Simulations of Swiss climate policy with a computable general equilibrium model

Philippe Thalmann

EPFL

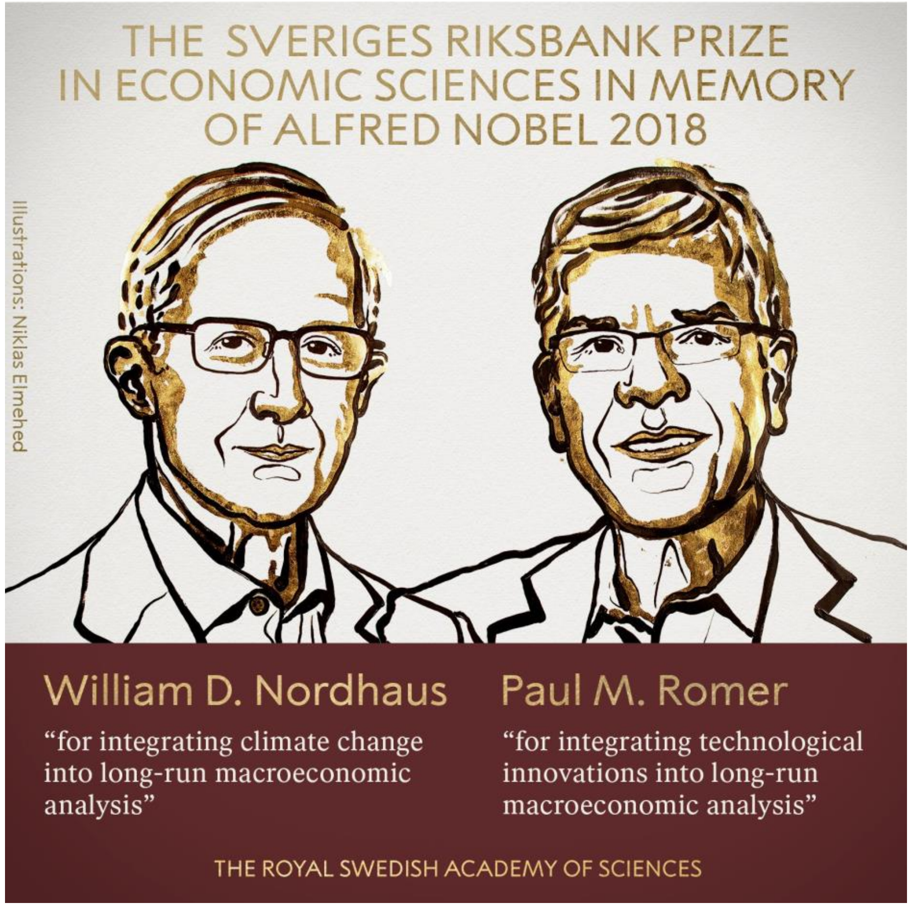
8 October 2019

Outline

1. Background: What economists can contribute to climate issues
2. Our models, e.g. GEMINI-E3
3. Some results of our simulations

BACKGROUND: WHAT ECONOMISTS CAN CONTRIBUTE TO CLIMATE ISSUES

William D. Nordhaus



Early contribution of Bill Nordhaus

CAN WE CONTROL CARBON DIOXIDE?

William D. Nordhaus

June 1975 WP-75-63

Nordhaus, W. D. (1975). Can We Control Carbon Dioxide? Laxenburg, Austria, IIASA. **IIASA Working Paper.**

Father of the 2°C limit

Nordhaus, William D. (1977). Strategies for the Control of Carbon Dioxide. New Haven, CT, USA, Cowles Foundation for Research in Economics, Yale University Cowles Foundation Discussion Papers

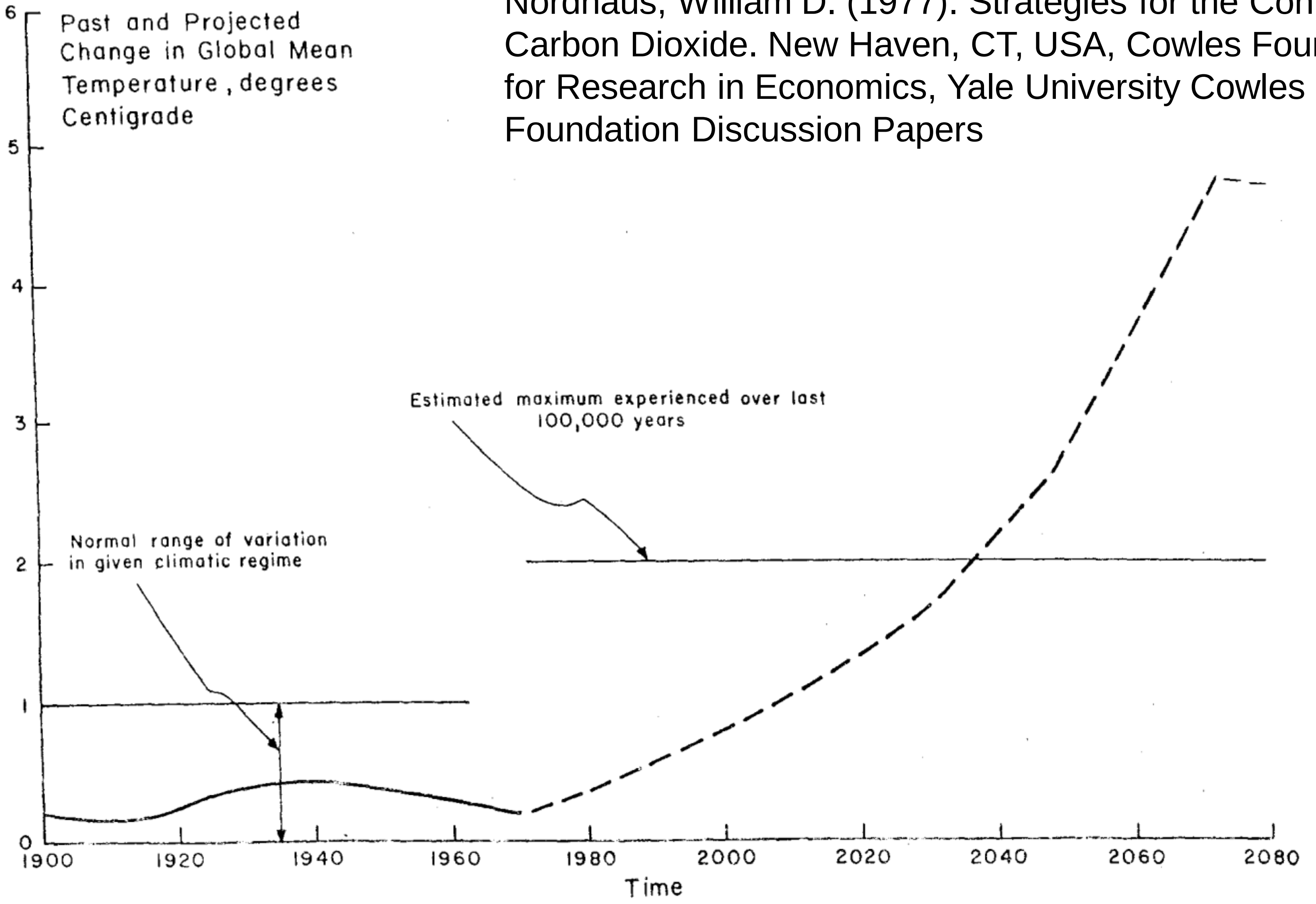
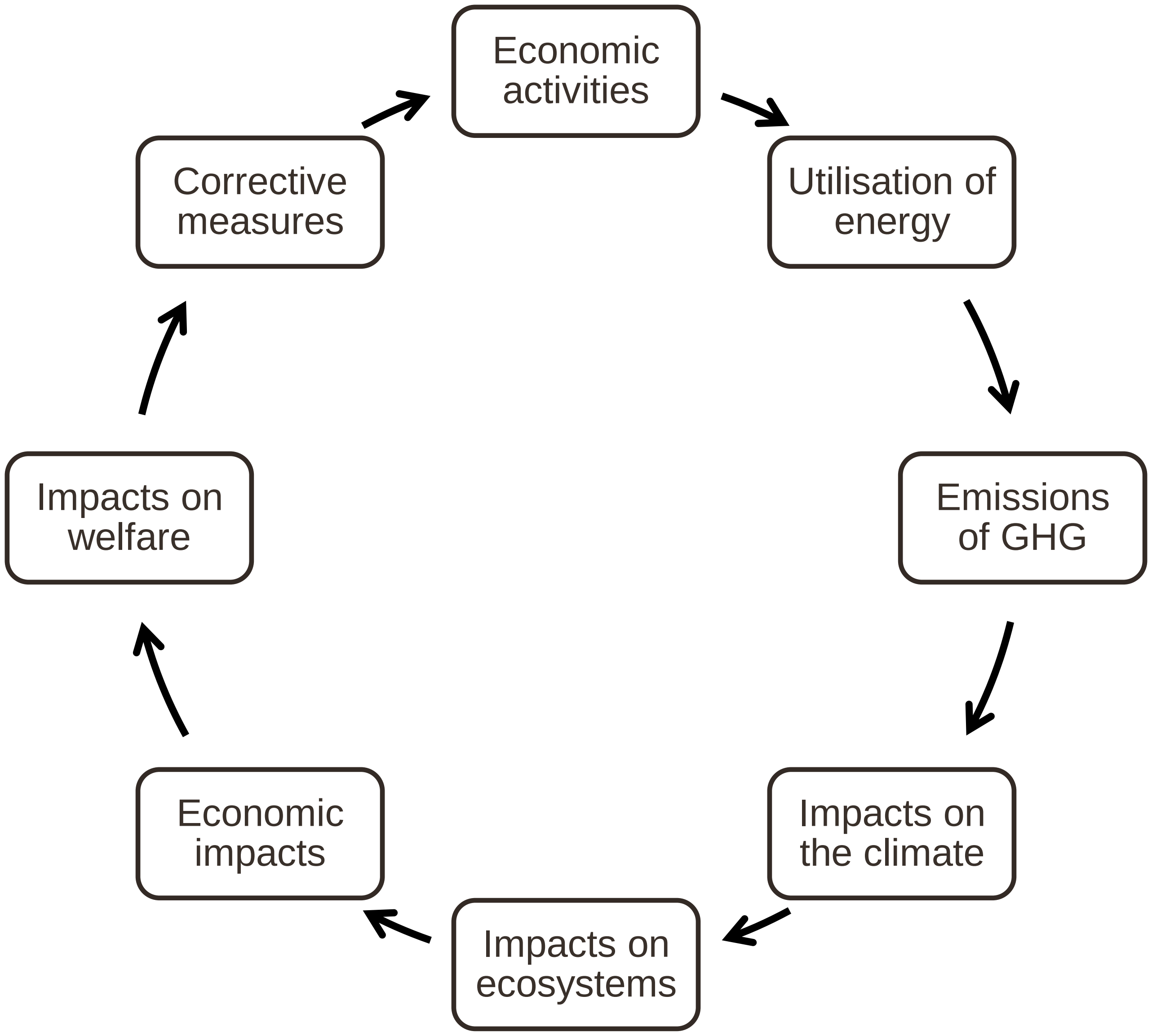


Figure 1. Past and projected global mean temperature, relative to 1880-84 mean. Solid curve up to 1970 is actual temperature. Broken curve from 1970 on is projection using 1970 actual as a base and adding the estimated increase due to uncontrolled buildup of atmospheric carbon dioxide.

