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Socrates Kypreos[1], Adriana Marcucci[2], Evangelos Panos[1]

[1] Energy Economics Group – Laboratory for Energy Systems Analysis, PSI Villigen

[2] Chair of Economics/Resource Economics, ETH Zurich

Is Direct Atmospheric Capture the needed backstop technology for decarbonising the global energy system, or does it just complement BECCS?

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Overarching questions

- What is the least policy cost for the 2^{o}C target and its regional distribution?
- How does this cost change if policy target were to be 2.5^{o}C instead of 2^{o}C?
- What is the role of Direct Air Capture (DAC) technology in climate stabilisation?
- Is DAC a backstop technology or does it just complement BECCS?
- What is the extra financial burden for the industrialised countries to convince Developing Countries for a global protocol in 2020?

Assessing the research questions - Outline

- Methodology:
  - the MERGE-ETL model
  - emission reduction scenarios

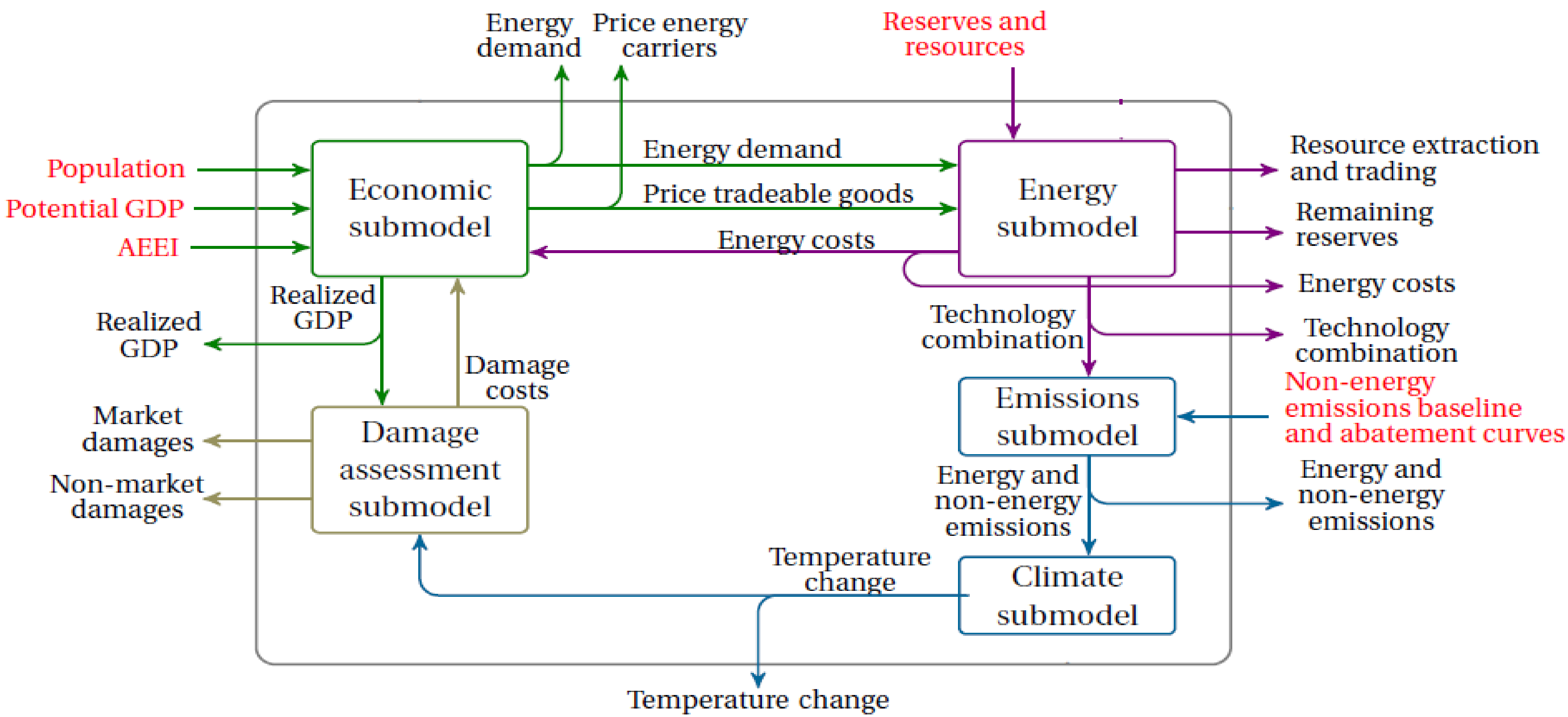
- Direct Atmospheric Capture (DAC):
  - technical and economic assumptions
  - impact of DAC on emissions and on shadow prices
  - regional penetration of DAC
  - impact of DAC on primary energy consumption
  - GDP losses with and without DAC

- Burden sharing schemes with DAC available:
  - Resource-sharing (equalitarian), effort sharing (equal GDP losses)
  - Full compensation of energy costs for DCs

