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Optimal Equitable Burden Sharing:
Modelling global macroeconomic impacts of the carbon constrained energy system using ETSAP-TIAM-MSA

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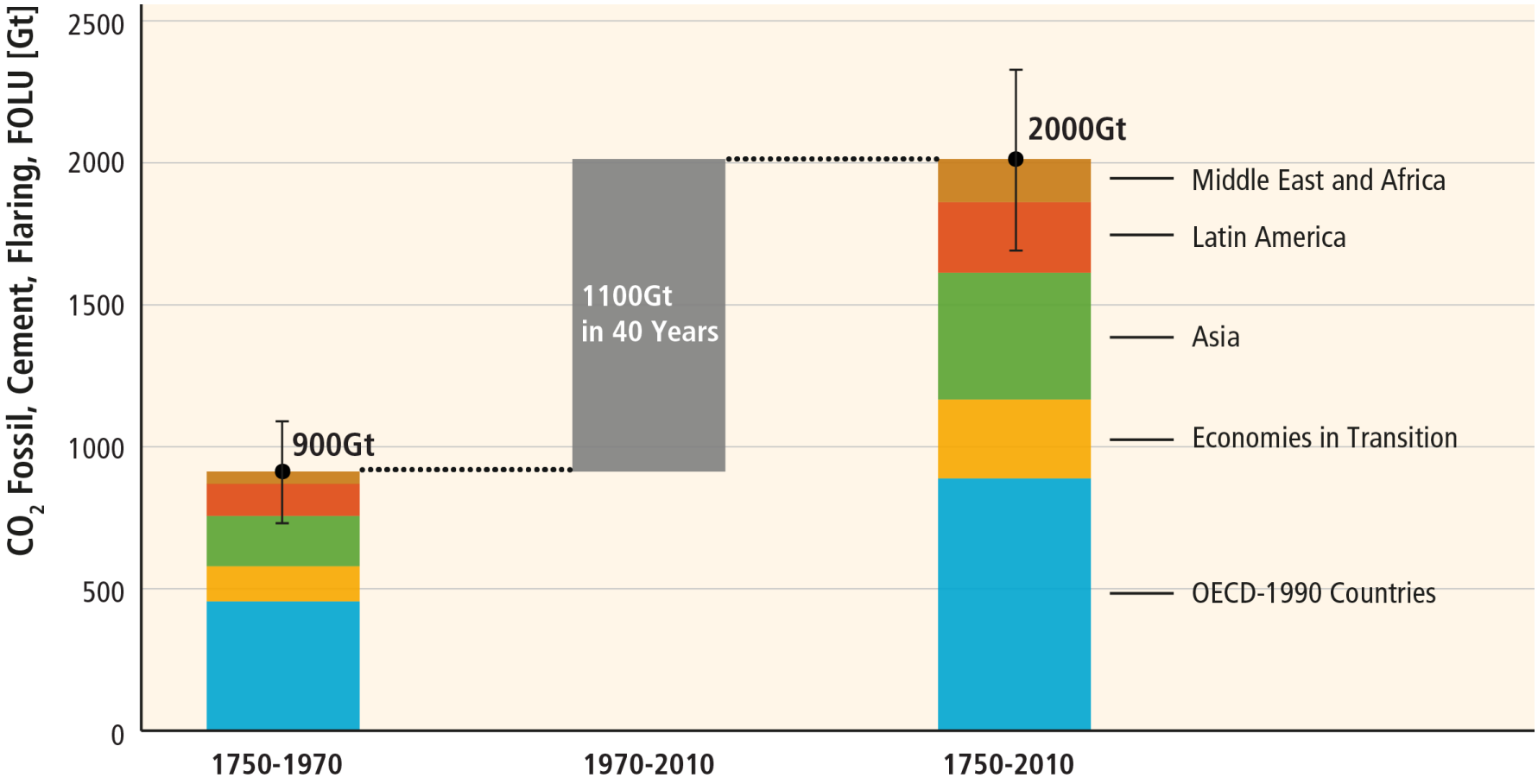
Acknowledgements

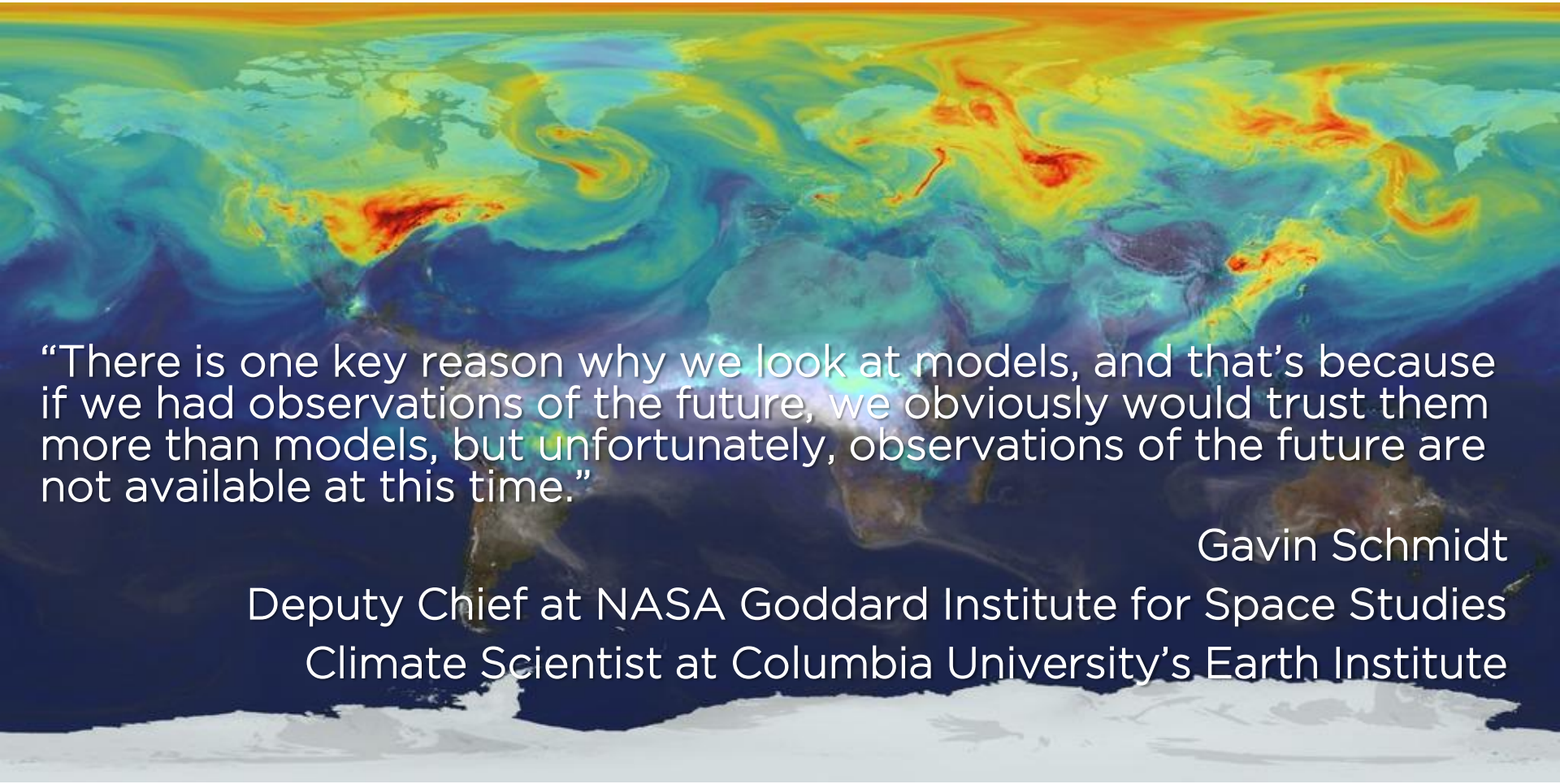
- ETSAP TIAM Project Group
- MSA Developers Socrates Kypreos (PSI) & Antti Lehtila (VTT)

CO2 emissions: who? when?



Source: IPCC, 2014. Climate Change 2014: Mitigation of Climate Change, Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Washington, USA.

A year in the Life of Earth's CO_2



"There is one key reason why we look at models, and that's because if we had observations of the future, we obviously would trust them more than models, but unfortunately, observations of the future are not available at this time."

Gavin Schmidt

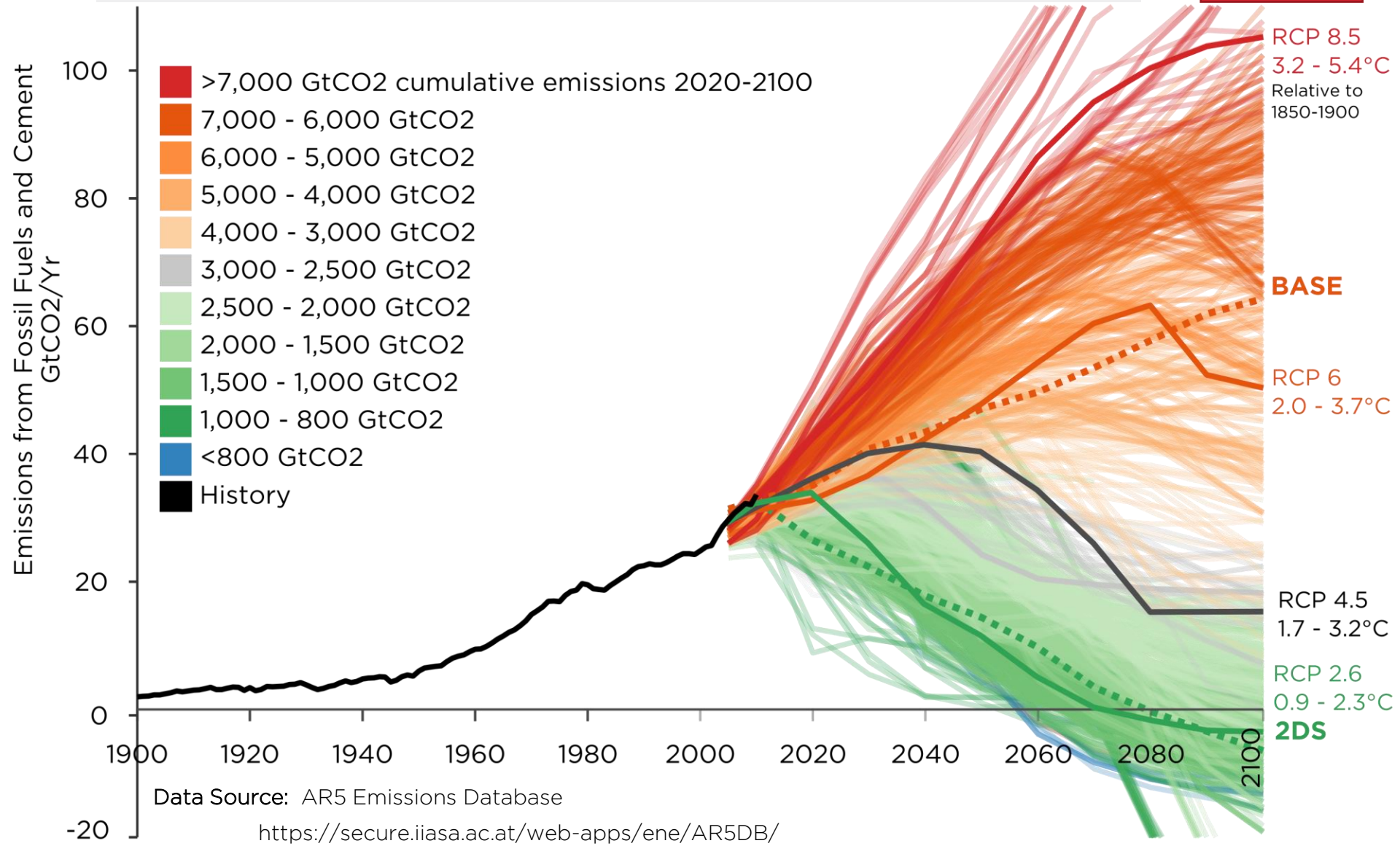
Deputy Chief at NASA Goddard Institute for Space Studies