Integrated assessment



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Questions asked of economists

- What are the costs of climate change?
- What are the costs of mitigation?
- What is the optimal level of mitigation?
- How to allocate mitigation efforts across countries?
- How to allocate mitigation efforts over time?
- What policies can achieve target mitigation at least cost?
- How to best adapt to climate change?

Questions we were (and are) asked

- Is decarbonization possible?
- How much would it cost?
- What measures would it take?
- What have we achieved up to now?
- What will the economic impacts of climate change be?

⇒ **Policy-driven research**

What we are expected to provide

- Quantitative results
- Generally forward looking (predictive), but rarely also backward looking (counterfactual)
- Economywide, with detailed results for sectors or policy instruments

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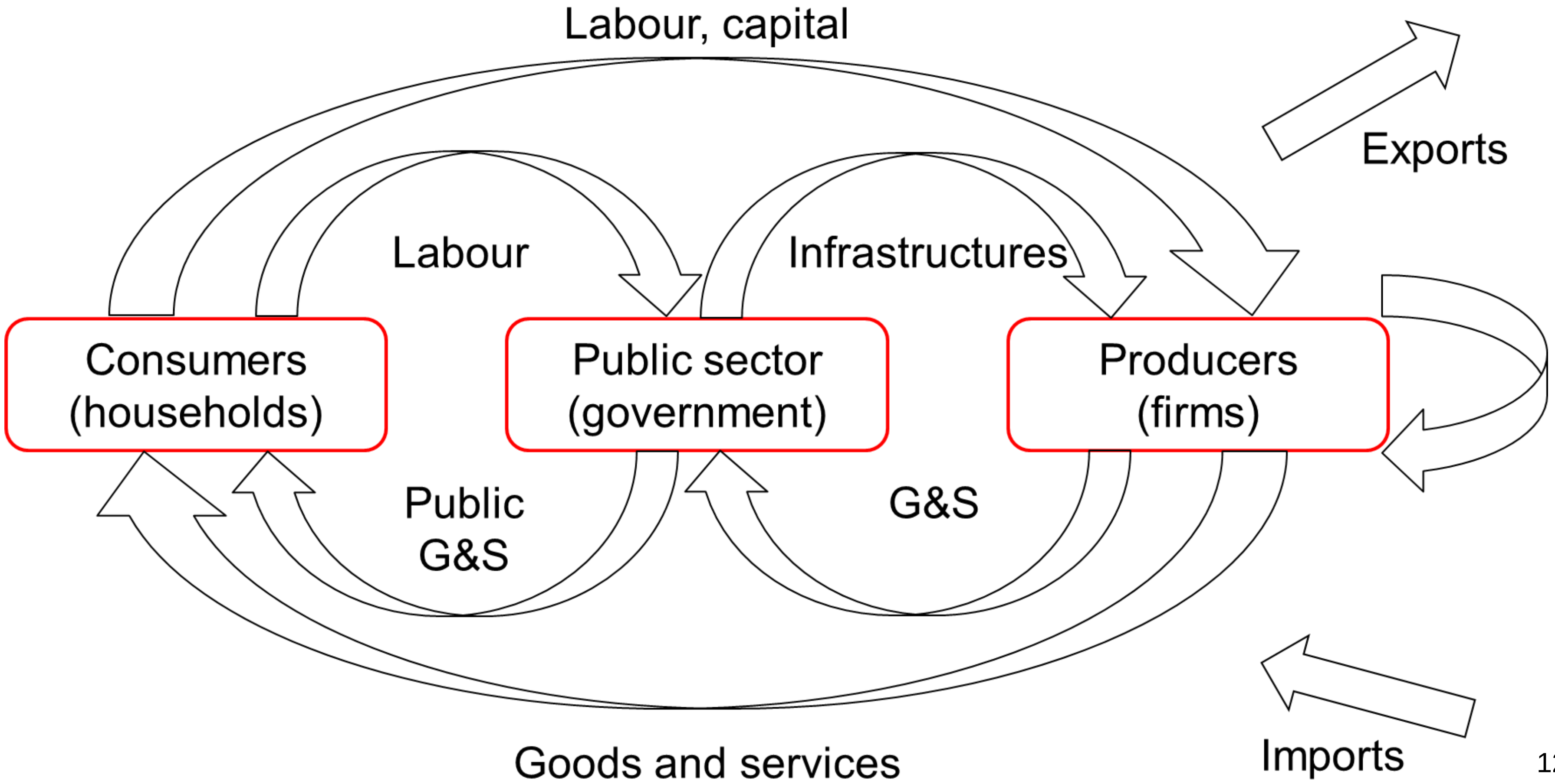
OUR MODELS, e.g. GEMINI-E3

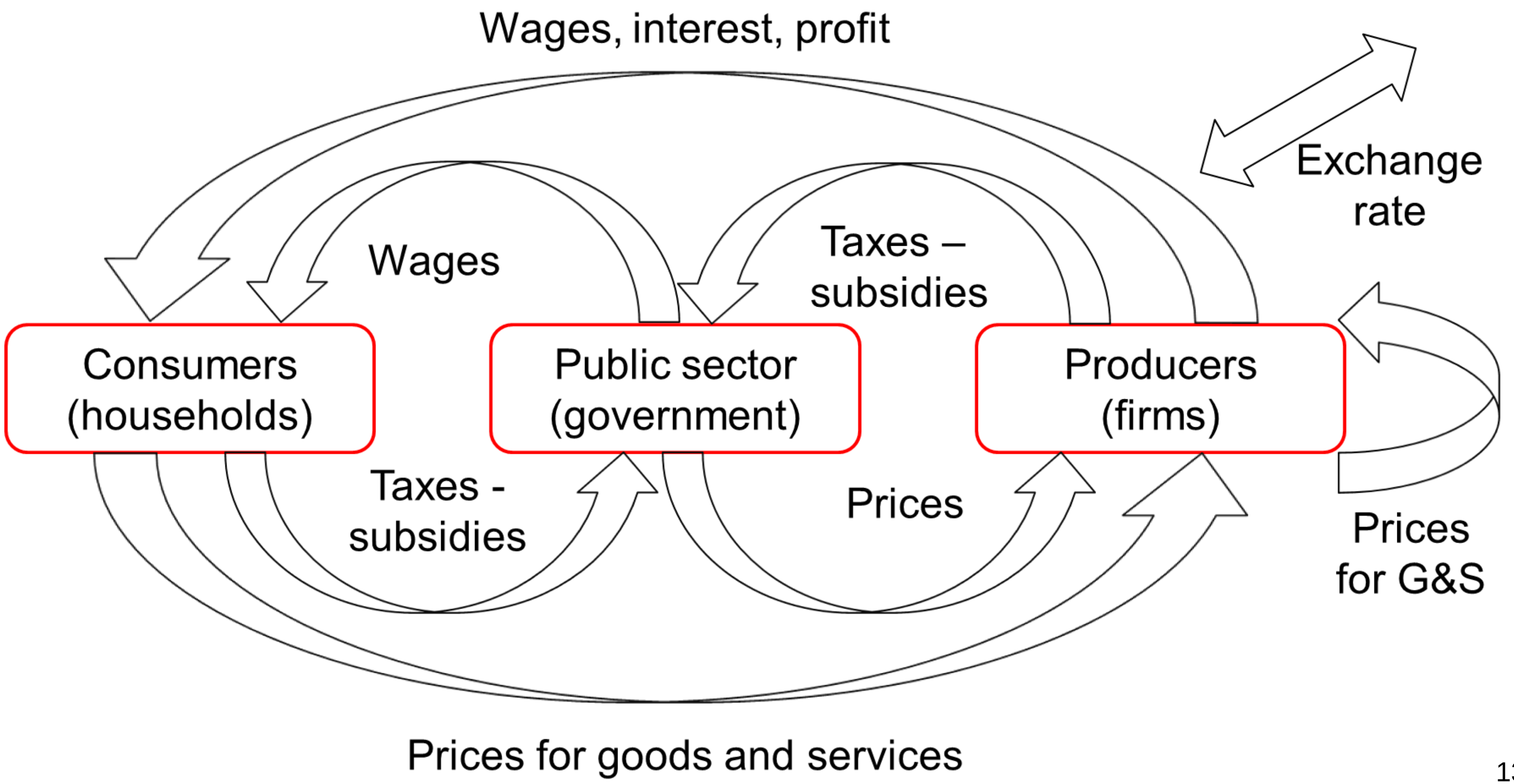
Real flows

- Macroeconomic, e.g. Switzerland as an open economy part of the World
- Grand categories:



Monetary flows

- Monetary flows match the real flows of goods, services, labour, capital
- Prices are endogenous (except some world prices, e.g. world energy prices)
- Grand categories:



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Markets

Catch a parrot and teach him to say 'supply and demand', and you have an excellent economist.

