Efficient and Equitable Scenarios of Climate Change

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PSI-5303, Switzerland

Outline

1. Questions and Methodology
2. Basic Scenario for Efficiency (2 °C) and its Variations
3. Energy, Power and Technology for the basic Scenario
4. Equity and Fairness
5. Sensitivities
6. Overall conclusions

Overarching Questions and Procedure

- Overarching Questions

  a) what is the least cost for the 2 °C and its regional distribution?

  b) what is the extra burden for the industrialized world for a global protocol in 2020?

- Approach

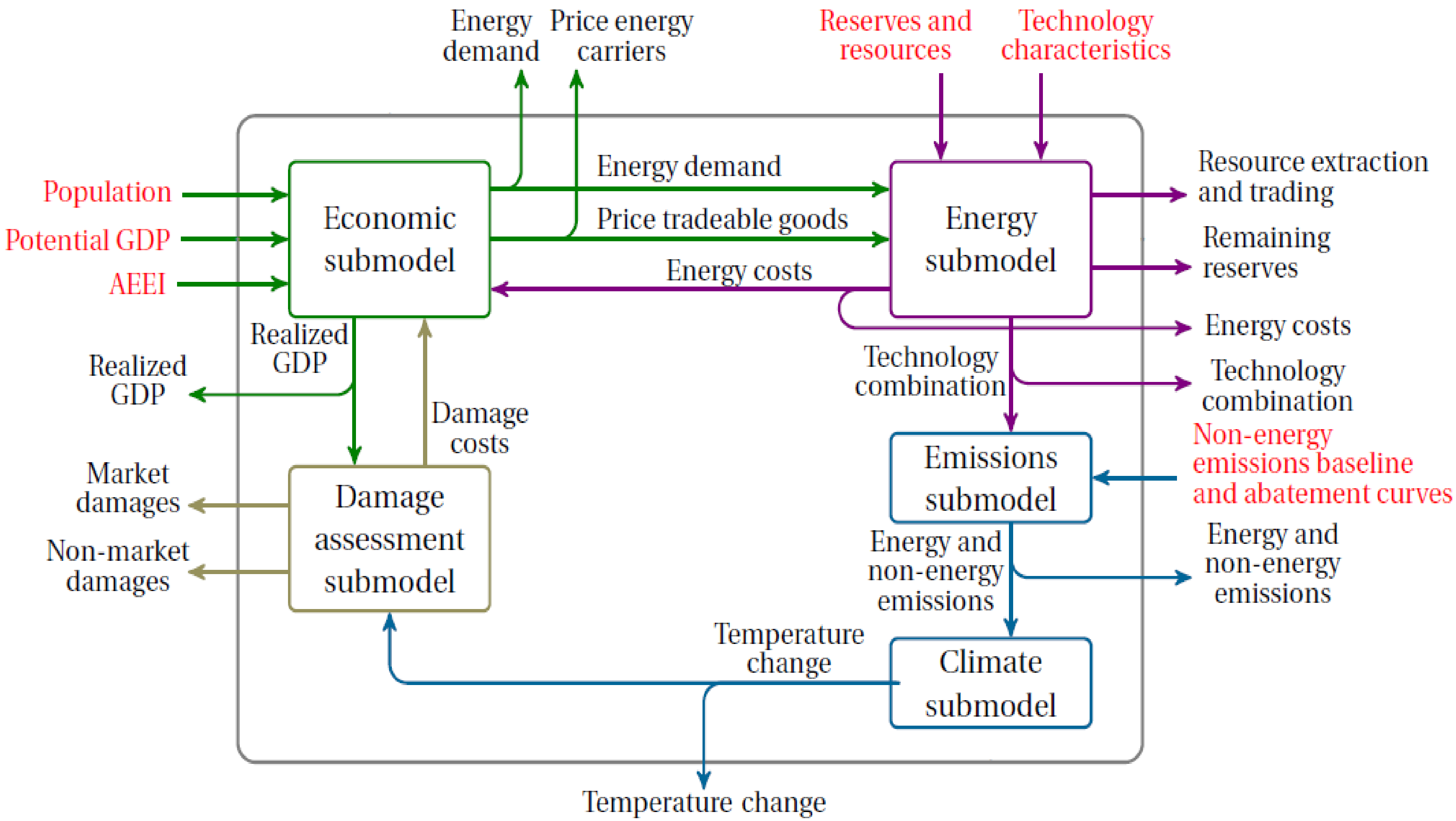
  a) The maximization of the global welfare under a cumulative constraint for emissions Quotas between 2020-2120 defines Economic and Environmental efficiency

  a) We apply different emission Quotas for different ΔT targets and associated probabilities

  b) Then, equity and fairness are investigated with different Burden Sharing rules like:

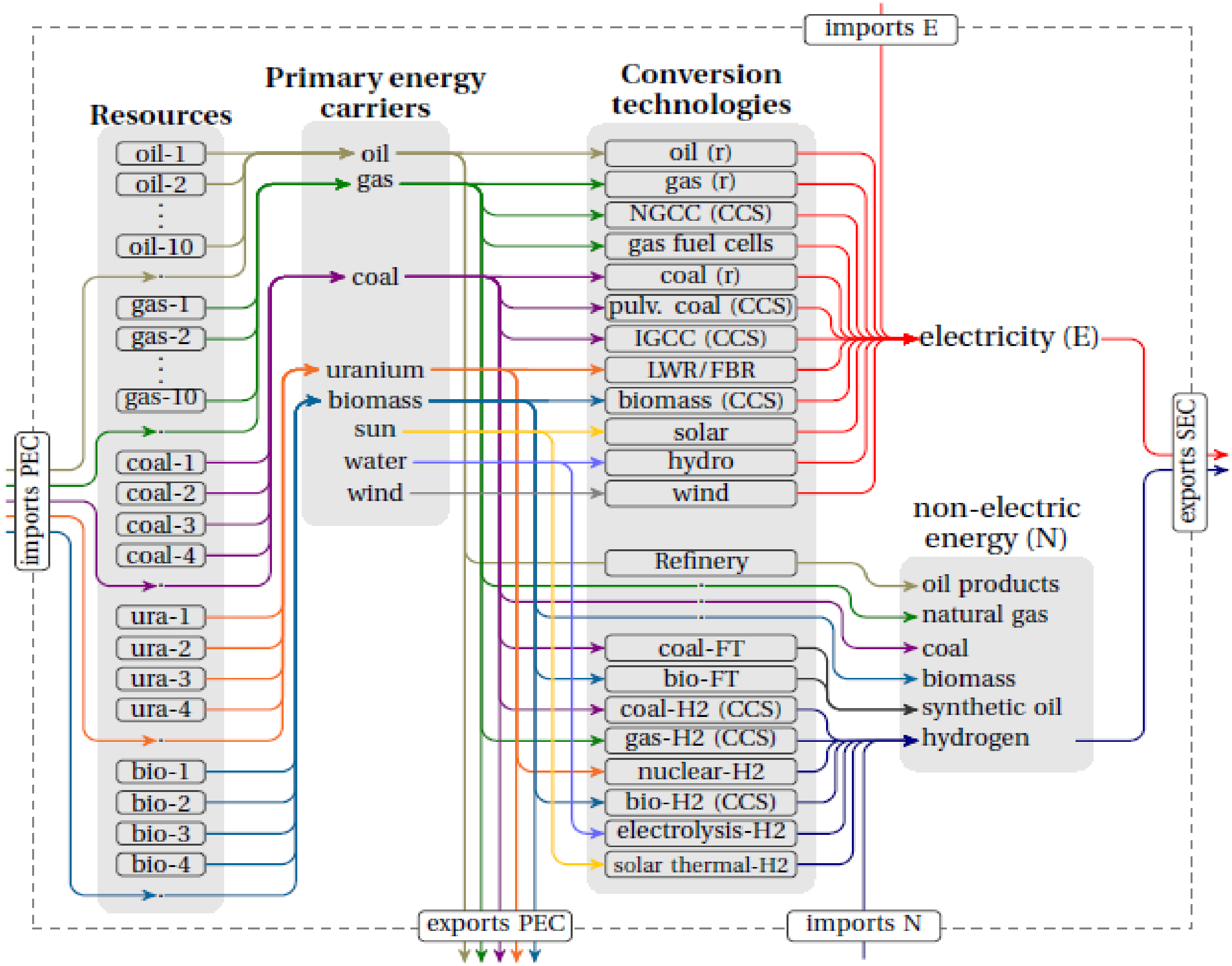
    - Resource sharing (equal emissions per capita after 2050)
    - Efforts sharing (equal relative regional energy costs)
    - Full compensation of energy costs for India and RoW
    - All above + Considering benefits of mitigation by simulating damages
    - Sensitivity

The Model: MERGE-ETL (PSI's Version)



Source; Adriana Marcucci; Input in Red; Output in Black

MERGE-ETL; The Reference Energy Flows & System



PEC=Primary energy carrier SEC=Secondary energy carrier

(r)=remaining (CCS)=technology with and without carbon capture and storage

MERGE-ETL; Regional disaggregation

With these changes the new regional definition (see Figure 3.13) includes 10 regions: European Union (EUP); Switzerland (SWI); Russia (RUS); Middle East (MEA); India (IND); China (CHI); Japan (JPN); Canada, Australia and New Zealand (CANZ), United States (USA); and the Rest of the World (ROW).

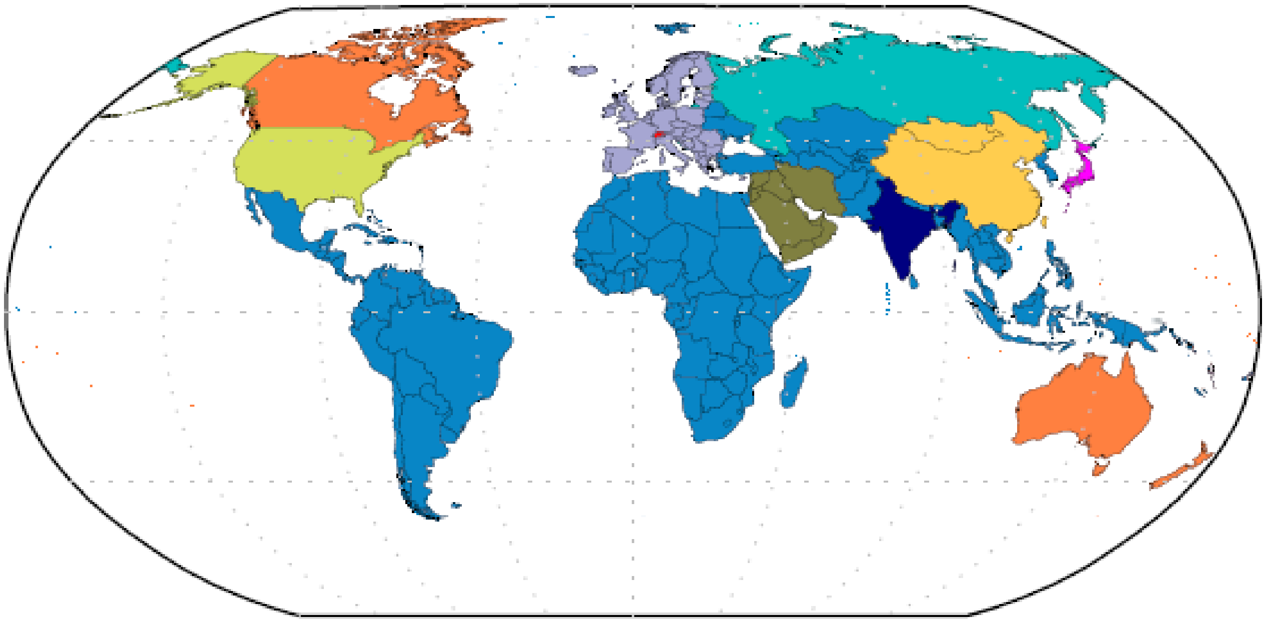


FIGURE 3.13: *New regions definition*

Different international statistics are used for the calibration years of 2000, 2005 and 2010