Climate Scientist at Columbia University's Earth Institute

Source: NASA Goddard Space Flight Centre.
http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11719

Model Emissions Scenarios

1150 scenarios from the IPCC Fifth Assessment Report are shown



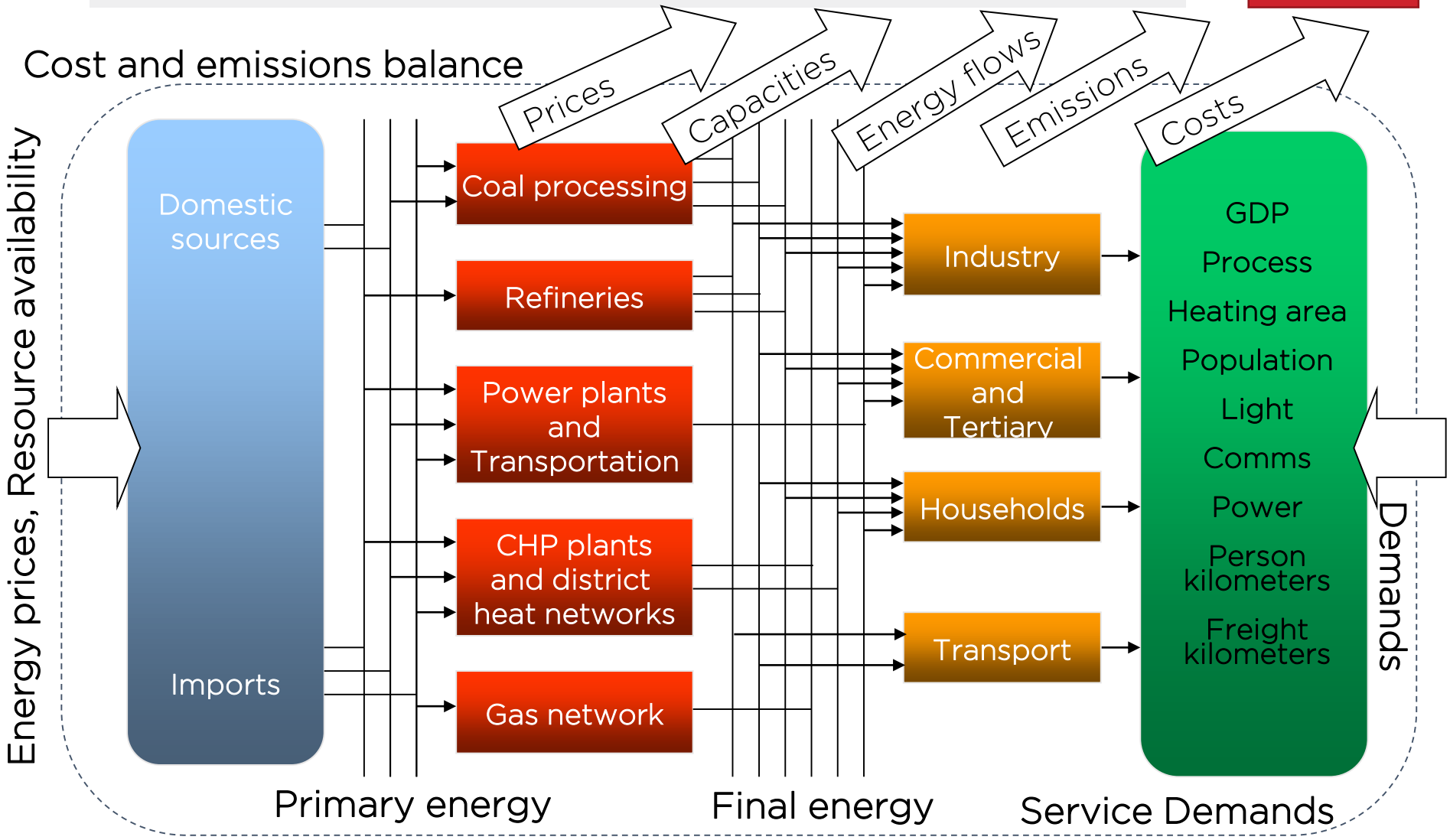
Data Source: AR5 Emissions Database

https://secure.iiasa.ac.at/web-apps/ene/AR5DB/

Outline

- Introduction to ETSAP-TIAM
- Overview of Macro Stand Alone (MSA)
- 2°C Decarbonisation Scenarios
- Macroeconomic consequences
- Equitable Efficient Burden Sharing
  - Appropriate capital transfers?
  - Post Optimisation Analysis (POA)
  - Grandfathering Rules
  - Fund technology transfer to LDCs