Popular joke in 19th century

- Production → supply of goods and services
- Consumption → final demand of G&S
- B2B → intermediate demand of G&S
- Markets: supply and demand for each G&S balance thanks to adjustments in prices; perfect competition
- Domestic and foreign G&S → international trade
- Markets for labour (→ wage), for capital (→interest rate)
- Taxes, subsidies, regulation…

GEMINI-E3

- **G**eneral **E**quilibrium **M**odel of **I**nternational-**N**ational **I**nteractions between **E**conomy, **E**nergy and the **E**nvironment
- Sectoral and regional disaggregation, which can be simplified *ad hoc*

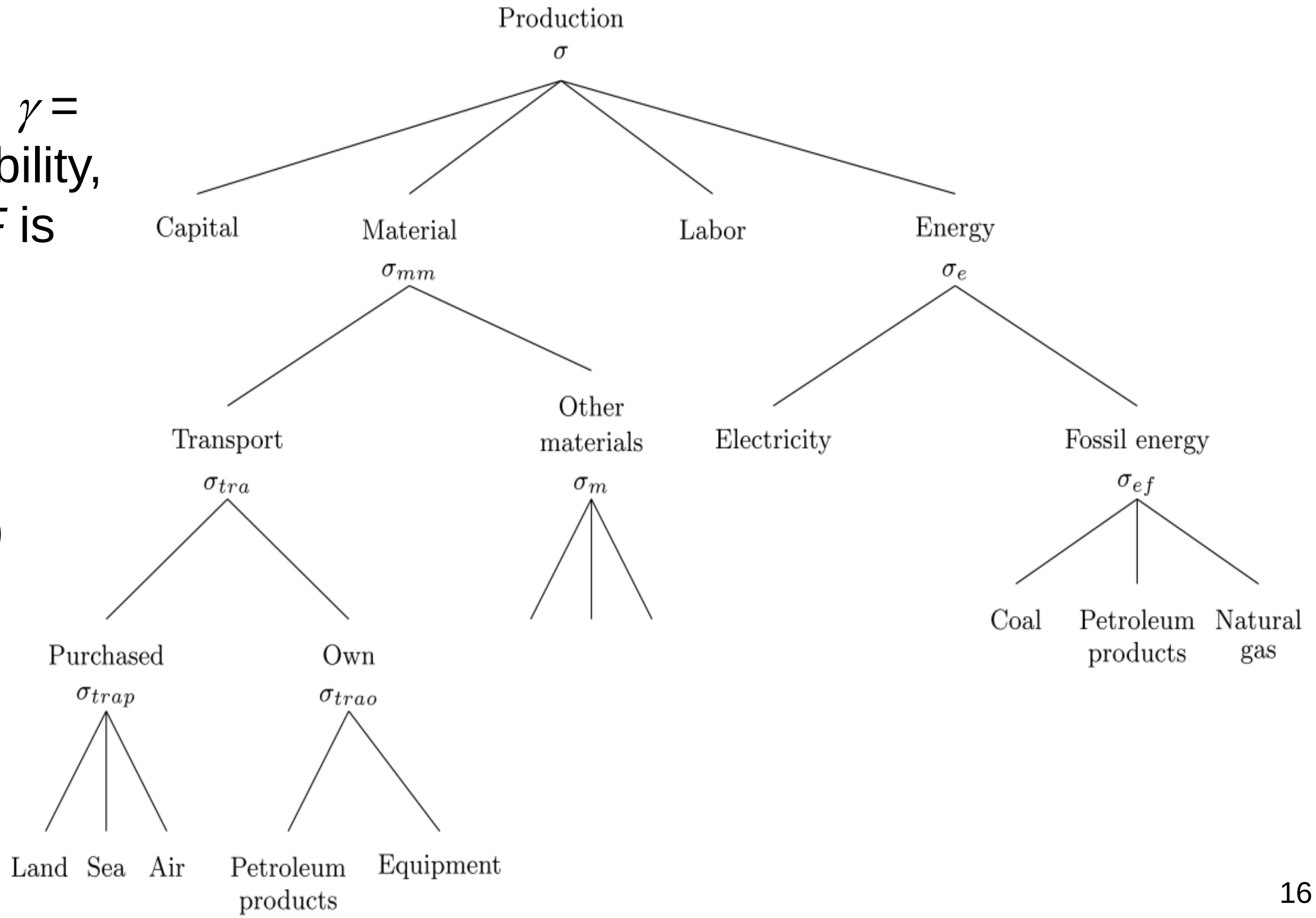
Sectors
Coal
Crude oil
Natural gas
Refined petroleum products
Electricity
Agriculture, forestry
Energy intensive industries
Other goods and services
Land transport
Sea transport
Air transport

Geographic regions
Switzerland
European Union (28)
United States of America
China
India
Brazil
Russia
Central and South America
Other Asian countries
Middle East
Africa
Rest of the World

GEMINI-E3: Production

$$Output = \left[\alpha_K K^{\gamma} + \alpha_L L^{\gamma} + \alpha_E \left(\left(\alpha_{EL} EL^{\gamma_E} + \alpha_{EF} EF^{\gamma_E} \right)^{1/\gamma_E} \right)^{\gamma} + \alpha_I I^{\gamma} \right]^{1/\gamma}$$

The α are value shares adding up to 1, the $\gamma = (\sigma - 1)/\sigma$ determine the degree of substitutability, *K* is capital, *L* is labour, *EL* is electricity, *EF* is fossil energy, *I* groups intermediate inputs



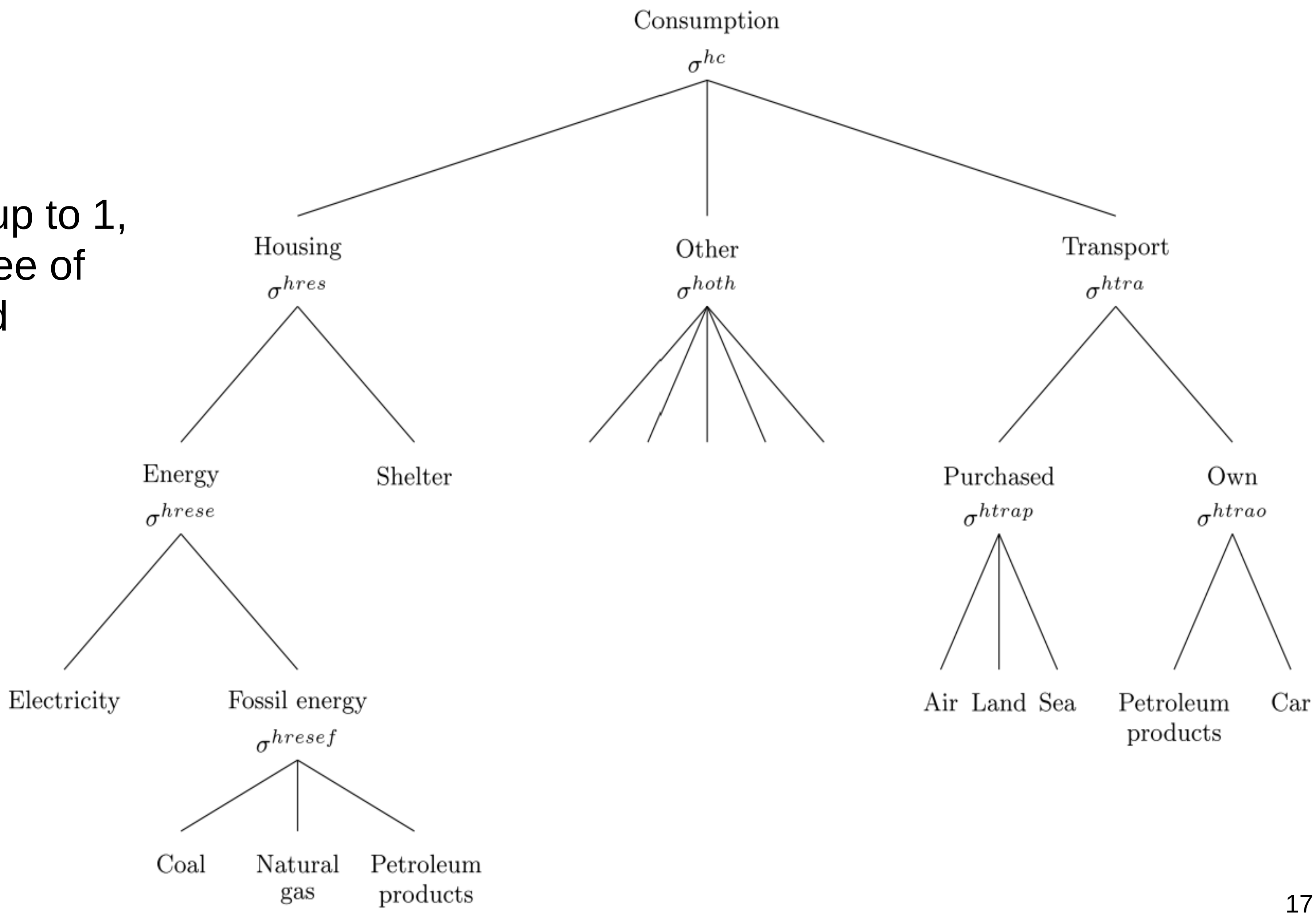
Production function

- Constant elasticity of substitution (CES)
- Input-output matrix for intermediates
- Productivities (not shown) and elasticities of substitution

GEMINI-E3: Consumption

$$Welfare = \left[\sum_i \alpha_i G_i^{\gamma} \right]^{1/\gamma}$$

The α are value shares adding up to 1, $\gamma = (\sigma - 1)/\sigma$ determines the degree of substitutability, G_i are goods and services from sector *i*



Welfare function

- Constant elasticity of substitution (CES)
- Productivities and elasticities of substitution
- Serves to model consumer choices and to measure welfare changes

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GEMINI-E3: costs

- Firms pay for their inputs and sell their products with a view to maximizing their profits; thus, they minimize their costs and respond to demand

$$Profit_i = p_i Output_i - p_K K - p_L L - p_{EL} EL - p_{EF} EF - \sum_j p_j I_j$$

- Households decide on labour, savings and purchases of G&S with a view to maximizing their welfare; they must balance their purchases with their income minus savings and taxes

$$p_K K + p_L L - Taxes = \sum_j p_j Q_j + Savings$$

Vielle, Marc, Philippe Thalmann, "An ex-post evaluation of the effectiveness of the Swiss CO2 levy. Final report module B", Report for Federal Office for the Environment, EPFL/LEURE, Lausanne, 10 December 2015