Remaining CEQ in GtC for after 2020 per scenario; Minimum number of scenarios is analyzed:

Scenario name	Stringency: 66 % probability	Stringency: 50 % probability	Timing: Protocol in 2020	Timing after 2020 BECCS & DAC All with CCS storage
BAU	Maximization of global utility			
CBA	Cost/Benefit with High Willingness to Pay			
2° C 66%	273 GtCe (1000 GtCO2e)		✓	2°C66% DAC (1000 GtCO2e)
2 °C 50%		355 GtCe & POA (1300 GtCO2e)	✓	2°C50% DAC (1300 GtCO2e)
2.5 ° C 66%	464GtC (1700 GtCO2e)		✓	-
2.5 °C 50%		560 GtC (2000 GtCO2e)	✓	-

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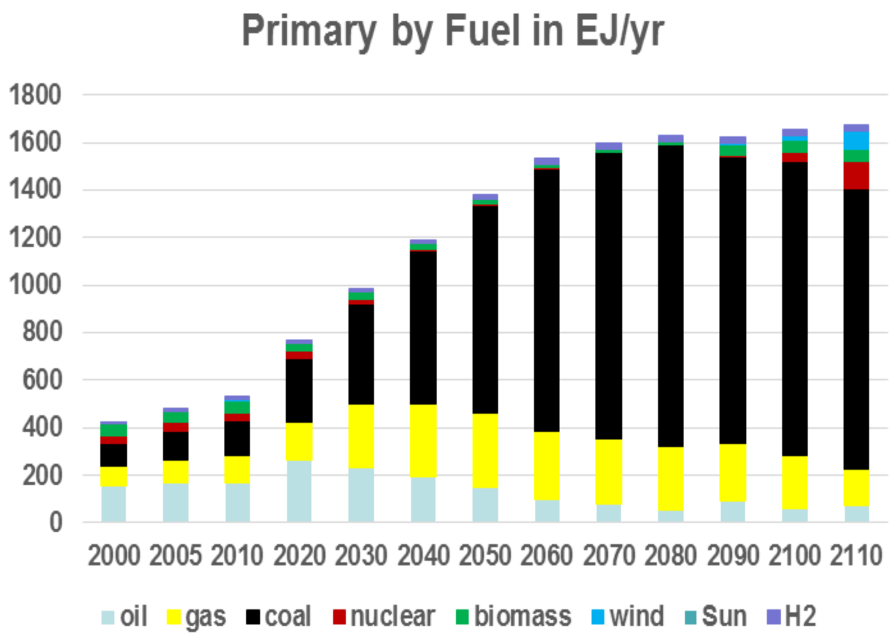
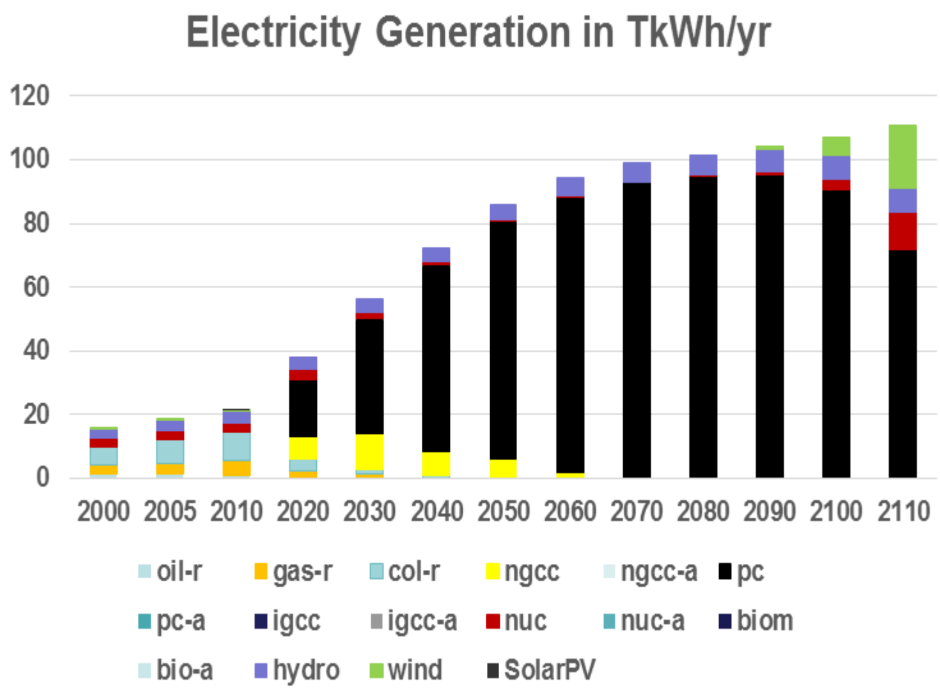
Source of RCEQ: Friedlingstein et al. 2014

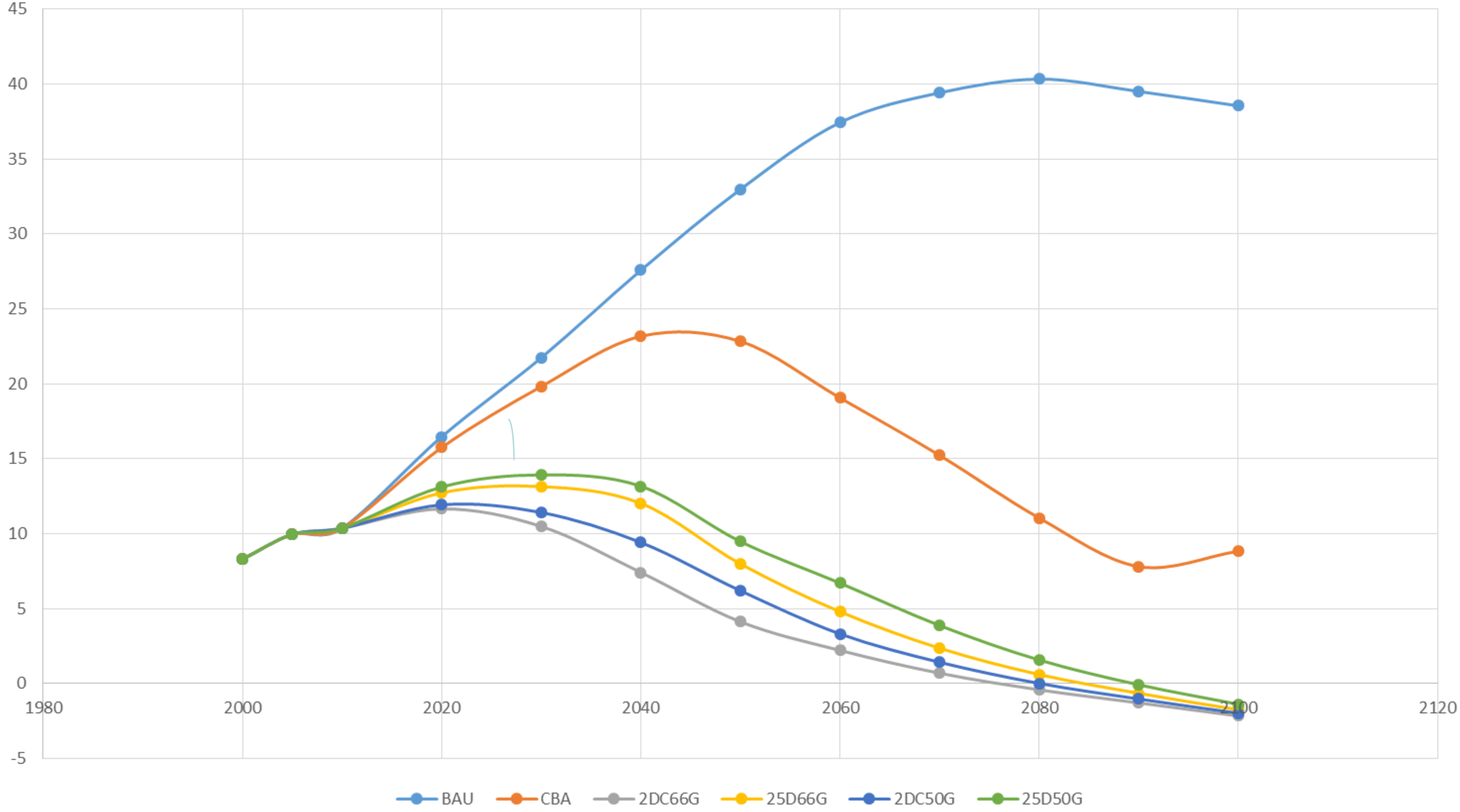
BAU with basic socio-economic assumptions of IIASA's B2 and its energy intensity





But BAU is a cost optimal solution dominated by coal and produces a significant amount of GHG emission.