TIMES Energy System Model

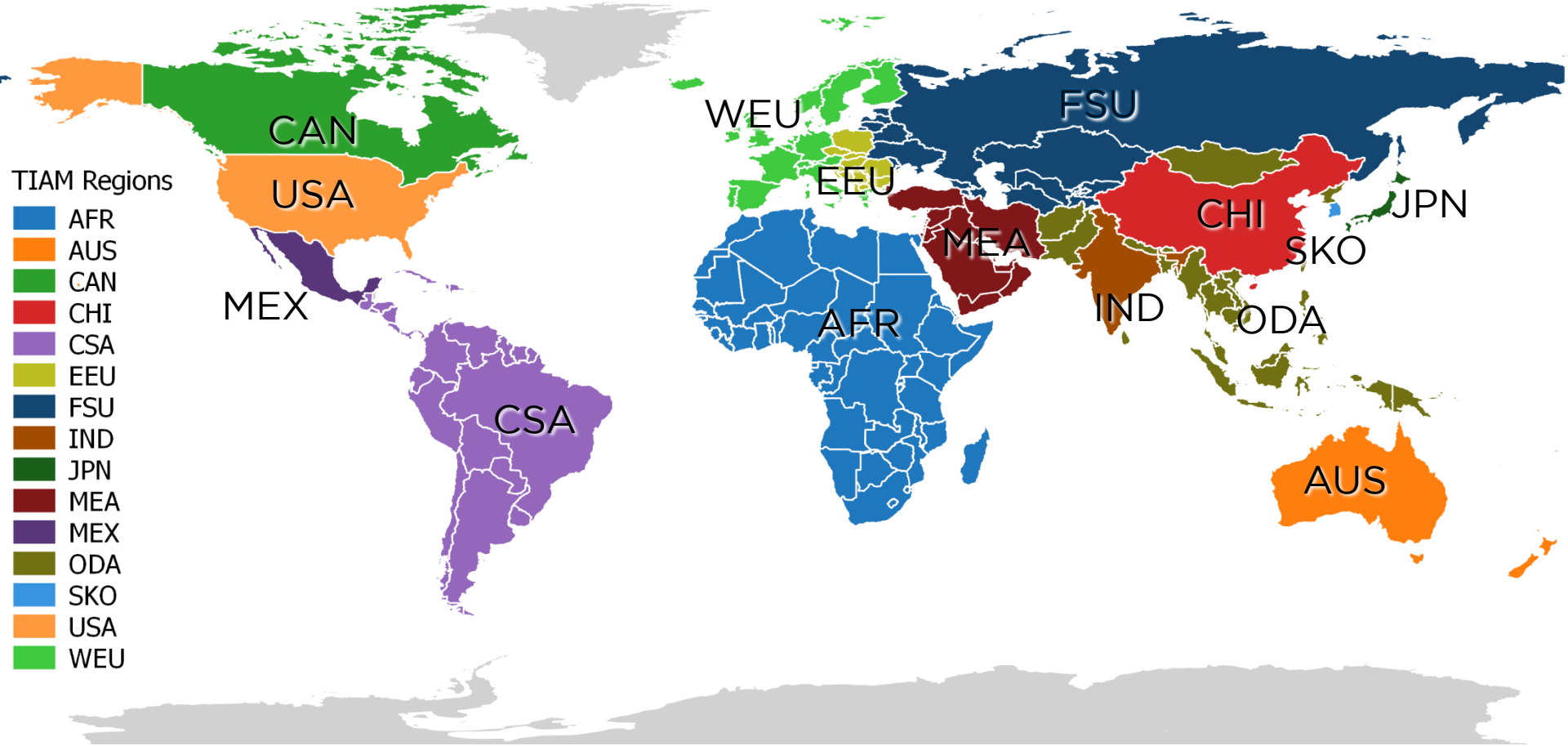


GLOBAL ETSAP-TIAM model

Built with the TIMES model generator

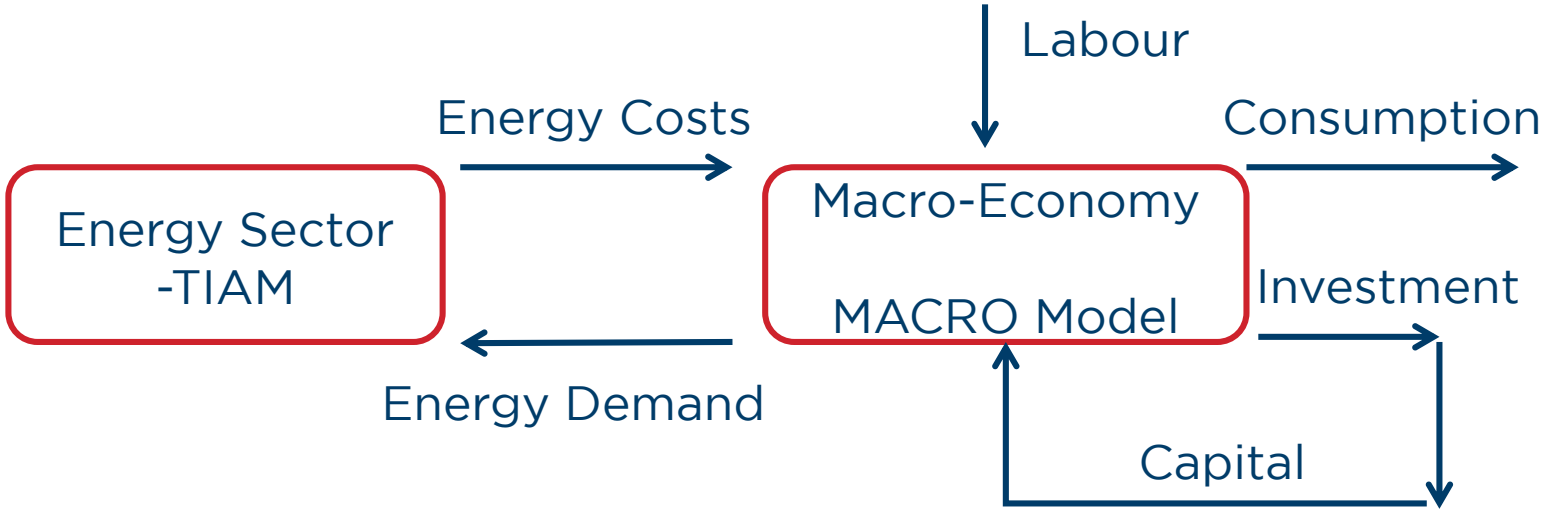
- The Integrated MARKAL-EFOM System of IEA-ETSAP
- Linear programming bottom-up energy system model
- Integrated model of the entire energy system
- Prospective analysis on medium to long term horizon (2100)
  - Demand driven by exogenous energy service demands
- Partial and dynamic equilibrium (perfect market)
- Optimal technology selection
- Minimizes the total system cost
- Environmental constraints
  - Integrated Climate Model
- 15 Region Global Model
- Price-elastic demands in the TIMES-ED version
  - Not included in Macro-Stand-Alone runs

ETSAP-TIAM 15 Regions



ETSAP-TIAM MSA (TMSA)
Macro Stand Alone

- Single-sector, multi-regional, inter-temporal general equilibrium model which maximises regional utility.
- The utility is a logarithmic function of the consumption of a single generic consumer.
- Production inputs are labour, capital and energy.
- Energy demand from ETSAP-TIAM model.
- MSA Re-estimates Energy Service Demands based on energy cost



What do we mean by equitable?

- What is equitable?
  - Minimise GDP Loss regionally?
  - Minimise GDP Loss per Capita?
  - Equal emissions regionally?
  - Equal emissions per Capita?
  - Affordability for Less Developed Countries
- What are appropriate technology transfer payments?

Cumulative Emissions Budget

nature geoscience

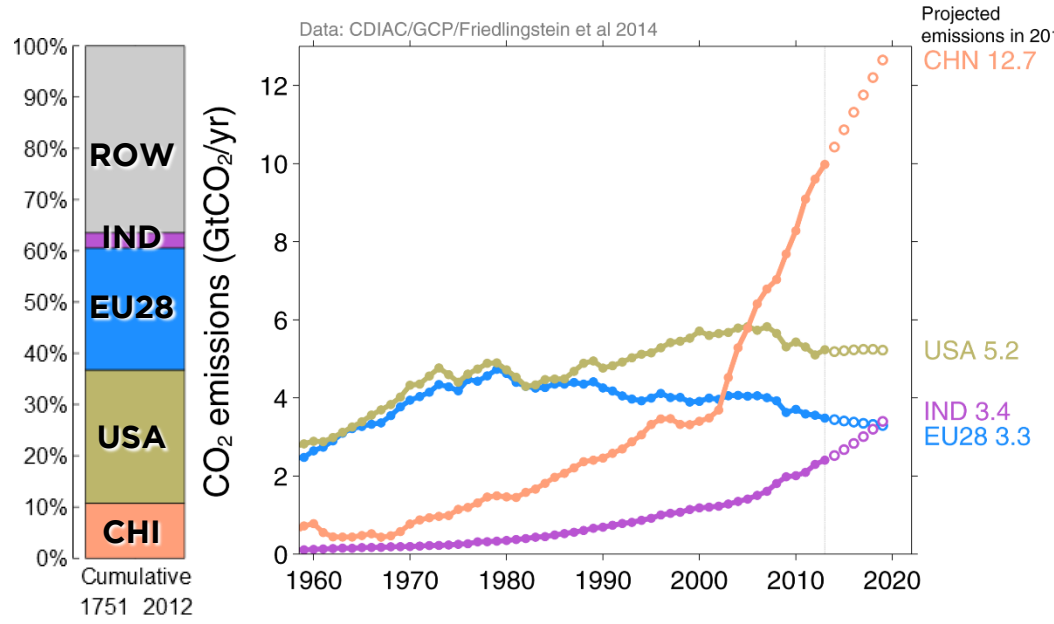
REVIEW ARTICLE

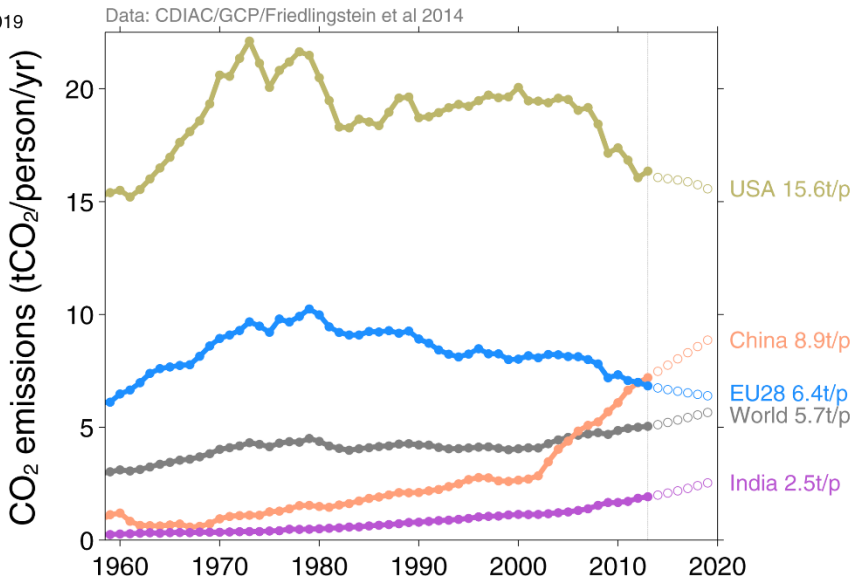
PUBLISHED ONLINE: 21 SEPTEMBER 2014 | DOI: 10.1038/NGEO2248

Persistent growth of CO_2 emissions and implications for reaching climate targets

P. Friedlingstein[1]*, R. M. Andrew[2], J. Rogelj[3,4], G. P. Peters[2], J. G. Canadell[5], R. Knutti[3], G. Luderer[6], M. R. Raupach[7], M. Schaeffer[8,9], D. P. van Vuuren[10,11] and C. Le Quéré[12]

	2°C	
	66%	50%
Cumulative budget (since 1870)	3,200 (2,900–3,600)	3,500 (3,100–3,900)
From 2015		
Remaining quota	1,200 (900–1,600)	1,500 (1,100–1,900)
Emission years	30 (22–40)	37 (27–47)
From 2020		
Remaining quota	1,000 (700–1,400)	1,300 (800–1,700)
Emission years	22 (15–30)	28 (19–38)