- Conclusions

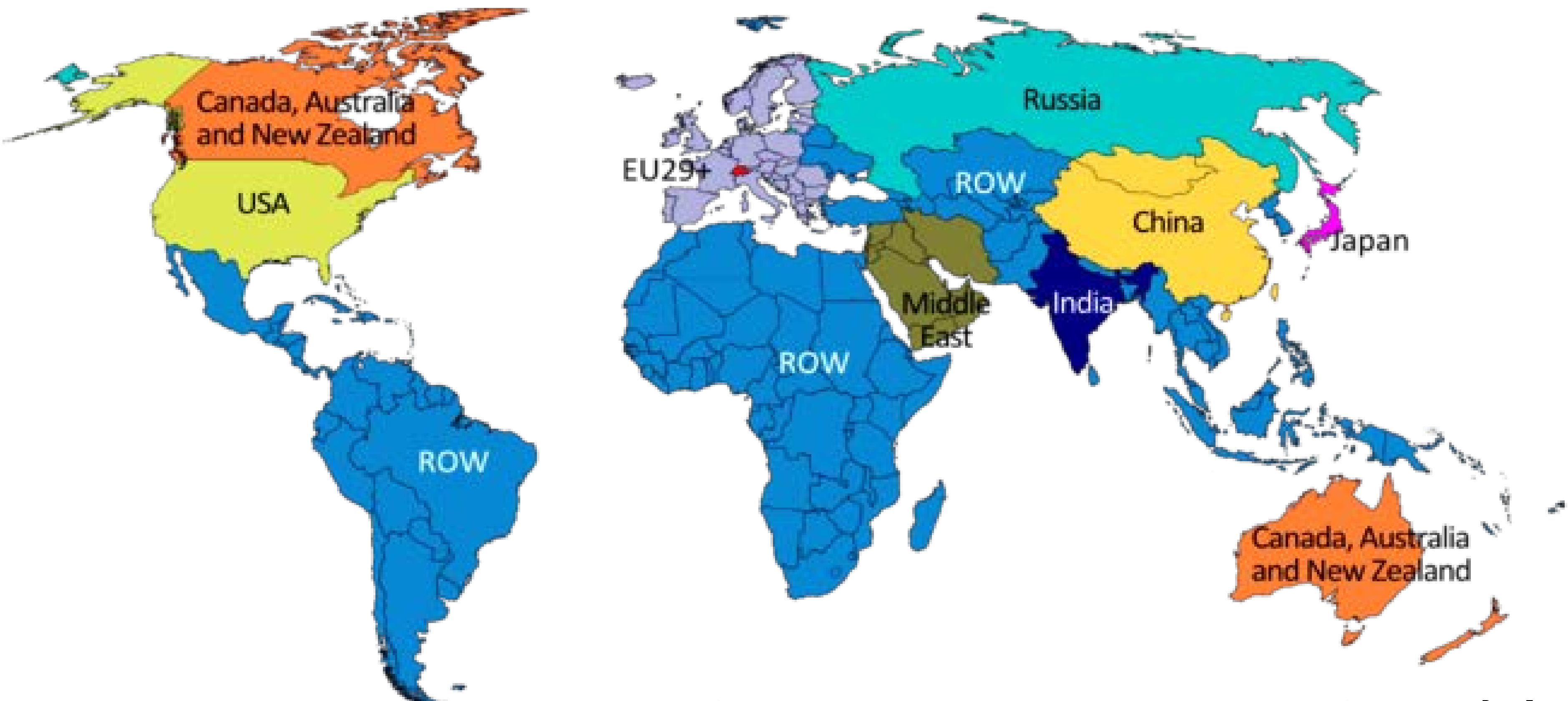
The MERGE-ETL model: structure

- Integrated Assessment Model maximising the global social welfare
- Bottom up description of the energy system with Endogenous Technology Learning
- Top down description of the economy (Ramsey-type)
- Simple climate cycle sub-model with optional damage function
- International trade of goods and resources



The MERGE-ETL model: structure

10 world regions with Negishi-weighted regional utility functions:
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); Rest of the World (ROW)



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GHG emission reduction scenarios

Full participation of all countries after 2020.

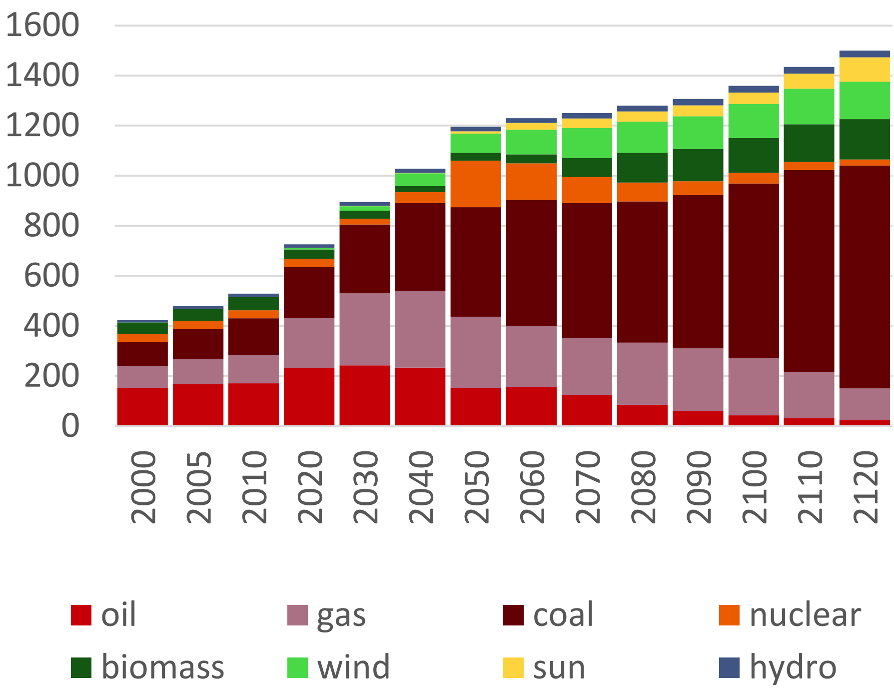
Acronym	**Description**	**REQ[1] constraint for 2020-2010:**
BaU	Business as Usual	No targets
2.5 DC 50	2.5^{o}C with 50% probability	645 Gt C
2.5 DC 66	2.5^{o}C with 66% probability	540 Gt C
2 DC 50	2^{o}C with 50% probability	390 Gt C
2 DC 66	2^{o}C with 66% probability	305 Gt C
2 DC 50 DAC	2^{o}C with 50% prob. and DAC technology available	Same REQ constraint as the corresponding emission reduction scenarios without DAC
2DC 66 DAC	2^{o}C with 66% prob. and DAC technology available	

[1] *Remaining Emission Quotas after 2020 for staying below the indicated post-industrial mean atmospheric warming and the corresponding probability: source IPPC AR5 WG3 and own estimations based on model runs*