CO2eq Emissions per case in GtCe/yr



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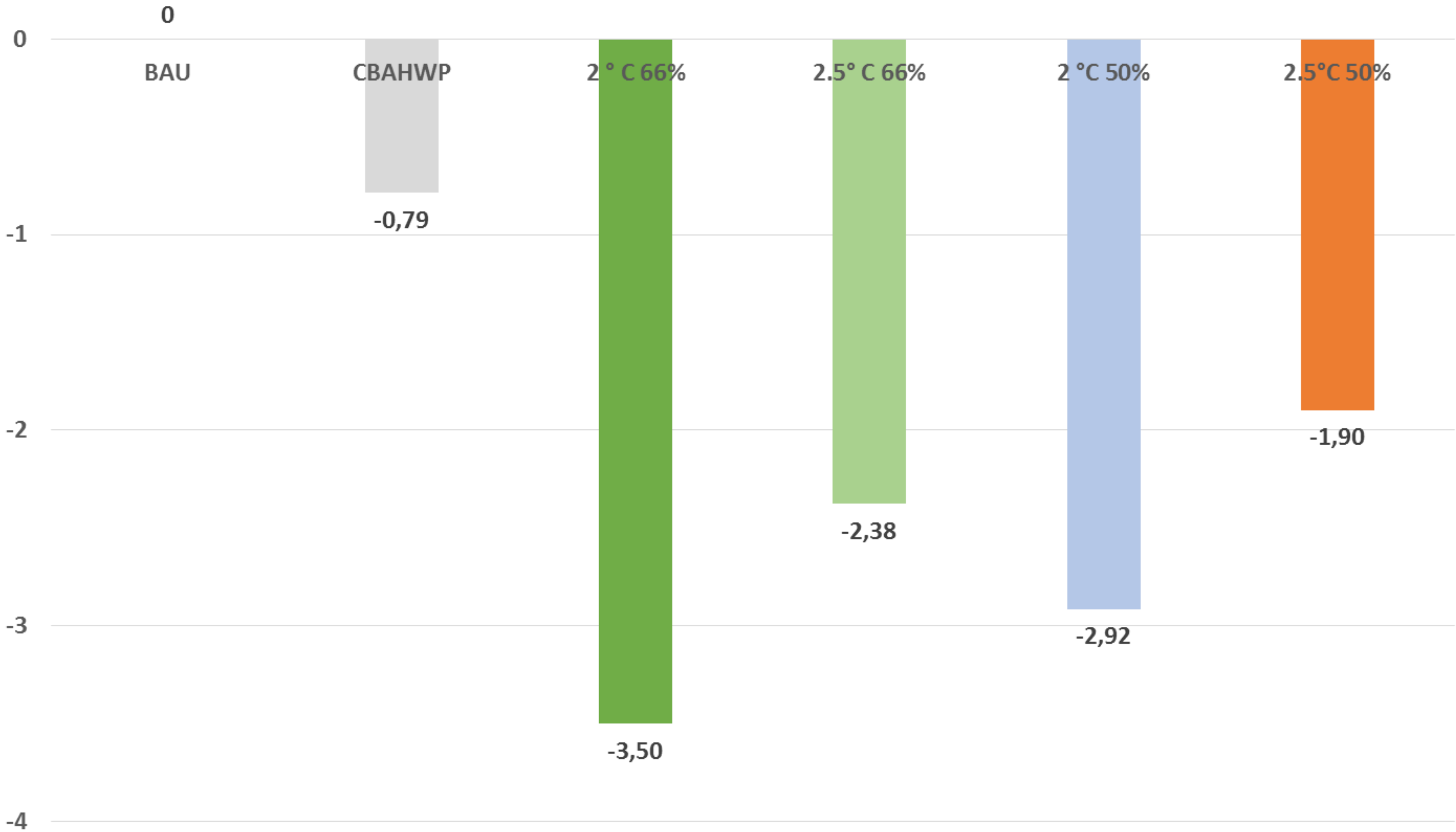
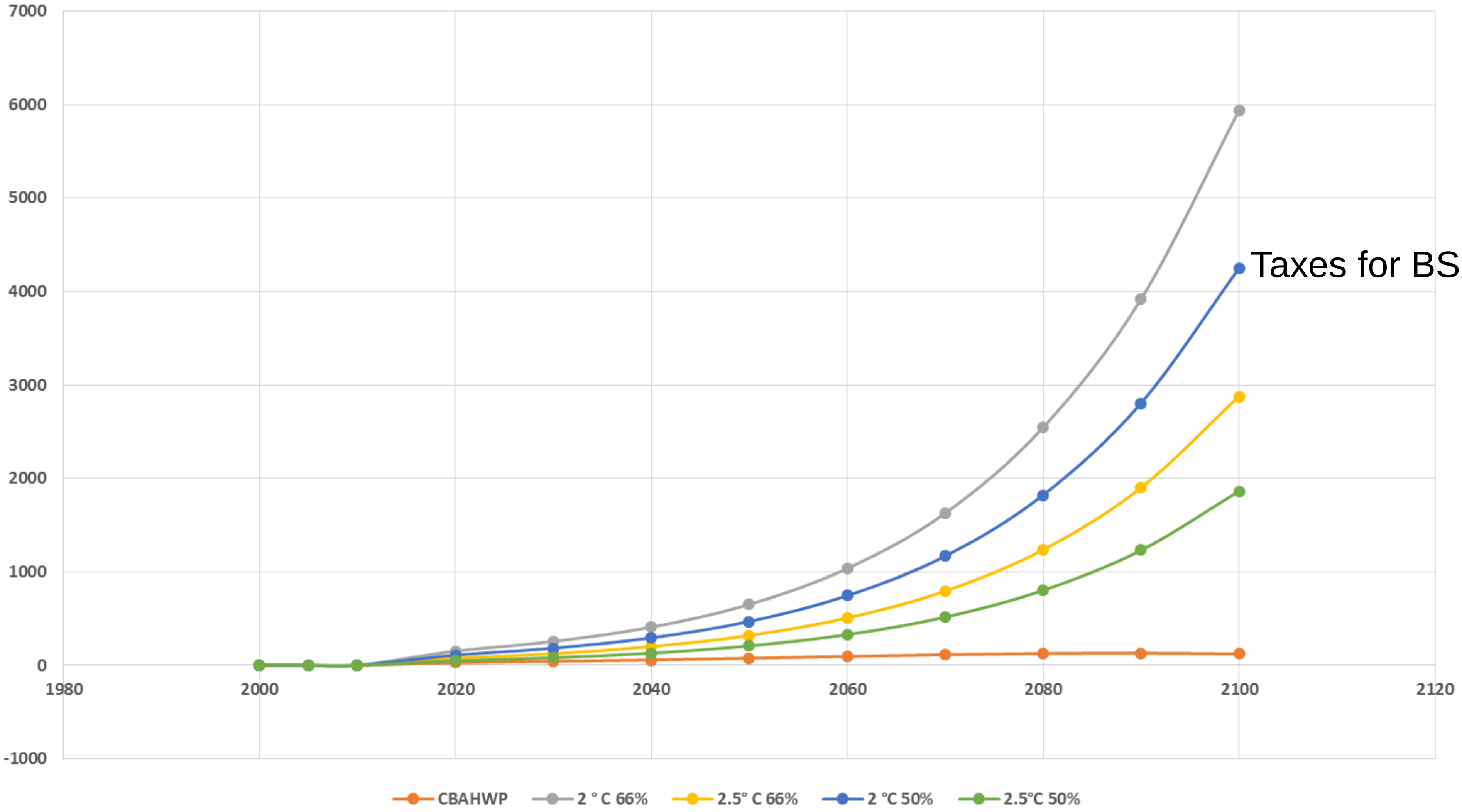
GDP losses relative to BaU (%)



Marginal cost $/t C



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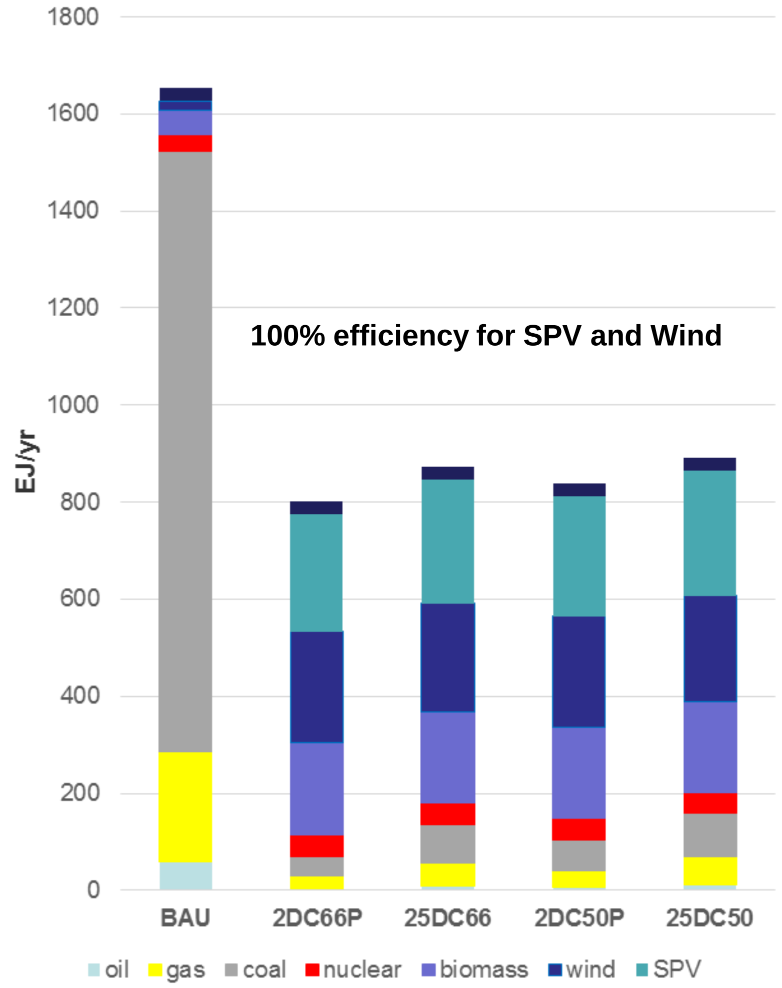
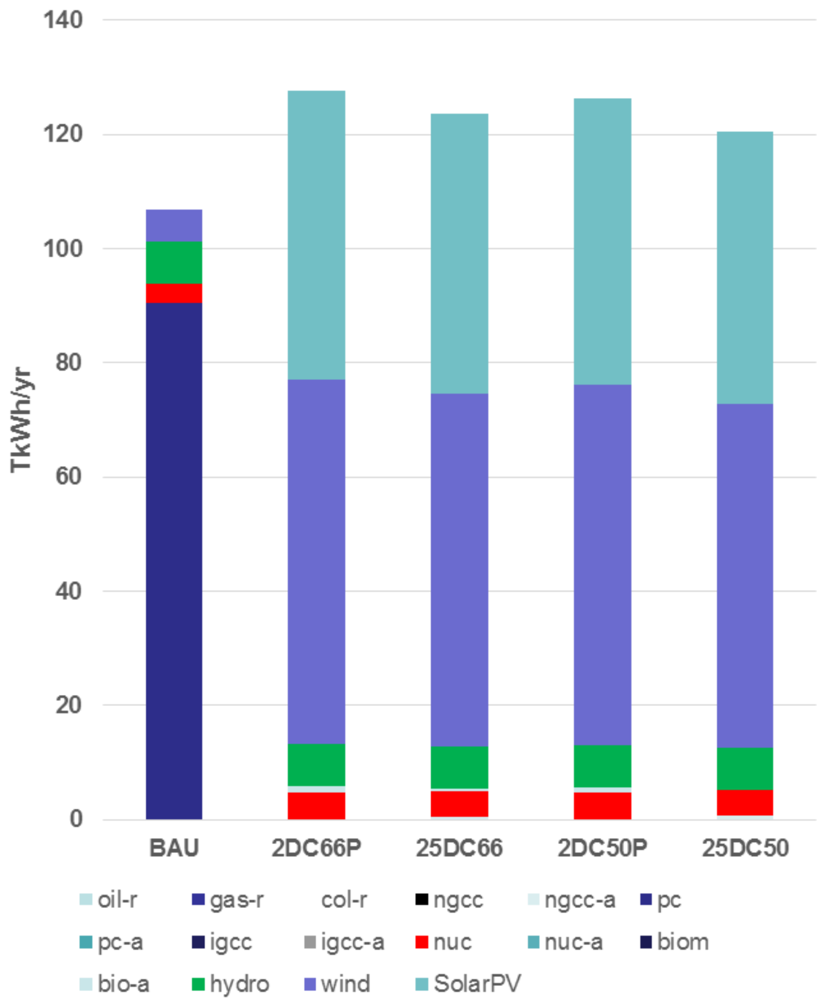
Primary by Fuel & Power Generation (2100)