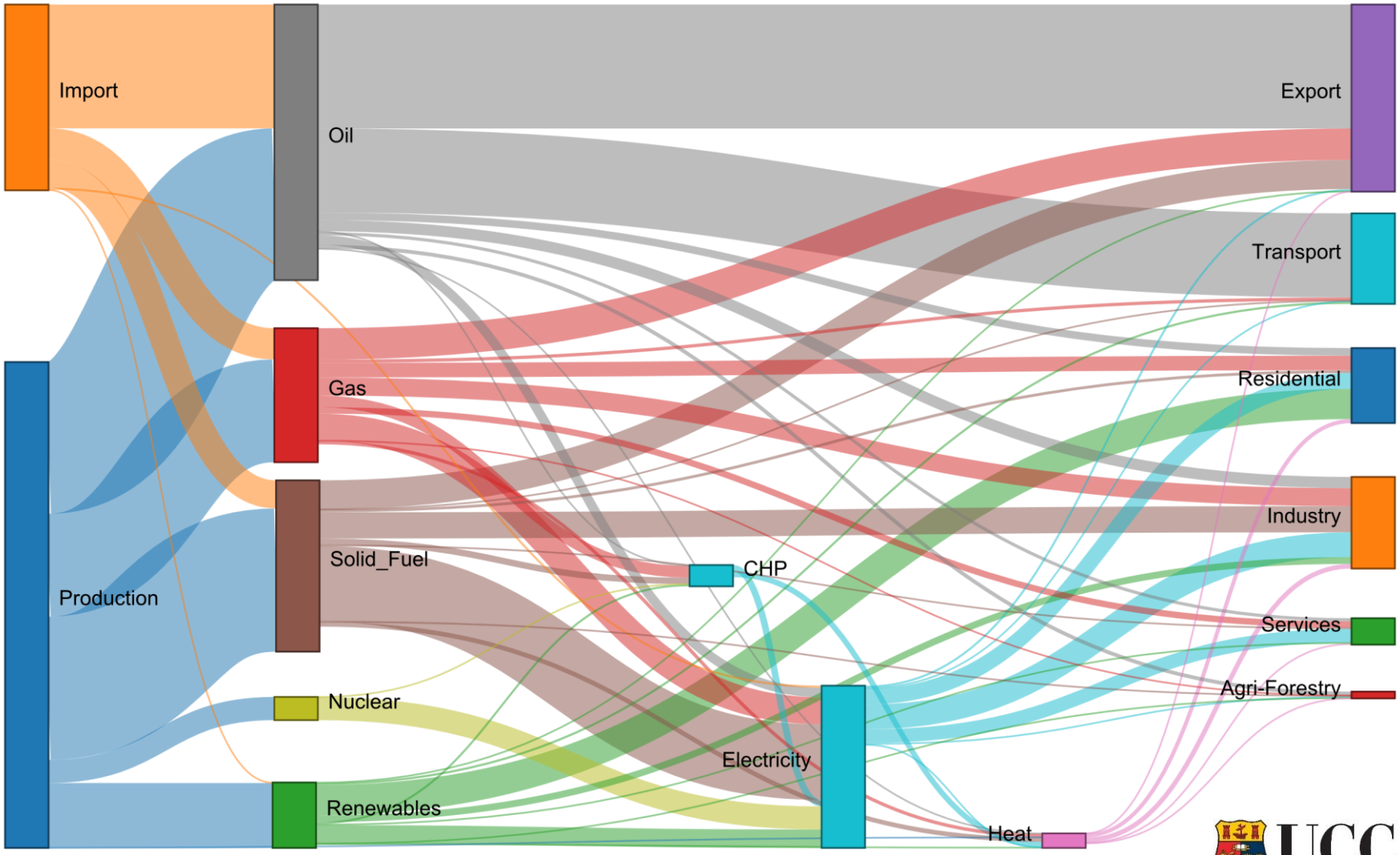




Scenario Outline

- BASE
  - Reference energy system, least cost optimal without policy constraints
  - Assumes rational optimising choices: not equal to business as usual
- 2DS – Remaining CO2 Emission Quota Budget
  - BASE with a cumulative on CO_2 emissions constraint to achieve the target 2°C (50% probability) set in Friedlingston et al.
  - 1400Gt CO_2e 2020 – 2100
  - No Significant policy action to 2020
  - Macro Stand Alone (MSA) active to re-estimate energy service demands relative to available capital & investment

Global Energy Balance - 2012



Data: IEA Energy Balances of OECD Countries, IEA Energy Balance of Non-OECD Countries

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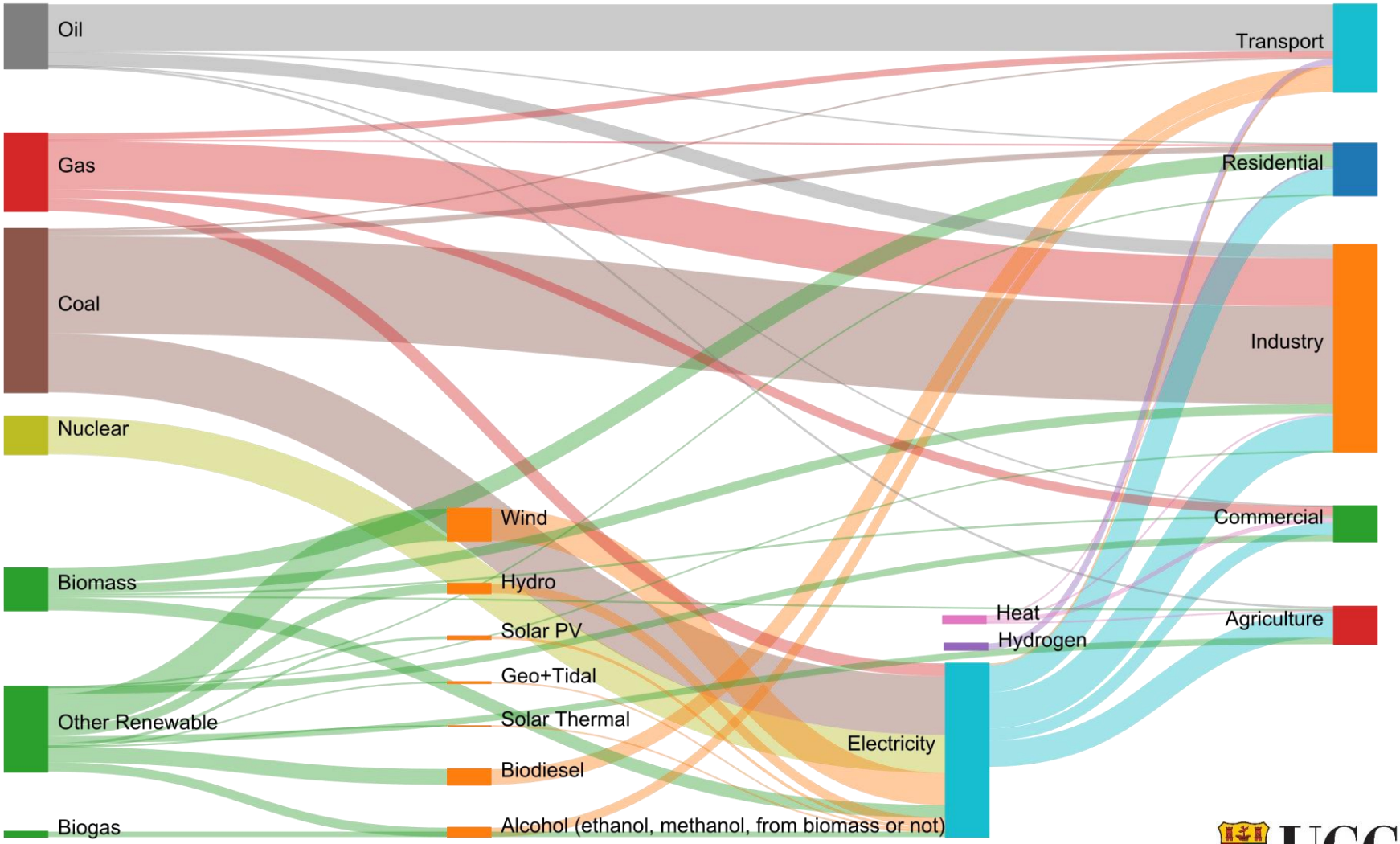
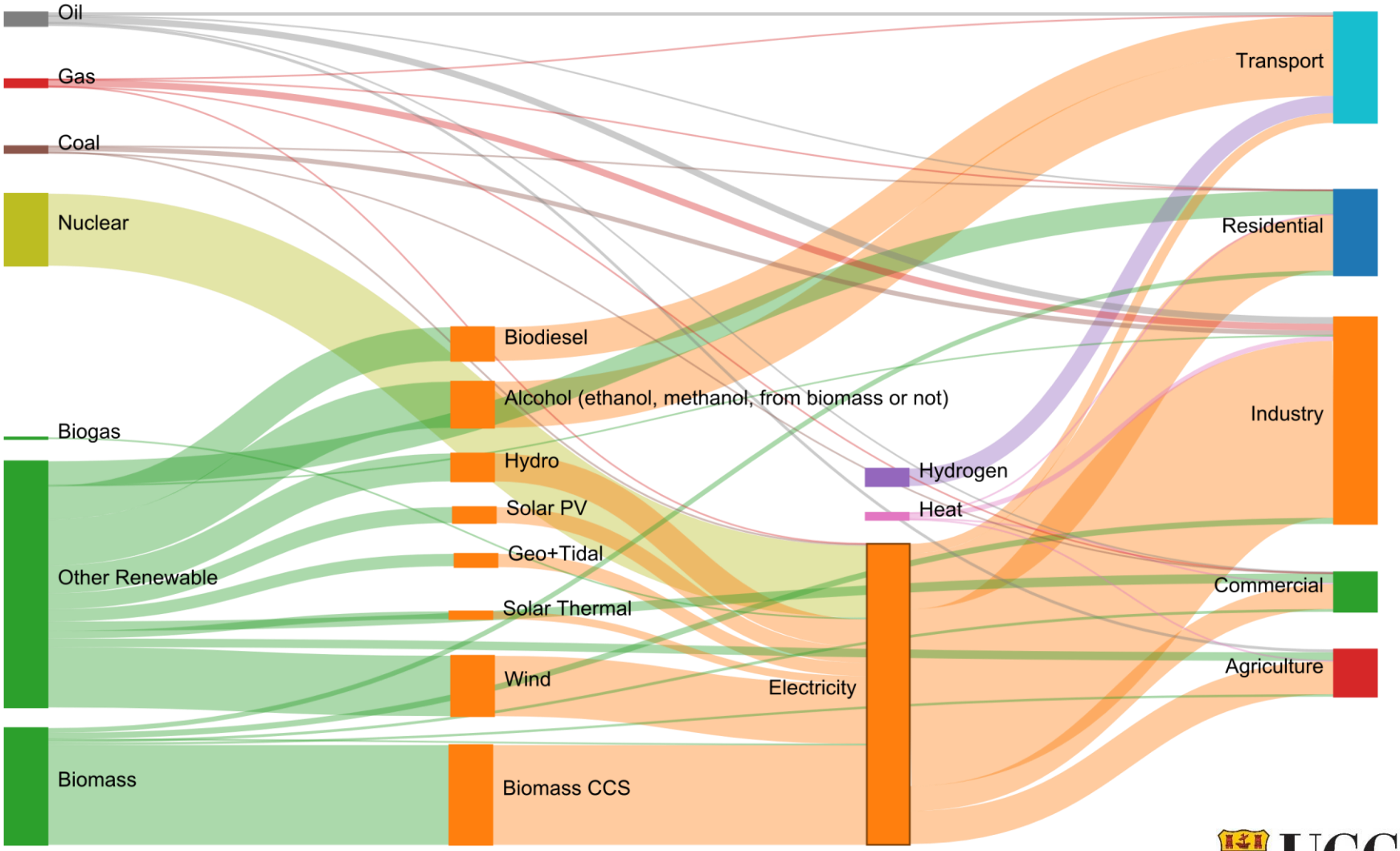
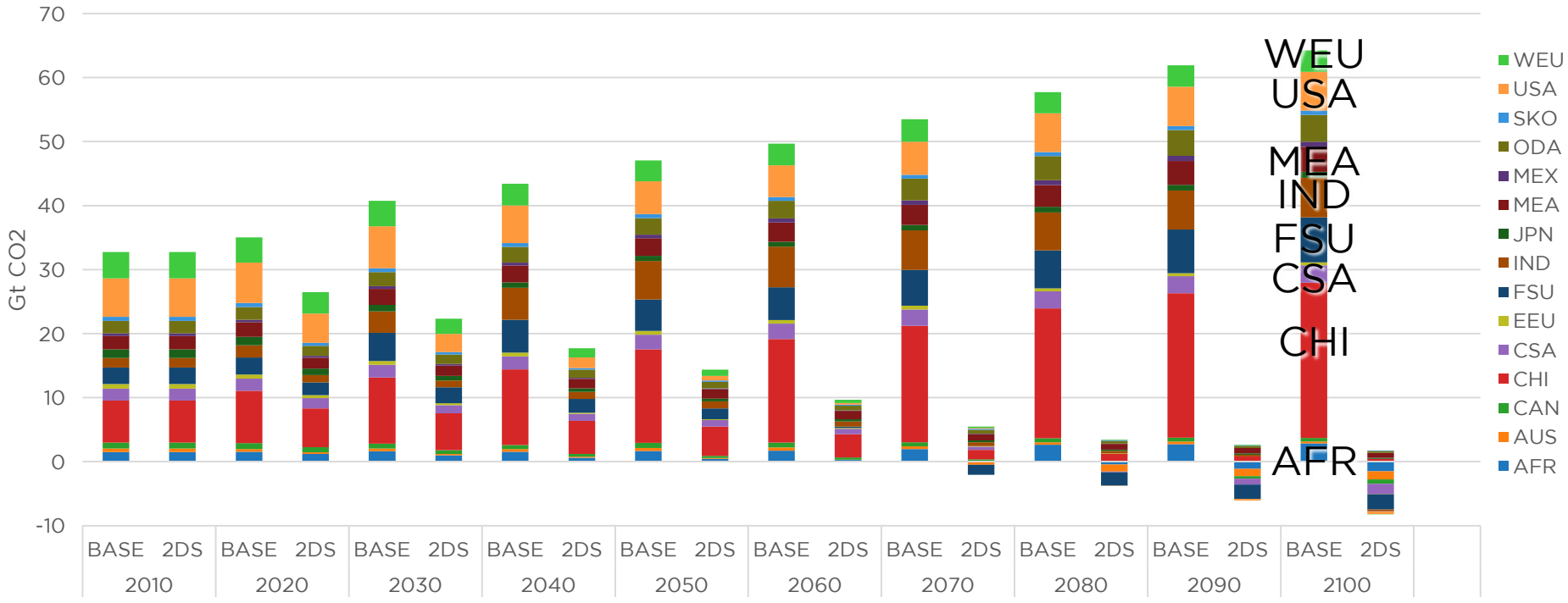
Final Energy- Base 2100