Some results

EFFECTIVENESS OF THE CO_2 LEVY

Effectiveness of CO_2 levy

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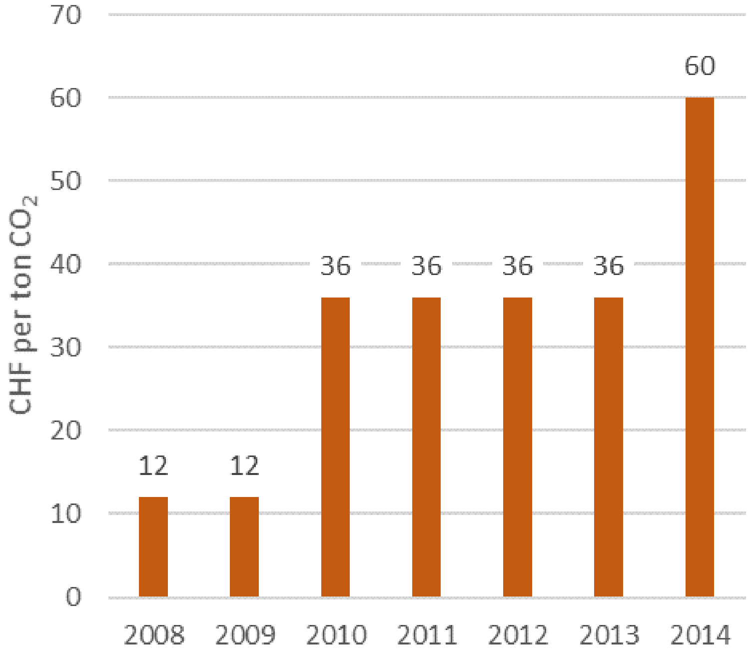
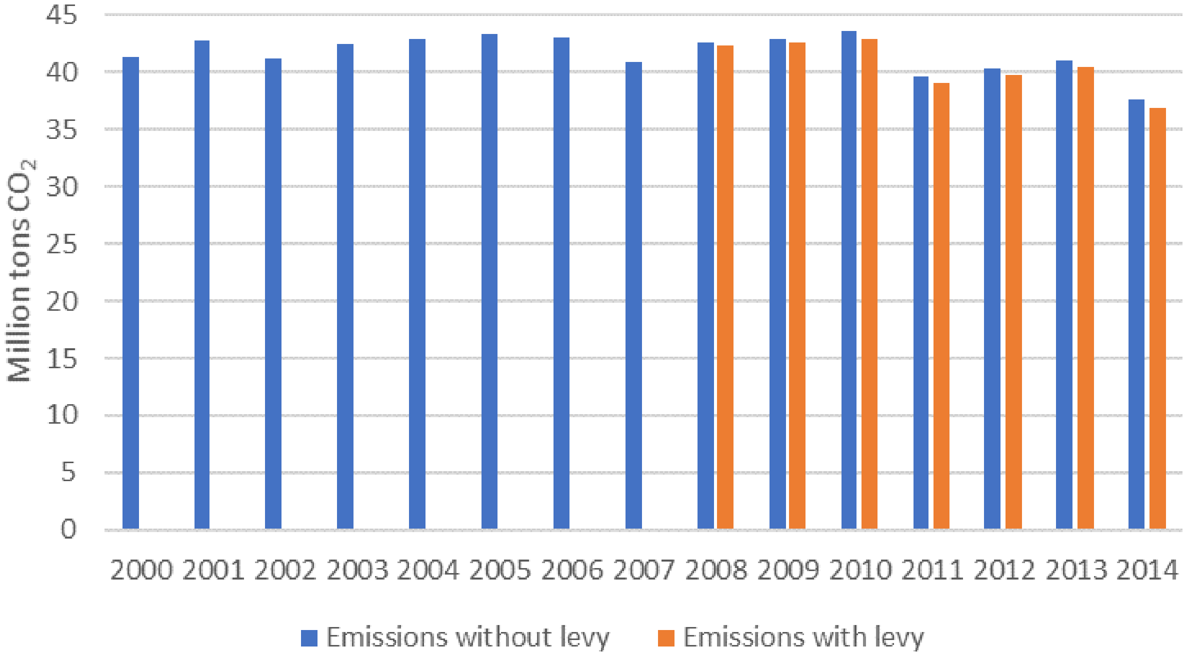
Rate of CO_2 levy



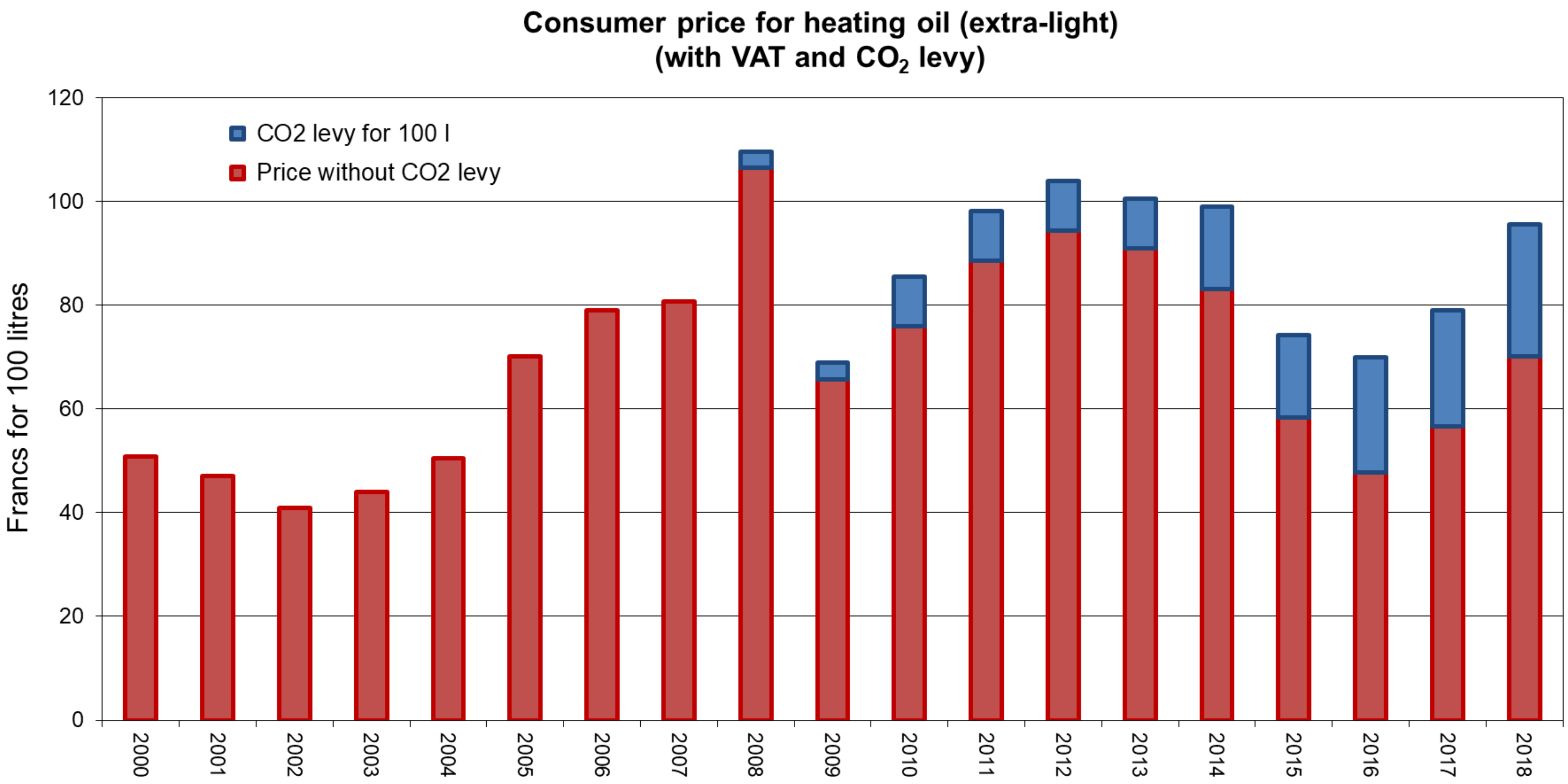
CO_2 emissions without/with levy



In each sector *i*, a firm could be facing four different prices for its emissions of CO_2 depending on its situation: the CO_2 levy, the ETS price, a cost of abatement related to its offsetting commitment or nothing if its emissions are not covered by the CO_2 Act; hence, the average CO_2 price in sector *i* is:

$$CO_2\,price_i = (1-\alpha_i-\beta_i-\mu_i)\cdot CO_2levy+\alpha_i\cdot PriceETS+\beta_i\cdot PriceNonETS+\mu_i\cdot 0$$