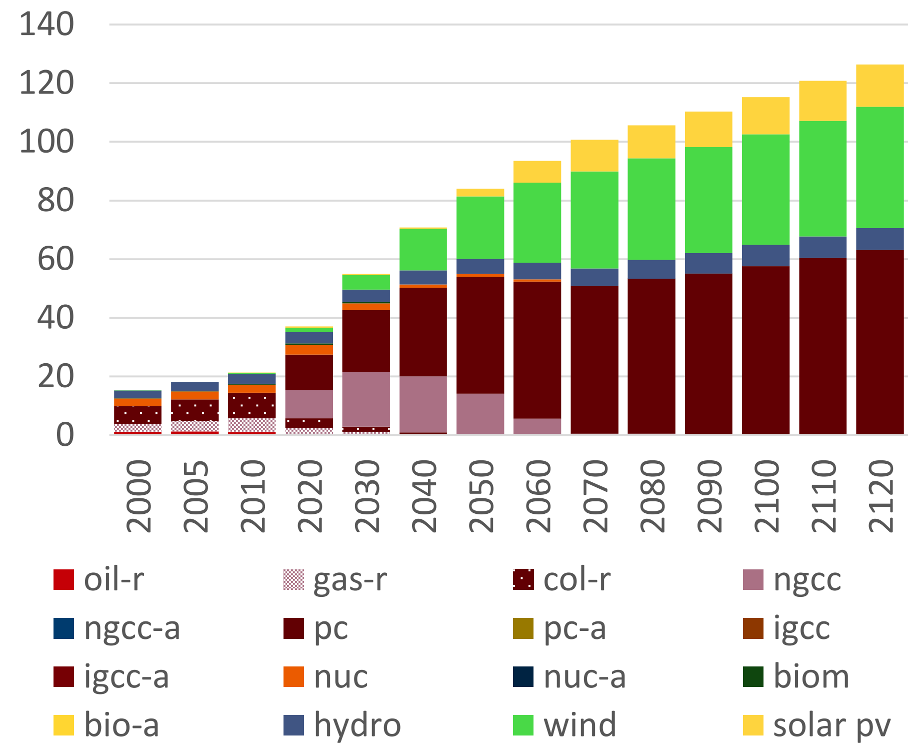
BaU scenario

- Based on IIASA B2 scenario for reference GDP, pop growth and adjustment of AEEI
- No carbon control policies other than some voluntary pledges of limited range
- Fossil based energy system, with renewables penetrating after 2050

Primary energy by fuel (EJ/yr)



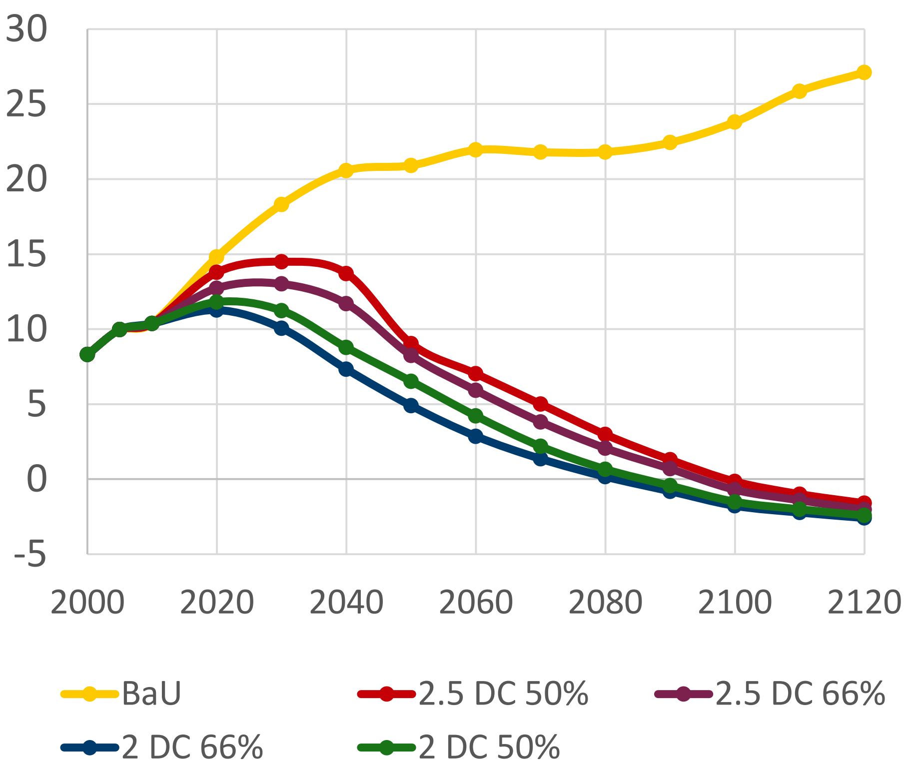
Power generation by tech. (PWh/yr)



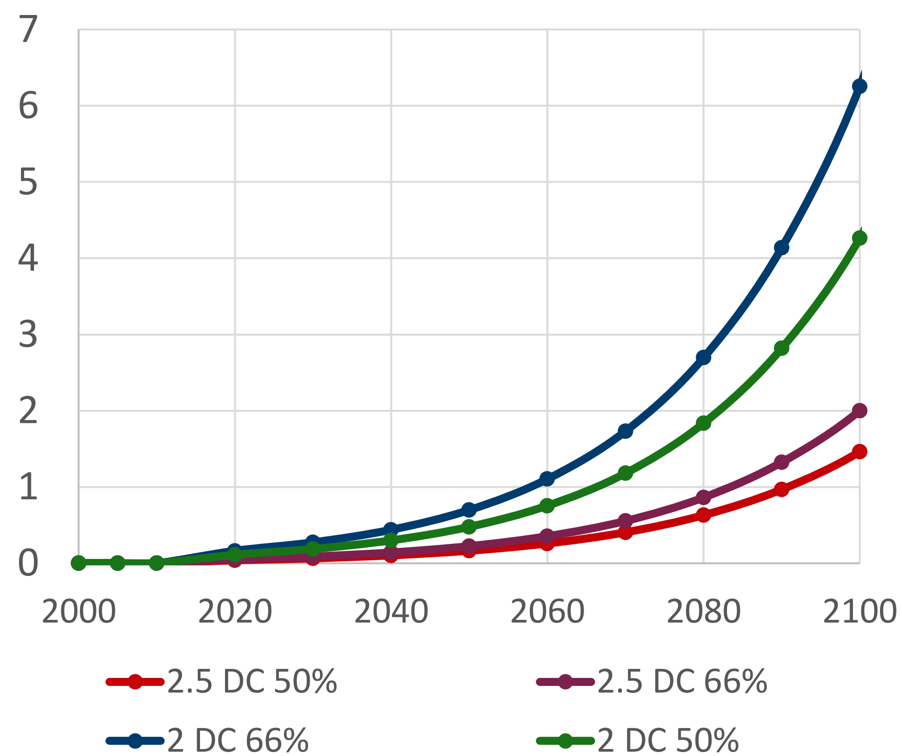
CO_2-eq emissions and prices without DAC

- In BAU emissions reach levels of 24 – 27 Gt C_e over the period of 2100 – 2120
- In carbon control scenarios emissions peak at around 2020 – 2030 and then go negative
- Significant reduction in shadow prices for the 2.5°C case compared to 2°C case

CO_2-eq emissions in GtC/yr



Marginal cost in thousand USD per ton C



Implementation of DAC technology

	APS estimates[1]:	Floor values[2]:
Annualised capital cost:	\$350/tCO_2 captured	\$115/tCO_2 captured
Annual O&M cost:	\$120/tCO_2 captured	\$40/tCO_2 captured
Heat consumption:	8.1 GJ/tCO_2 captured	5.0 GJ/tCO_2 captured
Electricity input:	0.5MWh/tCO_2 captured	0.5MWh/tCO_2 captured