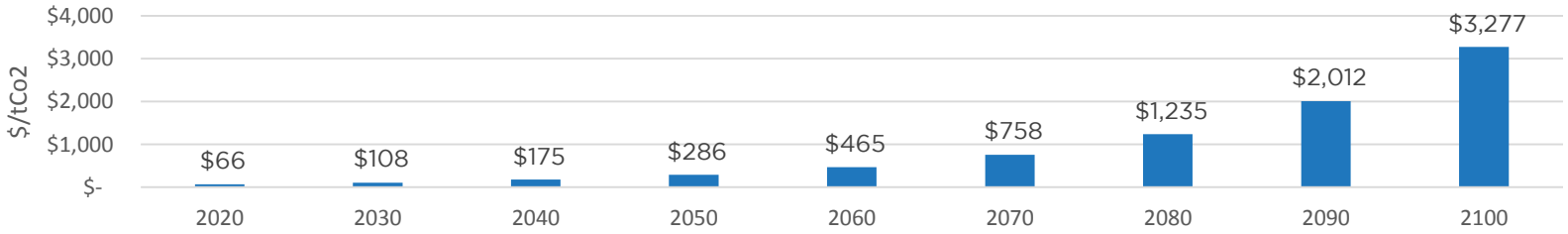


Final Energy - 2DS 2100



Net CO2 Emissions & CO2 Price





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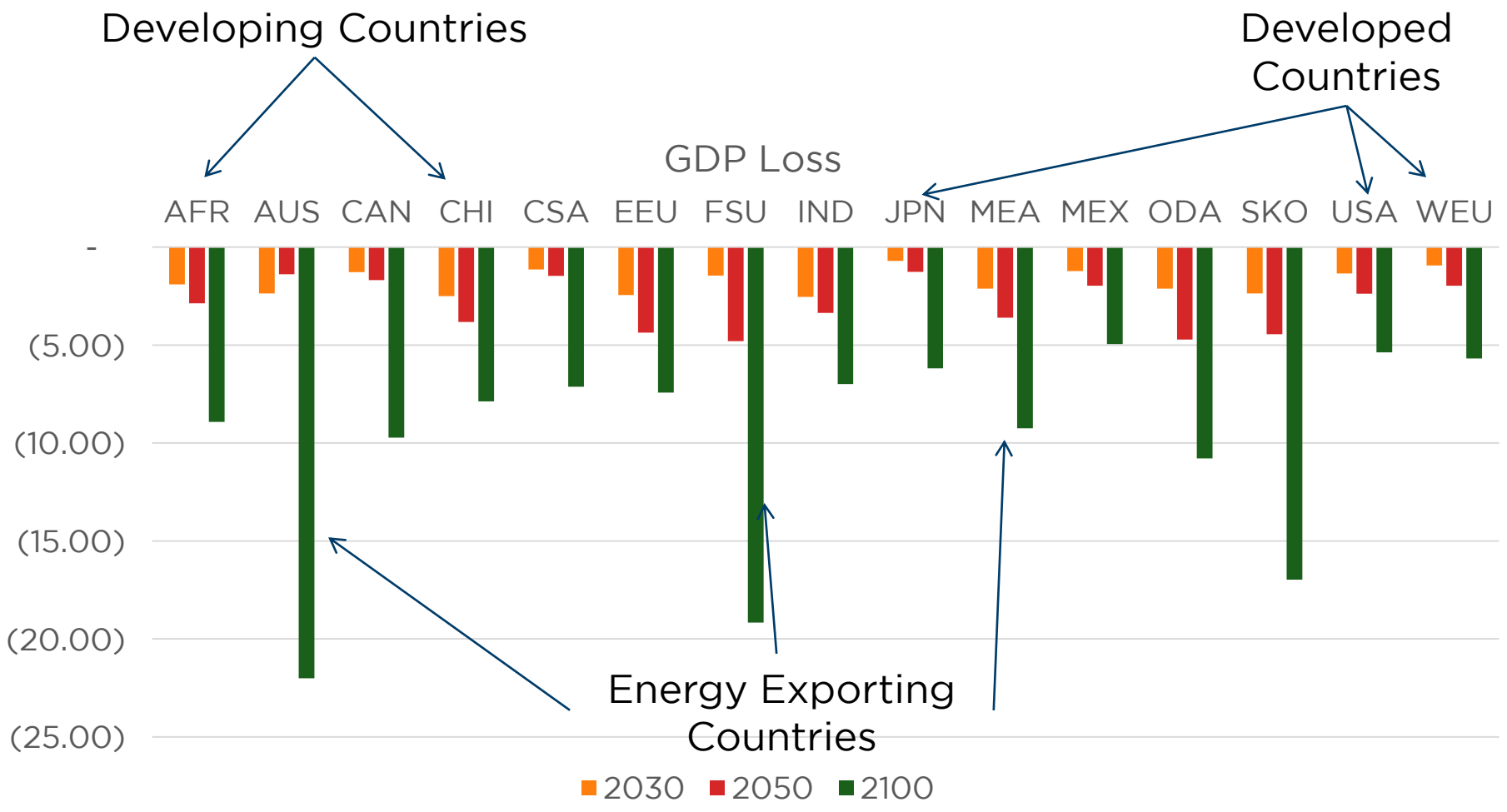
%GDP Loss 2030, 2050, 2100

