Swiss ETS) have negligible and varying side-effects, e.g. due to their impact on demand and marginal prices for electricity.

Figure 7. Swiss heat pump installations in buildings, by policy scenario and by year

Differences in volume between the no-policy scenarios and the reference scenario



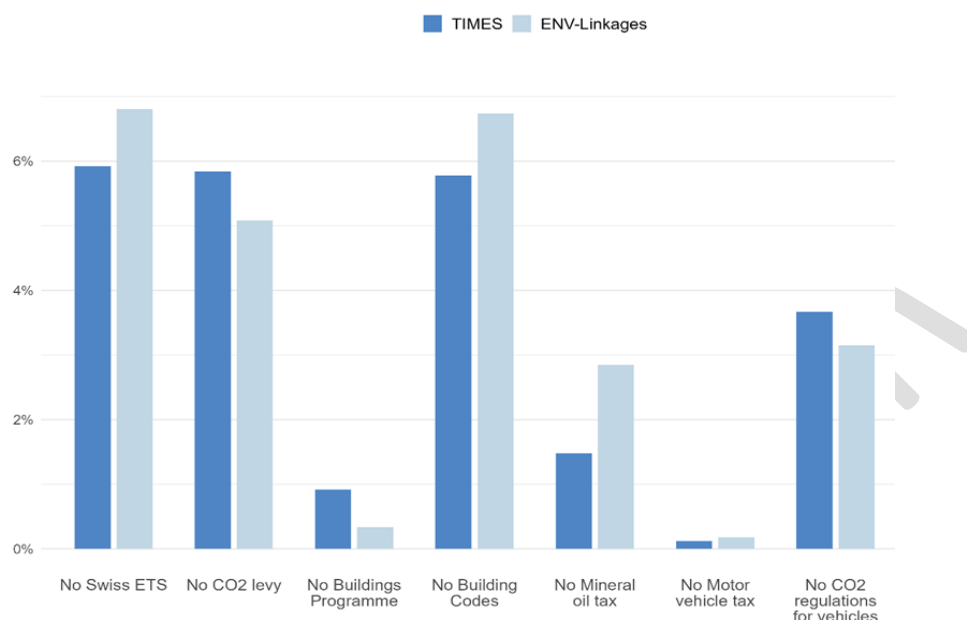
Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

37. The removal of the selected policies lead to sizable increase of approximately 1% to 7% of cumulative CO₂ emissions between 2023-2035 (Figure 8). The Swiss Emission Trading System (ETS) and the CO₂ Levy, that price carbon for industry and building sectors, are particularly effective in reducing emissions in the short to medium term, leading to respectively 6.8% and 5% of avoided cumulative CO₂ emissions between 2023-2035 (relative to the reference scenario)⁶. The policies explicitly dedicated to the buildings sectors (building programme plus building codes) have a similar impact around 7%. And finally, the three policies dedicated to the transport sector (mineral oil tax plus motor vehicle tax plus CO₂ emission regulations for new vehicles) also account for 6-8% of changes in CO₂ Emissions. The comparable impact of transport and building policies on emission relative to policies targeting energy-intensive and power sectors is a specific characteristic of Switzerland. Switzerland is an economy in which the typically most emission-intensive sectors have been largely decarbonised for around two decades (see Figure A 0.4 about historical sectoral composition in the annex). As a result, mitigation efforts in other sectors have grown in importance.

⁶ Changes in emissions associated with all carbon pricing – both the CO₂ levy and ETS – cannot be added and does not imply that they account for 12% together. An extra simulation, discussed in the annex, shows important leakage effects across these sectors and instrument such that, if both are considered together, the resulting change is about 10% together.

Figure 8. Swiss cumulative CO₂ emissions, for the sectoral and the CGE models, by policy scenario

Cumulative differences as percentage of total CO₂ between the scenarios and reference, 2023-2035



Note: The change in emissions is the cumulative difference in emissions when policies are removed, as a difference from the reference scenario, they are expressed as a share of the total cumulative emissions in the reference scenario. Figures only concern domestic emissions (excl. international aviation and LULUCF emissions).

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model and OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model. See also for more details (OECD, forthcoming^[30]).

38. The modelling exercise shows that the Motor Vehicle Tax has only a marginal impact on energy demand and therefore emissions. The main reason is that the policy functions like a lump-sum tax on car ownership and therefore is not designed to provide a real incentive to reduce fuel use. Moreover, only a few cantons offer small advantages for the ownership of cleaner cars, which are negligible compared to the total costs of using a car and therefore the policy does not imply any change in the type of vehicles (like it is the case for other policies as indicated in Figure 5).

39. The impact on emissions of the subsidies granted by the Buildings Programme is also very modest (less than 1%). The main limitation is that it primarily targets older buildings, where technological energy-saving interventions are limited and costly. Another reason is that the policy remains limited in intensity: in 2023, Switzerland spent CHF 478 million on subsidies for the federal and cantonal Buildings Programme, while total federal fiscal revenue for the same year was about CHF 80 billion.⁷ This budget was allocated to around 39 thousand subsidy requests, this is only a small part of the total Swiss building stock, which counted almost 1.8 million buildings in the residential sector in 2023.⁸

40. The comparison of emission changes across the sectoral JRC-EU-TIMES model and the economy-wide ENV-Linkages model, reported in Figure 8, shows substantial differences that reflect the importance of general equilibrium effects and justify the necessity of combining the two models. As explained in the previous subsection, the direct impacts of policies on energy and capital costs for the targeted sectors in the economy-

⁷ https://www.data.finance.admin.ch/superset/dashboard/finances_de_la_confederation

⁸ Source: "Gebäude mit Wohnnutzung in den Kantonen, 2023", [Gebäude | Bundesamt für Statistik - BFS](#)

wide model are aligned on the outcomes of the sectoral model. The differences that arise are therefore due to indirect economic effects reported by the economy-wide model. These indirect economic impacts of policies significantly change the estimated magnitude of quantitative assessments, compared to analyses that focus solely on *direct effects*. These impacts reflect changes in economic conditions, such as impacts on production and demand levels (i.e. “fundamental drivers of energy demand”), in response to price changes or income effects.

41. A central difference between the two models used in this analysis is how they treat the fundamental drivers of demand for energy services. The sectoral model uses exogenous projections for these drivers (like km per passenger for personal transport or projection of future steel production), that may change during the time period, but these projections remain unchanged across scenarios. All impacts on CO₂ emissions from removing a policy are a consequence of differences in explicit technological choices (i.e. *direct impacts*), required to fulfil the given levels of demands. In the CGE model, the demand for energy services is endogenous (through GDP, sectoral output, households’ end-use energy service demands). The CGE model also covers impacts on non-targeted sectors through endogenous changes in relative prices of commodities which drive demand and supply for these goods, as well as income effects.

Economic impacts

Macroeconomic impacts

42. Since most policies analysed imply distortions in the allocation of resources, they imply GDP gains, from 0.1 to 0.8% with respect to the reference scenario, if they are removed as shown in Table 3. A notable exception is the motor vehicle tax, because this policy is almost non-distortive and acts as a lump-sum tax so when it is removed the fiscal burden is transferred from all vehicles buyers (including transport sectors) to only households and therefore imply lower savings/investment.

43. Apart from the Building Codes, the positive impacts on GDP of removing these policies are modest. This suggests that these policies are either not very distortive, like the Swiss ETS or the CO₂ emission regulations for new vehicles, or that they shift resources away from consumption to investment such that the final impact on GDP is weak, like for the CO₂ levy or the Building Programme.

44. The Building Codes appear to be the most distortionary policy for two main reasons: it targets only one sector (construction), and it directly affects the trade-off between consumption and investment and therefore have a direct impact on the potential production of the economy (i.e. the capital to GDP ratio). To be more precise, the direct effect of the regulation is to increase the cost of production in the construction sector (because new buildings must be equipped with more expensive heating and cooling systems and must rely on more expensive materials for building insulation, etc.). Since construction is an important component of investment demand, an increase in its cost will be transmitted partly into an increase of investment price and partly in a decrease of overall net investment.

Table 3. Swiss key macroeconomic indicators in 2035, by policy scenario

Percentages changes with respect to the reference scenario

	No Swiss ETS	No CO2 Levy	No Mineral oil tax	No Co2 regulations for vehicles	No Motor Vehicle Tax	No Buildings Programme	No Building Codes
GDP (real)	0.1%	0.2%	0.2%	0.0%	-0.4%	0.0%	0.8%
Imports (real)	0.1%	0.1%	0.1%	0.3%	-0.2%	0.1%	1.5%
Exports (real)	0.3%	0.2%	0.3%	0.3%	-0.3%	0.1%	1.8%
Gross Investment (real)	0.0%	2.7%	0.0%	0.2%	-1.6%	2.4%	14.9%
Private consumption (real)	0.0%	-1.3%	0.0%	-0.1%	0.1%	-1.3%	0.4%
Net-of-tax household income (real)	0.0%	-0.2%	0.0%	-0.1%	0.1%	-0.3%	1.3%
Net-of-tax labor income (real)	0.2%	0.2%	0.0%	0.0%	-0.2%	0.2%	-2.3%
Household Saving (nominal)	0.1%	5.1%	0.0%	-0.1%	0.2%	4.8%	5.2%
Current account (real)	0.1%	-0.1%	0.0%	-0.3%	-0.2%	0.0%	1.3%
Trade Balance (real)	1.5%	0.8%	1.9%	0.0%	-0.7%	0.0%	4.4%
Trade Balance (nominal)	0.6%	0.5%	0.6%	-0.4%	-0.2%	0.0%	1.4%
Exchange Rate (nominal)	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	-1.9%
CPI (nominal)	0.0%	-0.1%	-0.1%	-0.2%	0.1%	0.1%	-1.0%
Capital to GDP ratio (real)	-0.1%	-0.1%	-0.2%	0.0%	-0.5%	-0.1%	-1.0%
Gross capital cost (real)	2.4%	-10.3%	0.6%	-2.8%	1.1%	-8.6%	-9.0%
Net Investment (real)	0.1%	12.4%	0.0%	0.6%	-4.1%	11.3%	4.0%
Net-of-tax capital return (real)	0.4%	-0.7%	0.3%	0.8%	2.3%	-1.1%	1.1%

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

45. The suppression of policies as they improved the allocation of resources also improved trade balance. Indeed, the positive income/GDP impact translates in both increase of export and imports (lines 2 and 3 of Table 3, but it also improves the competitiveness of Switzerland in such extent that exports increase slightly more than imports. In addition, removing the Building Codes redirects labour and investment away from non-tradable construction and compliance activities, increasing resources available to tradable sectors.

46. Removing the Mineral Oil Tax and CO2 Regulation for Newly Registered Vehicles would also increase trade, but to a smaller degree. The impact of the mineral oil tax weakens over time, reflecting the country's gradual shift away from fossil fuel dependence. Other policies such as the motor vehicle tax appear beneficial for overall export performance. Exports fall more than imports when the policy is removed, suggesting that the tax supports innovation, efficiency gains or economic activity that indirectly strengthens Switzerland's export capacity. Overall, policies that impose capital compliance costs, such as the Building Codes, have long-term effects that compound over time.

Sectoral economic impacts

47. While macro-economic costs of the policies studied have a negligible effect on GDP, this hides asymmetric impacts on individual sectors. Figure 9 shows that the impact of the removal of current policies on real gross output can be positive or negative across sectors. Overall sectoral economic costs are comparable and small for most different policies – including many regulatory instruments, thus demonstrating their efficiency and underlining their importance in the policy mix. There are however considerable sectoral impacts for the Building Codes which significantly lowers output in the real estate sector (sector included in category “business services”), in the construction sector, and in the cement sector

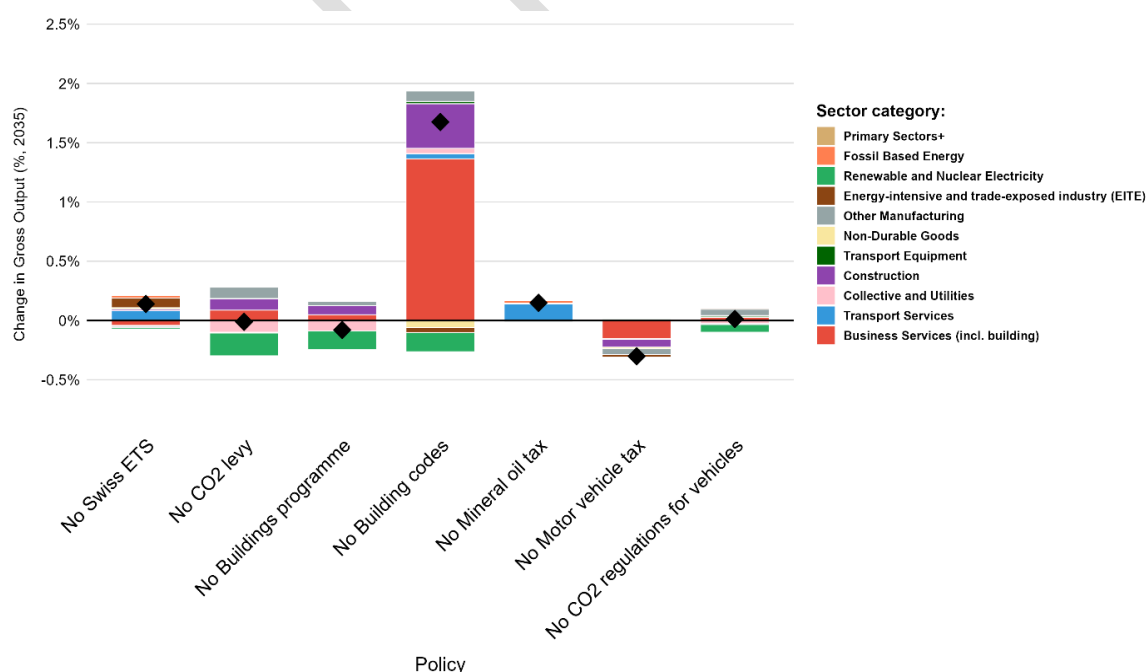
(included in the “non-metallic” minerals category). The Mineral Oil Tax also show sizeable sectoral effects on the activity of the “transport services” sector. Distributional effects across sectors are larger in size than the total aggregate effect, meaning that most policies shift output between sectors without strongly altering total output. It can also be shown that costs are lower in the short-term (i.e. in 2025) and become higher over time. This is particularly the case for policies that affect stocks with slow turnover rates, such as buildings or cars, where impact takes time to unfold.