A rising tax does not guarantee a rising price



Source: OFEN, Statistique globale suisse de l'énergie

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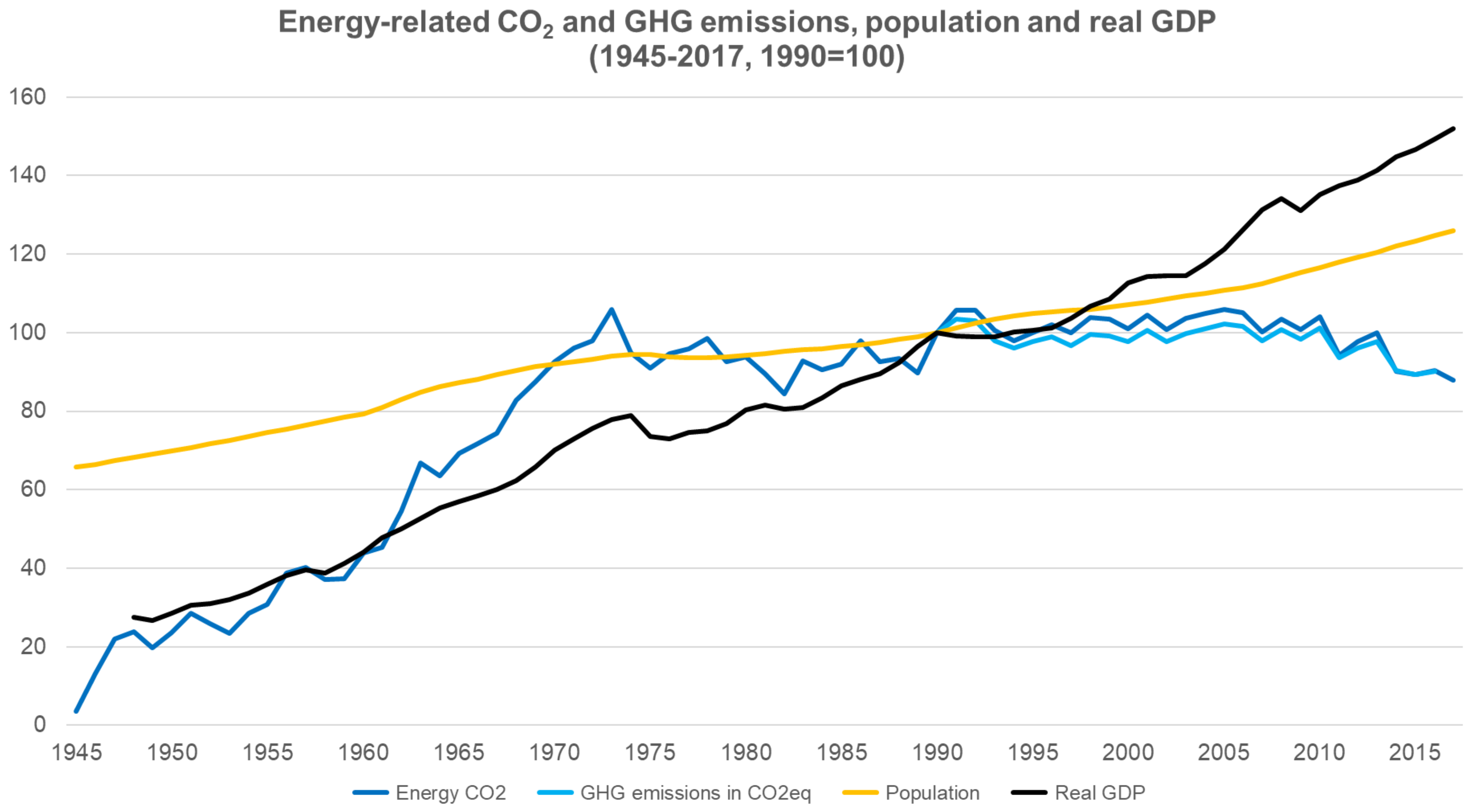
Vielle, Marc, and Philippe Thalmann, "Updated emissions scenarios without measures, 1990-2035", Report for Federal Office for the Environment, Lausanne, 12 October 2017

Some results

SWISS CO_2 EMISSIONS WITH AND WITHOUT MEASURES, 1990-2035

How much of the change in CO_2 emissions is due to climate & energy policy?



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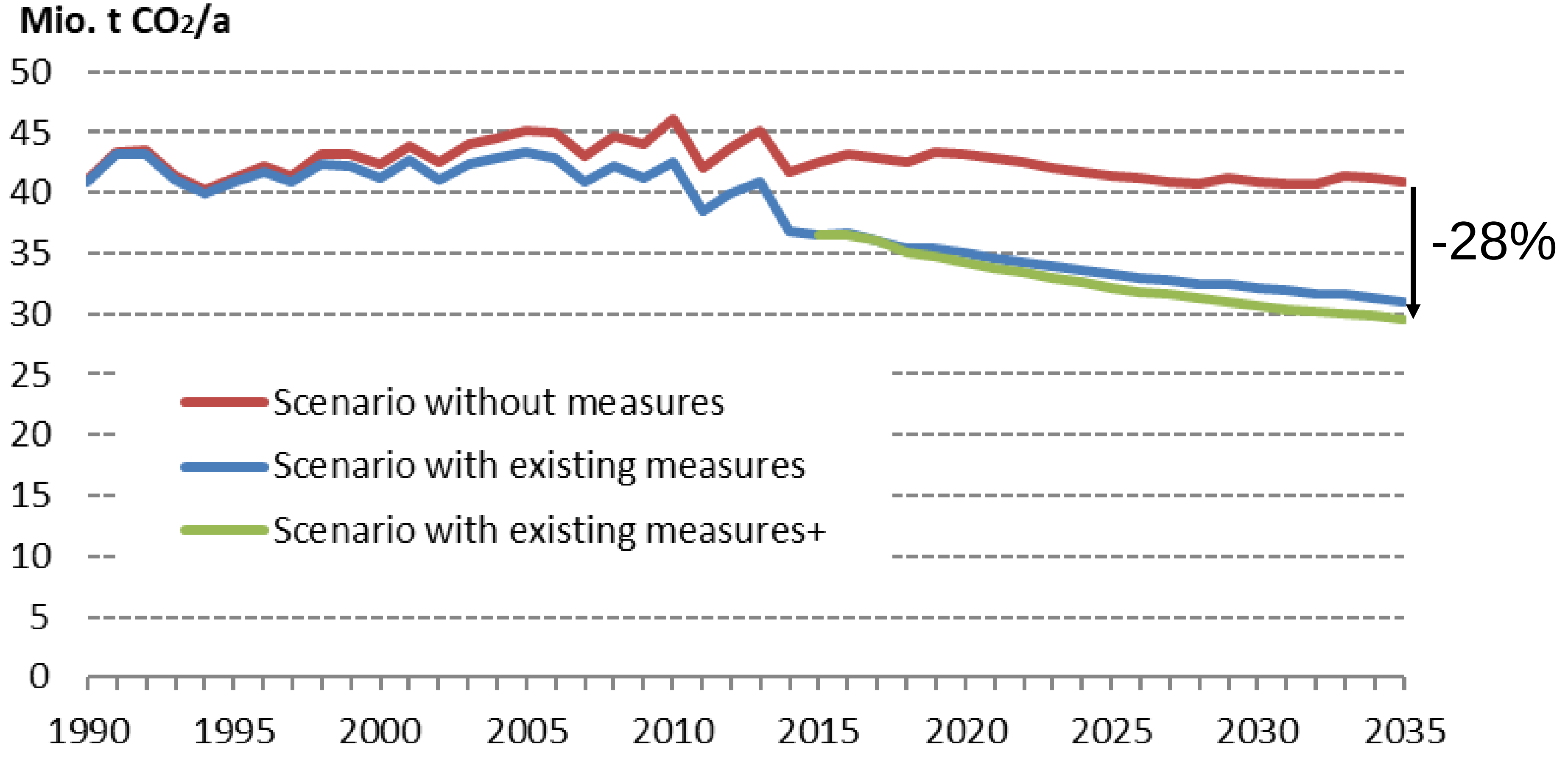
How much is attributable to policy?

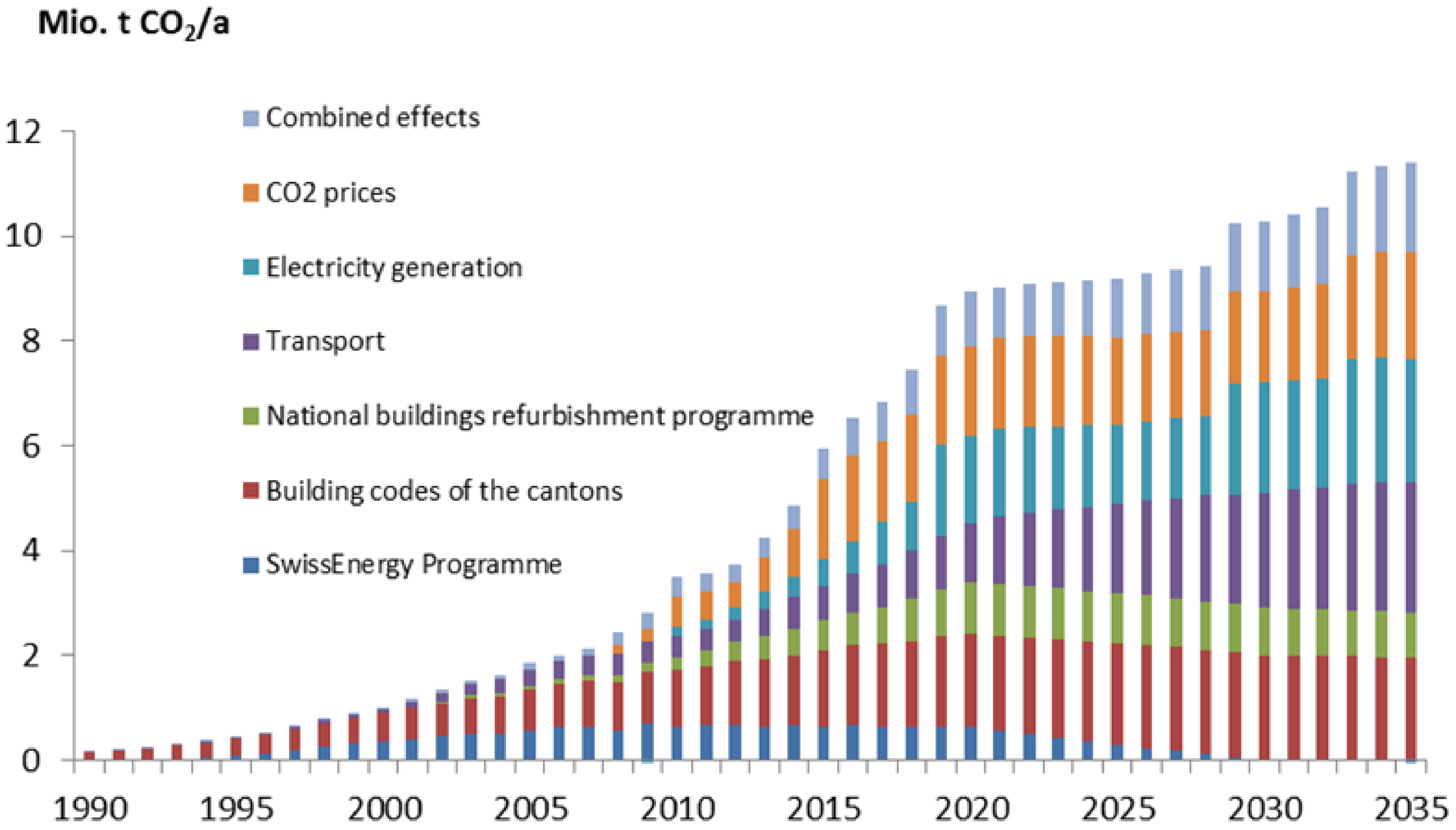
Energy-related CO_2 emissions in a scenario without measures and two scenarios with existing and announced measures (1990-2035)



CO_2 from combustion processes (1A)
Fig. 1 of Vielle and Thalmann (2017)