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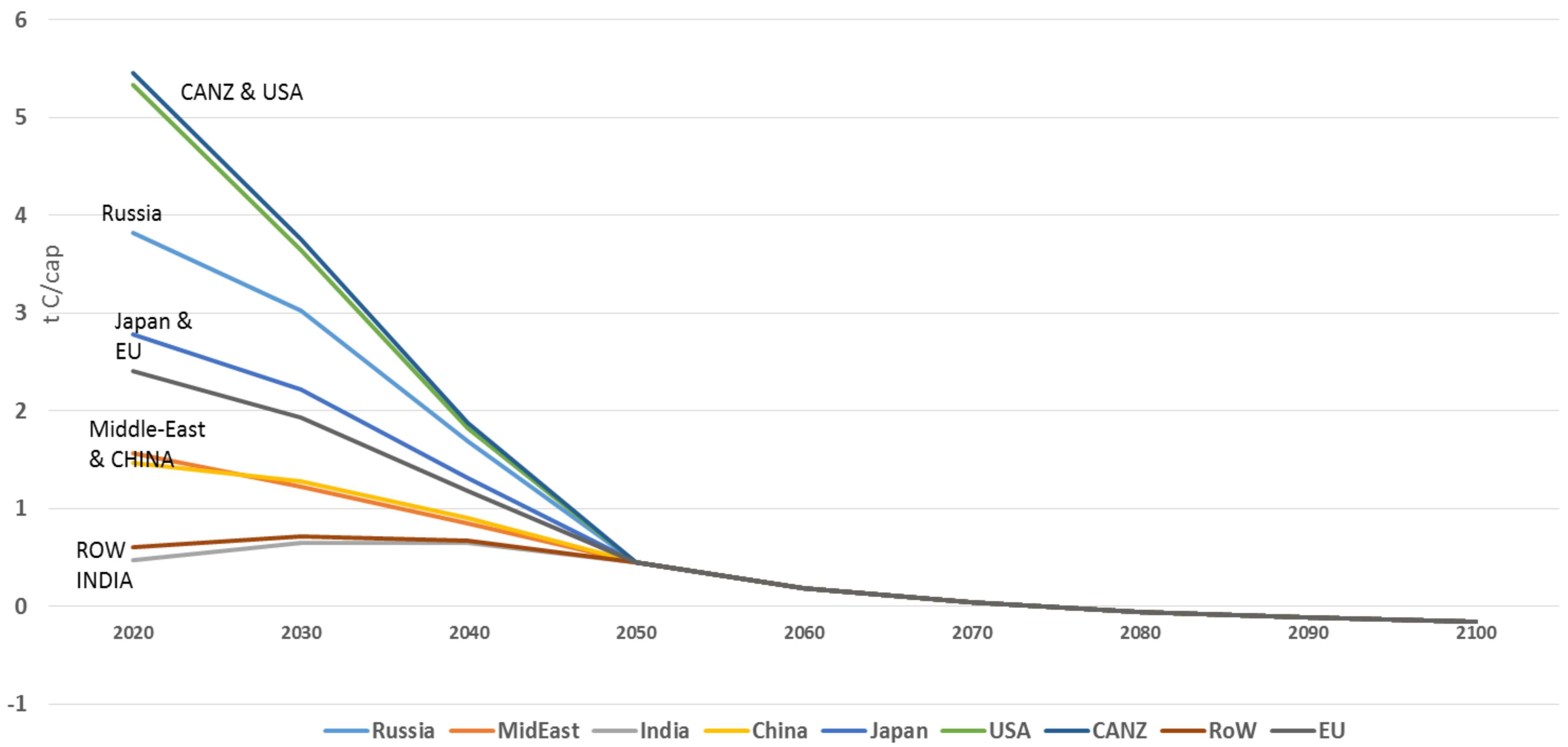
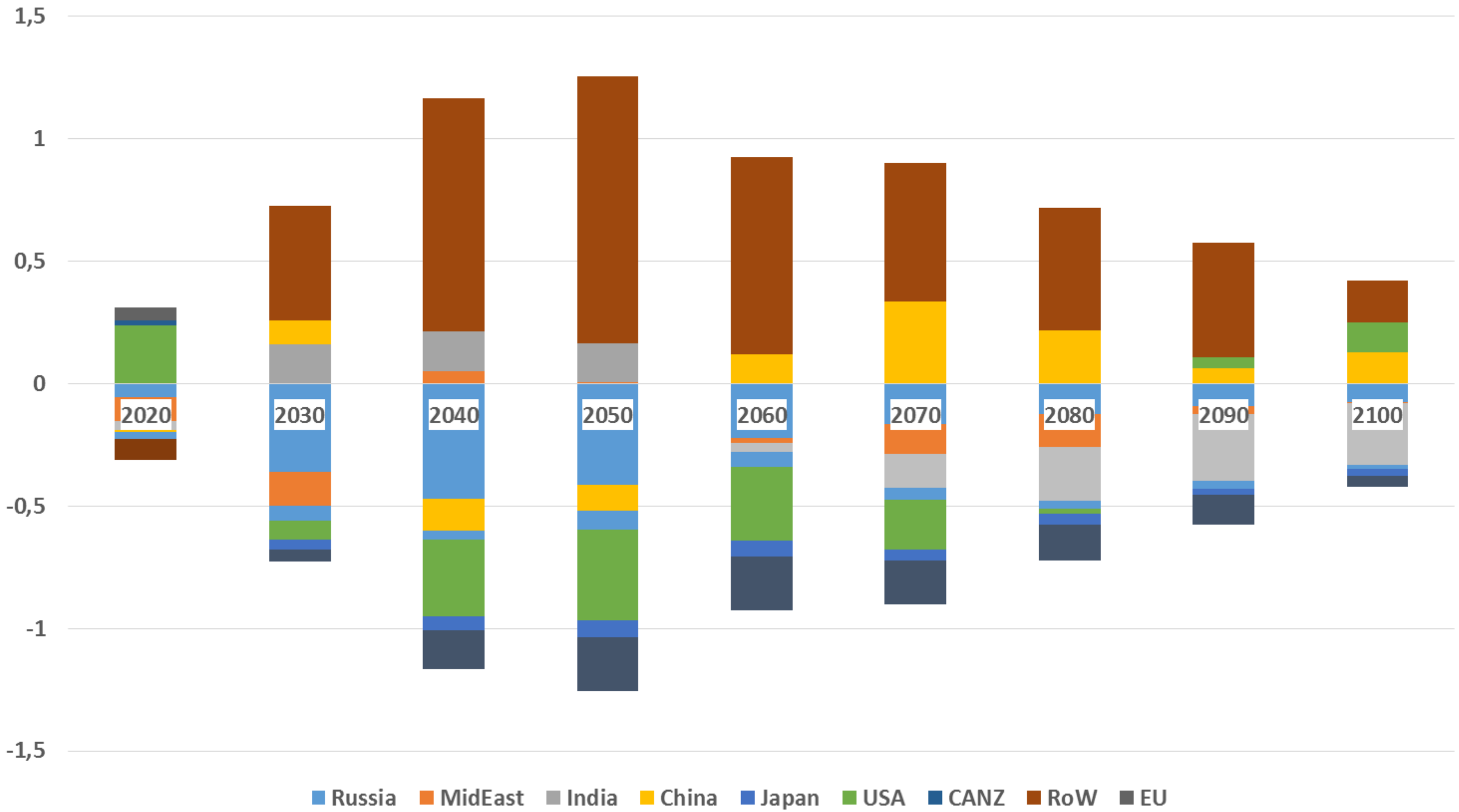
Emission per capita and year by region

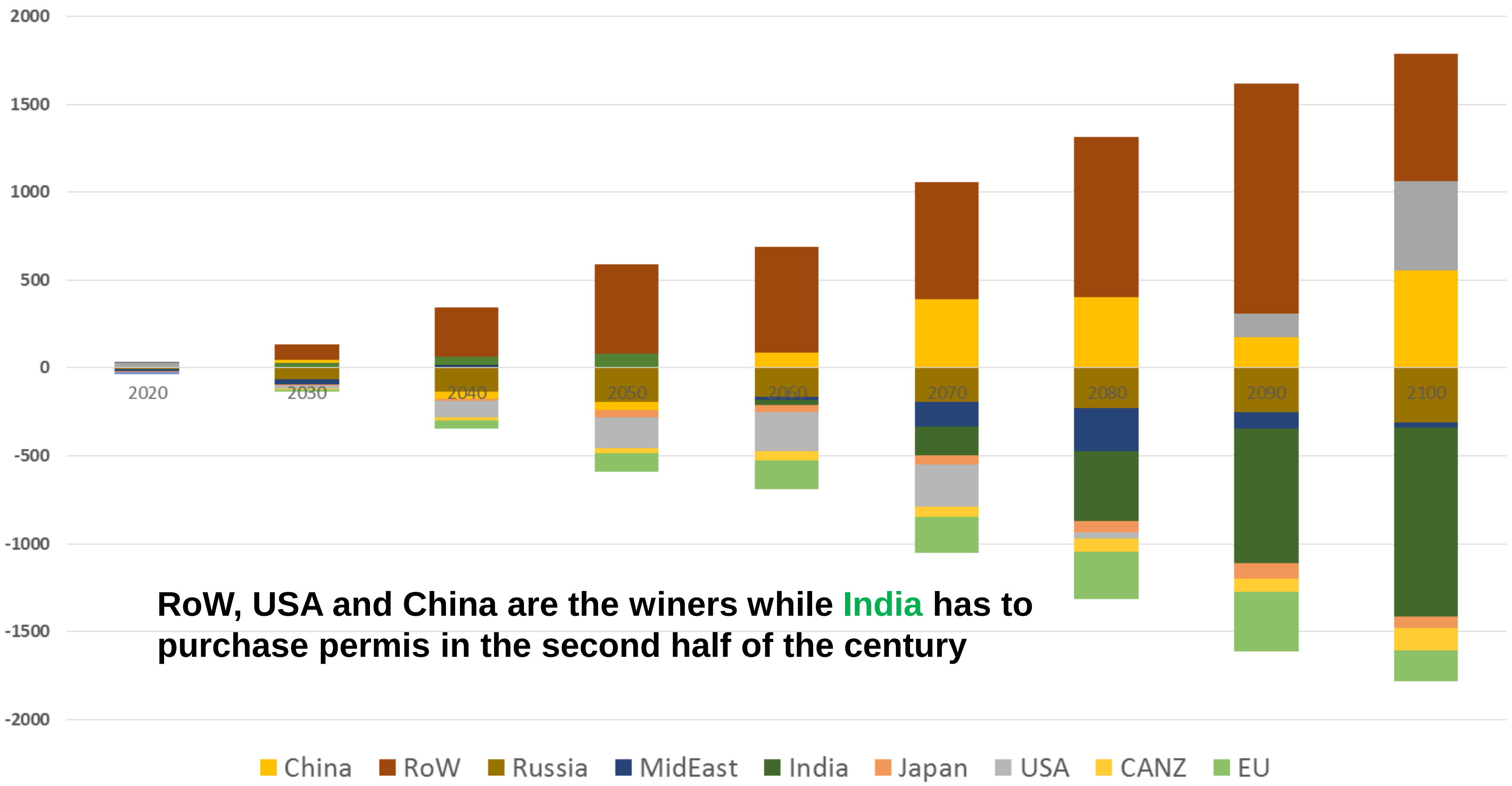
from grandfathering to equalitarian; Case 2 °C, with 50% chances