48. Some policies, such as the Swiss ETS, the CO₂ Levy, and the CO₂ regulation for vehicles have a near-zero effect. If incentive-based policies such as the CO₂ levy, the Buildings Programme and the Motor Vehicle Tax were removed, economic output would even be lowered. The CO₂ Levy’s revenue recycling generates net gains, while the Buildings Programme stimulates construction and services. The Motor Vehicle Tax, on the other hand, leads to an upgrade in the fleet, and tax recycling creates positive effects. Strict regulatory measures, such as the Building Codes, impose larger compliance costs and therefore their removal generates significant positive output gains. Transport-related taxes (i.e. mineral oil tax), on the other hand, disproportionately affect the output of the transportation service sector.

49. Most sectors do not see a big impact in terms of output reductions. Overall, private services (including real estate) experience some of the largest impacts, gaining when the Building Codes are removed and losing in the short term when the CO₂ levy and Buildings programme are removed and in the long term when the vehicle tax is removed. Moreover, construction and cement experience some of the largest swings (positive when the building codes are removed and negative when the Buildings Programme is removed). Power sector activity (including electricity distribution) would be particularly negatively affected in the longer run, following the reduction of electricity demand that would result from the suppression of the CO₂ Levy, the Buildings Programme or the Buildings codes.

Figure 9. Switzerland sectoral composition of the gross output in 2035, by policy scenario and by aggregate sector

Differences as percentage of total output between the no-policy scenarios and the reference, 2015 CHF



Note: the diamonds in the chart show the size of the total effect.

The sectoral composition of aggregate sectors is detailed in Table A 0.1.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

Employment

50. In turn these changes in sectoral activity translate partly to changes in employment: some sectors record employment gains while others show employment losses, generally following changes in output. While some analysed policies have a negligible effect on the job market (see in the annex Figure A 0.1), Figure 10 shows that the CO₂ Levy, the Buildings Programme and the Building Codes have substantial employment reallocation impacts across sectors. Removing the CO₂ levy increases employment in the construction and commercial services (including dwellings) in 2035. Since the removal of the policy implies lower use of heat pumps (see Figure 7), it also implies lower electricity demands and therefore less employment in both generation and distribution of electricity (the latter is included in the ‘utilities’). For the Building Codes and the CO₂ Levy the same decrease in electricity demands, relative to the reference scenario, explains the corresponding decrease in employment in this sector.

51. The main difference across the policies, in terms of effects on employment, is that the removal of the Building Codes leads to lower employment in the construction sector, despite an observed increase in output of this sector, this is because cost of capital is much lower once the policy is removed, and therefore firms in construction sector operate a substitution away from labour.

Figure 10. Switzerland sectoral employment in 2035, by selected aggregate sectors and selected policies

Difference in thousands of persons between the no-policy scenario and the reference



Note: The sectoral composition of aggregate sectors is detailed in Table A 0.1.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

Policy impacts on households

52. The changes in households' behaviour are another channel through which policies can affect the economy. Removing the policies would impact households' consumption, savings and commodity expenditure patterns, through changes in relative prices and quantity constraints imposed by standard policies, but also through an *income effect*.

53. Panel A of Figure 11 shows that removing some policies, like the CO₂ Levy or the Buildings Programme, could have a negative income impact on households (i.e. 'blue' bars). For the CO₂ Levy the (representative) household have lower disposable income when the levy is removed because they receive less transfers from the government (i.e. 'orange' bar), and this will offset the overall gains of higher factor incomes. Other policies, such as the ETS, the mineral oil tax or the CO₂ emission regulations for new vehicles do not have any substantial income effect: the disposable income is almost unchanged.

54. Panel B of Figure 11 shows that household demand for goods and services is lower when the CO₂ Levy is removed, while it remains almost unchanged under the ETS. This decrease in demand, resulting from the macro-economic income effect, explains why the increase of emissions is lower than what is found in the sectoral model that does not account for this income effect (as shown by the comparison of the two bars in Figure 8).

Figure 11. Illustration of the income effect: Swiss household budget in 2030, by policy scenario

Income and expenditure components, difference between no-policy scenarios and reference, 2015 CHE per capita



Note: On Panel A the net-of-tax disposal income is the sum of three other components: net labour income, net capital income and transfer.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

55. A similar negative *income effect* partly explains why the Building Programme shows higher emissions than in the sectoral model, while for the Motor Vehicle Tax it explains why the emission impact is *lower* in the linked results. In fact, the impact of this policy in the CGE model is almost exclusively driven by an *income effect*: the Motor Vehicle Tax is essentially an annual income tax on vehicle ownership and has a negligible impact on vehicle purchases.

Impacts on government finance

56. Except for the Buildings Programme, the removal of policies leads to net fiscal losses ranging from 0.25% to 1.2% of total revenues⁹ (see Figure 12). This illustrates the dual role of climate-related policy, generating both environmental steering and government revenue. The changes in government revenue occur firstly, because the policy considered implies a change in fiscal tools (mineral tax rate, building program subsidy rates, carbon prices) and, secondly, because the policy impacts the fiscal base, for a given level of fiscal tools. For tax-based instruments, the resulting impacts on fiscal revenues are not transitory but reflect a permanent cut in fiscal tools that would necessitate to be compensated by additional sources of revenues.

57. The mechanics of “tax base” effects explain that the decrease in overall fiscal revenue due to a tax removal is lower than what is expected from a simple account of direct fiscal effects. Indeed, after a tax removal, some other sources of fiscal revenue are increasing, because their corresponding fiscal bases are stimulated by the policy (through a negative relative price effect or a positive income effect). For example, the “mineral oil tax” removal leads to an overall decrease of fiscal revenue because the revenues from the excise tax disappear (indirect tax revenues in the charts decline), but the policy in turn stimulates fossil-fuel demand and therefore higher carbon tax revenues (the carbon prices are not phased out in this experiment).

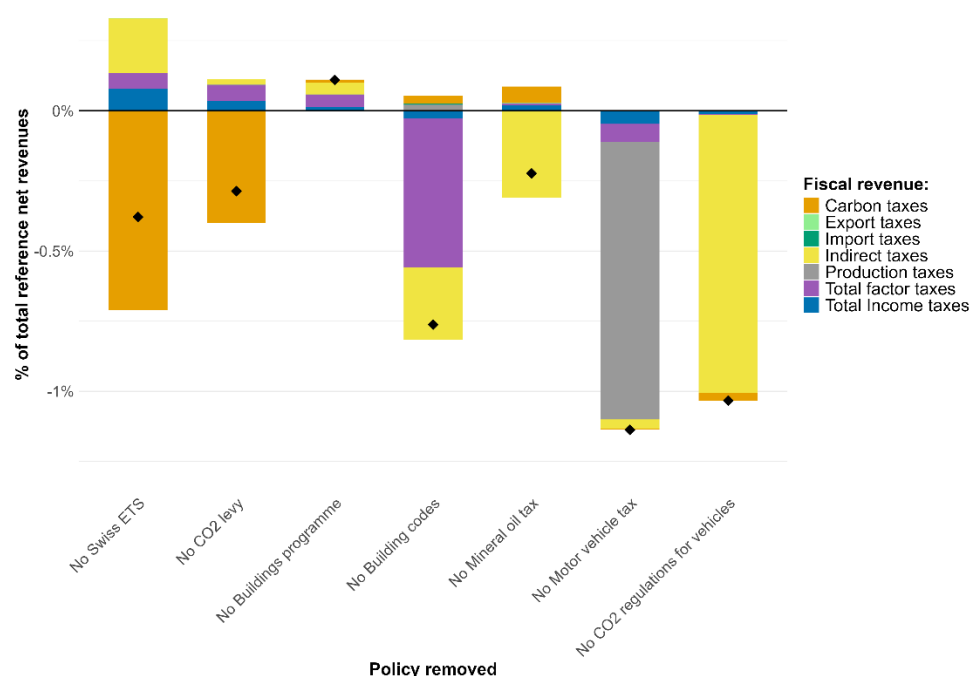
58. The “tax base” effect also explains why regulations impact public finance, even if they are not fiscal instruments. As shown in, Figure 12 the CO₂ emission regulations for new vehicles will decrease revenues from indirect taxation, both because of lower purchases of expensive and CO₂-intensive vehicles, which reduces revenues from the import tax and from lower consumption of fossil fuel energy (that reduces the revenues of the mineral tax). The building codes policy impacts public finance indirectly through changes in tax base, but most of the impact comes from a change in factor tax reflecting the lower social contributions from labour in the construction sector.

59. The Buildings Programme is mostly composed of financial grants for building renovation, so removing the policy implies fiscal space, primarily affecting industry composition rather than generating direct tax revenue. As a result, most of the fiscal impacts arise indirectly through changes in economic activity and sectoral output. Moreover, indirect and production taxes show strong second-order effects, reflecting adjustments in consumption, value added, and production levels across sectors - particularly construction and its upstream and downstream industries - rather than mechanical changes in tax rates or bases.

⁹ In the ENV-Linkages model, a closure rule about government should be defined to maintain the consistency of economic flows at the aggregate level. As government expenditures and public deficits trajectories are assumed to be identical across scenarios when a policy is implemented one fiscal tool should always be adjusted to guarantee government balance, in all experiments here it is assumed that lump-sum transfers (or taxes) to households plays this role. This constitutes a standard closure used in many economy-wide models by limiting the impact of recycling rule to income effects only. In practice government could find instead new sources of revenues to maintain constant the level of transfer and this will add distortions or could accept some increasing deficit, debt, that would reduce productive capital in long run. In the TIMES model, government accounts are not reported, and no such closure rule is envisaged, as in most of the partial equilibrium models.

Figure 12. Swiss government and cantons revenues in 2035, by policy scenario and by aggregate revenue category

Differences in revenues between the no-policy scenarios and the reference as percentage of total revenues



Note: Revenues categories are net of subsidies.

Diamonds show the percentage changes in total revenues (net of subsidies) with respect to the reference value.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

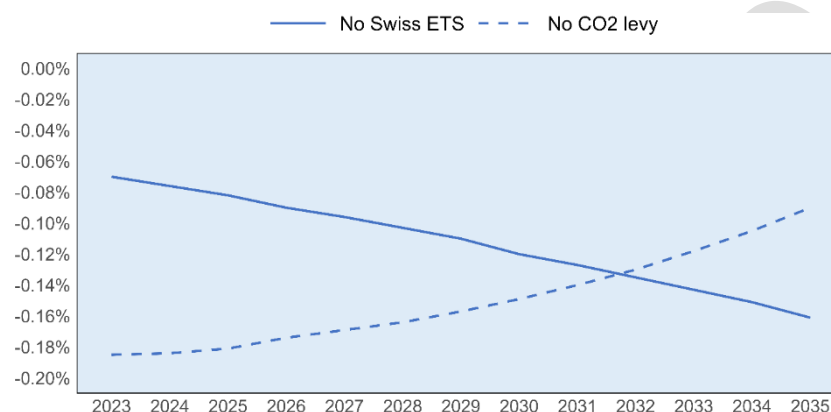
60. The two carbon pricing policies - ETS and the CO₂ levy - also create meaningful revenues from carbon taxation, that are redistributed as transfers to households and therefore imply a substantial positive income effect in the reference scenario. But these revenues are not stable over time and are partly offset by lower streams from other fiscal revenue sources (e.g. VAT revenues or production taxes) due to lower activity (such as a decrease in output or investment or a reduction of activity in energy-intensive sectors). Figure 13 reveals a striking difference in time profiles of carbon revenues between the removal of the Swiss ETS and the removal of the CO₂ levy: in the short-term, the carbon levy remains the most significant source of carbon revenue source. In the long-term, the ETS revenues become more critical, because the projected reduction of the ETS emission caps would imply an increase of carbon tax over time, the price of an ETS permit is projected in the reference scenario to increase from 80 (2015-euro/t of CO₂) in 2025 to 200 in 2035. On the contrary the taxation rate of the CO₂ Levy is not legislated to increase after 2022, the decline in CO₂ Levy revenue underscores the need to adapt to shrinking fossil fuel tax bases. The second reason why ETS is more pertinent in the long run than the CO₂ levy is that it covers mainly power and heavy industries. Since these sectors are more rigid in the short run, policies targeting these sectors take times to be fully effective. The CO₂ levy on the contrary mostly falls on the heating system, and here the turnover is quicker and more based on domestic and individual decisions.

61. The results of the policy-removal simulations should be interpreted in light of some modelling simplifications. In the current set-up, changes in government revenues are offset through lump-sum transfers to households, which abstracts from the possibility that additional revenues could be used to reduce distortionary taxes and generate further efficiency gains. While this may affect the magnitude of estimated

economic impacts, it is less likely to alter the core insights of the analysis, which focus primarily on the relative performance and interactions of policy instruments. In this regard, the OECD's Macrostructural Climate Framework will help address this limitation by explicitly incorporating fiscal interactions and analysing optimal policy mixes under various frictions and externalities, thus complementing the present approach and providing a more comprehensive assessment of how climate policies interact with the broader tax system and public finances.

Figure 13. Swiss carbon revenues of removing ETS vs. removing CO₂ Levy, 2023-2035

Differences in carbon revenues with respect to reference, in percentage of GDP



Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

External Impacts of policies

External Impacts: competitiveness

62. Switzerland's climate and energy policies exert differing effects on trade performance depending on the breadth of the policy, its price impacts and interaction with sectoral supply chains. Removing climate mitigation policies impacts the bilateral trade flows, particularly with major European trading partners such as Germany, France and Italy (Figure 14), showing that export competitiveness losses from policies are in line with the economic integration of the partner country. This indicates a responsiveness to Swiss cost structures and systemic competitiveness risks if Swiss policies changes production costs. For energy intensive goods, when Switzerland removes policies, it records an increase in its market shares and the EU, on the contrary, shows some reduction in market shares (see figure on market shares by EITE commodities in Figure A 0.2 reported in Annex).