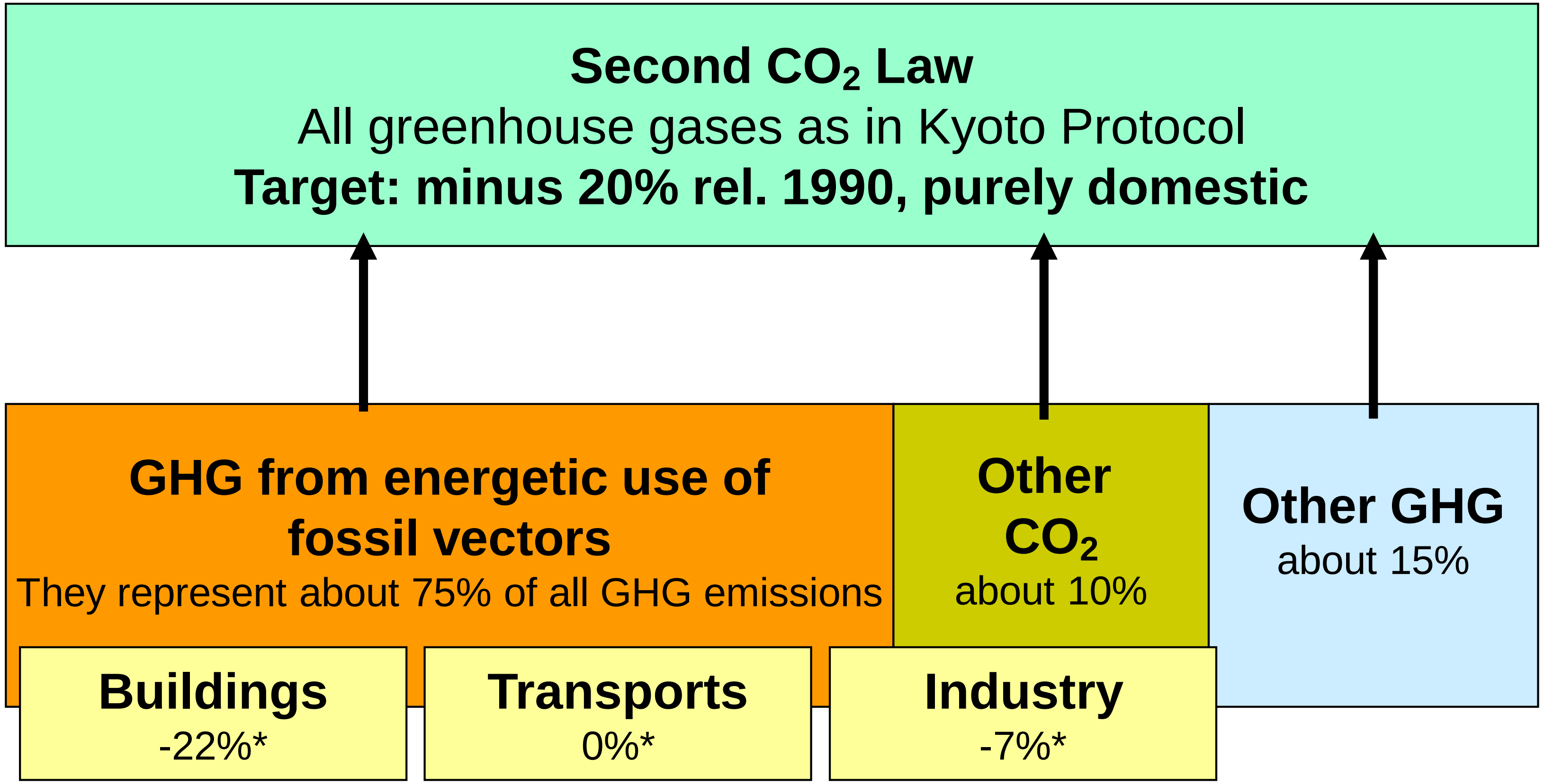
Effectivity of different components of energy and climate policy

Total reduction of CO_2 emission in scenario with decided measures compared to scenario without measures, by group of measures (1990-2035)



CO_2 from combustion processes (1A)
Fig. 2 of Vielle and Thalmann (2017)

Swiss climate policy under second CO_2 Law
(2011, in force since 2013)



*Intermediary objectives for **2015**, variation relative to 1990: they have not been updated ! Emissions from transports were still 3.3% above 1990 in 2018.

Policy measures in the 3 main areas…

Transports

– prescriptions on specific CO_2 emissions of new cars (target: 130 gram CO_2/km from 2015 on)

– required compensation by importers of transport fuels (max 10% of implicit emissions for max 5 ct/litre)

Impact in 2020:
~ 3 million tons CO_2

Buildings (housing and services)

– CO_2 levy on heating and process fuels (60 CHF/t in 2014-15, 84 CHF/t in 2016-17, 96 CHF/t in 2018-20, i.e. 25.6 ct/litre heating oil)

– Buildings Program

Impact in 2020:
~ 4,9 million tons CO_2

Industry

– tradable emissions permits (CH-ETS)

– exemption from tax in exchange for commitment (non-ETS)

Impact in 2020:
~ 0,8 million tons CO_2

Thalmann, Philippe, and Marc Vielle, "Lowering CO_2 emissions in the Swiss transport sector", Swiss Journal of Economics and Statistics 155(1), December 2019, doi:10.1186/s41937-019-0037-3

Some results

LOWERING CO_2 EMISSIONS FROM THE SWISS TRANSPORT SECTOR

Include transport fuels under the CO_2 levy for cost efficient emissions reduction

- Uniform cost of carbon (2018-2019: 96 CHF/tCO_2, only for thermal fuels, with exemptions for large emitters, so only 36% of total CO_2 emissions in 2018)
- When an overall reduction target is set, privileges for one sector imply a higher burden for the other sectors
- Example:

Table 3: CO_2 prices and welfare cost in 2050

		1.5 t			1.0 t		
	Ref.	Uni	Uni-ETS	Diff-ETS	Uni	Uni-ETS	Diff-ETS
Average CO_2 price	82	652	637	746	1089	1010	1255
-ETS sector	252	652	193	196	1089	174	176
-transport fuel	0	652	738	419	1089	1331	794
-thermal fuel	121	652	738	1676	1089	1331	3175
Cost (in% of household cons.)		0.74%	0.85%	1.01%	1.33%	1.60%	1.88%

Are high CO_2 levy rates feasible?

	Tax (francs/l)			Yearly rise from 2020 to 2050 (ct./l)		
CHF/t CO2	**gasoline**	**diesel**	**heating oil**	**gasoline**	**diesel**	**heating oil**
96	0.224	0.266	0.254			
100	0.233	0.277	0.265			
652	1.519	1.806	1.728	5.06	6.02	4.91
1089	2.537	3.017	2.886	8.46	10.06	8.77

Date: 04.10.2019

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Vers une taxe carbone de 1,70 franc par litre?

Des chercheurs de l'EPFL ont calculé le montant le plus efficace pour atteindre les objectifs de l'Accord de Paris.

Date: 04.10.2019

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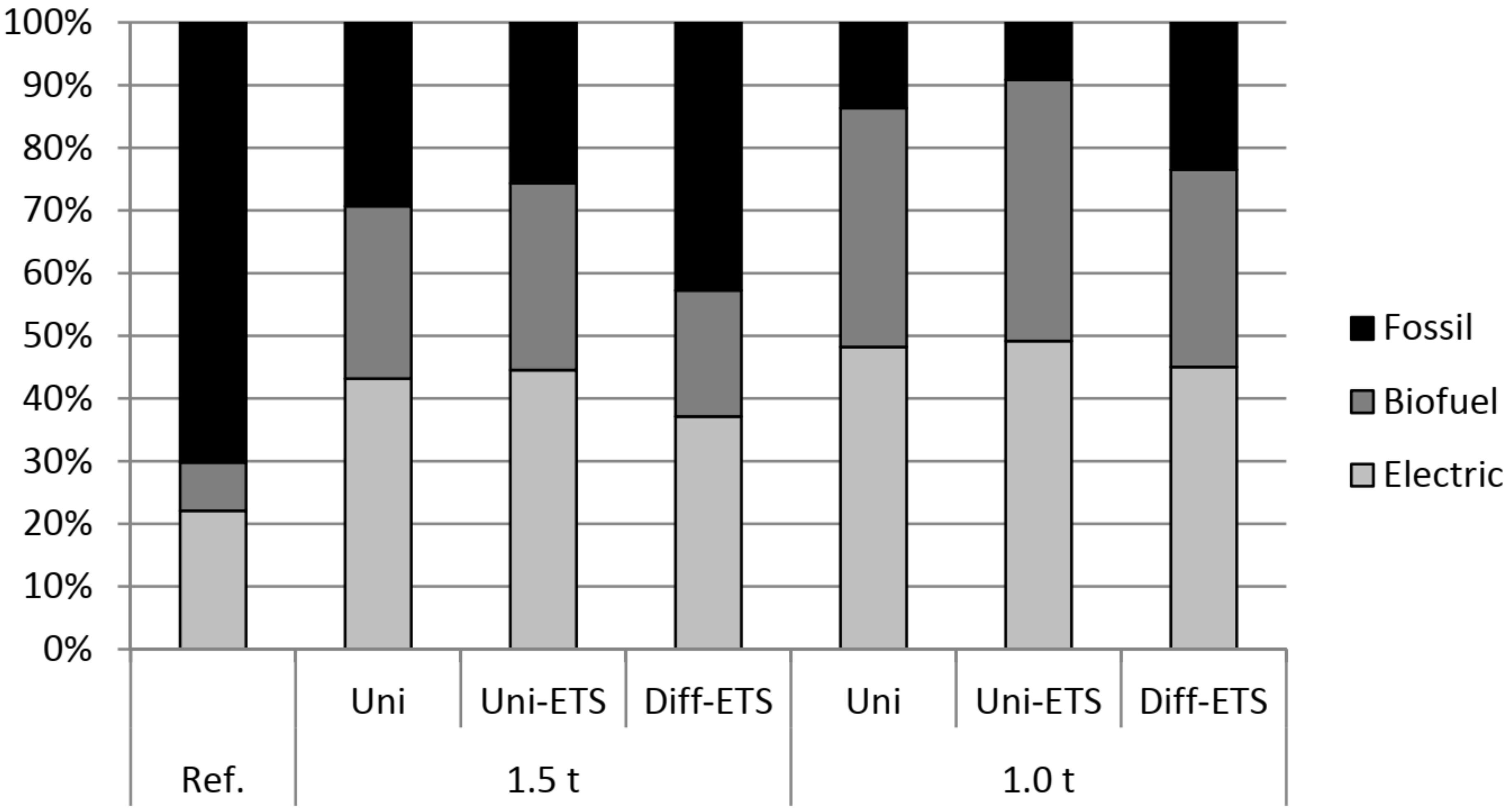
Lausanne | CO_2-Abgabe auf Treibstoff und Heizöl

