Energy needs for adaptation significantly impact mitigation pathways

Enrica De Cian[1,2,3]

Co-authors: Francesco Pietro Colelli[1,2,] Johannes Emmerling[2,3], Giacomo Marangoni[2,3], Malcolm Mistry[1,2]

1 - Department of Economics, Ca' Foscari University of Venice, 30121 Venice, Italy
2 - Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), 30175 Venice, Italy
3 - European Institute on Economics and the Environment (EIEE), 20144 Milano, Italy

FSR 7th Climate Annual Conference

November 29, 2021

1. State of the Art

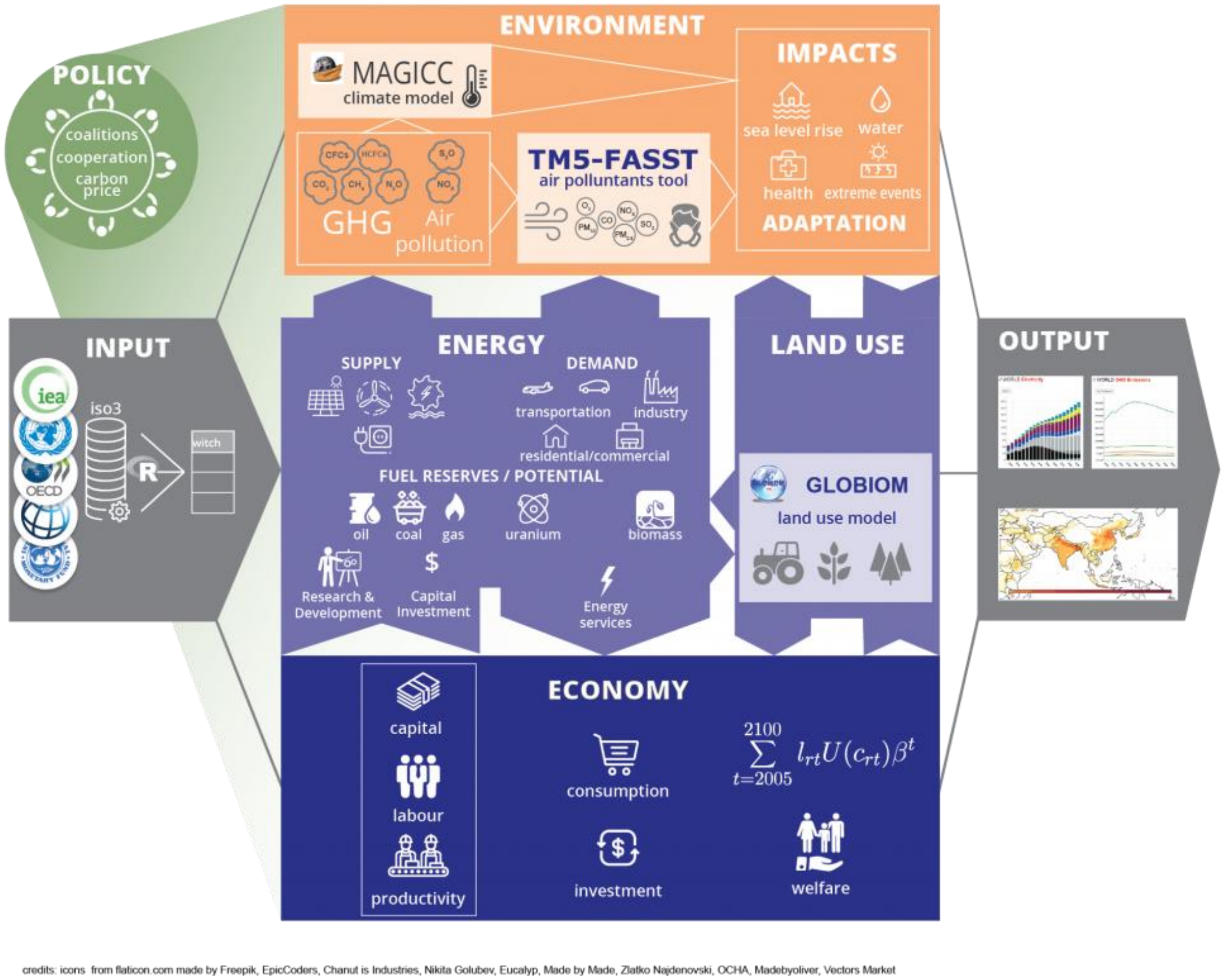
- **Integrated Assessment Models** (IAMs) prominently contributed to the elaboration of energy scenarios and future mitigation pathways

- While the feasibility of 1.5°C scenarios call for an **energy demand to decarbonize that is as low as possible**, to extent of additional energy needs of adaptation has been overlooked

- Lacking long-run adaptation and focusing on residential demand **underestimates the additional adaptation energy needs**

- The **adaptation-energy feedback is rarely included** in up-to-date energy scenarios and mitigation pathways