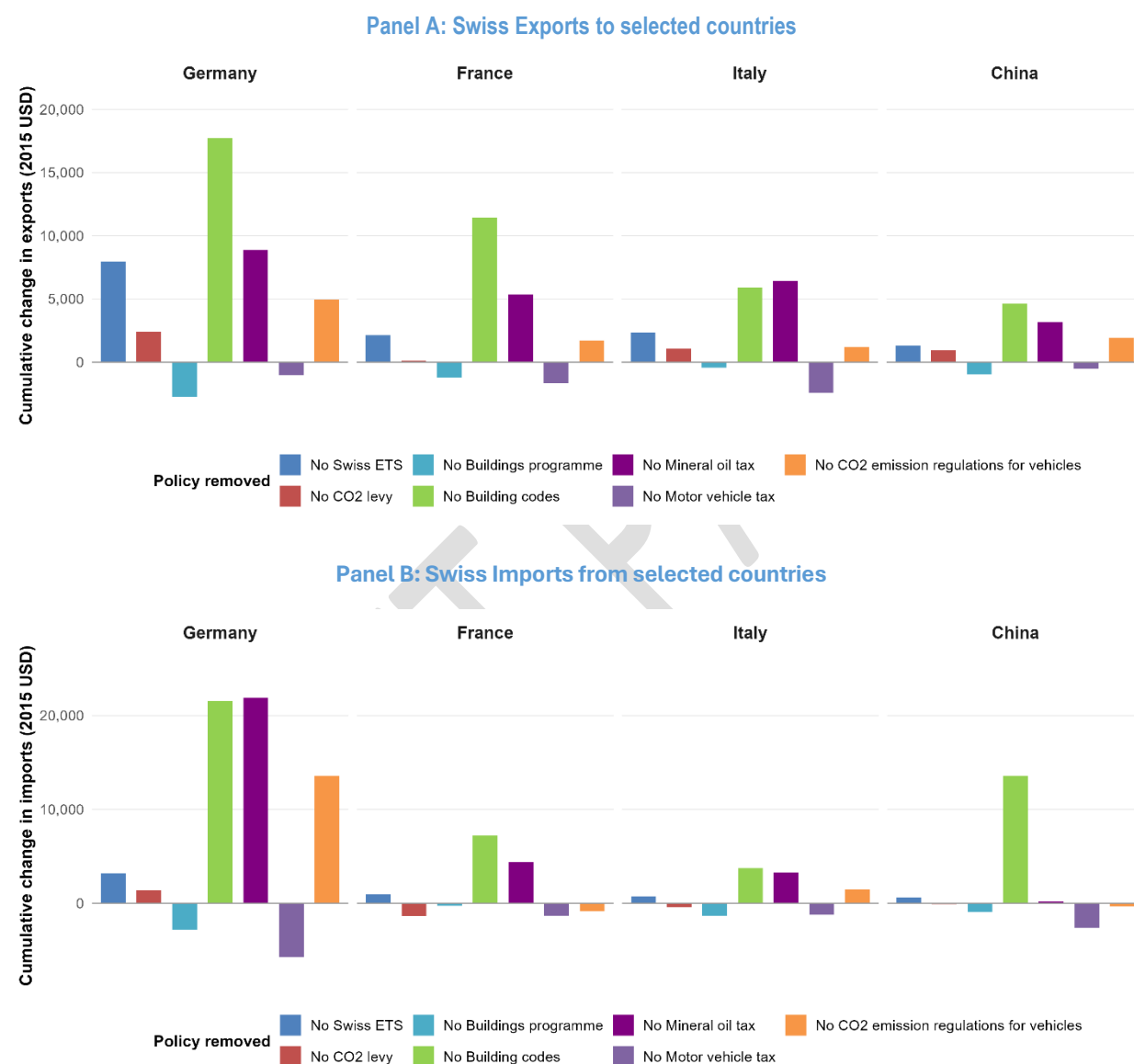
63. Policies differ in their impact on trade patterns. Removing the building standards leads to strong import and export increases across all partners (particularly Germany and France), confirming that the Building Codes generate economy-wide cost pressures that cascade through to the tradable sectors (mostly non-metallic mineral). Energy-related taxes, such as the mineral oil tax, also disproportionately affect industrial supply chains. The removal of these policies strongly benefits the European markets: Germany, France and Italy see large import and export gains under the Mineral Oil Tax removal, reflecting their demand for Swiss intermediate and industrial goods with energy-intensive supply chains. Other partner countries such as China show similar patterns, though responses are smaller.

64. The CO₂ emission regulations for new vehicles have a milder and more uniform impact across trading partners. Removing this policy yields modest export gains everywhere (particularly in Germany), indicating that this policy imposes limited competitiveness costs and operates mainly through efficiency channels. The motor vehicle tax removal consistently reduces exports in all countries and particularly for Italy. The Motor

Vehicle Tax, on the other hand, appears to support productivity and technological upgrading within Switzerland, therefore indirectly enhancing export capacity.

Figure 14. Swiss exports and imports, by partner country and by policy scenarios

Cumulative change in exports (imports), no-policy vs. reference scenario, 2023 – 2035, 2015 USD



Note: the cumulative change in total imports to Switzerland from each partner country between 2023 and 2035 is calculated as the difference between the no-policy scenario and the reference scenario.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

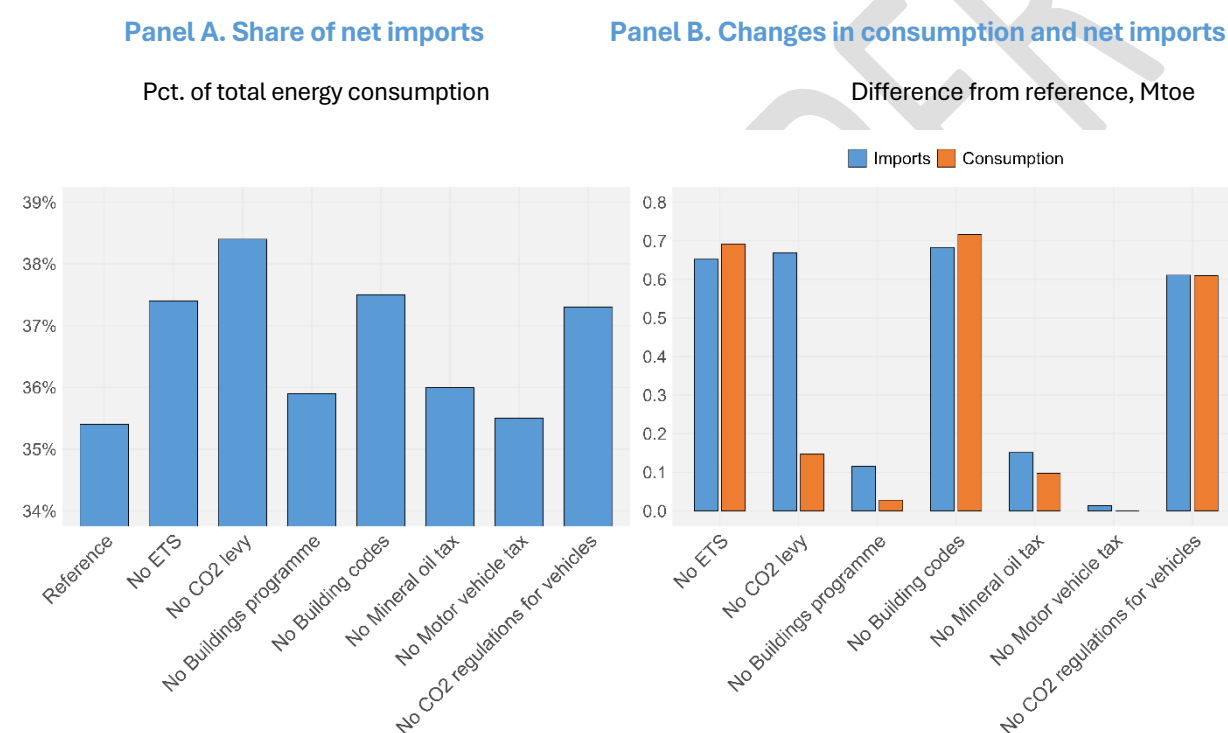
External Impacts: energy security

65. Each of the policies selected improves the Swiss energy security. Figure 15 shows that when a policy is suppressed the share of imported energy will increase (Panel A), even in absolute value the imports of primary energy always increase relative to the reference (Panel B). Thus, by reducing reliance on imported

primary energy and supporting a shift toward more domestically sourced energy use, maintaining the policies strengthens Switzerland's resilience to external supply disruptions and international energy price volatility.

66. As for other indicators, the different policies impact the energy security through slightly different channels: an increase of oil imports for the removal of carbon price policies, for the Mineral Oil Tax and for the CO₂ regulations for vehicle; the removal of the Building Codes would imply an increase in gas imports for heating systems. Besides these impacts on fossil fuel imports, another channel of energy trade, going in the opposite way, is the increase of electricity exports of Switzerland when the Mineral Oil Tax or the CO₂ regulations for vehicles are removed, since in these two cases less power would be devoted to electricity use for electric vehicles.

Figure 15. Swiss net-imports of primary energy in 2035, by scenario



Note: The primary energy above excluded E-liquids and e-gases, that are not considered in ENV-Linkages but are marginal and mostly invariant in the JRC-EU-TIMES projections. In the left chart the “net imports” of electricity are accounted, instead in the right chart the “consumption” accounts for the primary sources of electricity (Wind, Solar, Hydro...).

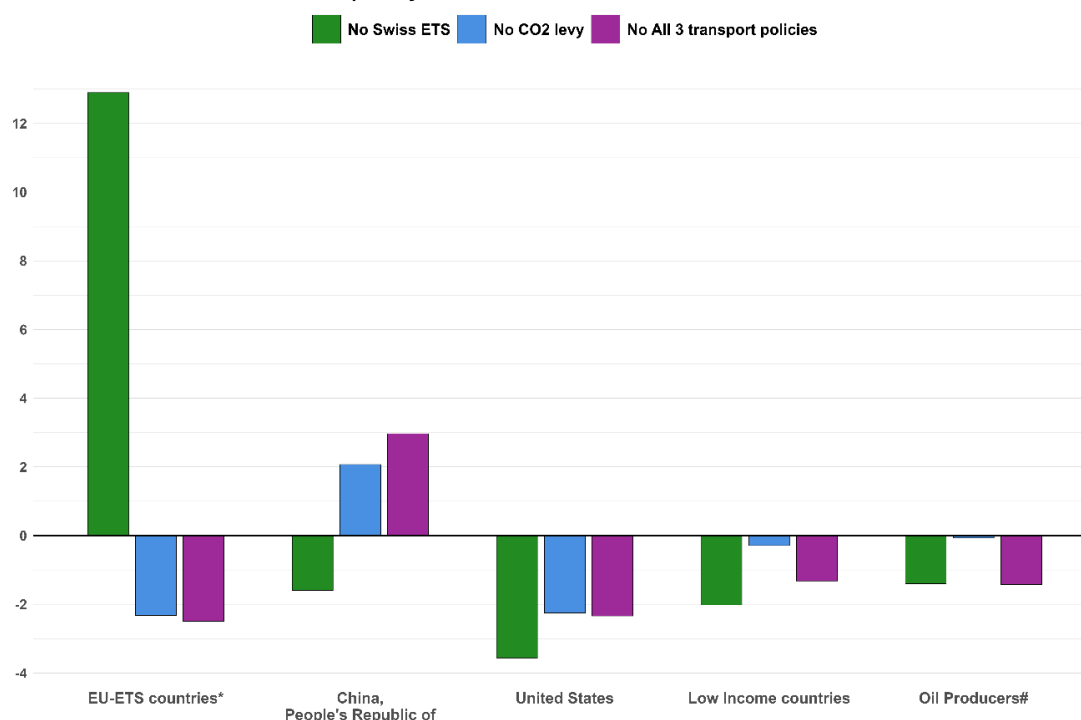
Source: OECD ENV-Linkages model using PSI's JRC-EU-TIMES model inputs.

External Impacts: international policy spillovers

67. Policies implemented in Switzerland can have a significant impact on other countries' CO₂ emissions through international spillovers. The main channels for international spillovers are 1) the changes in Swiss competitiveness (as for example, indicated by changes in Swiss marginal costs of production); 2) the changes in international energy markets; and 3) the trade of emission permits (in the case of EU-ETS). The two first effects are so-called “carbon leakage” impacts.

Figure 16. CO₂ emissions in selected partner countries, by selected Swiss policies

Cumulative difference between no-policy and reference scenarios, 2023-2035, Mt of CO₂



Note: # "Oil producers" include OPEP and former USSR oil exporting countries. * "EU-ETS countries" include all countries linked to the EU-ETS, excluding Switzerland but including Norway and United Kingdom.

Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

68. As shown in Figure 16, removing Swiss policies leads to lower emissions in the United States, lower income countries and oil producers. This occurs because Swiss production becomes more competitive, meaning more production shifts to Switzerland and less production happens abroad. This is particularly the case for the transport policies, which lead to an increased fossil fuel demand from Switzerland. The CO₂ levy on the other hand mainly affects domestic heating and building energy use and thus has weaker international spillovers. In the case of the CO₂ levy, China sees an emission increase, which is due to higher demand for carbon-intensive imports.

69. The case of the Swiss ETS is more complex because the policy implies linking the Swiss ETS to the EU-ETS, so it impacts mostly other European countries participating in the joint ETS. Emission reductions are substantial in other EU-ETS member countries. Hence, once the Swiss ETS is removed, emissions in EU-ETS countries increase by roughly 13 Mt of CO₂.

70. Compared with its partners, Switzerland's initial average emission intensity is lower, but other ETS countries have greater "low-hanging-fruit" potential for reducing emissions in the power and industrial sectors. Therefore, when Switzerland joins the ETS, it becomes a net importer of emission allowances, leading to a part of Switzerland's original "share" in emission reductions being achieved by other ETS countries. It is worth mentioning that the carbon price faced by EU countries is therefore slightly higher than when Switzerland joins (EUR 201 per ton of CO₂) than when Switzerland does not participate (EUR 198 per ton of CO₂)¹⁰.