Balance of Permits (GtC/yr) Imports (negative) and Exports (Positive)



Transfers across regions for permit trade in billion US $; Equalitarian



RoW, USA and China are the winers while India has to purchase permis in the second half of the century

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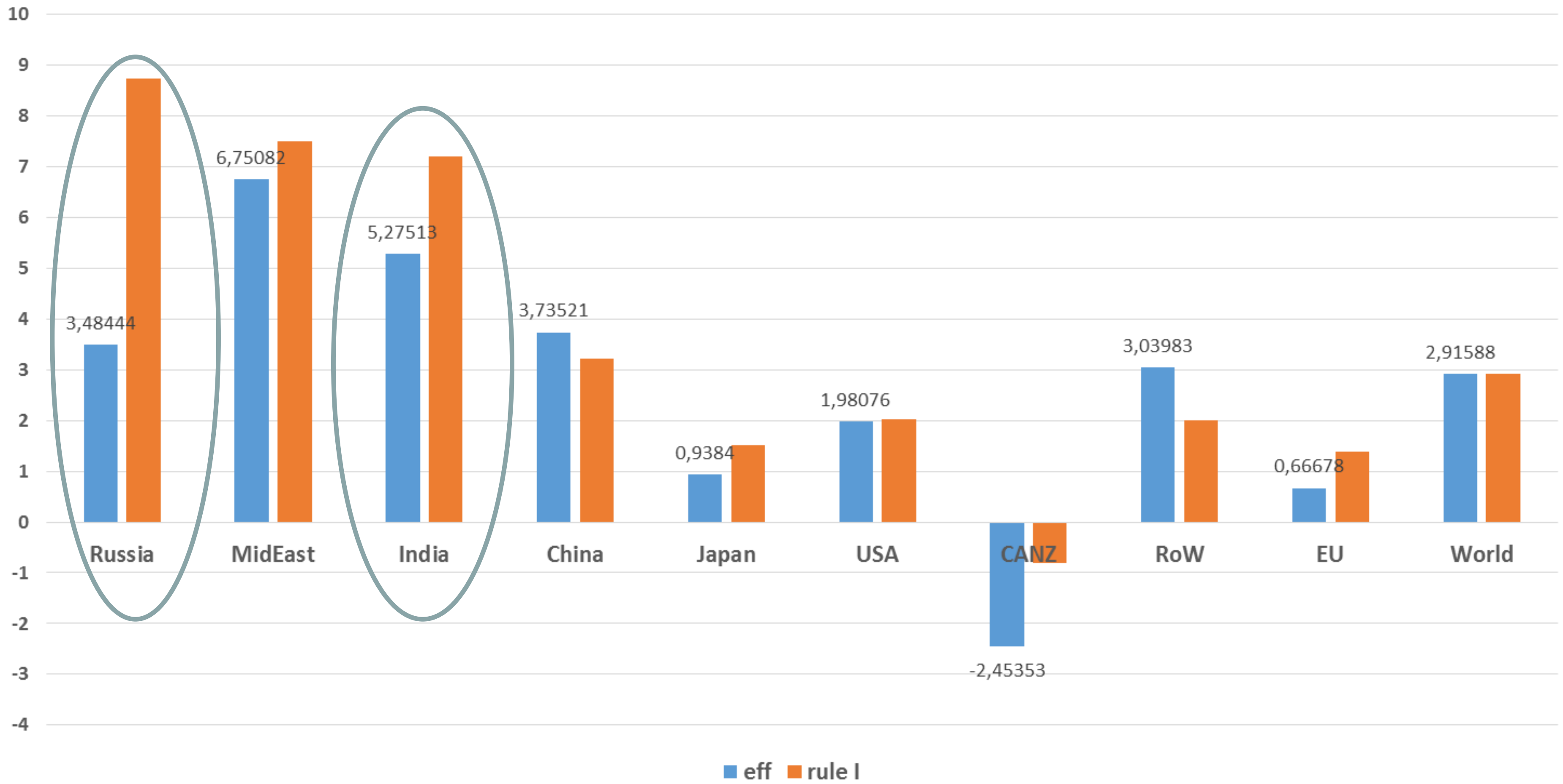
Regional GDP losses relative to BAU in % for the efficient and the equalitarian case; 2 °C with 50% probability



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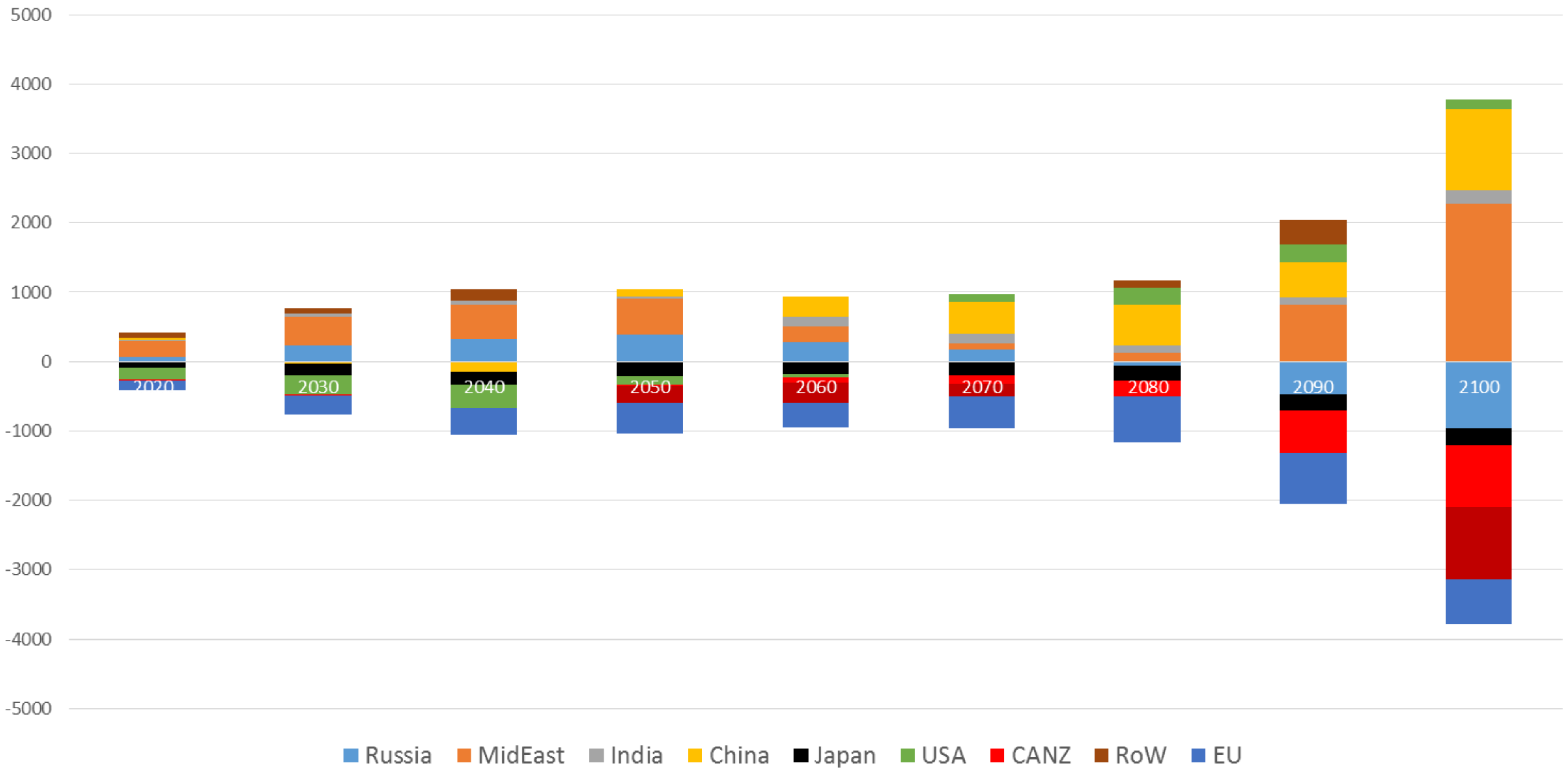
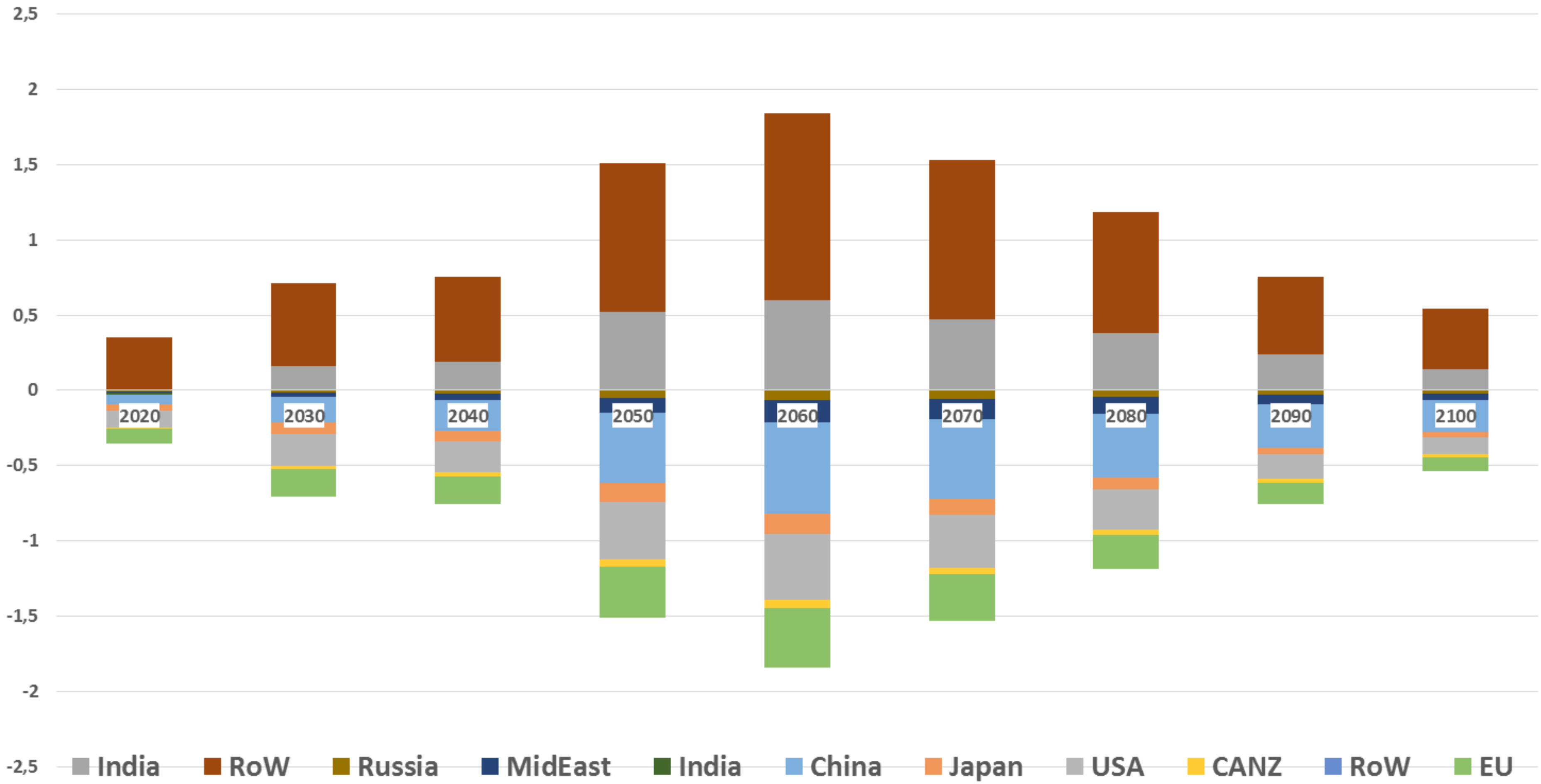
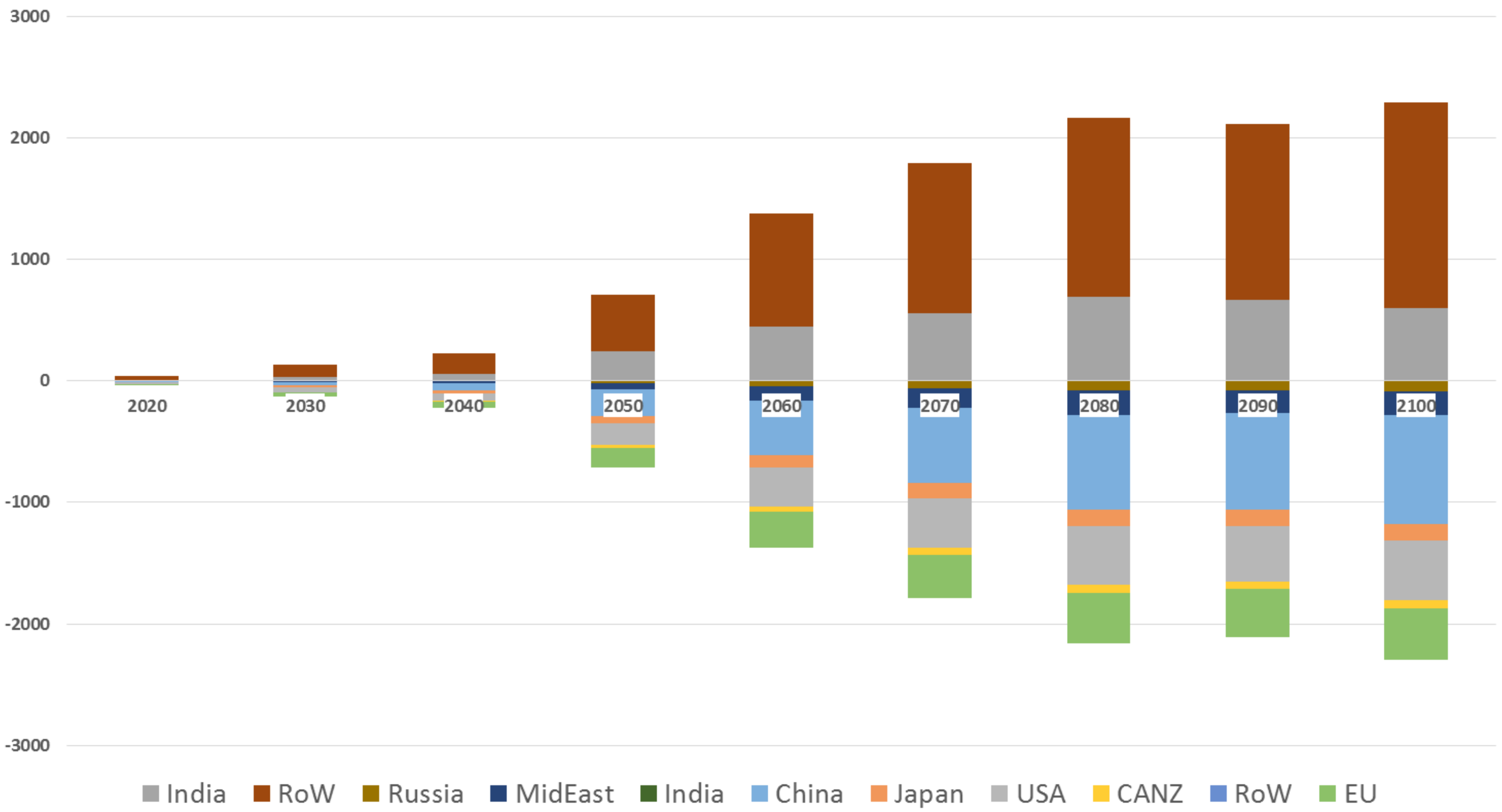
Capital transfers due to trade of permits in billion $/yr; Equal relative energy costs; Case 2 °C with 50%