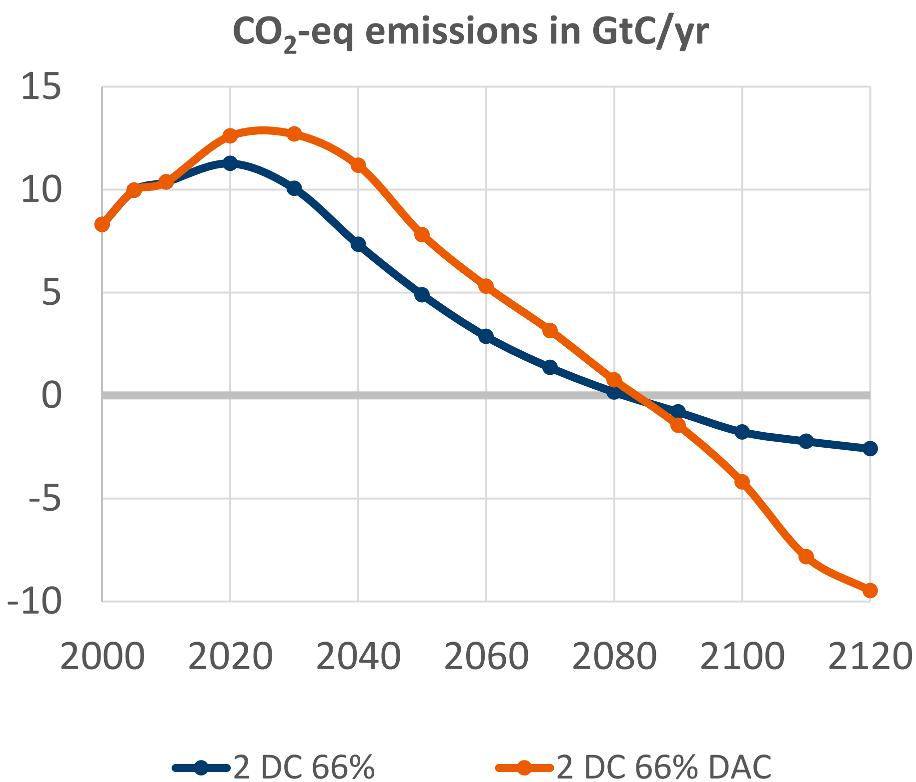
- Learning by doing and learning by research (learning rate 10%)
- Built next to the disposal facilities of pressurised CO_2
- Available from 2060 with maximum deployment rate 7.5% per year

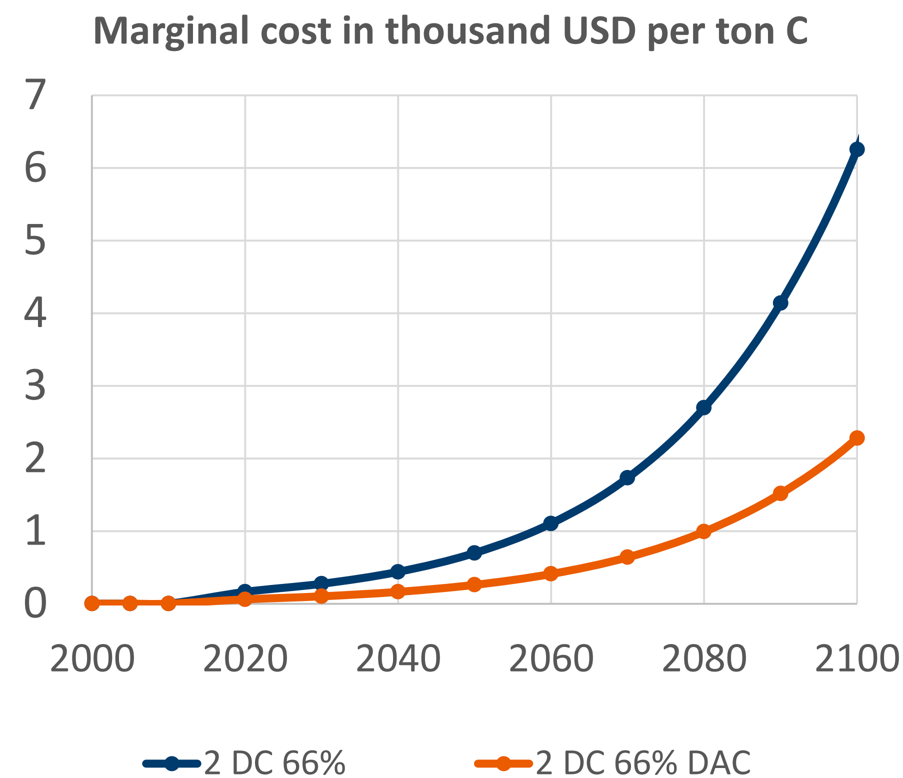
[1] *Direct Air Capture of CO2 with Chemicals. A Technology Assessment for the APS Panel on Public Affairs, APS, June, 2011*

[2] *From literature e.g. Zeman (2007), Lackner (2012), Keith (2009), Baciocchi (2006),etc. and own estimates*

Impact of DAC in CO2 emissions and prices

- When DAC options are available there is reduced mitigation with late compensation:
  – higher emissions in 2020 – 2030 → stringent reduction rates at the end of horizon
- Significant reduction in CO_2 shadow prices compared to non-DAC scenarios
  – Initially due to lower mitigation effort, after 2060 due to DAC deployment