¹⁰ The changes in the "endogenous" price of EU-ETS permits discussed here is the result of the ENV-Linkages model, and not from the from PSI's JRC-EU-TIMES model that also features trade of emission permits across ETS member countries.

Policy interactions

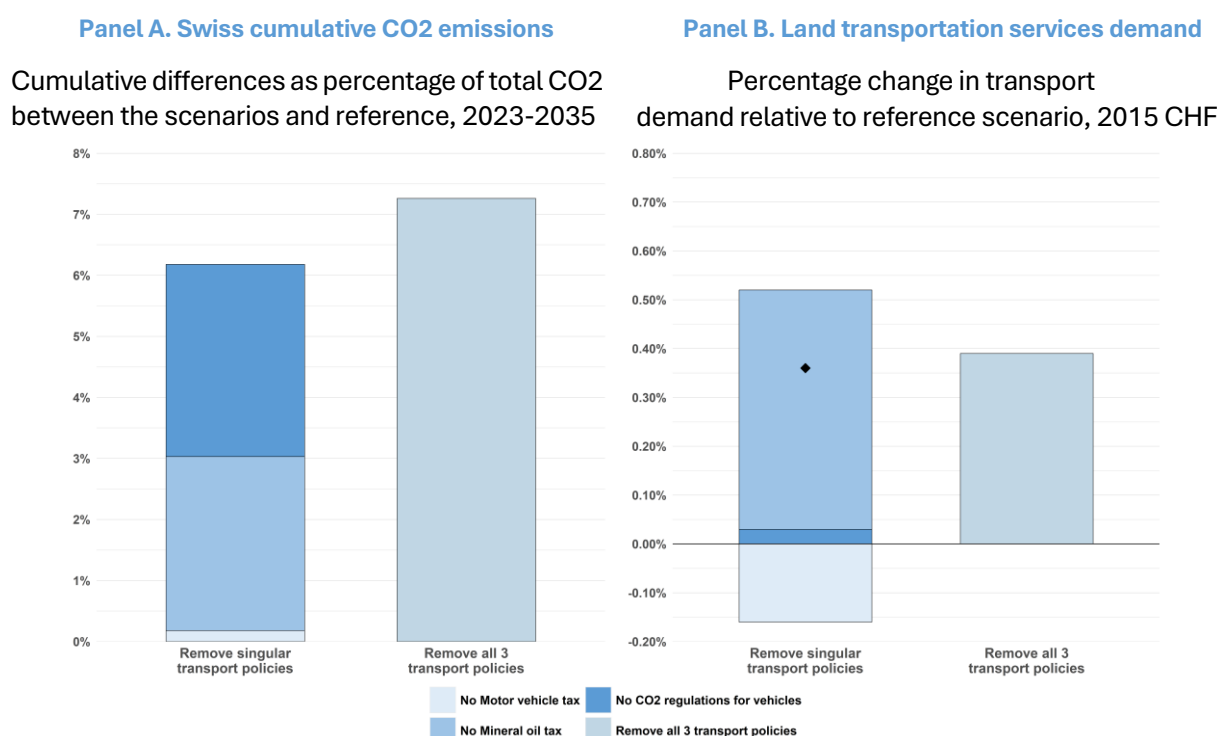
71. Understanding how policies interact is essential for effective policy design, as instruments rarely operate in isolation and their combined effects can differ significantly from the sum of their individual impacts. The current integrated modelling framework is particularly useful in this context, as it allows for the systematic assessment of overlapping measures within a consistent economy-wide setting and helps reveal complementarities, trade-offs and potential unintended effects.

72. The way in which policy interactions impact emission reductions depends on how policies interact in either (1) influencing a single type of technology or fuel choice decision, or (2) on how they interact with each other through market adjustments. Panel A of Figure 17 provides an illustration of the first case, in which policy instruments reinforce one another. An additional simulation, in which all transport policies are removed simultaneously, shows that the three instruments operate in a mutually supportive way rather than independently. When the fuel excise tax is removed in isolation, the increase in purchases of high-emission vehicles remains limited because the CO₂ regulation for new vehicles still affects the choice about vehicle types. Conversely, removing only the CO₂ regulation for vehicles does not lead to a substantial shift toward high-emission vehicles, as drivers still face relatively high fuel costs due to the excise tax. However, when both instruments are withdrawn at the same time, these constraints no longer offset one another: high-emission vehicles become both cheaper to purchase and less costly to operate. This highlights the importance of analysing policy interactions explicitly.

73. An additional simulation from the JRC-EU-TIMES model in which both the ETS and the CO₂ Levy are removed together provides an example of the second type of interaction (see Annex C.3 for a detailed discussion). In this case, the policy interaction operates in the opposite way: the combined removal of the policies shows a lower emission increase than the sum of the individual policy removals. The reason is that these policies target different parts of the Industry and the Buildings sectors, but cause competition for the same resources, compared to the energy use that one policy by itself would induce. Both policies cause a complex web of interactions of energy use within and between sectors, resulting in competition for electricity, which is in high demand from all sectors, as well as for solid biomass and biogas, whose resources are more finite. This competition leads to a need for more expensive low carbon solutions and slowing somewhat energy transitions.

74. Besides differing impacts on technology and energy markets, differences between removing policies individually or jointly also arise from economy-wide transmission channels including relative price changes, fiscal adjustments, trade competitiveness, etc. Because these channels operate simultaneously and non-linearly, joint policy removal can produce outcomes that differ substantially from the sum of individual effects. Panel B of Figure 17 shows the difference in demands for land transportation services between individual policies and the policy package of all three transport policies. Joint removal of transport policies increases transport demand more than individual removal policies, as individual policies partially offset each other. This points to policy complementarities. Transport policies seem to not simply reduce emissions through price signals but also act on behaviour, efficiency and mobility structure. Given higher transport demand leads to increased fuel use, economic activity in transport-linked sectors and import dependence, removing the policy package of all three policies leads to higher emissions than removing the policies individually (as shown in Panel A of Figure 17).

Figure 17. Impact of removing Swiss transport policies on cumulative CO2 emissions and transport demand: comparison of the sum of impacts of the 3 transport policies and the impact of all 3 policies together



Note: The left-hand side of each chart is reproducing the sum of the impact of the three isolated policies reported in Figure 8.
Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

Lessons for policy making

75. **Market-based instruments offer efficient policy options, although non-market-based policies are less costly than commonly expected, thus showing the importance of policy mixes.** Market-based instruments emerge as efficient policy options in the modelling results, consistently achieving emissions reductions at comparatively lower marginal and GDP costs. However, the analysis also reveals that non-market based measures like the CO₂ emission regulations for new vehicles - often presumed to be expensive or inefficient - may deliver substantial mitigation at costs lower than commonly expected when implemented under realistic behavioural and technological constraints (Goulder and Parry, 2008^[1]). The Building Codes instead appear to be slightly more costly than the CO₂ levy to decarbonize the building sector. However, the buildings sector also constitutes a sector which is hard-to-abate due to the granularity of the sector with many actors involved, site-specific conditions and the slow capital turnover (Edelenbosch et al., 2024^[31]). Hence, emissions in the buildings sector can be costly to abate.

76. **The exercise shows that no single type of instrument in a given sector dominates across all the indicators analysed.** Rather than pointing to a universally superior policy type, the results highlight the importance of combining market-based and non-market based approaches when designing climate policy and thus taking a holistic approach. The analysis of comparing single policy instruments to the combination of several instrument types in the transport sector shows that the combination of market-based and non-market-based instruments is more effective than instruments in isolation. This further underlines the importance of policy mixes and means that interaction effects should be more central to the type of analysis, as performed in this case study for Switzerland. In practice, dimensions not considered in this exercise (such

as political feasibility or distributional objectives) may also constitute important drivers of policy choices and justify the importance of one instrument type over another.

77. **The broader the fiscal base of a fiscal instrument, such as excise taxes on fuels or carbon prices, the stronger its income effects.** These effects can, in turn, influence the fiscal incidence of a policy, for example, by changing the level of consumption. Some fiscal policies cover a large share of economy-wide energy expenditures (i.e. the tax base) and thus constitute a substantial part of total government revenues. Therefore, these policies, once implemented, have non-negligible income effects that can reinforce (or offset) the direct price effects. For instance, the Mineral Oil Tax on transport fuel use shows price effects that reduce fuel consumption. But if the collected tax is not directly redistributed back to households, it can result in an additional negative income effect that could also reduce the consumption of other goods.

78. **Some existing Swiss policies may intuitively target a part of GHG emissions, but still, they can have a negligible effect on emissions.** There are two main reasons for such an outcome. First, certain policy instruments do not effectively influence the fuel-mix associated to a technology (i.e. inelastic tax base). Second, some policy instruments have an insufficient size to provide meaningful incentives. The first example is the Motor Vehicle Taxes: it does not affect the level of vehicle use (kilometres driven) and is also imposed on clean vehicles in most Swiss Cantons. Subsidies for building renovation, under the Building Programme in Switzerland, provide a second example: the subsidy rates are rather low, thereby limiting their effectiveness.

79. **Interactions between domestic policies, within or across sectors, matter for policy effectiveness.** Based on simulations from the JRC-EU-TIMES model¹¹, some policies in Switzerland are found to reinforce each other, like the CO₂ emission regulations for vehicles and the mineral oil tax. In other words, the combined effect of the policies exceeds the sum of their individual impacts when implemented in isolation. These two policies influence different choices: the tax impacts vehicle use, while the regulation impacts drivetrain choice. Therefore, the regulation reduces emissions from new cars, and the tax reduces the use of inefficient gasoline- and diesel-powered cars and provides a stimulus to replace them with newer, more efficient cars. On the other hand, policy interactions can also partly offset each other. This is the case for CO₂ levy and the ETS where the sum of the emission impacts when removed together appears to be lower than the sum of their individual effects. Here the cause is that both policies cause competition for the same low-carbon resources, notably biomass and electricity, thereby slightly reducing the trade-off between technologies in the disadvantage of clean technologies.

80. **Country interdependencies between commodity markets and energy-related policies alter the effectiveness of Swiss policy.** The interactions between Swiss policies and those of its European partner countries, together with the level of integration in the European energy market, create an additional channel that influences the effectiveness of Swiss policies. For instance, because Switzerland is part of the EU ETS, withdrawing from the system would both exempt Swiss entities from acquiring emission permits and reduce the supply of allowances in the market, thereby increasing permit prices for EU-ETS members. At the same time, it will also imply higher domestic mitigation costs, as Swiss installations that are currently under ETS will lose the option to buy allowances and will be exposed to the CO₂ levy. The CO₂ emission regulations for new vehicles and electricity trade provide further examples of the country's strong integration with its neighbouring countries' regulations and markets. These examples highlight that the effectiveness of Swiss policies cannot be assessed in isolation, as cross-border market and regulatory linkages play a key role in shaping both costs and emission outcomes.

81. **Country-specific economic structures play an important role in the success of the policy in reducing emissions.** Therefore, conclusions about the impact of a given policy instrument cannot be directly transferred to countries with different economic structures or sectoral emission profiles. In the case of Switzerland, the country starts from a very low baseline of emissions in energy-intensive industries, while its

electricity generation sector is almost carbon-free. This implies that the cost of implementing domestic mitigation measures is higher in Switzerland than in other European countries. Therefore, simulations indicate that Swiss ETS sectors can comply more cost-effectively by importing allowances than by using only domestic measures, as many other EU-ETS countries still have low-cost emission-reduction opportunities in industry and power generation. Beyond economic structure, factors such as the availability of domestic clean energy resources and the age and composition of existing equipment (e.g. vehicles fleets, heating systems) and building stocks also shape policy effectiveness.

Conclusion

82. The paper presents the novel modelling approach developed under the OECD's Inclusive Forum on Carbon Mitigation Approaches (IFCMA) combining technological details with macroeconomic consistency to evaluate current real-world climate mitigation policies across a large set of countries. The modelling exercise thus employs ex-ante modelling tools to help assess the likely impacts of currently implemented policies instead of hypothetical future or stylized policies, explore how they operate and interact even under data constraints, and support the evaluation and improvement of both new and existing real-world policy designs over time. In a case study, the paper links a sectoral energy system model (JRC-EU-TIMES) with an economy-wide CGE model (OECD ENV-Linkages). This enables simultaneous assessment of detailed technological pathways and broader economic adjustments resulting from policy implementation, offering a more comprehensive view of policy impacts than either model alone.

83. Combining these two types of models also enables policy evaluation of a wide range of current policies with high sectoral realism. The JRC-EU-TIMES model incorporates detailed engineering characteristics, technology vintages, and system constraints, allowing the framework to represent how specific regulatory policy instruments, such as building codes, affect technology uptake in a realistic, technology-specific manner. This enlarges the types of policies that can be assessed compared with a CGE model.

84. The combined outputs allow for comprehensive cost-benefit analysis of current real-world policies. Such an approach is especially valuable under fiscal constraints, helping governments prioritise policies that maximise net social benefits while preserving budgetary discipline. As the modelling strategy generates information to assess economy-wide impacts and spillovers, it can also shed light on the relative efficiency of different policy approaches and their interactions. This enables analyses of policy spillovers, impacts on trade flows and competitiveness, thus helping policy makers to shape the path towards Net Zero.

85. This modelling approach offers a practical, scalable modelling framework suitable for diverse countries. Moreover, it can be applied to any other kind of other policy domains that rely on a mixture of fiscal instruments and regulations and that are expected to imply structural changes, such as industrial policies.

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Annex

The sectoral JRC-EU-TIMES model

86. The JRC-EU-TIMES model is an open-source energy systems model developed and maintained by the Joint Research Centres of the European Commission, which is further maintained and developed by PSI. It is based on the TIME energy systems model framework developed by the IEA-ETSAP. It is a partial equilibrium framework representing the entire energy system of 36 European countries, including Switzerland, from an engineering techno-economic perspective. It has a full range of energy processes, including exploitation, conversion, transmission, distribution, storage, and energy end-use. The model covers the following sectors of the energy system: a) upstream sector, including the production and extraction of resources, energy imports and exports; b) transformation sector that includes electricity & heat production, hydrogen production and production of biofuels and e-fuels; c) final energy consumption sectors including industrial sectors, services, residential and transport.