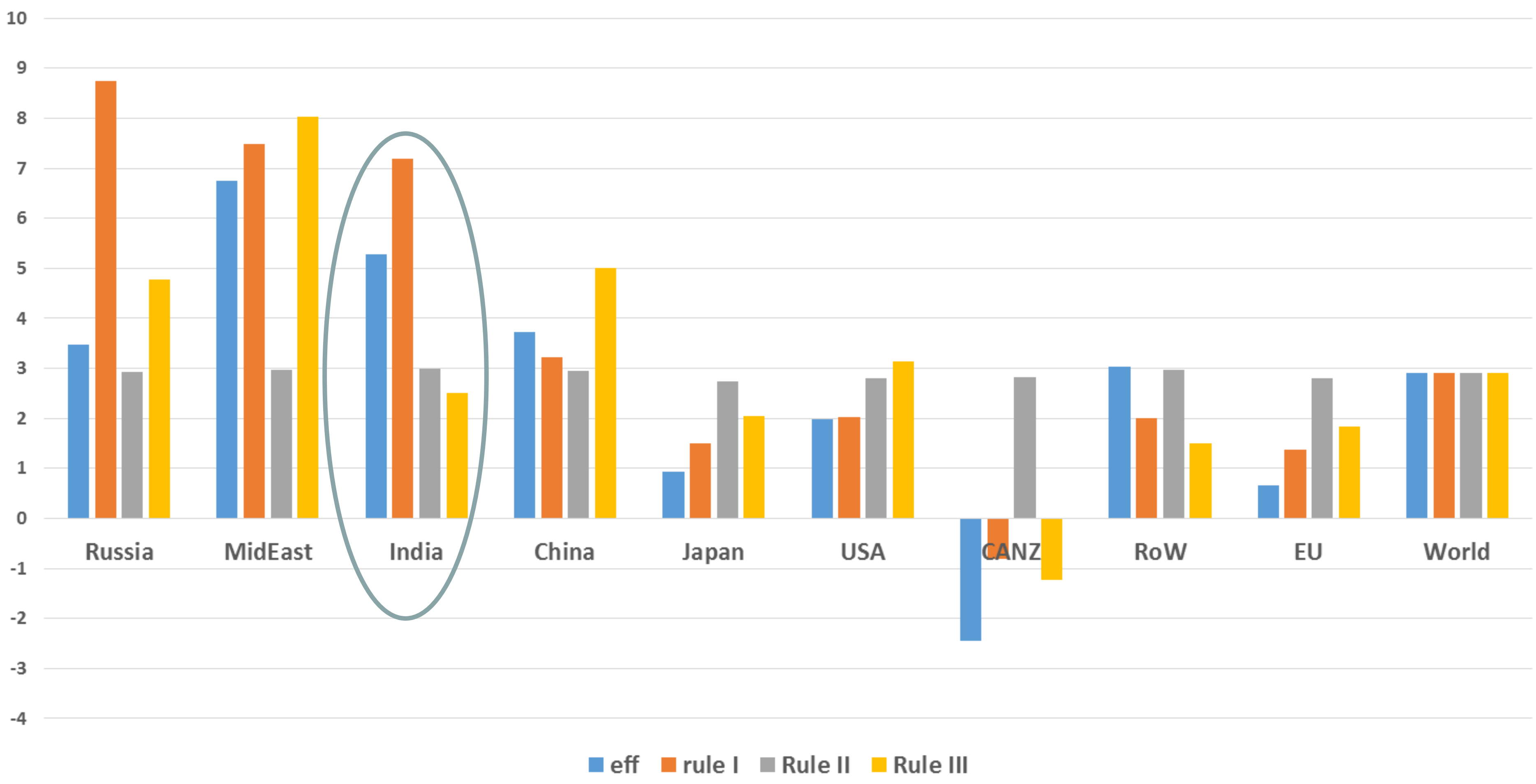
Permits trade in GtC/yr; Full compensation of the EC for India & RoW; Case 2 °C 50%



Transfers due to trade of permits in billion $/yr for RoW and India; Case 2 °C with 50% probability



Cumulative GDP losses for different BS rules net of permits-trade in %;

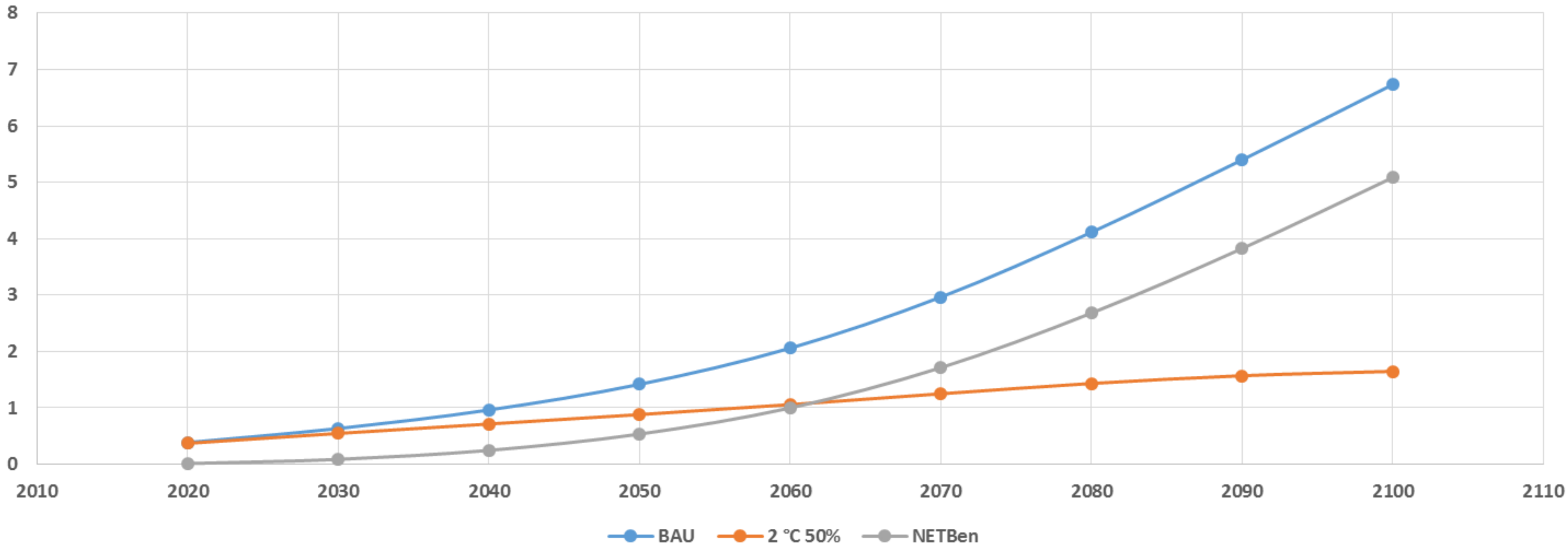


Climate Damages and net-benefits are simulated and defined as percentage of GDP-BAU

$$ELF_{rt} \cong [1-(\Delta T_t / \Delta T_{catt})^{2.5}]^{hst} \text{ Economic Loss factor}$$

$$NMD_{rt} = (1 - ELF_{rt}) \cdot C_{rt}$$

$$MD_{rt} = param_{rt} \cdot \left(\frac{\Delta T_t}{2.5} \right) \cdot GDP_{rt}$$