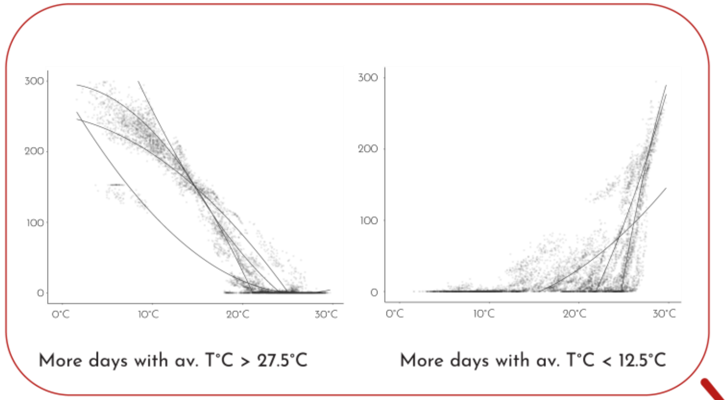
2. The WITCH model



- **Hybrid model**: Macro-economic structure is hard-linked to the energy sector
- **Scale**: global, 17 regions
- **Economy**: top-down intertemporal optimal growth model, dynamic, perfect foresight
- **Energy**: bottom-up description of technological options.
- **Endogenous technical change** – Learning-By-Doing and Learning-By-Researching
- **Climate**: damage feedback via temperature change
- **Strategic**: non cooperative interactions between regions

2. WITCH adaptation-energy feedback loop

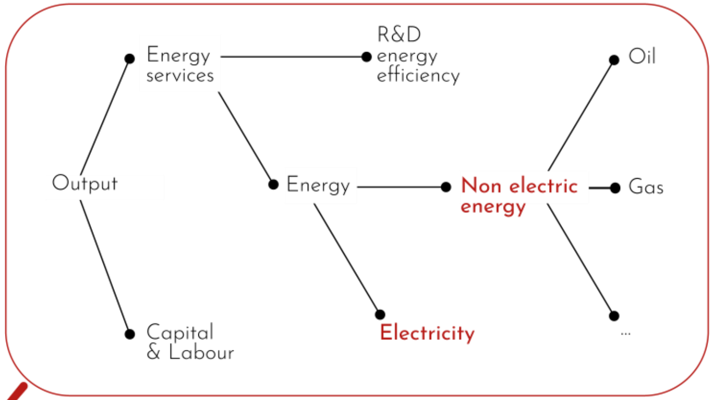
Regional occurrence of extreme temperatures

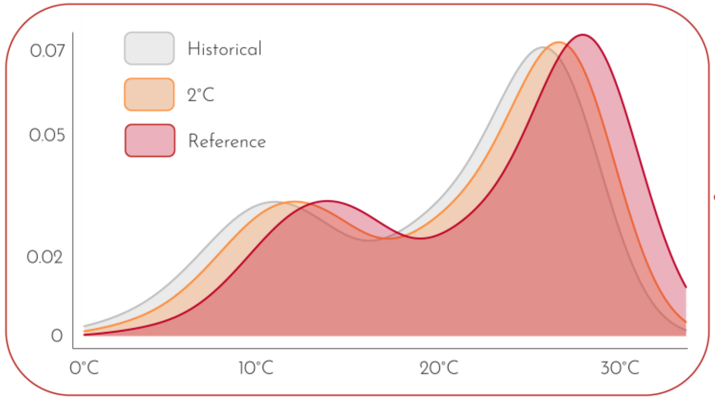


Response of energy demand to extreme temperatures

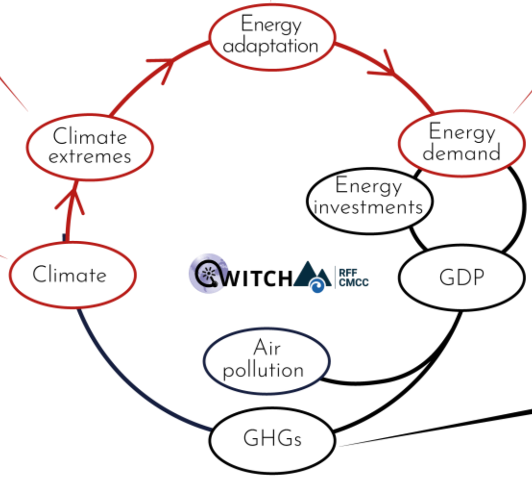
Region	Sector	Electricity	Gas	Oil
More days with av. T°C > 27.5°C				
Temperate	Residential	1.5%		
	Commercial	4.7%		
	Industry	0.9%	3.3%	
Tropical	Residential			
	Commercial	0.8%		-1.7%
	Industry	0.8%	1.1%	0.5%
More days with av. T°C < 12.5°C				
Temperate	Residential		2.3%	2.1%
	Commercial	-0.6%		1.2%
	Industry			
Tropical	Residential			
	Commercial			-1.4%
	Industry	-2.8%		