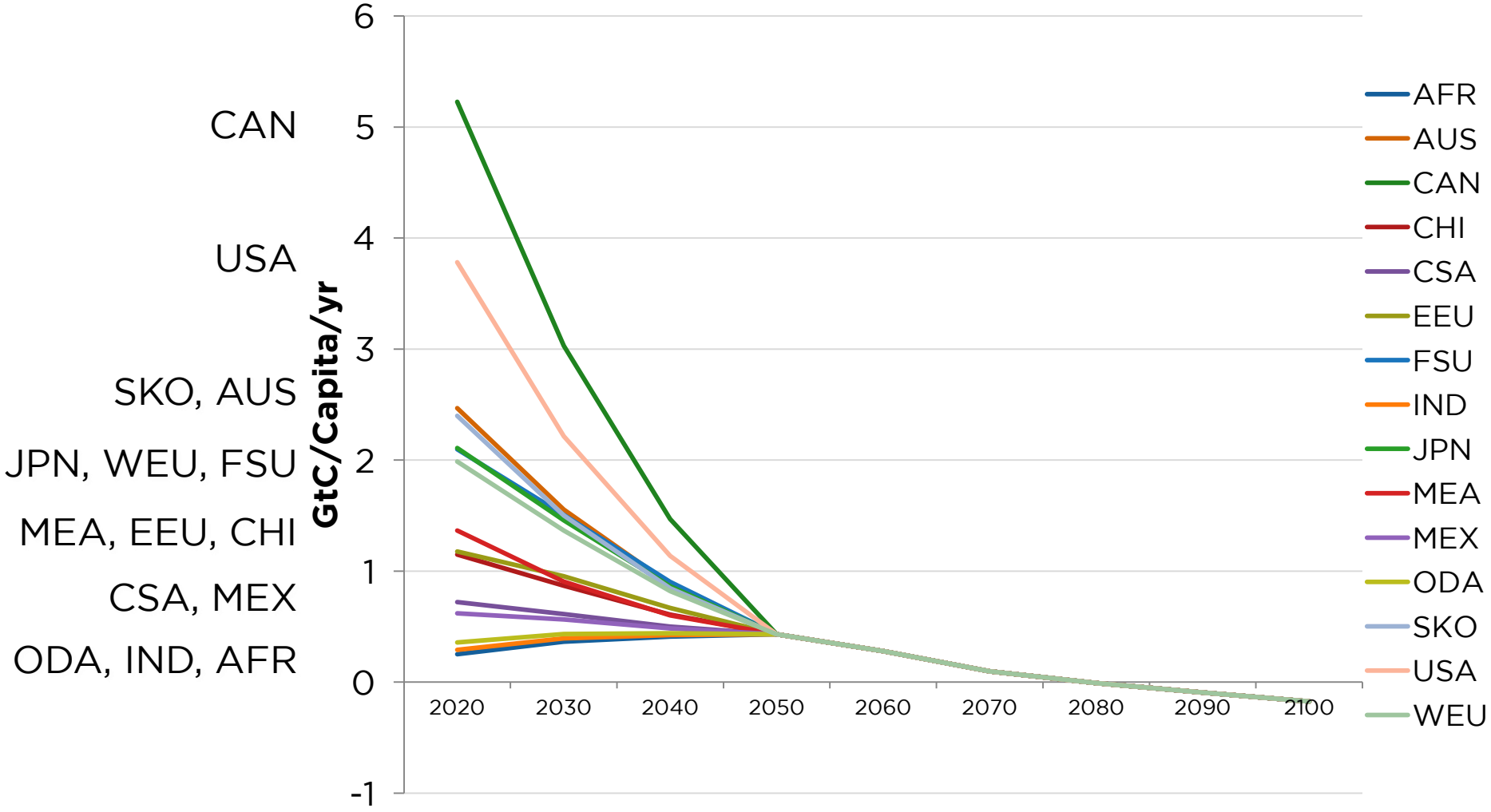


Burden Sharing Rules

- Efficiency [Eff]
  - Least Cost Optimal Energy System with Maximised Discounted Utility under cumulative emission quota of 1,400GtCO_2e
  - TIAM-MSA Result without Post Optimisation Analysis
- Rule 1 (R1) – Equalitarian Emissions Per Capita
- Rule 2 (R2) – Equal relative regional energy cost
- Rule 3 (R3) – Compensated Non-Annex-1 Countries for energy cost losses

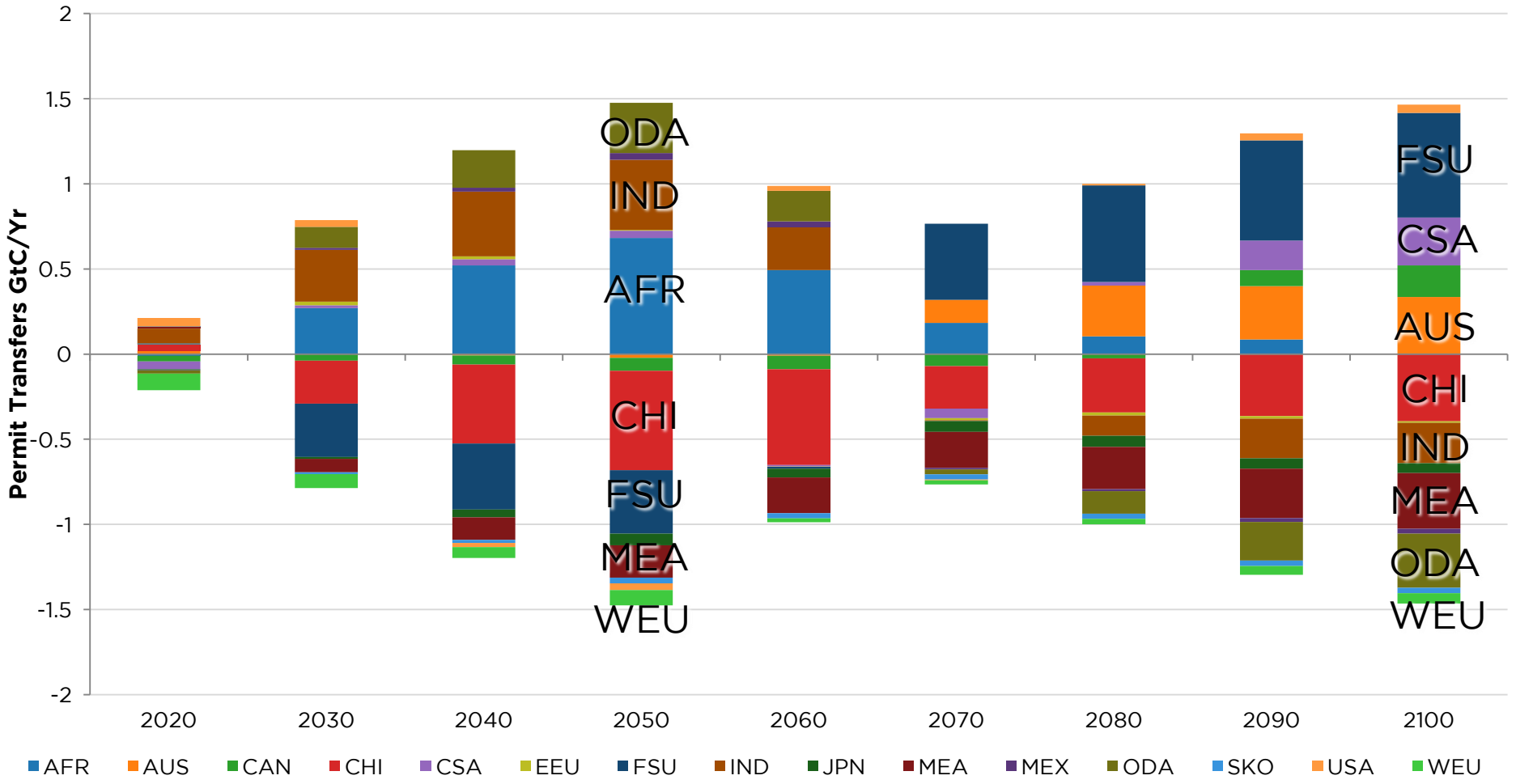
Rule 1 (R1) – Equalitarian

Grandfathering to 2050 equal emission/capita



Permits Balance

(R1) GtC/yr – Imports Negative, Exports Positive



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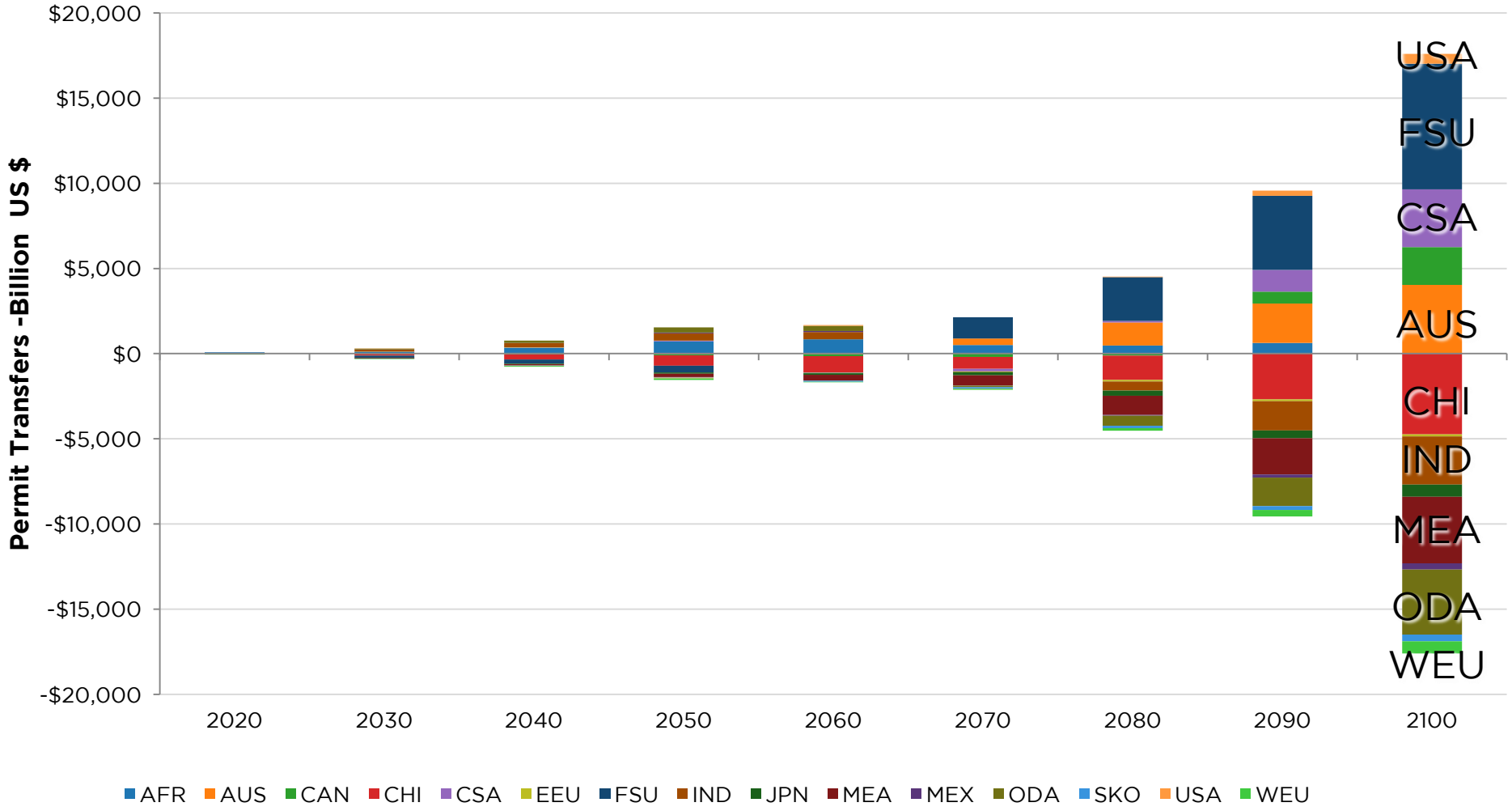
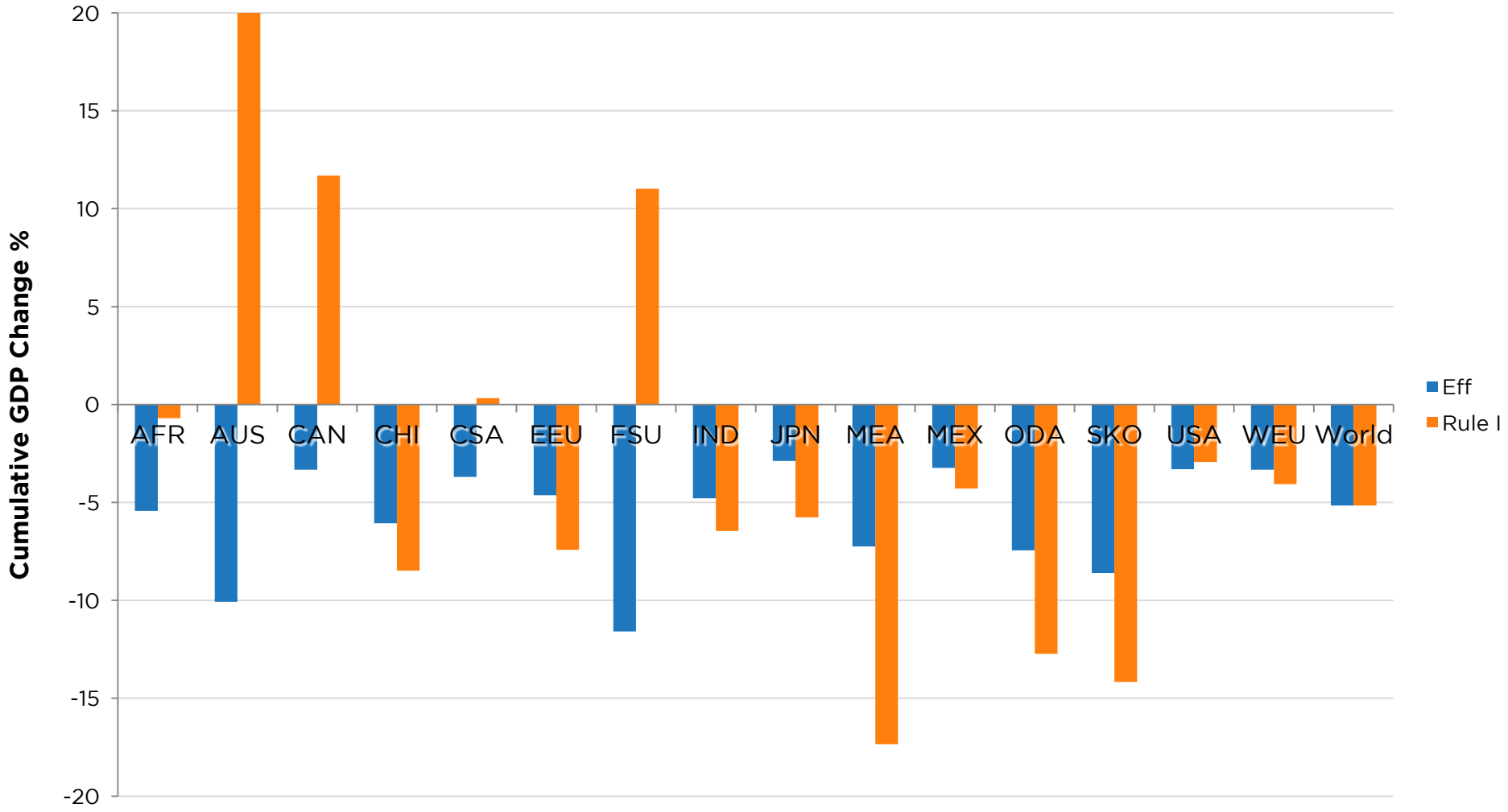
Capital Transfers – Billion US $