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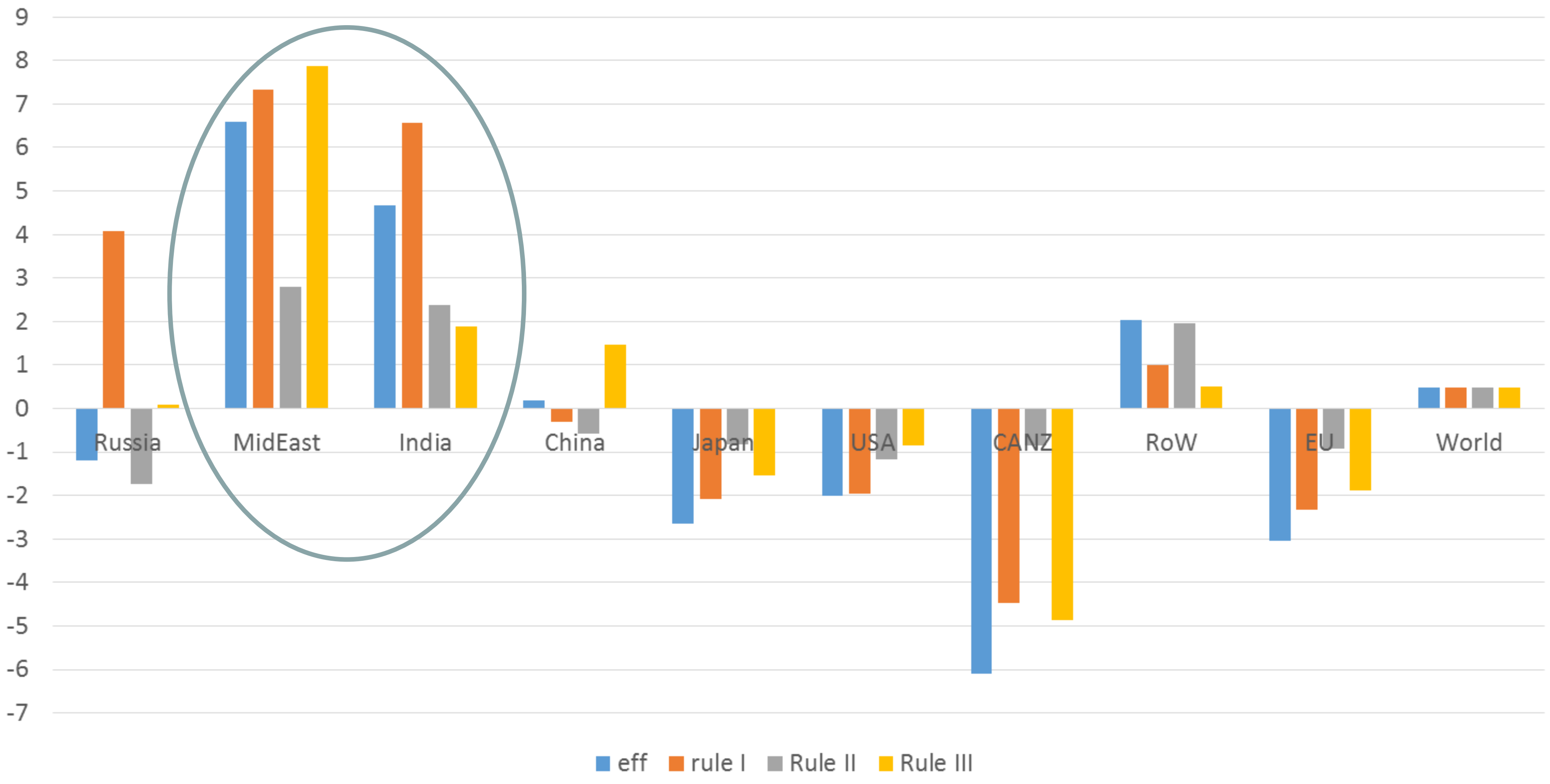
Cumulative GDP losses for different BS rules net of permits-trade and mitigation benefit in %;



Overall Conclusions

- Key technologies for power generation are wind, solar PV and BECCS, while production for synfuel and H_2 is based on coal and gas with CCS
- The environmental goal of 2 °C is feasible but practically impossible to be obtained as the estimated marginal cost are around 2000 - 6000 $/t C at the end of the century
- The CBA case with HWP and 1% utility discount rates gives C-prices below 150 $t/C but it never satisfies the 2 °C target
- The scenarios assume already optimistic technology development and availability; but much more must be done in terms of technology R&D&D;
- The 2 °C with 50% probability gives 2.9% GDP losses that could be reduced by 2 p.p. if the benefits of improved global climate and reduced LAP are considered;

Perhaps Direct Air Capture & Removal (DAC) should be included in the portfolio of options to get lower marginal costs of carbon control

(Keith D., Climate strategy with CO_2 capture from the air; Climatic Change (2006) 74: 17–45)

BS Arrangements must be flexible e.g., short in duration, re-evaluated and re-defined with time

- The equalitarian rule (and probably the Brazilian one) is not in favor of all LDCs;
- Attractive BS rules would be either equal EC losses or full compensation for LDCs.
- Although the extra efforts undertaken by the industrialized world could be promising there are always regions with very disatisfactory results as e.g, the Middle-East.
- SOME SENSITIVITIES:

a) 2° C with 66% instead of 50% probability	means	0.6 pp more losses
b) 2.5 °C instead of 2°C	means	0.6 pp cost reduction
c) Extra cost when paying for India and RoW	means	+1 pp for OECD & CHINA

d) Regional GDP losses are higher than the global average (+7% for Middle-East)

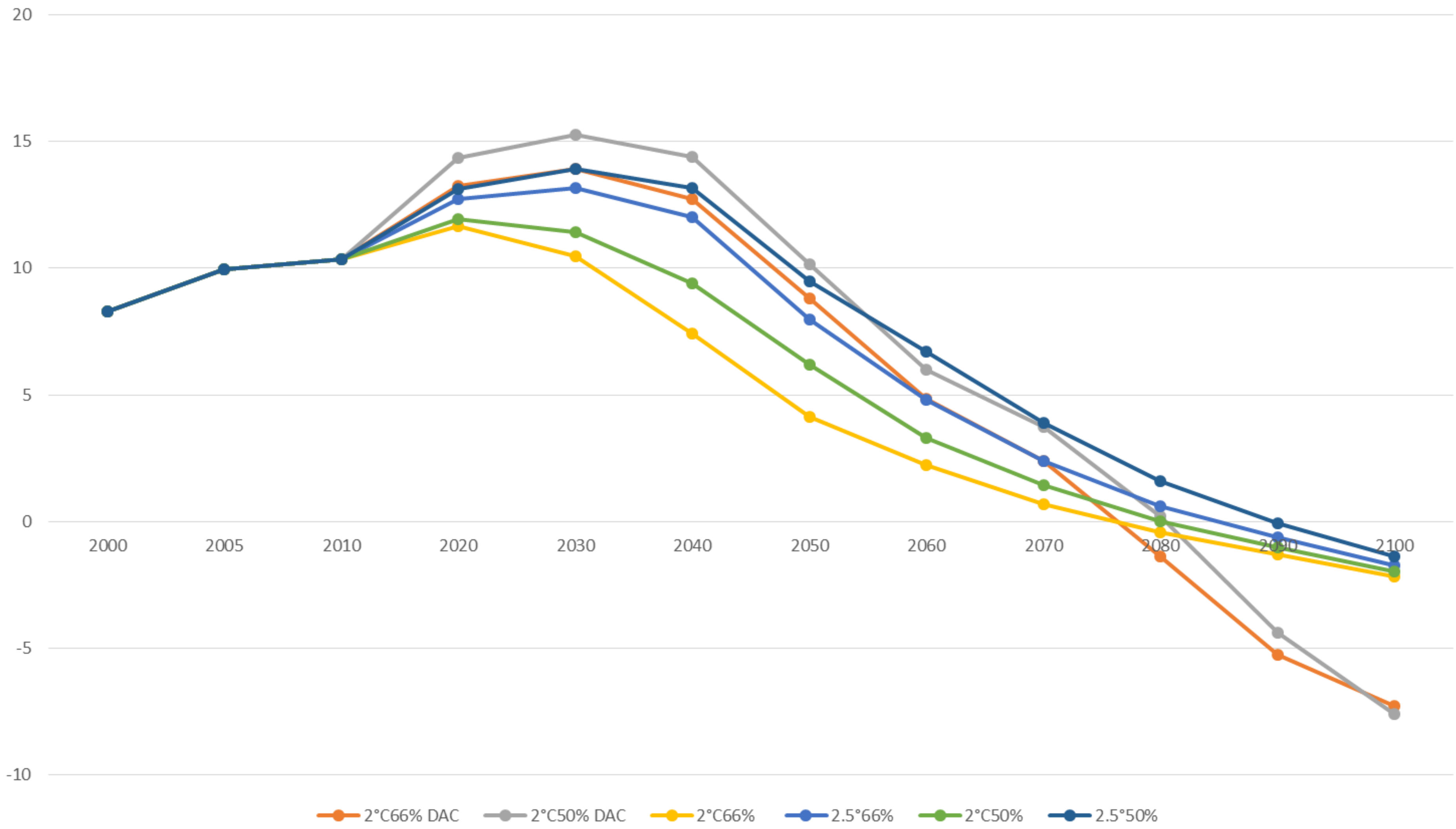
Negative Emissions Options in MERGE: BECCS & DAC

Until now only BECCS are considered (about 190 EJ/yr no DAC)
But now: BECCS + DAC (“unlimited” global storage capacity 2000 Gt CO2)

DAC technology Data (APS, 2011) (rather conservative) :
Annualized capital cost plus O&M $500/tCO2-removed and
8.1 GJ /tCO2 is used as fuel input (e.g., gas or oil)
and 0.5 MWh/tCO2 is needed as electricity input

APS, June, 2011: Direct Air Capture of CO2 with Chemicals. A Technology Assessment for the APS Panel on Public Affairs

GHGs emissions in GtCe/yr
with Direct Atmospheric Capture (DAC)