87. The JRC-EU-TIMES aims to supply the energy services at a minimum energy system cost by simultaneously making energy technology investments and operating decisions to reach an energy demand-supply equilibrium state. The optimisation considers several constraints related to policy, technology deployment, resource potentials, or other constraints surrounding the configuration of the future energy system. The equilibrium has the property of maximising the total surplus. JRC-EU-TIMES models perfect competitive markets, meaning that the equilibrium state the market price of each energy carrier is equal to its marginal price. While the objective of the model is to maximise the overall surplus, it is also true that each economic agent in TIMES maximises its own surplus. This property is akin to the famous ‘invisible hand’ property of competitive markets. The model has a long-time horizon, and explicitly accounts for the construction times, decommissioning, lifetime extensions and retrofits of the energy infrastructure assets.

88. The main role of JRC-EU-TIMES is in the policy cycle anticipation, with a focus on technology-oriented policy. Technology policy analyses with the model can complement the European Commission’s reference analyses in the areas of energy, transport and climate actions. The baseline scenario of the model is aligned with the latest EU reference scenario from the European Commission. The JRC-EU-TIMES can support studies which require 1) modelling at the level of the energy system; 2) a high level of detail of technologies and 3) inter-temporal results on the evolution of the energy system and emissions from fuel combustion and industrial processes.

The economy-wide ENV-Linkages model

89. The OECD’s dynamic computable general equilibrium (CGE) model ENV-Linkages is used as the basis to estimate the effect of fiscal, trade, climate and energy policies on economic and environmental outputs. ENV-Linkages is a multi-sectoral, multi-regional model that links economic activities to energy and environmental issues. A more comprehensive model description is given in (Château, Dellink and Lanzi, 2014^[24]).

90. The model is based on the Social Accounting Matrices (SAM) contained within the GTAP 11 database (Aguar et al., 2023^[32]), for the base year 2014. This database describes bilateral trade patterns, production, consumption and intermediate use of commodities and services, including capital, labour and tax revenues and use.

Table A 0.1. ENV-Linkages sector aggregation considered in this report.

Aggregate Sectors	ENV-Linkages production sectors
Primary sectors+	(1) Crops, (2) Livestock, (3) Forestry, (4) Fisheries, (5) Mining,
Non-Durable Goods	(6) Food, (7) Textiles,
Construction	(8) Construction,
Collective and Utilities	(9) Collective services, (10) Electricity transmission and distribution, (11) Water supply; sewerage; waste management and remediation activities,
Fossil Based Energy	(12) Crude Oil extraction, (13) Coal extraction, (14) Natural gas: extraction plus manufacture & distribution, (15) Petroleum and coal products, (16) Coal powered electricity, (17) Oil powered electricity, (18) Gas powered electricity,
Non-Fossil based electricity	(19) Hydro power, (20) Wind power, (21) Solar power, (22) Other power (including biomass power), (23) Nuclear power,
EITE [#]	(24) Non-metallic minerals, (25) Iron and Steel, (26) Chemical products, (27) Pulp, Paper & Paper Products, (28) Non-ferrous metals,
Transport Equipment	(29) Motor vehicles, (30) Other Transport Equipment,
Other Manufacturing	(31) Basic pharmaceuticals, (32) Electronics, (33) Fabricated metal products, (34) Electrical equipment, (35) Machinery and equipment n.e.s., (36) Wood products, (37) Rubber and plastic products, (38) Other manufacturing (includes recycling),
Transport Services	(39) Water Transport, (40) Air Transport, (41) Land transport (including pipelines),
Business Services+	(42) Business Services (including commercial and residential buildings).

Note: [#] Energy-intensive and trade-exposed industry (EITE)

Source: OECD ENV-Linkages model.

91. Production in ENV Linkages is assumed to operate under cost minimisation with perfect markets and constant returns-to-scale technology for most economic sectors. The production technology is specified as nested Constant Elasticity of Substitution (CES) production functions in a branching hierarchy. This structure is replicated for each output, while the parameterisation of the CES functions may differ across sectors. The model adopts a putty/semi-putty technology specification, where substitution possibilities among factors are assumed to be higher with new vintage capital than with old vintage capital. In the short run this ensures inertia in the economic system, with limited possibilities to substitute away from more expensive inputs, but in the longer run this implies a relatively smooth adjustment of quantities to price changes. Capital accumulation is modelled as in the traditional Solow/Swan neo classical growth model, where economic growth is assumed to stem from the combination of labour growth, capital accumulation and technological progress.

92. Household consumption demand is the result of static maximisation behaviour which is formally implemented as an “Extended Linear Expenditure System”. A representative consumer in each region – who takes prices as given – optimally allocates disposal income among the full set of consumption commodities and savings. Saving is considered as a standard good in the utility function and does not rely on forward looking behaviour by the consumer. The government in each region collects various kinds of taxes to finance government expenditures. Assuming fixed public savings (or deficits), the government budget is balanced through the adjustment of the income tax on consumer income. In each period, investment net-of-economic depreciation is equal to the sum of government savings, consumer savings and net capital flows from abroad.

93. International trade is based on a set of regional bilateral flows. The model adopts the Armington specification, assuming that domestic and imported products are not perfectly substitutable. Moreover, total imports are also imperfectly substitutable between regions of origin. Allocation of trade between partners then responds to relative prices at the equilibrium.

94. Market goods equilibria imply that, on the one side, the total production of any goods or services is equal to the demand addressed to domestic producers plus exports; and, on the other side, the total demand

is allocated between the demands (both final and intermediary) by domestic producers and the import demand.

95. ENV-Linkages is fully homogeneous in prices, and only relative prices matter. All prices are expressed relative to the *numéraire* of the price system that is arbitrarily chosen as the index of OECD manufacturing exports prices. Each region runs a current account balance, which is fixed in terms of the numéraire.

96. As ENV-Linkages is recursive-dynamic and does not incorporate forward-looking behaviour, price-induced changes in innovation patterns are not represented in the model. The model does, however, entail technological progress through an annual adjustment of the various productivity parameters, including e.g. autonomous energy efficiency and labour productivity improvements. Furthermore, as production with new capital has a relatively large degree of flexibility in choice of inputs, existing technologies can diffuse to other firms. Thus, within the CGE framework, firms choose the least-cost combination of inputs, given the existing state of technology. The capital vintage structure also ensures that such flexibilities are larger in the long run than in the short run.

Models' horizon: historical and projection periods

97. To keep the JRC EU-TIMES model manageable and solvable, the model version used for the pilot study reports specific milestone years in 5-year steps (i.e. 2020, 2025, etc.). The chosen time horizon of the simulations is 2020-2050, as the model is forward looking and needs to consider investment for the future system as well, and not just until 2035. Each milestone year represents an average of a multi-year period¹², while still considering the lead times, hurdle rates, and ageing of capital stock up for renewal (e.g., power plants, boilers, buildings, vehicles) on an annual basis. The model is calibrated on energy statistics of 2019 and 2020. The year 2020 is also part of the model resolution period, but the energy system is still heavily constrained by the given capital stocks and investments. The first impact of the policy removal can therefore only be observed in milestone year 2025. To adapt to the use of milestone years, it is thus assumed that the removal of existing policies of the year 2023 starts in 2023, which is part of the 2025 multi-year period.

98. The OECD ENV-Linkages is defined on a year basis, for this Pilot the dynamic horizon retained is 2015-2050. By symmetry with the JRC EU-TIMES model the projections start in 2023 and therefore the removal of existing policies is effective in 2023. National accounts and international trade flows are in the first year 2014, using the GTAP11 database as well as IEA Energy balance database and IEA-EDGAR database for GHG emissions. Historical period up to 2022 use historical data for energy balance and OECD Economic Outlook database. The short-term and long run changes to the economy reflect projections of the OECD Economics Department in short term (OECD, 2024^[33]) and in the long term, using the Long Term Model projections (OECD, 2025^[34]). Energy projections are calibrated on IEA WEO (2023) projections and PRIMES model projections for EU countries. Calibration of the dynamic reference projections follow the method described in (Foure et al., 2020^[35]) for macro-economic trends and (Chateau et al., 2020^[36]) for sectoral and energy trends.

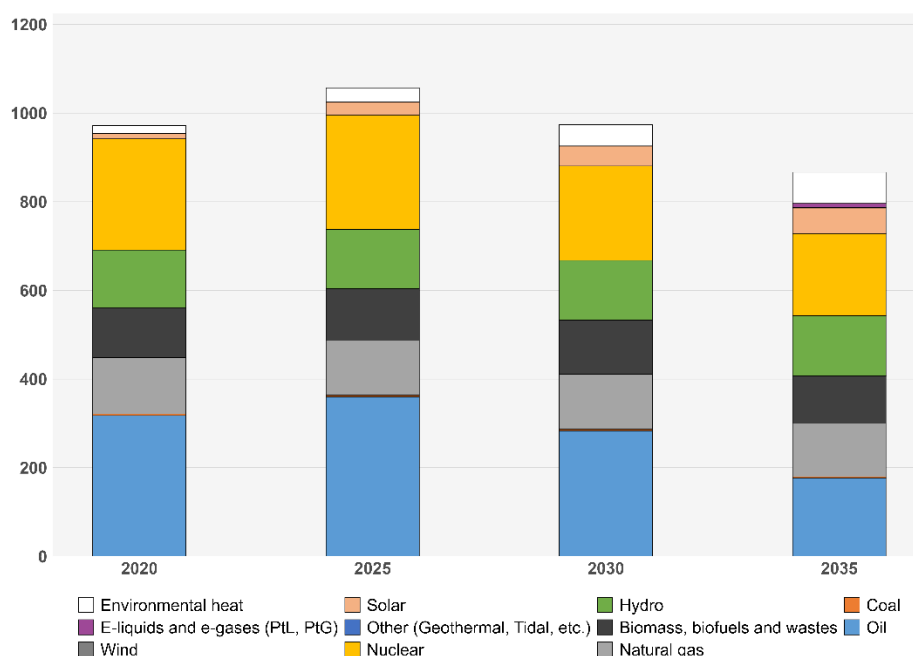
Reference trends in energy use in JRC-EU-TIMES

99. The scenarios presented in this paper account for projected changes in Swiss energy supply and demand. The combined impact of the policies selected for this study and of other (autonomous) trends on primary energy use in Switzerland (excluding international aviation) is shown in Figure A 0.1, as projected in the Reference scenario with the JRC-EU-TIMES model. There is a clear increase in solar energy use for production of renewable electricity, while in heating systems more ambient or environmental heat is used

¹² The time horizon is usually split into several periods which are represented by so called milestone years. Each milestone year represents a point in time where decisions may be taken by the model, e.g. installation of new capacity or changes in the energy flows. This time structure allows the model to effectively track vintages and calculate annual cash flows.

efficiently, thanks to the use of electric heat pumps, while in transport electricity use substitutes oil products at the expense of electricity exports mostly (trade in electricity is not shown in the figures).

Figure A 0.1. Swiss primary energy consumption mix in the Reference scenario, 2020-2035 (in PJ)



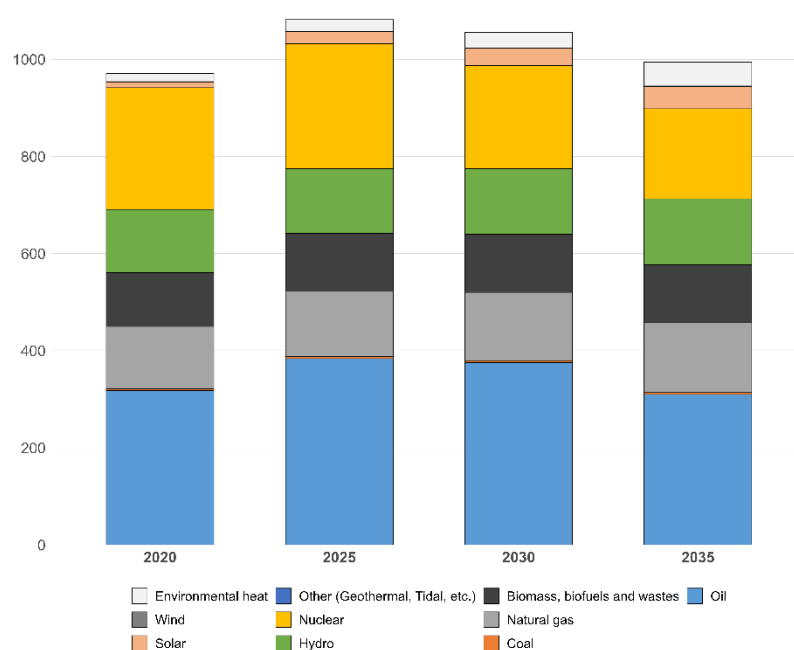
Note: * Primary energy for nuclear energy is accounted with a conversion rate to electricity of 4:1; ** Hydro and wind energy is accounted with a conversion rate to electricity of 1:1; *** Solar energy consists by majority of solar power, a minor part is solar thermal. Solar power is accounted with a conversion rate to electricity of 1:1.

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

100. These changes in primary energy use partly also result from other trends, like baseline technological developments, on which Switzerland has limited influence. These developments form relevant context to understand the impacts of policies¹³. The evolution of primary energy consumption without the selected policies is shown in Figure A 0.2. For Switzerland, they imply that even without any of the selected policies, fossil fuel use decreases to some extent in the transport and buildings sectors, as some increase in the use of electric vehicles will always takes place from 2030 onwards, while also heat pumps will be replacing oil heaters to some degree in buildings. Besides, in power generation, a sector which already has low emissions in Switzerland, a certain increase in solar power is expected under all circumstances. Therefore, use of petroleum products decreases, while use of renewable energy and environmental heat with (electric) heat pumps increase, and the efficiency of energy use also rises.

¹³ These developments form *baseline* assumptions for the Swiss energy system in the JRC-EU-TIMES model. Its baseline scenario is finely calibrated on official Swiss energy projections, notably the Energy perspectives 2050+¹³ report, and it is also informed by the expertise of the international TIMES modelling community managed by IEA-ETSAP. See also: <https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html>, and: <https://iea-etsap.org/>.