(R1) Equalitarian

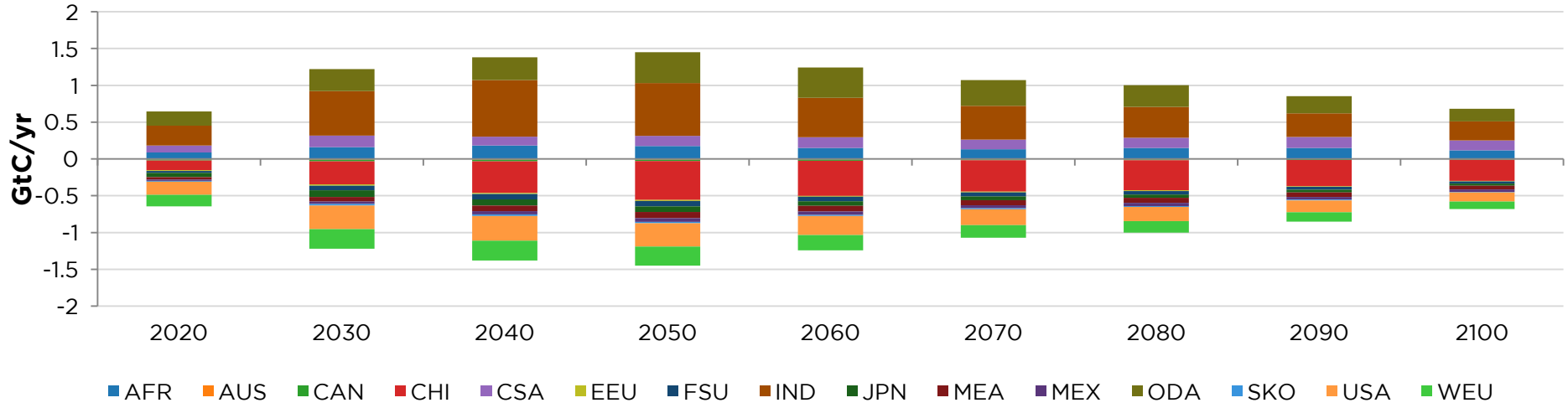


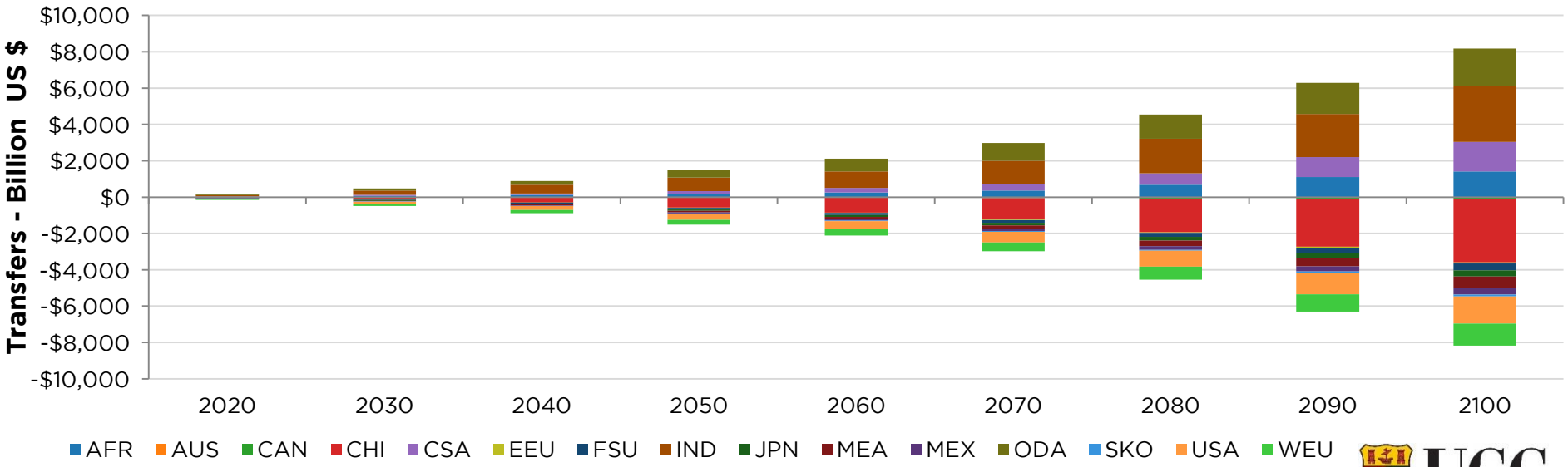
Cumulative GDP Change
(R1) Burden Sharing Rule