1.70 Franken pro Liter wären nötig

A high tax on a small base does not hurt much

Figure 3: Share of each vehicle type in distance traveled in percentage in 2050 - Cars



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Babonneau, Frédéric, Philippe Thalmann and Marc Vielle, "Defining deep decarbonization pathways for Switzerland: an economic evaluation", Climate Policy 18(1), 2018, 1-13 (published online 07 Nov. 2016, doi:10.1080/14693062.2016.1227952)

Schäppi, Bettina, Alexander Wunderlich, Jürg Füssler (INFRAS), Marc Vielle, and Philippe Thalmann (EPFL), “Pathways to deep decarbonisation – Results of a modelling exercise”, Final report for the Federal Office for the Environment, Zurich and Lausanne, 20 December 2016

Vielle, Marc, Bettina Schäppi, Philippe Thalmann, and Jürg Füssler, "Simulations of proposed deep decarbonisation pathways – Phase 2: A contribution to Switzerland decarbonisation pathways", Report for the Federal Office for the Environment, Lausanne et Zurich, 20 December 2016

Some results

DECARBONISATION PATHWAYS FOR SWITZERLAND

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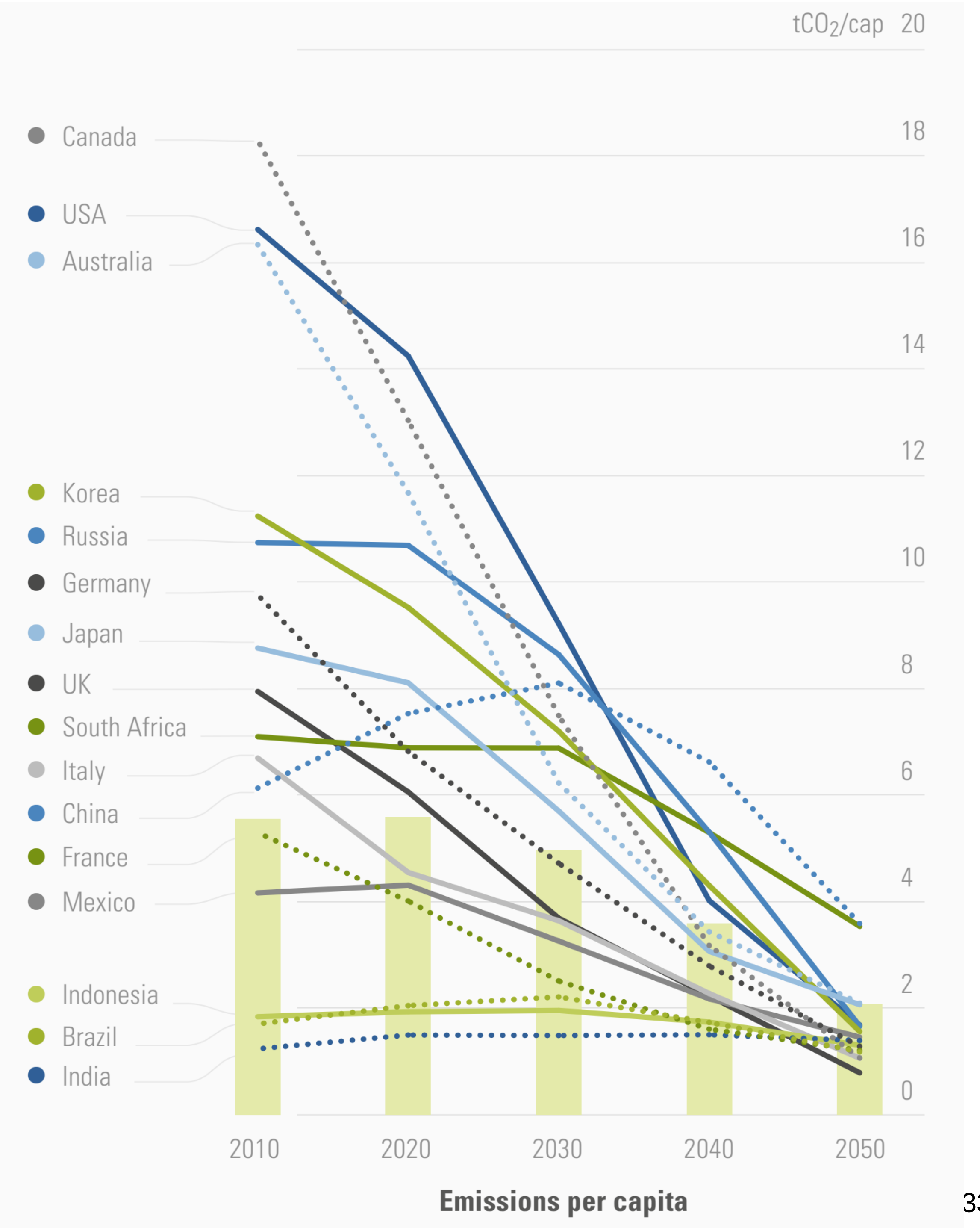
Decarbonisation pathways for Switzerland

In parallel with *Deep Decarbonization Pathways Project* (DDPP) launched in October 2013 in view of COP21 (Paris)

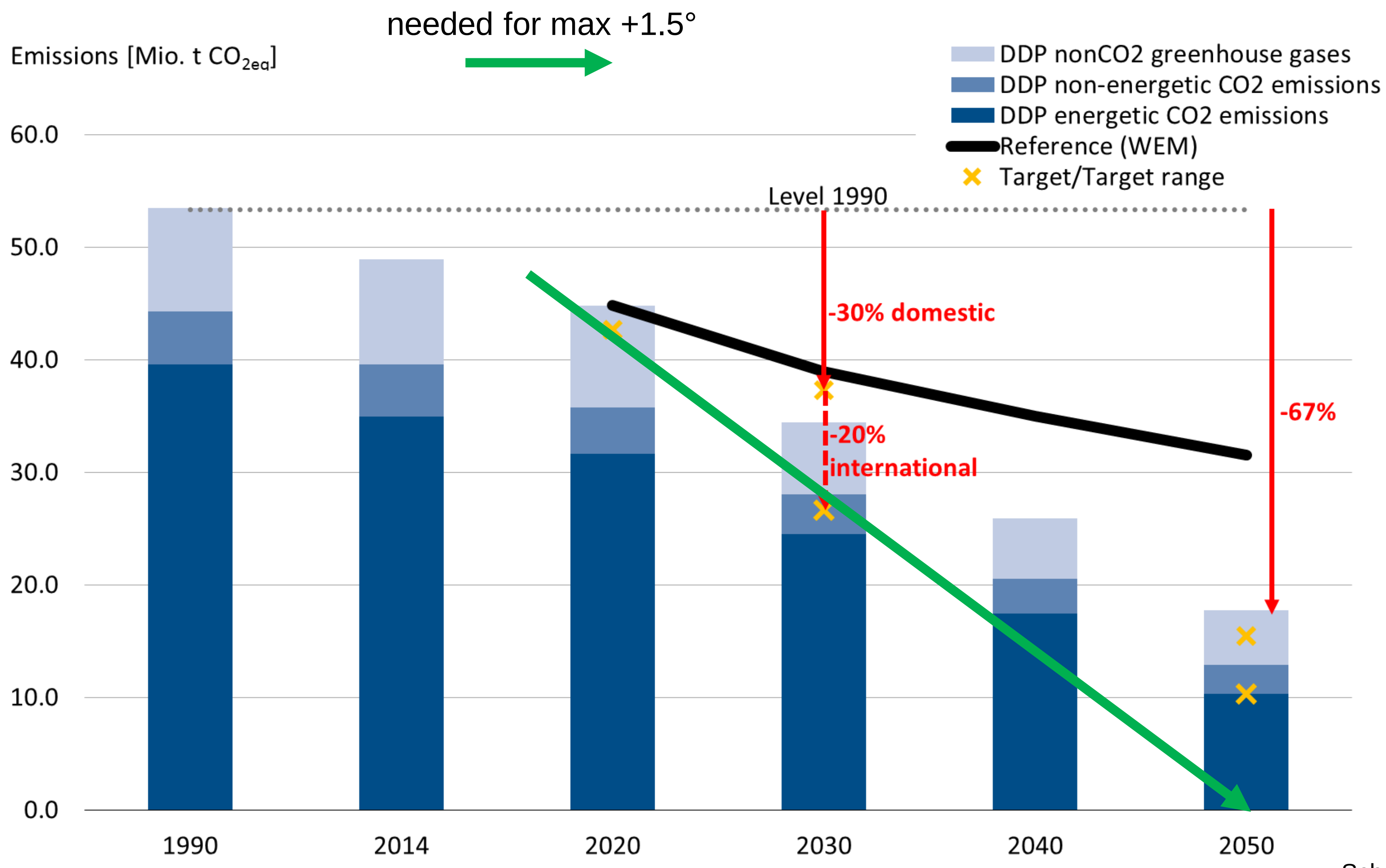


Deep Decarbonization Pathways Project (2015), Pathways to deep decarbonization 2015 report - executive summary, SDSN – IDDRI, Fig. 2

Decarbonisation pathways for Switzerland

- Ambitious but realistic target: **1-1.5 tCO_2eq/capita** in 2050 (all GHGs without air transport and without LULUCF)
- Same target as the "NEP" scenario of the Energy Perspectives (Prognos, 2012) and as the Swiss INDC for COP21
- This target was seen as compatible with **+2° warming**
- Imagine and calculate the instruments necessary to achieve this: use existing instruments plus generalised CO_2 levy

Deep decarbonisation pathways (for max +2°)



Schäppi et al. (2016)