Figure A 0.2. Baseline Swiss primary energy consumption mix (Remove-all-policies scenario), 2020-2035 (in PJ)



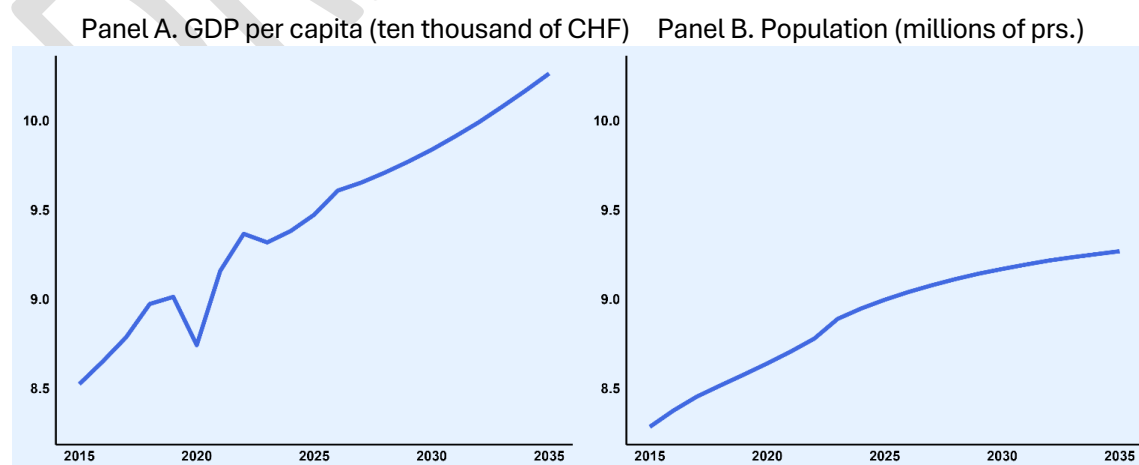
Note: * Primary energy for nuclear energy is accounted with a conversion rate to electricity of 4:1; ** Hydro and wind energy is accounted with a conversion rate to electricity of 1:1; *** Solar energy consists by majority of solar power, a minor part is solar thermal. Solar power is accounted with a conversion rate to electricity of 1:1.

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

Historical and reference economic projection in ENV-Linkages

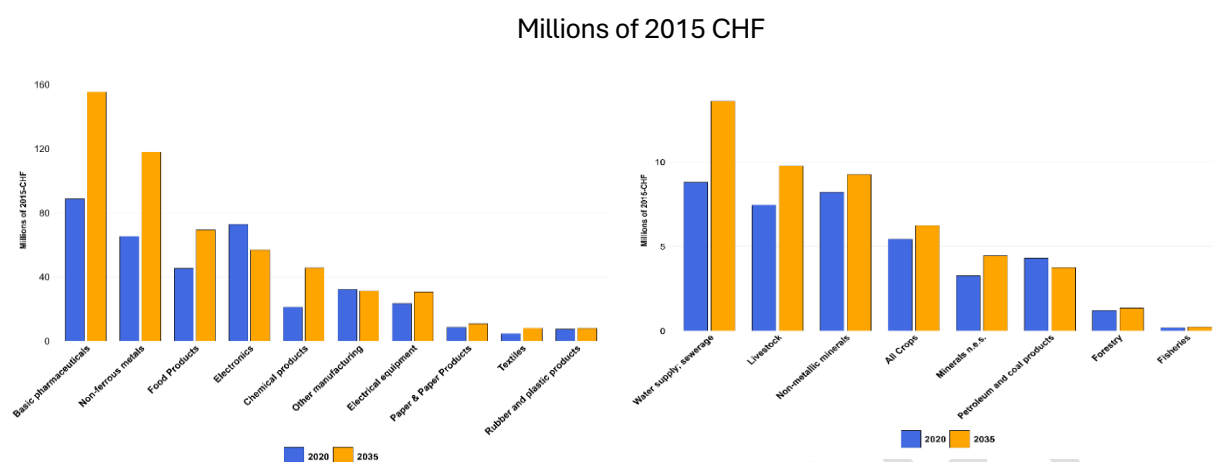
101. This section reports the real GDP and population calibrated in both models, as well as the change in Swiss sectoral composition of the economy projected by ENV-Linkages in the reference scenario. The composition of Switzerland output shows that the country is already largely decarbonized in its sectoral structure and will be projected to be more and more specialized in service activities by 2035.

Figure A 0.3. Switzerland GDP and Population in the Reference Scenario, 2015-2035



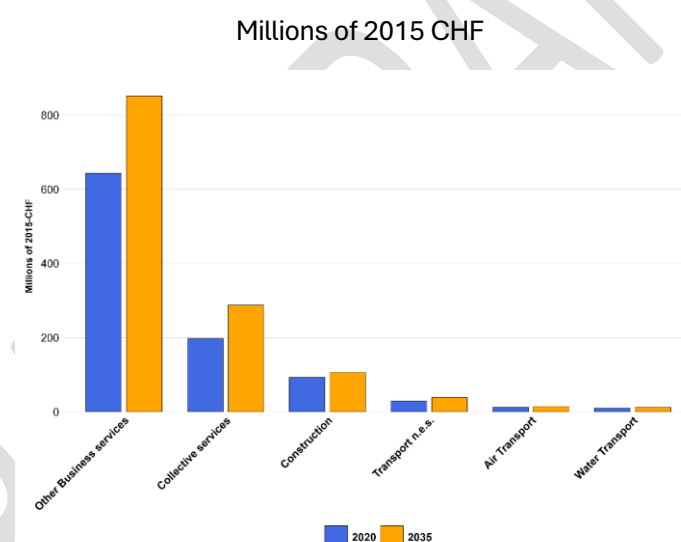
Source: OECD ENV-Linkages model using inputs from the OECD LTM model.

Figure A 0.4. Swiss Manufacturing sectors output, in 2020 and reference projection in 2035



Source: OECD ENV-Linkages model.

Figure A 0.5. Swiss Services sectors output, in 2020 and reference projection in 2035



Source: OECD ENV-Linkages model.

Details on policy implementation and model linking

Policy implementation in the JRC-EU-TIMES model

CO₂ regulations for newly registered vehicles

102. The following targets of the revised *CO₂ regulations for newly registered vehicles* are implemented in the TIMES model:

- 2021 – 2025: 118 gr CO₂ per km for passenger cars, 186 gr CO₂ per km for LCVs (WLTP cycle)
- 2025 – 2029: 93.6 gr CO₂ per km for passenger cars, 153.9 gr CO₂ per km for LCVs

- 2030 onwards: 49.5 gr CO₂ per km for passenger cars, 90.6 gr CO₂ per km for LCVs

103. These standards are implemented through a constraint on the annual CO₂ emissions that can be emitted from all newly registered vehicles based on their mileage and fuel consumption (i.e. the standard is imposed on the use of the vehicle within the year of its first registration, which is an outcome of the optimisation). In the TIMES model, the policy is defined at the end-use level, while in the regulation the policy is defined at the manufacturers' level (in the EU) and at the importer level (in Switzerland). This applies to all EU member states and Switzerland in reference scenario. However, after 2030, the regulation in Switzerland is kept constant (as legislated), while for EU it becomes more stringent (European Parliament and Council of the European Union, 2017^[37]). Swiss vehicle importers are subject to this requirement and must pay a fee if they do not meet their individual CO₂ targets

Motor vehicle tax

104. Since the JRC-EU-TIMES model represents Switzerland as a single region, a national average is calculated for the canton-specific *Motor vehicle tax*. Depending on the Canton, the tax is either calculated based on the car's physical weight, the CO₂ emissions, the power of the engine, or a combination of these characteristics. For implementing the policy in the model, twenty types of vehicles were used as references to calculate a national average over the Cantonal regulations. The national average used the number of vehicles (per fuel/engine type and size) currently registered in the different Cantons as a means of weighting. Based on the national averages, the taxes were calculated for each car type, in CHF per vehicle and year. The annual tax is kept at the 2023 level for the whole modelling horizon.

Mineral oil tax and surtax

105. The *mineral oil tax* is implemented in the model as an excise tax on the consumption of fossil liquid and gaseous fuels. It differs depending on the fuel (gasoline, diesel, light fuel oil, LPG, natural gas, heavy fuel oil) and the use (automotive or stationary applications). A "surtax" is added for the use of fossil-based motor fuels. This policy's intensity is kept at its 2023 levels, based on the IFCMA stocktake (see Table A 0.2).¹⁴ Reduced rates for non-motor fuels are considered, while other exemptions and reduced rates are not taken into account.

Table A 0.1. Modelled motor vehicle taxes by car type, in CHF per vehicle and year

	ICE gasoline	ICE diesel	Hybrid	Plugin	Electric
Small	310	320	290	350	200
Low-medium	370	380	310	380	250
Upper-medium	430	410	320	390	330
Executive/Large	1510	500	410	710	410

Source: Authors, Paul Scherrer Institute

Table A 0.2. Implemented levels of the mineral oil tax

Sector	Fuel	Tax	Surtax
Transport	Diesel	458.7 CHF/1000l	314.6 CHF/1000l
	Gasoline	439.5 CHF/1000l	315.2 CHF/1000l
	Natural Gas	112.5 CHF/t	109.7 CHF/1000l
	LPG	88.3 CHF/1000l	126.7 CHF/1000l

¹⁴ These rates are not adjusted (reduced) for specific exemptions.

Stationary sectors	Heavy fuel oil	3.6 CHF/t	
	Light fuel oil	3 CHF/1000l	
	Natural Gas	2.1 CHF/t	
	LPG	1.1 CHF/1000l	

Source: Authors, Paul Scherrer Institute

Swiss Emissions Trading System (ETS)

106. The *Emissions Trading System* (ETS) is implemented according to the latest revision of EU 2023/959 (European Parliament; Council of the European Union, 2023^[38]). Given that a European model is used, the same applies to Norway but not to the United Kingdom. It caps emissions from the most CO₂-intensive industrial sectors, including electricity and heat generation, energy-intensive industries and intra-zone aviation flights. The revision foresees a reduction of 62% of the ETS emissions by 2030 compared to 2005 levels, which is imposed as a constraint in the model on the CO₂ emissions from the sectors participating in the ETS. While the targets in these regulations are defined for all GHG emissions covered (i.e., CO₂, N₂O, PFC), they are implemented only for the CO₂ emissions from fuel combustion and industrial process¹⁵. The Swiss ETS is linked to the EU ETS, so the Swiss ETS sectors are included in the EU ETS's overall emissions reduction targets in the model. The sectors participating in the ETS in the model are:

- Electricity and heat generation (including waste incineration plants)
- Energy-intensive industries (refineries, steel works, iron and steel, aluminium, metals, cement, lime, glass, ceramics, paper and pulp, and organic chemicals).

107. In the JRC-EU-TIMES model, participation in the ETS applies to the whole sector, and there are no exemptions for small installations or other types of exemptions foreseen in the regulation. After 2030, emissions covered by the ETS are further reduced to levels feasible with the JRC-EU-TIMES model's current technological coverage, and they approach zero by 2050. Switzerland is not projecting any future implementation of the new emissions trading system (EU-ETS 2), which covers CO₂ emissions from fuel combustion in buildings, road transport and additional sectors in EU member states.

CO₂ levy

108. The CO₂ levy, introduced in 2008 under the Swiss CO₂ Act, is imposed on the production, extraction and import of thermal fuels, on stationary sources that are not covered by the ETS. The levy rate, set at CHF120 per ton of CO₂ in 2023, is kept at the same levels for the whole horizon. Two-thirds of the revenues from the CO₂ Levy are distributed to households and firms, while the remaining third is used to finance energy-efficient renovations and renewable heating energy through the Federal and Cantonal Buildings Programme (see Building sector policies below).

109. Hence, the Buildings Programme remains in place when the levy is removed. Greenhouse gas intensive installations can be exempted from the levy if they commit to reducing their emissions. The model does not consider exemptions of the CO₂ levy via voluntary reduction commitments that are foreseen in the Swiss legislation.

¹⁵ For the non-CO₂ GHG emissions from energy and industry sectors, the assumptions based on EP2050+ emissions reductions in the ZERO-Basis scenario is adopted.

Federal and Cantonal Buildings Programme

110. The *Federal and Cantonal Buildings Programme* is implemented based on information collected from the Harmonised Funding Model of the Cantons (HMF2015)¹⁶. Given this is a subnational policy, the model constraint is based on the reference cost provided in the HMF2015 for implementing the measure and the minimum level of support to be provided by the Cantons. The subsidies of the Buildings Programme implemented in the TIMES model are the following:

- The M-01 thermal insulation, implemented as a 20% capital subsidy on the corresponding building renovation costs, for buildings built before 2000.
- The M-02 to M-08 technology-specific capital subsidies on heating systems were all implemented as a capital subsidy of 20% on the specific investment costs of the corresponding technologies.
- For each of the measures M-11 to M-13, a set of new renovation options was introduced in the model to represent the six different classes of improvements identified in M-11 to M-13. A subsidy was implemented based on the reference cost of the measure for each class and support scheme.
- The M-16 new construction/replacement has been introduced with additional construction costs from new buildings not compatible with these standards. The level of financial support provided by the HMF2015¹⁷ has been directly implemented.
- For the M-18 (New construction/expansion of district heating network): a direct subsidy of 20% was implemented for the capital cost of the district heating network technology represented in the model.
- Finally, other measures were not implemented because the model was not suitable for them, or because they were not relevant for the exercise.

The Building energy codes

111. The *Building energy codes* of the cantons (MoPEC/MuKEn) impose limits on the energy consumption for space heating, water heating, air cooling, and ventilation of the buildings, as well as for the electricity production within the buildings; includes optional elements, primarily applying to new buildings and to a lesser extent existing buildings. The latest revisions, which are also considered in the JRC-EU-TIMES model can be found in Table A 0.3.

112. Moreover, under the regulation, fossil-based heating systems are limited to a maximum share of 10% in new buildings and 20% in refurbished buildings.¹⁸ The Secretariat implements the policy in the model in accordance with the MuKEn regulation. The model has the option to construct a new building by choosing a “2020-average” new building, a Minergie-P building, or a MuKEn 2014 building.¹⁹ Since the incremental costs are in reality case-specific, the penetration of the MuKEn 2014 and Minergie-P performance standards is steered according to the assumptions followed in a business-as-usual scenario (WWB) of the EP2050+ study (SFOE, 2020_[39]). This scenario assumes that MuKEn 2014 will be implemented in the 2020s so that by 2050, the specific consumption for space heating is reduced to around 30-40 kWh/m² for new buildings and 45-55

¹⁶ See Harmonisiertes Fördermodell der Kantone (HFM 2015) EnDK <https://www.endk.ch/de/ablage/dokumentation-archiv-muken/hfm2015.pdf>. This document describes the different financial supports provided by the 26 Cantons.