R2 – Equal Relative Energy Cost

Permit Trade GtC/yr & Capital Transfer bn$





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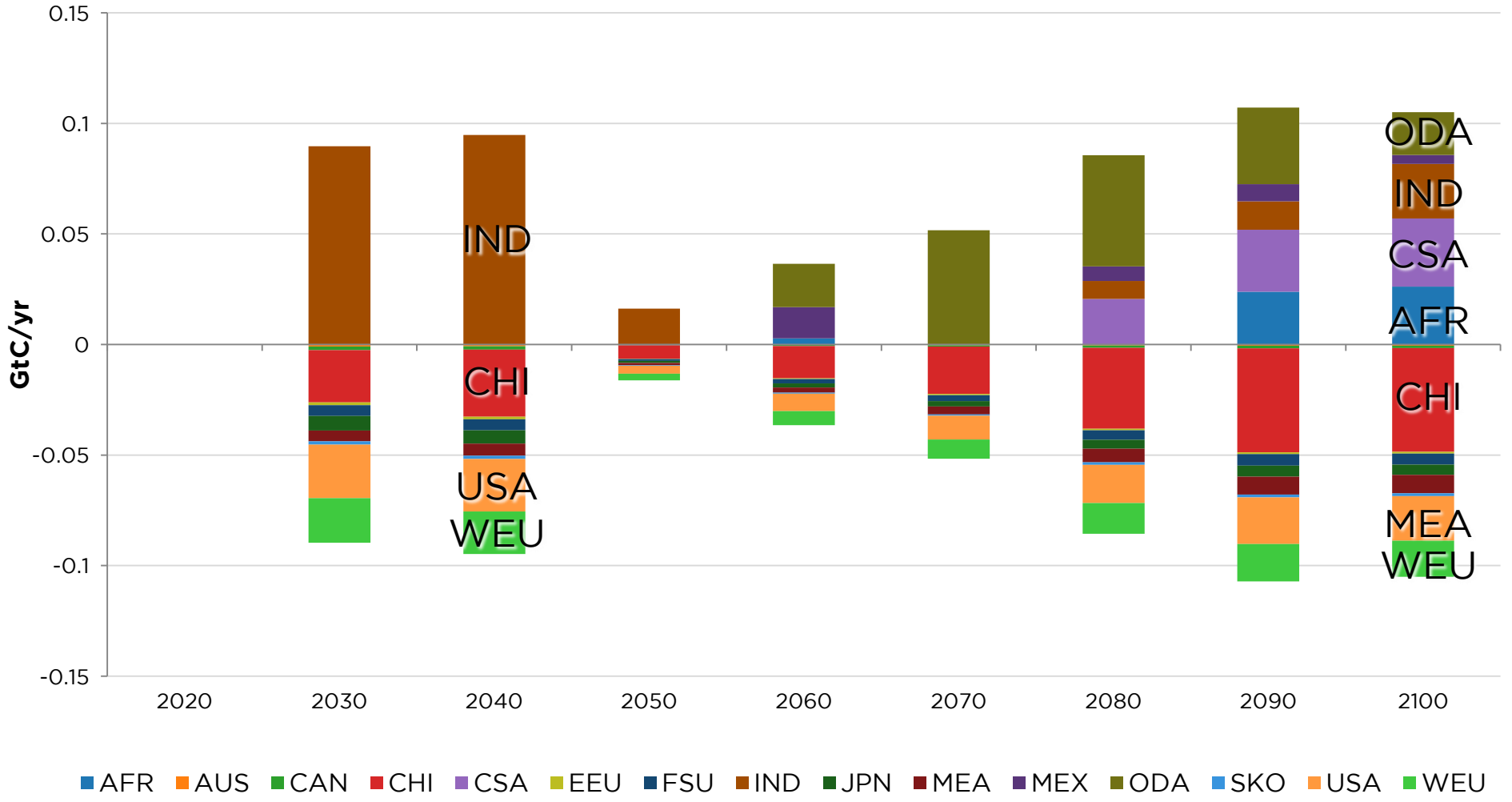
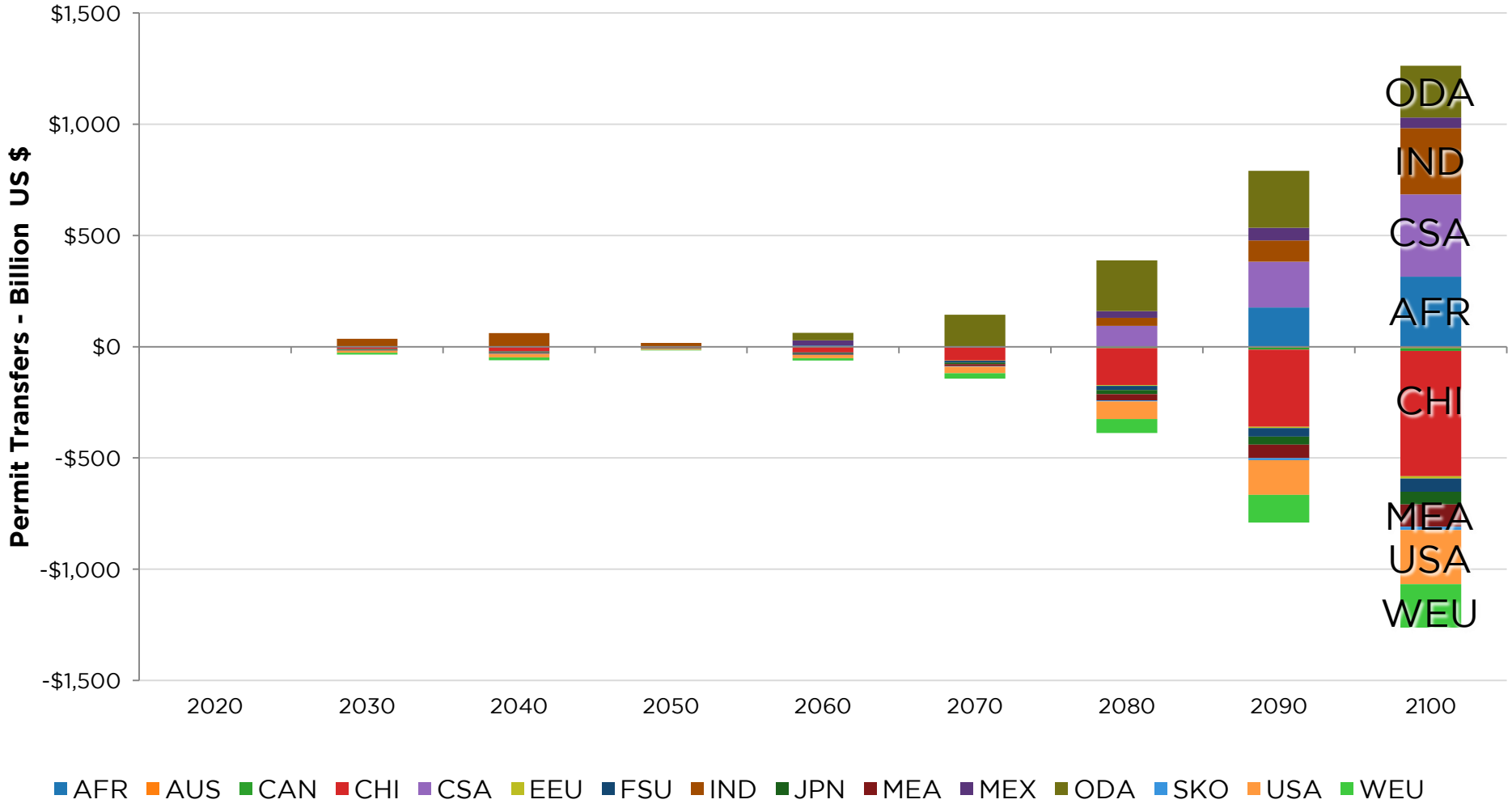
Permits Trade GtC/yr
(R3) Non-Annex-B EC Compensation

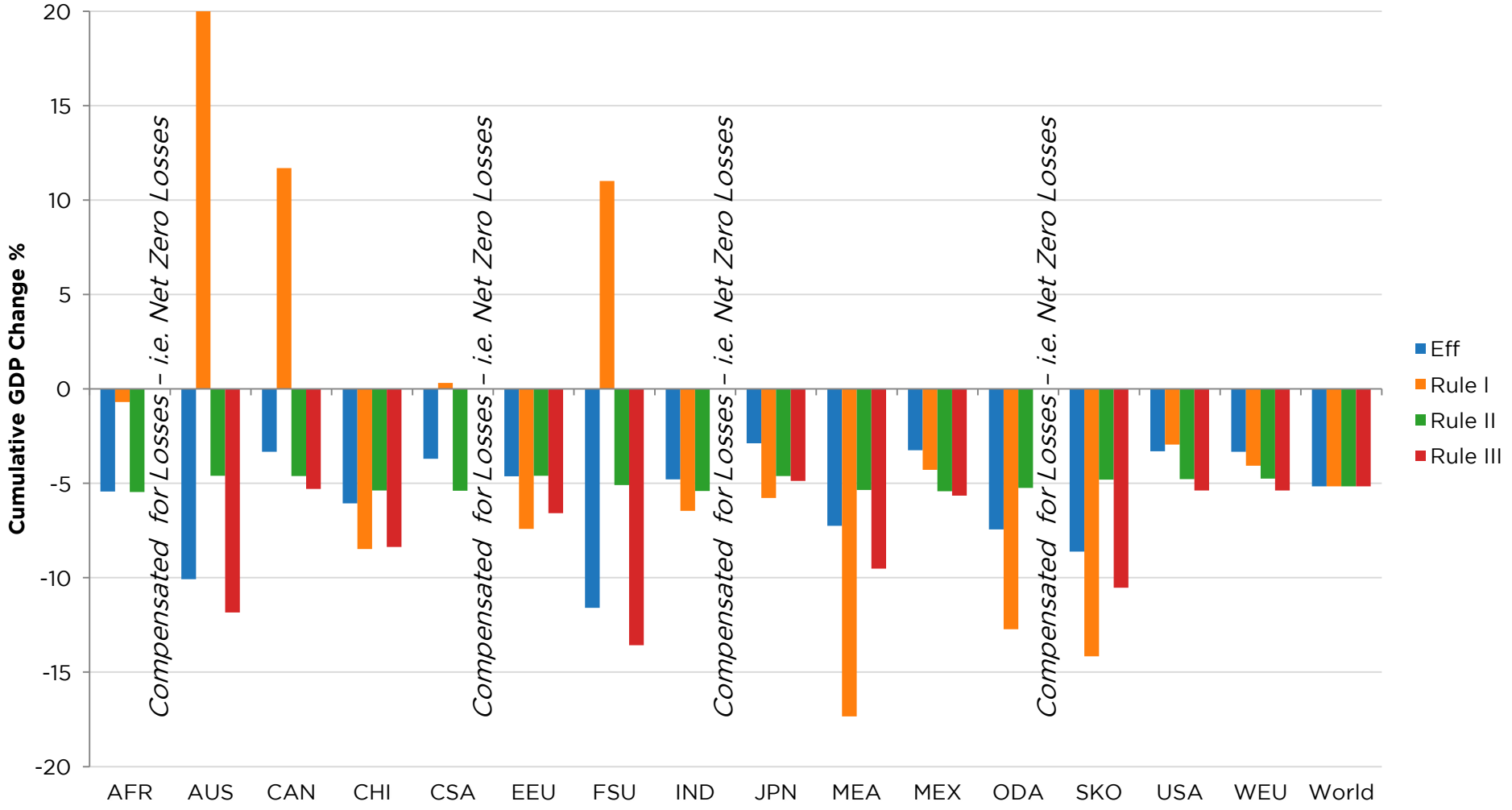


Capital Transfers - Billion US $

(R3) Energy cost equalisation



Cumulative GDP Change
3 Burden Sharing Rules



Conclusions

- The 2 Degree goal is barely technically feasible and comes with prohibitively expensive marginal abatement costs.
  - New Technology, New Behaviour & New Politics required
- The technologically efficient global cumulative cost of the 2 Degree goal is 5% GDP on aggregate with regional variations of between 2.5% and 11% GDP.
- Equitable burden sharing rules require high capital transfers of trillions US $ (undiscounted) per year in the second half of the century.
- There is no silver bullet although the equal relative energy cost losses is the most preferable; clearly back-stop technologies around $500/tCO2e abated must be invented! (Possibly DAC – Direct Air Capture)

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