How to get to 1t CO_2/capita in 2050

	2020	2030	2040	2050
CO_2 levy (CHF_{2013}/tCO_2)	177			
Price of CO_2 certificates (CHF_{2013}/tCO_2)	82			
Tax on gasoline and diesel (CHF_{2013}/l)	0.05			
Same CO_2 levy on all fossils (CHF_{2013}/tCO_2)		88	189	511
Social cost (% household consumption, relative to reference scenario)		0.11	0.42	0.78

Vielle et al. (2016). Scenario with induced technical progress (CCS is allowed)

511 CHF/tCO_2 with emissions of 1 tCO_2/capita on average in 2050 is comparable to 128 CHF/tCO_2 for current emissions of 4 tCO_2/capita

511 CHF/tCO_2 amount to 1.35 CHF/litre heating oil, which are added to the expected pre-CO_2-levy price of 1.40 CHF/litre in 2050

Kaya decomposition of central DDP

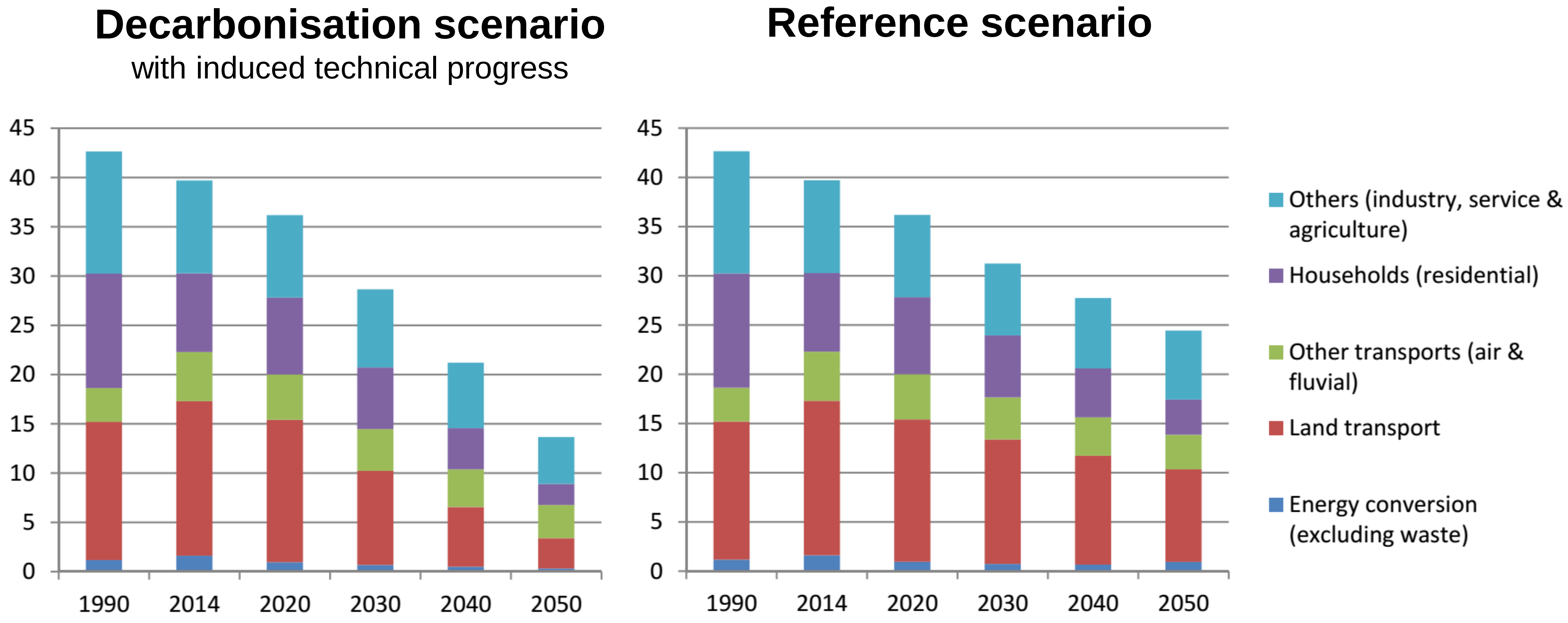
Mean annual rate of change per decade

	2010-2020	2020-2030	2030-2040	2040-2050
Population	+1.6%	+0.4%	+0.3%	+0.2%
Reference scenario (existing policies)				
GDP per capita	+0.1%	+1.3%	+1.2%	+0.9%
CO_2 emissions	-2.8%	-1.0%	-0.6%	-1.2%
Decarbonisation scenario with induced technical change				
GDP per capita	-0.1%	+1.0%	+0.9%	+0.7%
Energy intensity	-2.7%	-2.8%	-2.8%	-2.9%
Carbon intensity	-0.7%	-1.1%	-1.6%	-3.1%
CO_2 emissions	-1.9%	-2.5%	-3.4%	-5.1%

Vielle et al. (2016, unpublished table)

All sectors must contribute

CO_2 emissions (with international aviation, Mt)



Vielle et al. (2016, Fig. 2 + 15)

The cost depends on technological progress and what the ROW does

Swiss deep decarbonization scenario	Social cost in 2050 (% household consumption, relative to reference scenario)
Central (with CCS and induced technical progress)	-0.8%
Central without CCS	-1.1%
Central without induced technical progress	-0.8%
Central with international DDP	-1.3%

Vielle et al. (2016)

Take home messages

- Switzerland can reduce its energy CO_2 emissions to 1 t/capita and its total GHG emissions to 1.5 tCO_2eq/capita by 2050
- This would cost as much, in terms of welfare, as if households had to reduce their overall consumption by 1%
- Non-monetary benefits (e.g. less air pollution) are not yet taken into account
- The building sector will play a central role in decarbonisation, encouraged by an increasingly high price of fossil fuels
- Other sectors (mobility) must also contribute
- For the other countries, comparable scenarios have been calculated and proven

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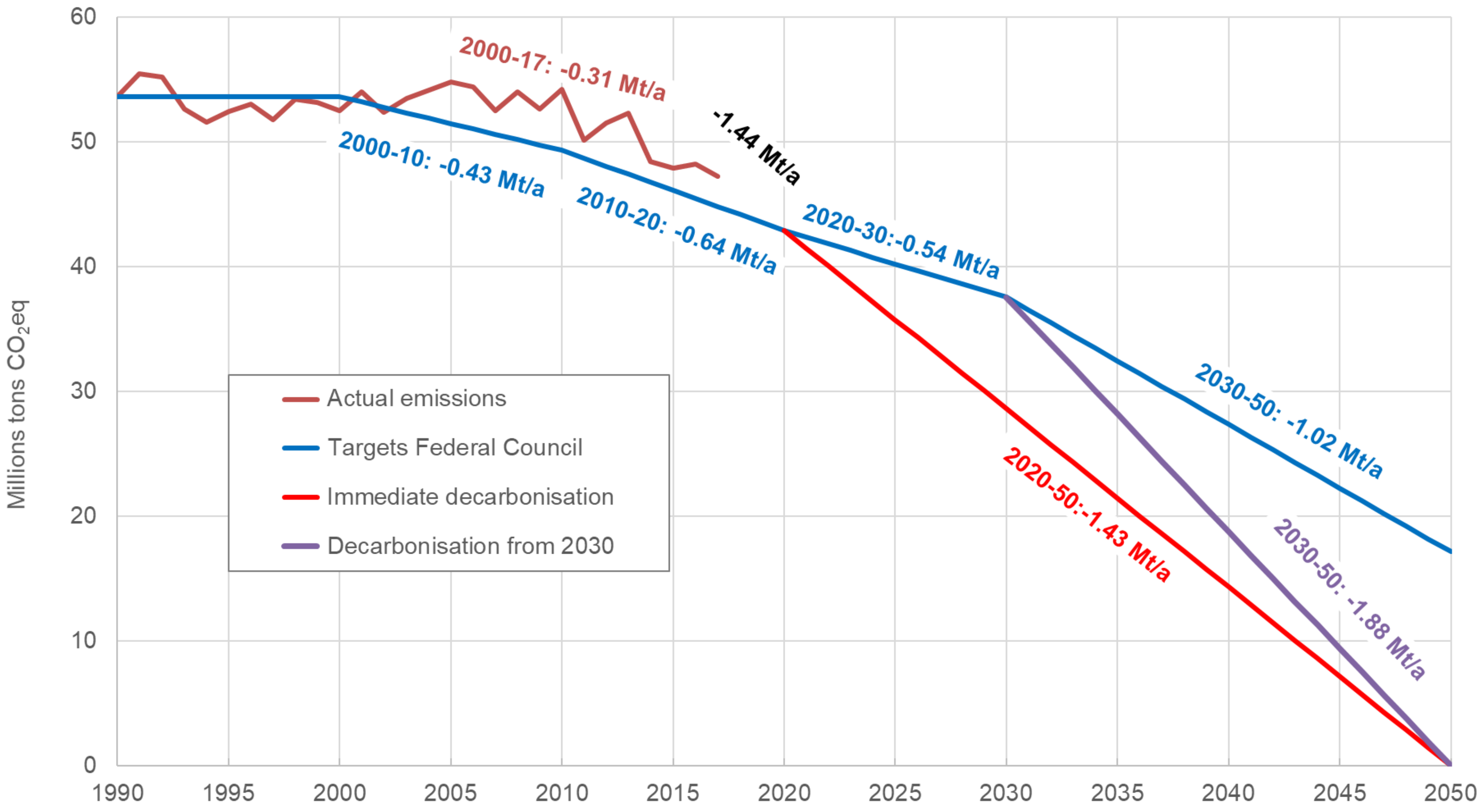
FINAL COMMENTS

The longer we wait, the greater the effort needed



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What speaks for full decarbonisation by 2050

- GHG emissions decline(but not fast enough) for several reasons, even without strengthening climate and energy policy: technical progress, EU policies, slowing growth, energy prices
- Welfare costs are moderate, even with high CO_2 tax rates
- The CO_2 tax could be kept lower by using its revenues to facilitate substitutions and strengthen effects
- No one modelled full decarbonisation of Switzerland yet!

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Conclusions

- Pushing firms and households to decarbonize through price signals will call for high taxes … hardly acceptable, hardly doable (even if actual welfare cost is small)
- A 'New Climate Deal' is needed
- Example: decarbonisation of Swiss railway transportation between 1918 and 1950!

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verdi liberali

?

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Thank you for your attention

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Even with a small bucket:
everybody, every country must contribute !