¹⁸ See https://www.endk.ch/de/ablage/grundhaltung-der-endk/MuKEn2014_d-2018-04-20.pdf for more information (in German).

¹⁹ The “2020-average” new building has an average energy consumption in kWh/m² for space heating, domestic hot water, ventilation and air conditions according to the average consumption of all new buildings in 2010-2020. The Minergie-P and MuKEn 2014 buildings have an average consumption in kWh/m² for the same end-uses as in the table above, while they entail an incremental cost compared to the “2020-average” building.

kWh/m² for full renovations. This implies that by 2050, on average, all new residential buildings will meet the MuKE standards.

Table A 0.3. Limits to the MuKE regulation²⁰

Building function	Average energy consumption for space heating, water heating, ventilation and air conditioning in kWh/ m ²	Energy consumption for space heating in kWh/ m ²	Requirement for electricity production within the building in W/m ²	Minergie-P standard average energy consumption for space heating, water heating, ventilation and air conditions in kWh/m ²
Multi-family house	35	13	10 (max 30 kW)	30
Single-family house	35	16		30
Administration	40	13		25
School	35	14		25
Shop	40	7		25
Restaurant	45	16		40
Hospital	70	18		45

Source: Authors, Paul Scherrer Institute.

Policy implementation in the OECD ENV-Linkages Model

113. This annex section describes the procedure for model linking between the TIMES and ENV-Linkages as referred to in the main text. To link the two models, the same policies were implemented in the OECD ENV-Linkages model together with the use of granular information extracted from the output of the TIMES model's policy simulations.

114. Policies were implemented one by one in the ENV-Linkages model (i.e. removed relative to the reference scenario) by controlling the model such that it reproduces the change in technology choices from the TIMES model. For a given sector, ENV-Linkages is calibrated on the changes in capital cost²¹ induced by the reaction to a policy, as well as to the corresponding changes in energy costs. This calibration is done by endogenizing changes in efficiency parameters for these inputs in the CGE model. Since any changes in quantities result in price effects in ENV-Linkages, this implies changes in the demand for a commodity produced by the specified sector. In turn, these changes in demand are also controlled for in a preliminary simulation run in ENV-Linkages, to avoid this feedback price effect. Moreover, in this preliminary simulation of ENV-Linkages, we also controlled as much as possible: (i) the other drivers that are fixed in the sectoral model; and (ii) the markets that are not covered by sectoral model.

115. After calibrating policy responses, in the preliminary simulation for a “controlled” (partial) version of ENV-Linkages, the policy is run again but now with the fixed efficiency trends for capital and energy demands

²⁰ This table presents regulatory energy consumption limits for various building types as defined by the MuKE regulation. Each row corresponds to a specific building function, and the columns list the maximum allowable average energy consumption in kWh/m² for different categories: Average energy consumption for building services (including space heating, water heating, ventilation, and air conditioning), energy consumed solely for space heating, and the electricity generation requirement within the building (in W/m²). The last column shows the stricter Minergie-P standard for total energy consumption for comparison purposes.

²¹ Regarding “capital costs” different modelling communities might use different definitions. In energy systems modelling capital expenditure includes expenditure on things like cars and appliances, besides what is considered capital in social accounting terminology, which for example covers industrial installations and buildings.

calculated in the first run, allowing all endogenous variables to adjust freely to assess the full general equilibrium effects.

116. The above strategy is directly suitable for the taxes and subsidies considered in this pilot, but the procedure should be adapted for regulation policies when they are also included in the reference scenario. For the two regulatory instruments, the *building energy codes* and the *CO₂ emissions regulation for new vehicles*, the modelling strategy requires some adjustments, since the ENV-Linkages model does not allow for detail on vehicle and building types and vintages. Instead, ENV-Linkages only reports expenditures on motor vehicles or demand for construction by the investment sector. Therefore, the CGE model needs to “aggregate” the price impacts of such regulatory policies from the detailed sectoral level, which are typically asymmetric for different types and vintages of vehicles or buildings and building equipment. In the case of regulatory instruments, and in addition of the calibration of capital and energy efficiencies to target the changes in capital costs and energy expenditures (extracted from the sectoral model), shadow costs to consumer-prices or to investment, respectively for vehicles and construction, are added in the full version of ENV-Linkages to keep track of the regulations “cost”.

117. In ENV-Linkages, the entire economic system is balanced and consistent with macro-economic national accounts identities at each period. This requires the adoption of closure rules to guarantee that each agent has a balanced budget, including the government. Hence, when a policy is removed, impacting tax rates and tax bases, a government policy tool must be adjusted to keep budget equivalent that of the reference scenario. In all policy removal simulations, the government budget is assumed to be balanced through adjustment in transfer to households.

Soft-linking the sectoral TIMES model with the CGE ENV-Linkages Model

118. The section 3 describes the general modelling framework envisaged in the IFCMA modelling analysis linking sectoral models to the global OECD CGE model. This annex precise this exercise in the case of the Swiss study where the sectoral model chose is the EU-JRC-TIMES model.

119. For the first step, harmonisation, the IFCMA exercise draws on a shared data foundation for both the CGE and bottom-up models, including the IFCMA Climate Policy Data base (OECD, 2025^[25]) and technology data supplied by the Paul Scherrer Institute. To achieve a high level of consistency between the macroeconomic and sectoral projections that define the reference scenarios in each model the harmonised macroeconomic and sectoral projections of the OECD ENV-Linkages model adjusted its baseline to some of Switzerland’s country-specific sectoral trends - particularly in construction and transport. In practice this means that ENV-Linkages relies on the TIMES model for these sectors, which is directly calibrated to national energy and sectoral projections.

120. In the second step, the consistent common reference scenario, all selected existing and legislated policies (see Table 1 above) are first fully implemented in the first implemented in TIMES, as described in Annex B. The TIMES reference scenario also incorporates relevant EU, Norwegian, and UK legislation, such as the revised EU Renewable Energy Directive. Consistent with Swiss legislation, most policy intensities are held at 2023 levels over the projection horizon, while dynamic policies (such as EU ETS trajectories under Directive 2023/959 and tightening CO₂ standards for new vehicles) follow legislated paths. The TIMES Reference scenario informs the calibration of ENV-Linkages on the aspects of energy supply and use that are impacted by the policies. The calibration of the Reference scenario and implementation of each of the policies in ENV-Linkages is also specified in Annex B. Besides considering inputs from the TIMES model, additional policy specifications, like data on total tax revenue and subsidy expenditure by the Swiss government were added to complete the Reference calibration.

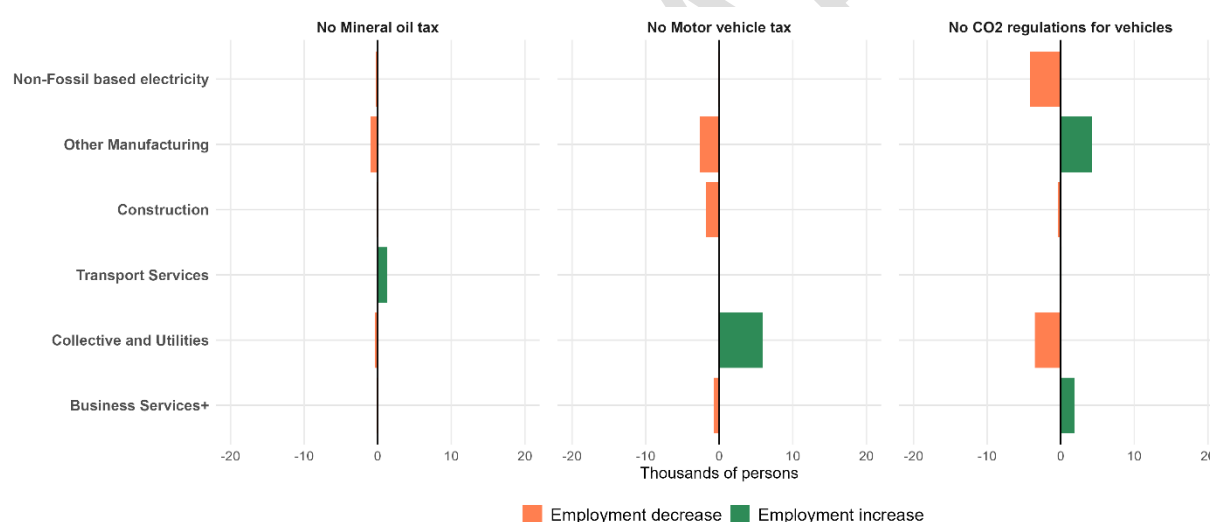
121. In the third step, policies are removed sequentially in the TIMES model starting from its first milestone year (2025).²² Policy impacts are calculated as the difference between the reference and counterfactual outcomes. The reference scenario aligns historical data and projections the two models about GDP and socio-demographic trends, sectoral outputs growth, energy trends and initial CO₂ emissions. The two models are therefore also linked by exchanging outputs resulting from the policy assessment scenarios. For example, capital and operating expenditures from the energy system, subsidies and taxes on energy technologies and fuels, ETS prices and emissions caps, sectoral emissions and levelized costs of energy carriers that are calculated by JRC-EU-TIMES form essential input to ENV-Linkages so that the model is informed about the configuration of the energy system before calculating macroeconomic implications.

Additional analysis

Employment

Figure A 0.1. Changes in sectoral employment: removing selected policies in 2035

Changes in employment for selected aggregate sectors (difference in thousands of persons with reference)



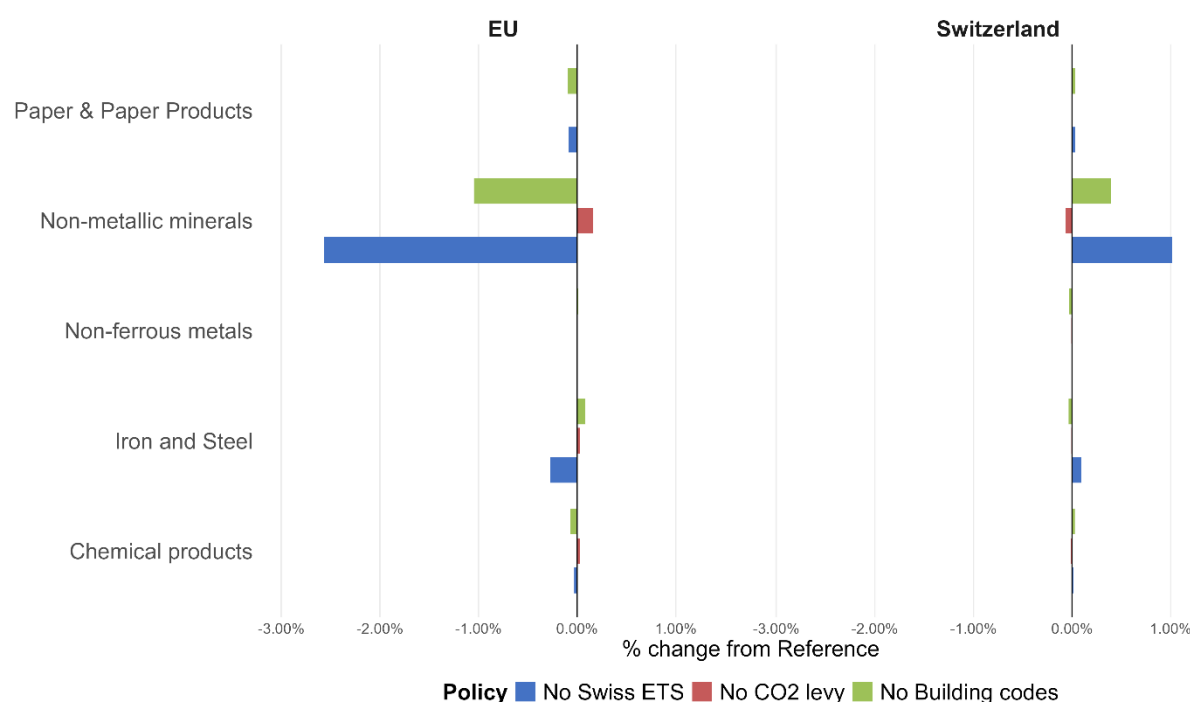
Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

²² Beyond individual policies, the analysis includes combined policy packages and additional sensitivity simulations (e.g. joint transport measures, ETS removal for Switzerland and the EU, and alternative ETS reduction pathways) to obtain a better understanding of policy interactions. These supplementary results are not reported here.

Trade

Figure A 0.2. Changes in EU and Swiss trade share for EITE industries: selected policies in 2035

Country export as percentage of world total market share, percentage point difference with respect to reference



Source: OECD ENV-Linkages model using inputs from PSI's JRC-EU-TIMES model.

Policy interaction effects of the Swiss ETS and CO2 levy based on JRC-EU-TIMES

122. The Swiss ETS system and the CO2 levy are both policies which aim to reduce CO2 emissions from industry and there are reasons to expect interaction effects between these policies with consequences for their effectiveness in reducing CO2 emissions. While each policy targets different sectors and installation sizes, the technological alternatives whose uptake they stimulate are often the same, and the policies could therefore cause competition for the same solutions or resources, like biomass, or renewable electricity production. Also, when combined they might cause a price-reduction in fossil fuel energy supply which could reduce the effectiveness of either policy. E.g. district heating based on waste incineration (for which roughly half of CO2 emissions is from fossil fuel-based sources, like plastics, and therefore requires ETS allowances) could possibly remain relatively more advantageous than using boilers based on solid biomass (which does not require ETS allowances).