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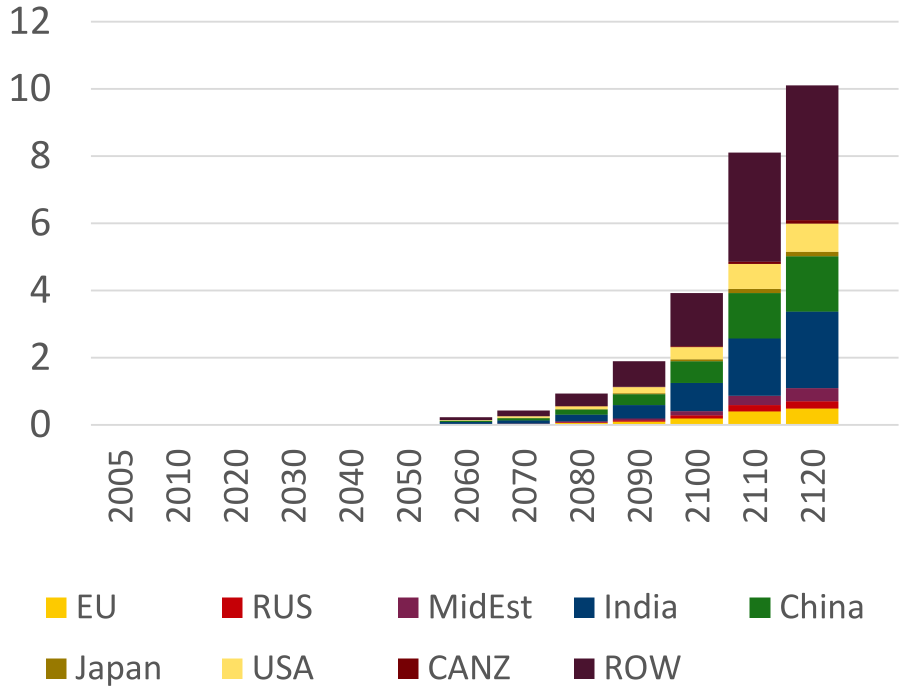
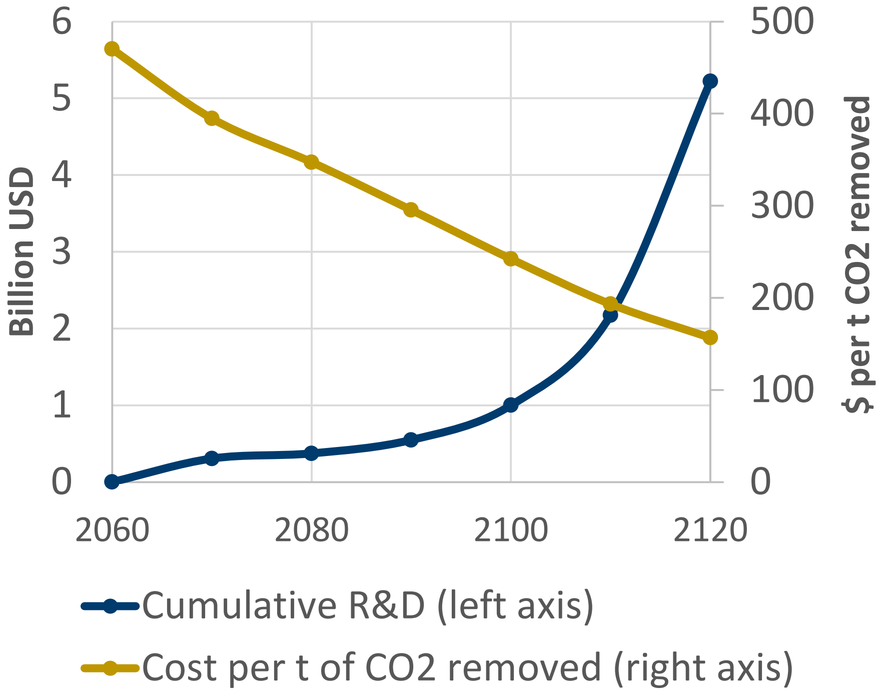
Penetration of DAC technology

- Conservative penetration of DAC indicating a complementary role to CCS
  – low-carbon options benefit also from the resulting carbon shadow prices
- Emerging economies and DCs show larger DAC deployment rates
  – large CO_2 storage availability & abundant energy resources for input to DAC facilities