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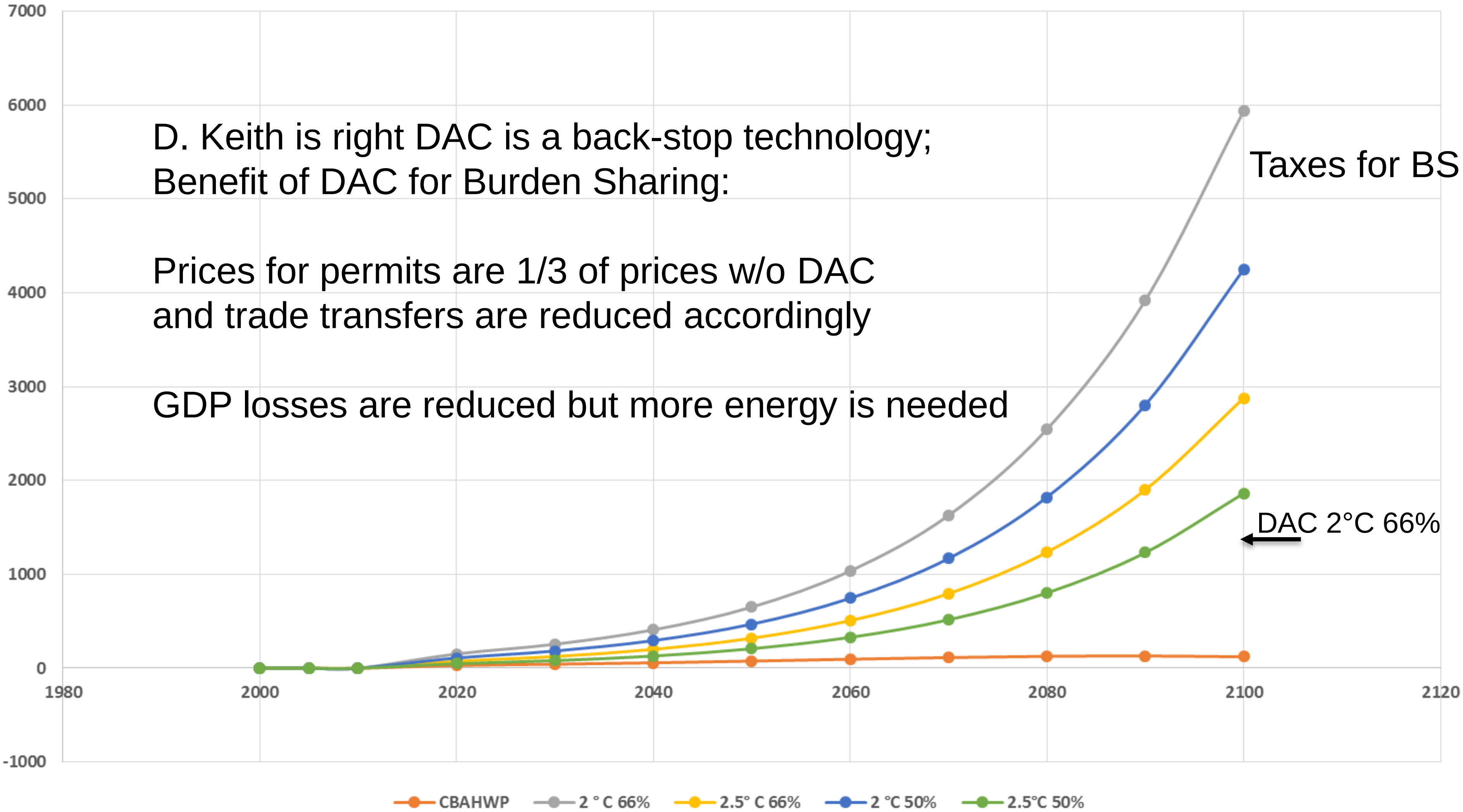
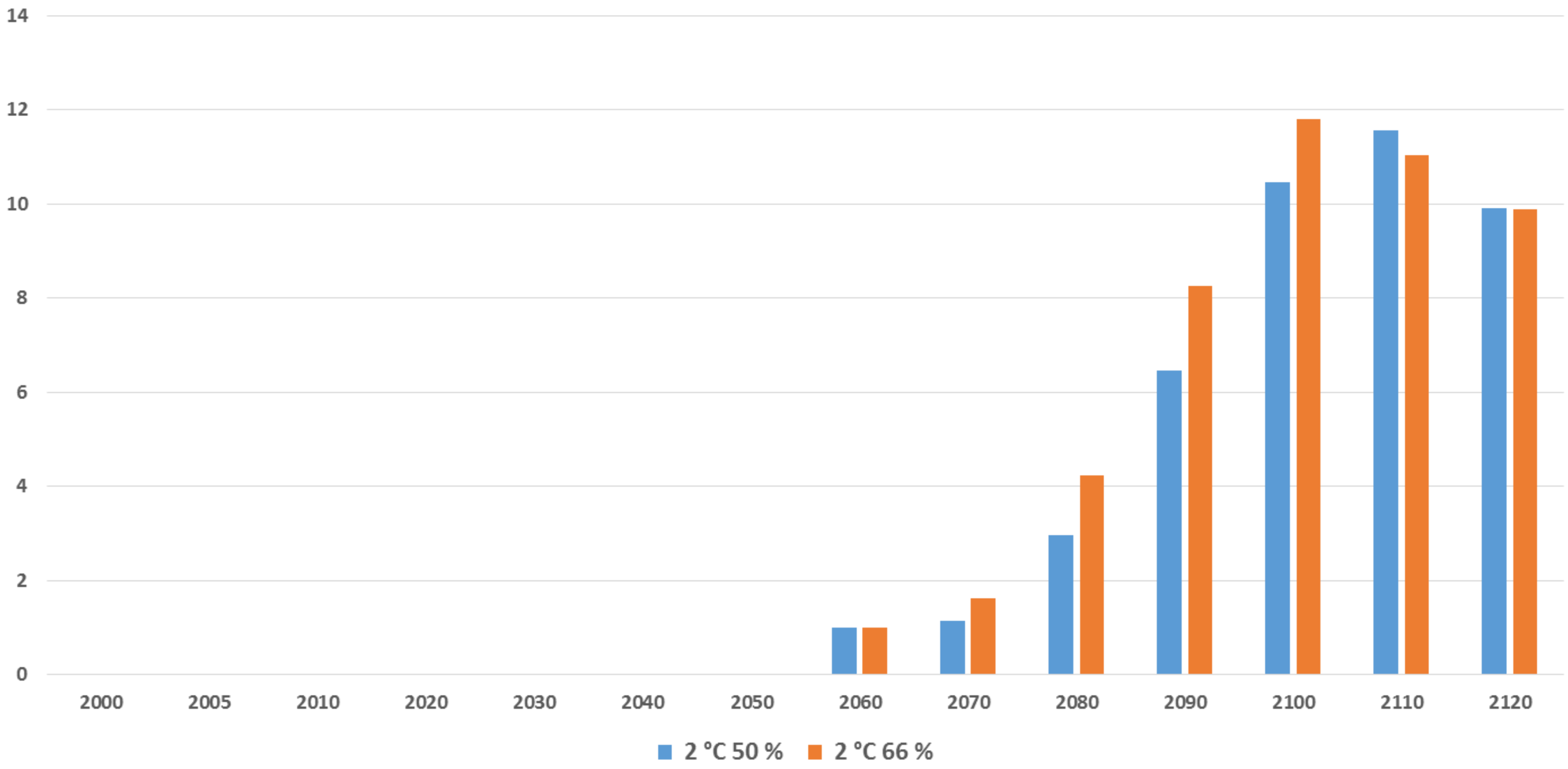
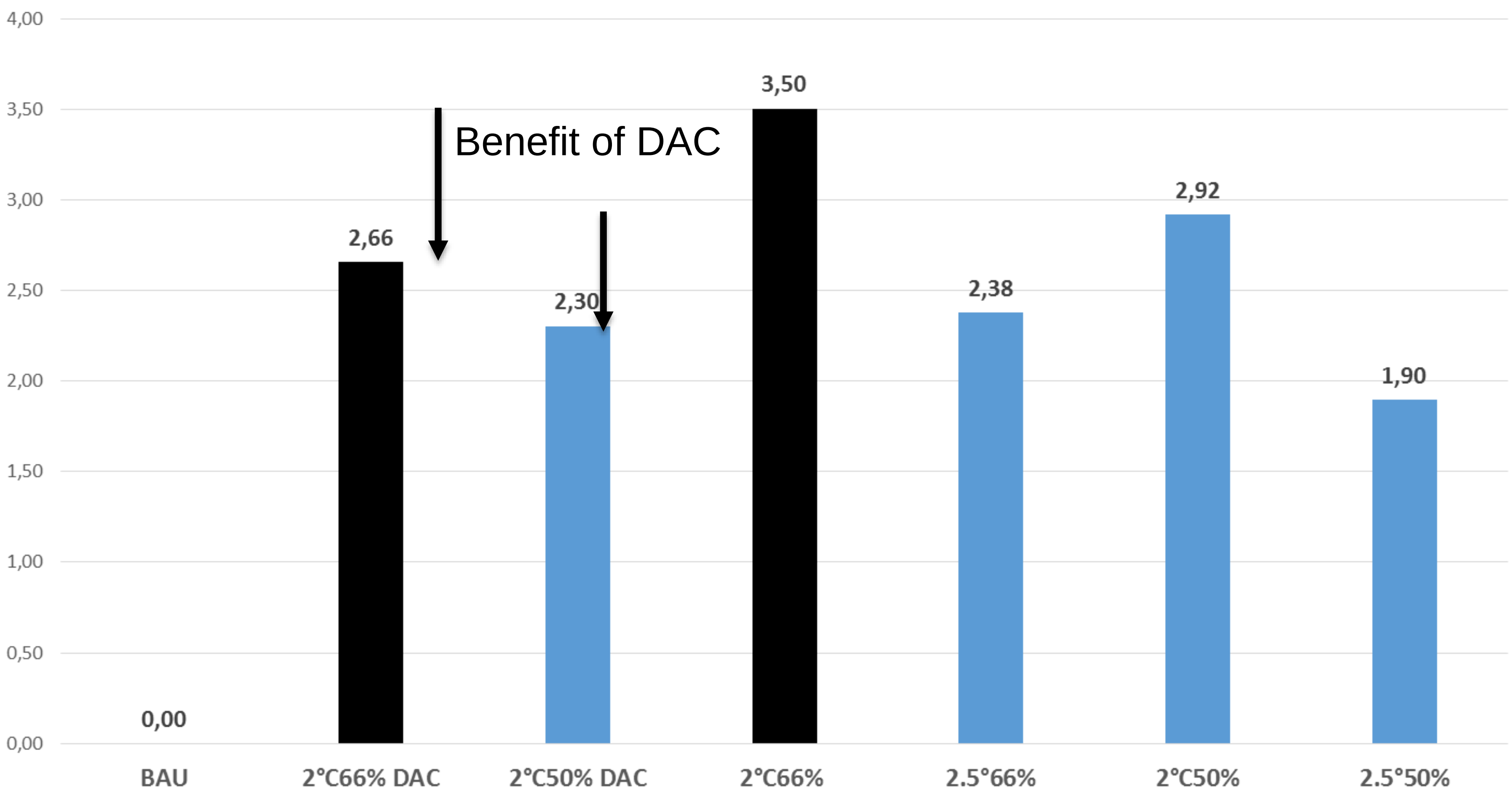
Marginal cost $/t C



Direct Air Capture (DAC) in Gt C/yr



GDP losses relative to BaU (%)



Primary by Fuel w/o and with DAC (2100)