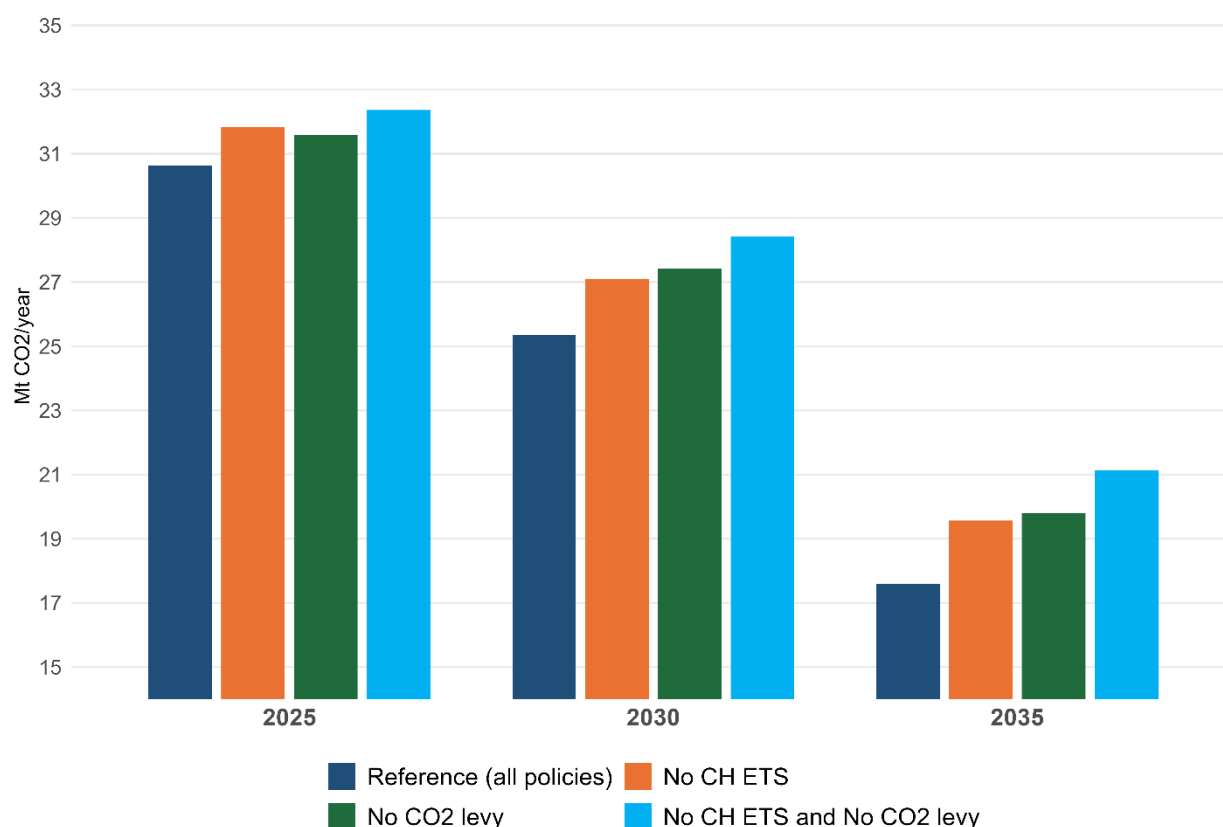
123. Figure A 0.3 shows that if one would remove the Swiss ETS, or if one would remove the CO2 levy, this causes a sizeable increase of Swiss CO2 emissions.²³ If one were to remove both, then emissions increase more than for each individually, but less than the sum of the two. (Table A 0.2). This means that the effect of

²³ Note that the following analysis is based on sectoral modelling results only, as this specific combined scenario was not implemented in ENV-Linkages, as an additional model re-calibration was out-of-scope.

additional removal of the other policy is less than the impact of the initial removal. This signals that the policies partially reduce each other's effectiveness in emission reduction. As both policies aim for different parts of the industry sector (and the CO₂ levy also other sectors) this means that the policies interact through energy markets, e.g., by competition for the same resources or technological solutions.

Figure A 0.3. Domestic CO₂ emissions with and without Swiss ETS and CO₂ levy

Net domestic* CO₂ emissions in Mt CO₂/year, JRC-EU-TIMES results



Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.

124. A closer look at the changes in the energy system shows that energy market interactions differ between the combined removal and the sum of the individual removals (compare panel C and panel D in Figure A 0.4). This is particular the case for the use of oil, and natural gas, and biomass/waste which increase less in combined removal than for each of the policies individually. On the other hand, the use of heat pumps decreases (visible as primary energy consumption of environmental heat) less when than for the sum of the individual policies.

125. The reduced combined emission impact is a clear consequence from the reduced impact on oil use and not a lesser extent the use of natural gas. Both policy removals individually cause changes in the need for alternatives for oil, and to a lesser extent natural gas (the latter energy carrier sometimes figures as a cleaner alternative and sometimes as a more carbon-intensive alternative, depending on the context). To understand these substitution effects, one needs to consider a relatively large set of energy system interactions which the policies have. Isolating these impacts first by sector (see Table A 0.1) helps identifying the overall effect. The common line is that in some sectors, for some fuels, both policies have opposite impacts. Only the reduced consumption of electricity is stronger for both policies combined than for the two individually. A central

explanation is that the combined policy removal leads to lower biomass prices and therefore a relatively higher use of biomass than when policies would have been removed individually. This has knock-on effects, like higher use of biomass in district heating freeing up use of “waste” as an energy input for industry. There is also higher availability and thus not much reduction of use of biogas, and to a lesser extent natural gas. This and other opposing energy use developments for different sectors (see Table A 0.1) lead to a delayed “phase-down” of oil. Lastly, lower electricity prices are relatively beneficial for heat pumps too, which use does not reduce as much as for each policy individually.

Table A 0.1. Comparison of sectoral energy system impacts of the Swiss ETS and CO2 levy individually and when combined

	ETS removal	CO2 levy removal	Combined removal
Key elements for policy interaction effects	<i>There is a shift in biogas consumption from Industry to Buildings.</i>	<i>In Buildings, the direct impacts of the CO2 levy removal are stronger than the indirect impacts of the ETS.</i>	<i>Lower combined impacts on oil use and CO2 emissions than for the sum of both individual removals, while the combined impact is higher for electricity use. Implies less substitution of alternatives by oil.</i>
Electricity & District heating energy consumption	Lower consumption of electricity and higher exports. District heating reduces use of solid biomass and strongly increases use of waste.	<i>Side-effect:</i> A bit of reduction in electricity consumption and increase in electricity exports, but much smaller than for ETS removal.	A larger combined impact on consumption (reduced) & exports (increased) of electricity than for both removals. Generation is similar. <i>More biomass and less waste go to District heating than for ETS removal alone.</i>
Industry energy consumption	Consumption of electricity, oil, and district heating (mostly from natural gas) goes up. That of natural gas goes down. Use of biogas, biomass & waste goes down too.	Increased use of oil A small increase in use of gas. Reduced biomass use.	Less increase in oil use than for the sum of both removals. Opposite impacts on gas consumption (less reduction than for ETS alone). Reduction in biomass use lower than for sum of both removals, as cost of biomass is lower than for ETS removal alone. <i>Increased use of waste vs. ETS removal alone.</i> Paralleled by a lower increase in use of district heating versus for ETS removal alone.

	ETS removal	CO2 levy removal	Combined removal
Services buildings energy consumption	<i>Side-effect:</i> Oil use goes down. Gas, Biogas, and Electricity consumption <i>increases</i>. Heat pump use goes down.	Sizeable increase in oil use. Increase in biomass for oil boiler backup-systems. A bit <i>less</i> use of gas and biogas. Reduced use of solar thermal, heat pumps.	<i>Opposite impacts on both oil and gas use lead to lower increase in oil use than for CO2 levy removal alone.</i> The reason is a side-effect of ETS removal, which increases availability and consumption of natural gas and biogas. Services' biomass use similar to the sum of both removals.
Residential buildings energy consumption	<i>Small Side-effects:</i> Heating Oil use goes up (phase down delayed), so no competition with industry, but an overflow of LFO/HFO from Services to Residential. Biogas use goes up. Solid biomass goes down.	Longer/continued (increased) oil use. A slower introduction of heat pumps, and a reduction in biomass use.	Impacts on oil use similar to those of CO2 levy, and lower than sum of both removals, likely due to more abundance of other sources, like gas and district heating. Residential biomass use similar to that of CO2 levy alone. Side-effect of ETS removal on electricity prices, and then on residential biomass use disappears. Likely due to District heating biomass demand.
Effects on transport energy consumption	Direct impact on inter-EEA aviation. Side-effect on road transport via price of biofuels.	The CO2 levy does not interact with final energy use of waste (in none of the sectors). It also does not have an impact on international aviation.	Side-effects and impacts on other sectors (transport and international aviation) similar to those of ETS removal.
Impacts on Other metrics (electricity exports and price, and biomass price)	Decreases the future price of electricity (notably beyond 2035 - agents partially anticipate this). One reason is less domestic electricity need. Some stranded assets in space heating for services buildings.	A very limited impact on electricity prices, and until 2035 also has hardly any impact on biomass prices. Avoids sizeable amount of stranded installations in the residential sector and in the services sector (more than ETS removal).	It reduces biomass prices a bit when there is a combined removal with ETS relative to only ETS removal. Combined removal does not alter avoided stranded assets in the residential and services sectors much compared to CO2 levy removal alone.

Table A 0.2. Additional emissions impact of Swiss ETS and CO2 levy in different combinations

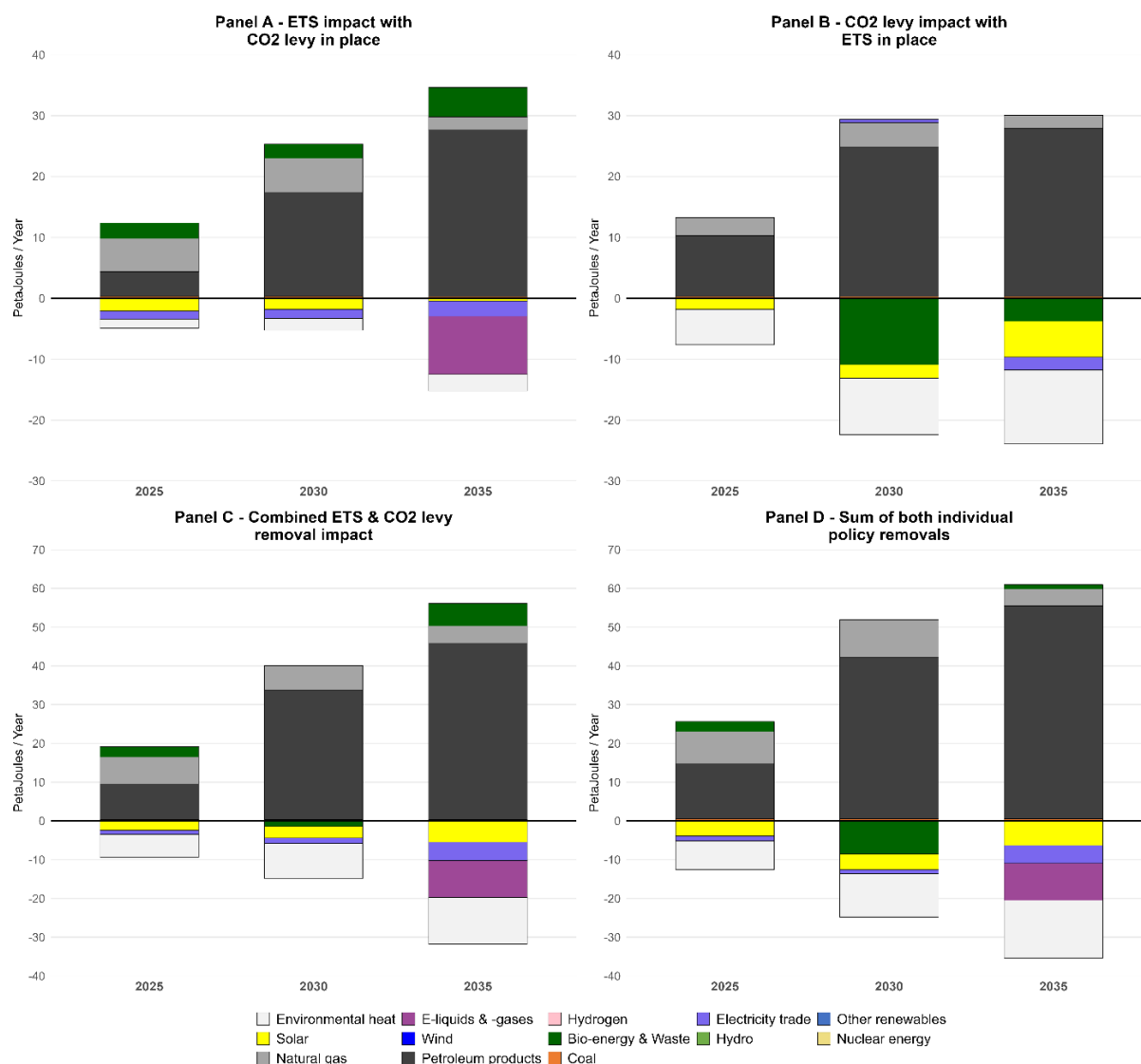
Avoided domestic* CO2 emissions attributed to the mentioned policies in Mt CO2/year, JRC-EU-TIMES results

	2025	2030	2035
A. Combined ETS & CO2 levy impact	1.7	3.1	3.5
B - ETS impact with CO2 levy in place (<i>Standard IFCMA policy removal</i>)	1.2	1.7	2.0
C - CO2 levy impact with ETS in place (<i>Standard IFCMA policy removal</i>)	0.9	2.1	2.2
Total of B + C	2.1	3.8	4.2

Notes: * Domestic CO2 emissions exclude those from international aviation, which is partly (for intra-EEA flights) affected by the ETS systems of Switzerland and the EU).

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model

Figure A 0.4. Impacts of Swiss ETS and CO2 levy policies on domestic primary energy consumption



Note: * Primary energy for nuclear energy is accounted with a conversion rate to electricity of 4:1; ** Hydro and wind energy is accounted with a conversion rate to electricity of 1:1; *** Solar energy consists by majority of solar power, a minor part is solar thermal. Solar power is accounted with a conversion rate to electricity of 1:1.

Source: Authors' own calculations based on results from PSI's JRC-EU-TIMES model.