GtC/yr removed via DAC by region
2 DC 66%

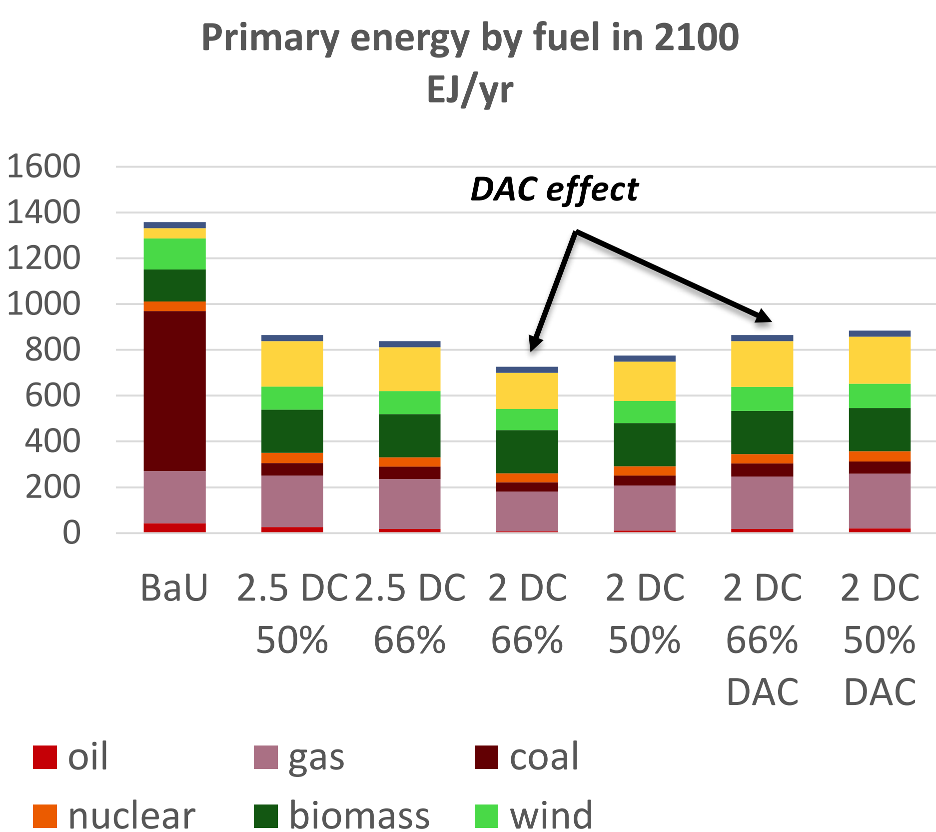


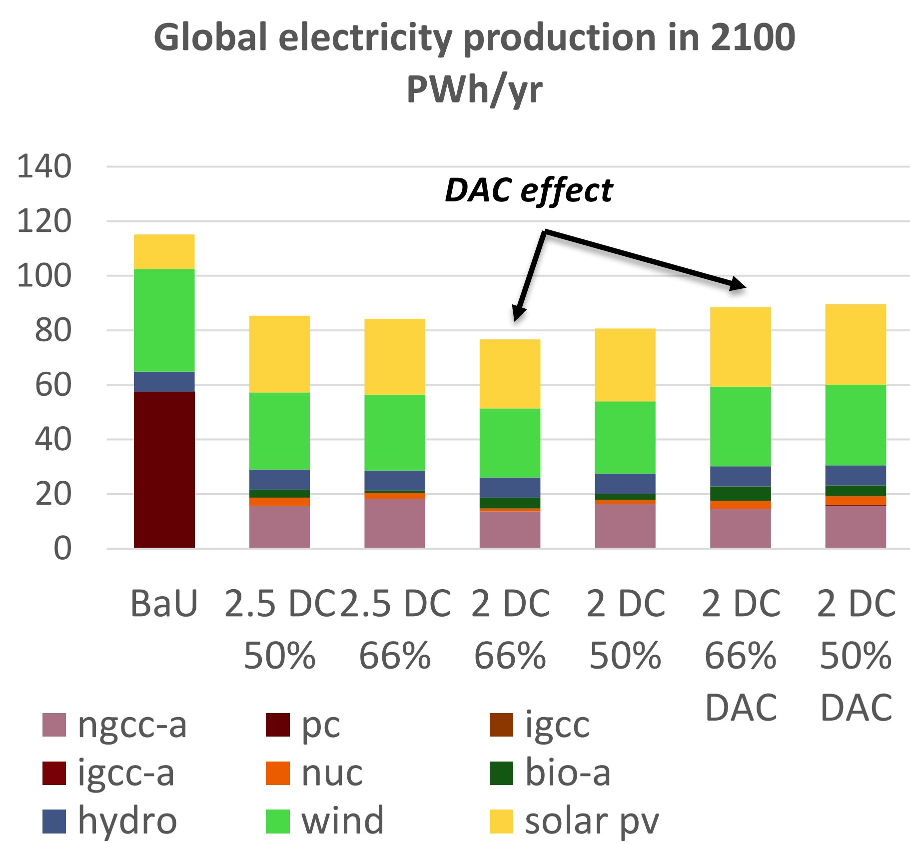
Effect of ETL in DAC cost reduction and penetration



Impact of DAC on primary energy consumption

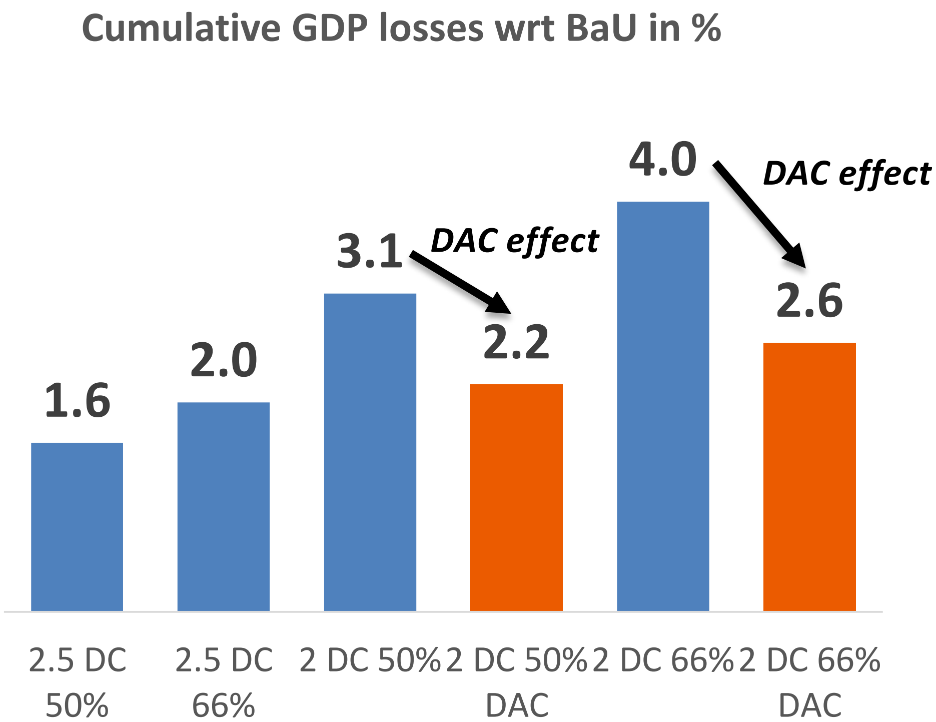
- 19 - 22% increase in primary energy consumption in case of DAC
- Heat needed for DAC is produced mostly from gas and oil
- Electricity needed for DAC is produced by renewables

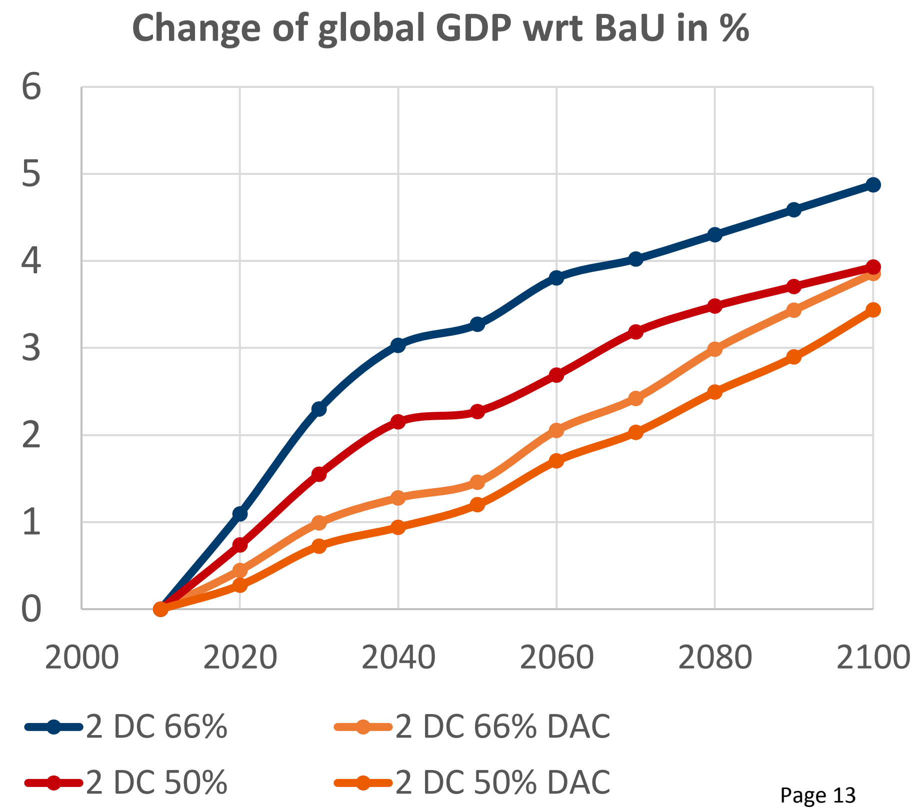




GDP losses with and without DAC, 2020-2100

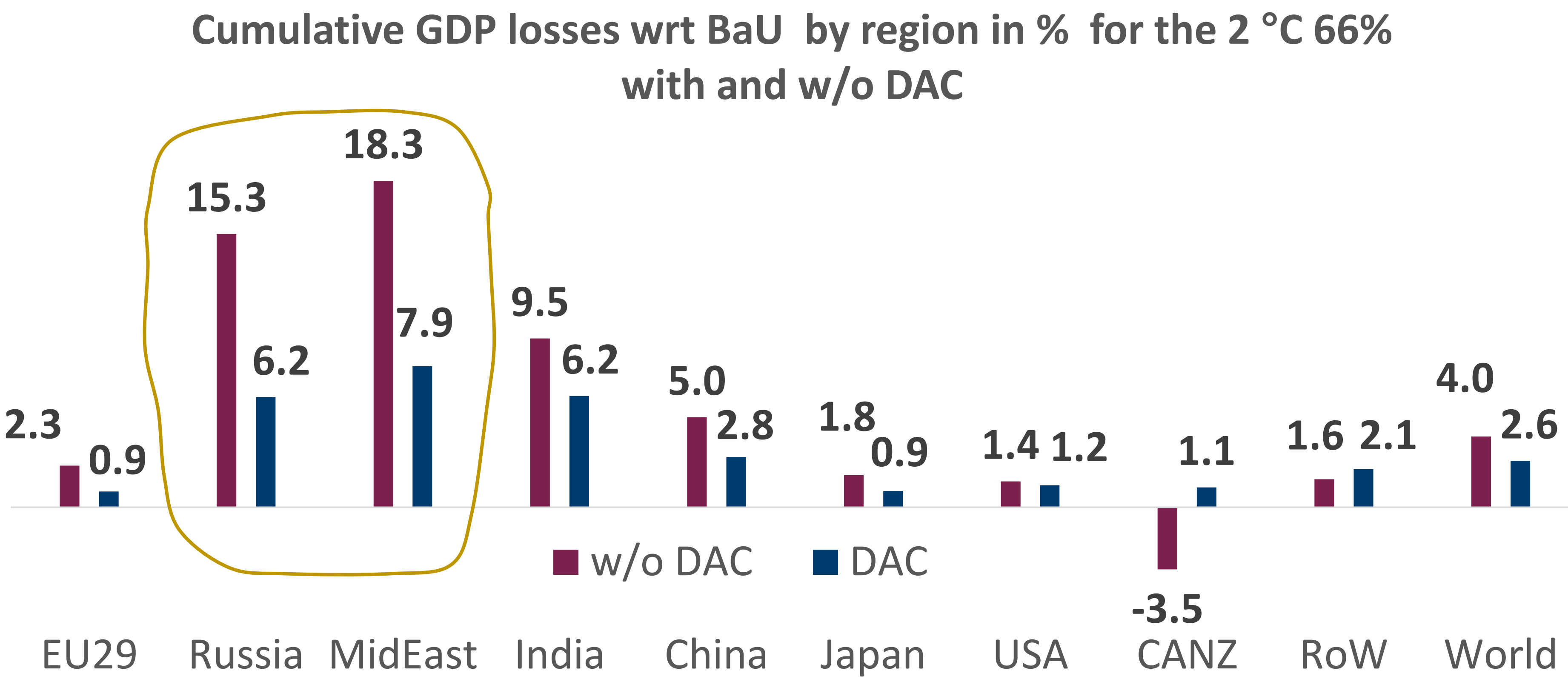
- Climate change mitigation effort varies 1.6 – 4.0% of the cumul. global GDP
- The 2.5°C target reduces global GDP losses by 50% compared to the 2°C case
- DAC reduces the total cumulative abatement cost by 30% - 35%
  – the differenece shrinks towards the end, due to more mitigation in the DAC case





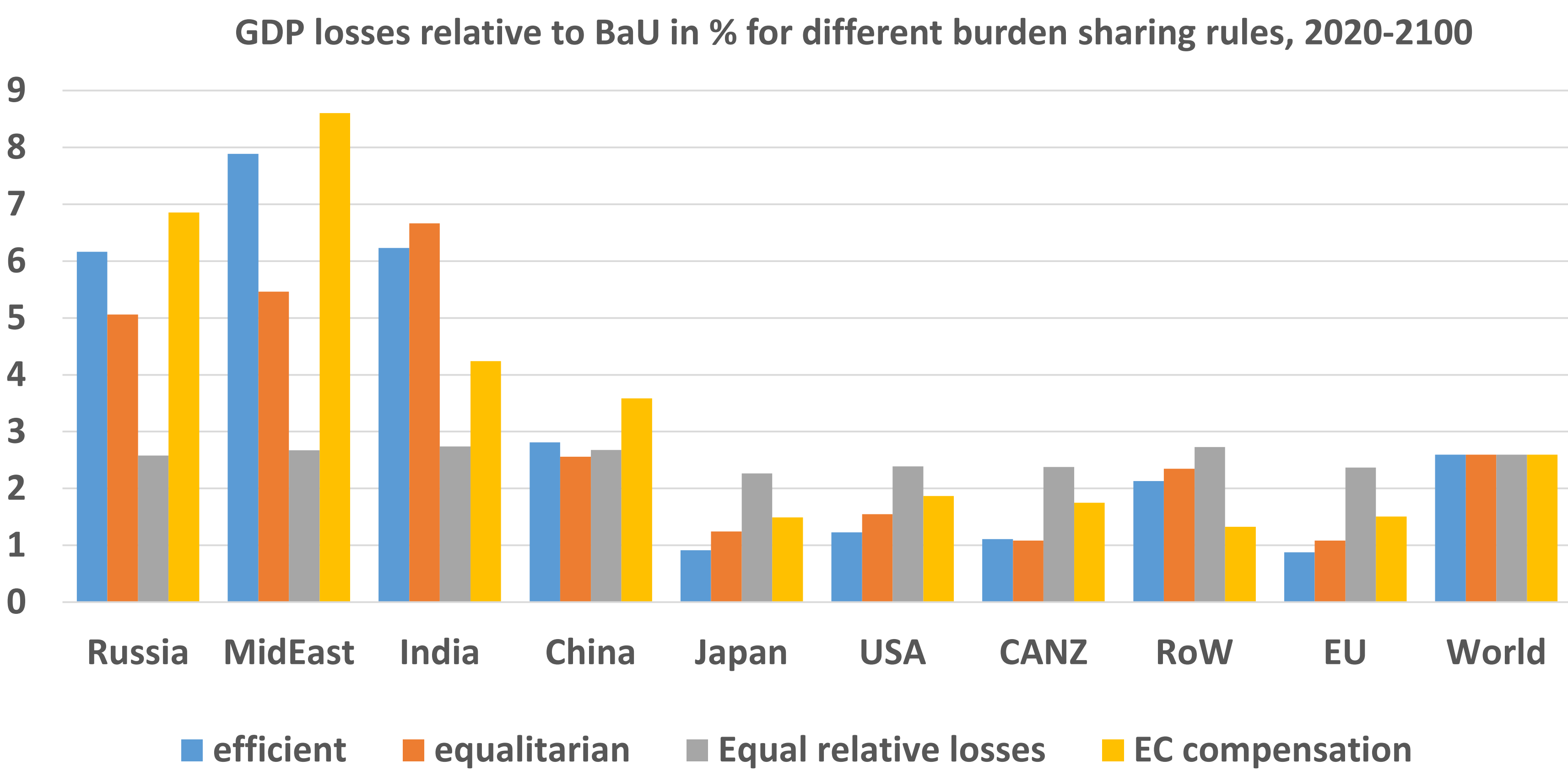
Impact of DAC on regional GDP losses, 2020-2100

- 35% reduction in global GDP losses in the 2°C with 66% probability case
- GDP losses for oil and gas producers reduce with DAC by 55% – 70%:
  – preservation of the value of oil and gas reserves
  – international oil and gas trade does not fall as in the case w/o DAC
  – gains from the carbon market (less imports of permits, some become exporters)



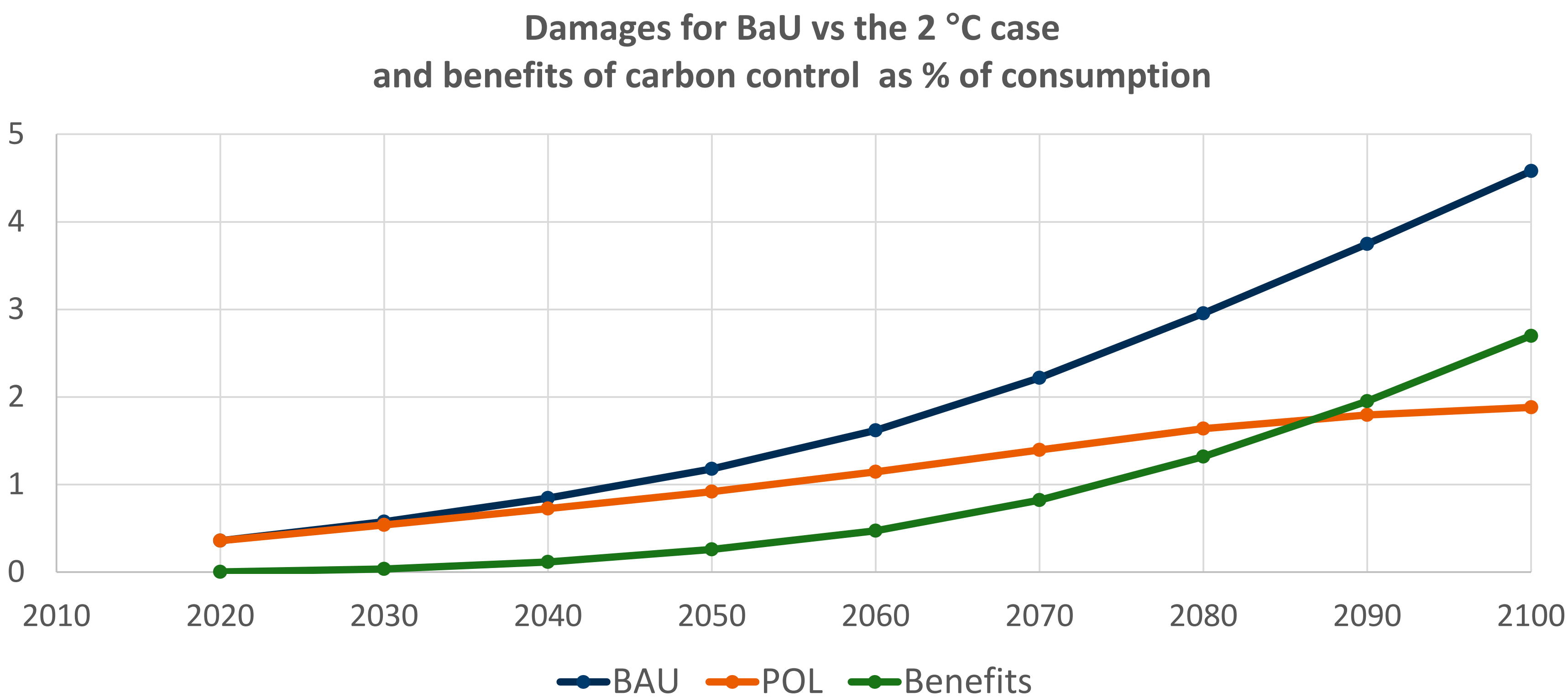
Burden sharing with DAC 2°C with 66% prob.

- Perfectly functioning carbon markets are assumed
- **Efficient rule →** *strong regional differences in GDP losses*
- **Equilitarian rule →** *picture is not changed for India and RoW (high population)*
- **Relative GDP losses →** *most balanced but industrialised countries pay higher costs*
- **Energy Cost compensation: →** *less expensive for the industrialised countries*



Damages due to climate change and benefits of emissions control

- Market damages are assumed to be proportional to temperature change
- Non market damages are assumed to be quadratic in temperature rise
- The avoided market and non-market damages become apparent in the 2nd half
- Benefits of CO_2 emission control and those of improved LAP may change the picture of winners and losers by region → can motivate for policy actions



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Conclusions

- The 2°C is technically feasible and if we choose the proper burden sharing rule it can also be equitable

- Equal relative GDP losses is a balanced burden sharing allocation:
  - Full compensation of the energy cost for India and RoW is less expensive for the industrialised countries
  - Perhaps a combination of both could convince DCs to participate in a global protocol

- The climate change mitigation costs can be further reduced if benefits of climate change mitigation (avoided damages) and reduction of LAP are considered

- Key technologies for power generation are wind, solar PV and BECCS, while for energy conversion, synfuel and H_2 from biomass, coal and gas with CCS

Conclusions…

- DAC reduces marginal costs and global GDP losses by factors of two to three
- GDP losses become more balanced in the case of DAC for oil and gas producers
- DAC in our analysis with conservative assumptions is rather complementary to CCS and not the backstop technology
- DAC needs definitely R&D&D spending to become mature and has good chances to complement BECCS

Thank you for your attention !