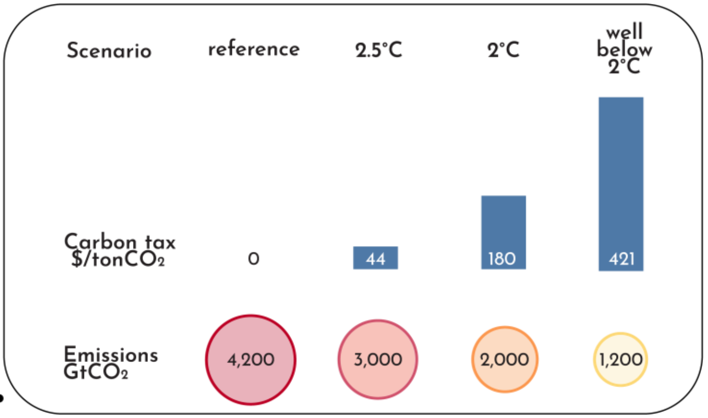
Impacts on the economy





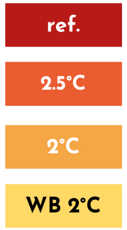
Regional temperature increase



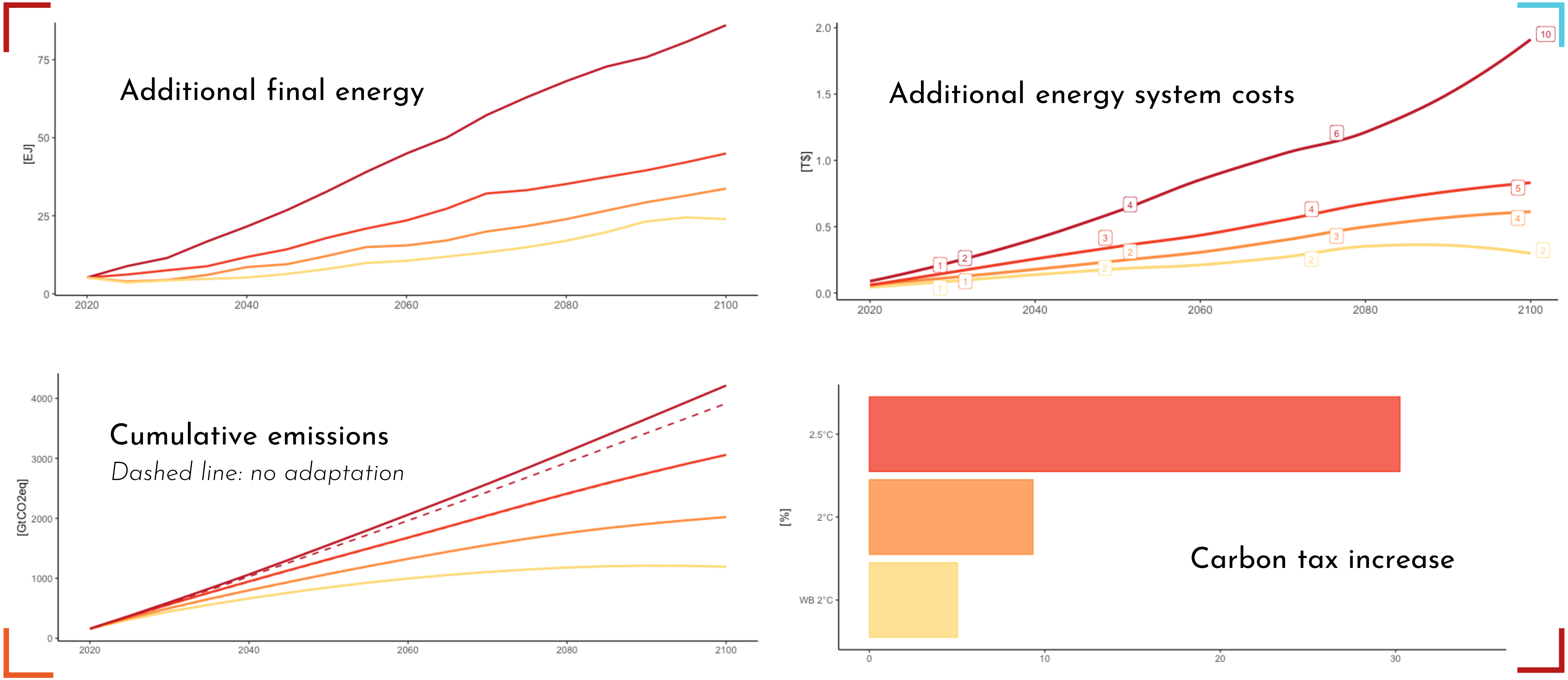


Mitigation Policy in 2100

3. Results



ref.
2.5°C
2°C
WB 2°C



Additional final energy
[EJ]
0
25
50
75
2020
2040
2060
2080
2100
Additional energy system costs
[T$]
0.0
0.5
1.0
1.5
2.0
2020
2040
2060
2080
2100
Cumulative emissions
Dashed line: no adaptation
[GtCO2eq]
0
1000
2000
3000
4000
2020
2040
2060
2080
2100
Carbon tax increase
[%]
2.5°C
2°C
WB 2°C
0
10
20
30

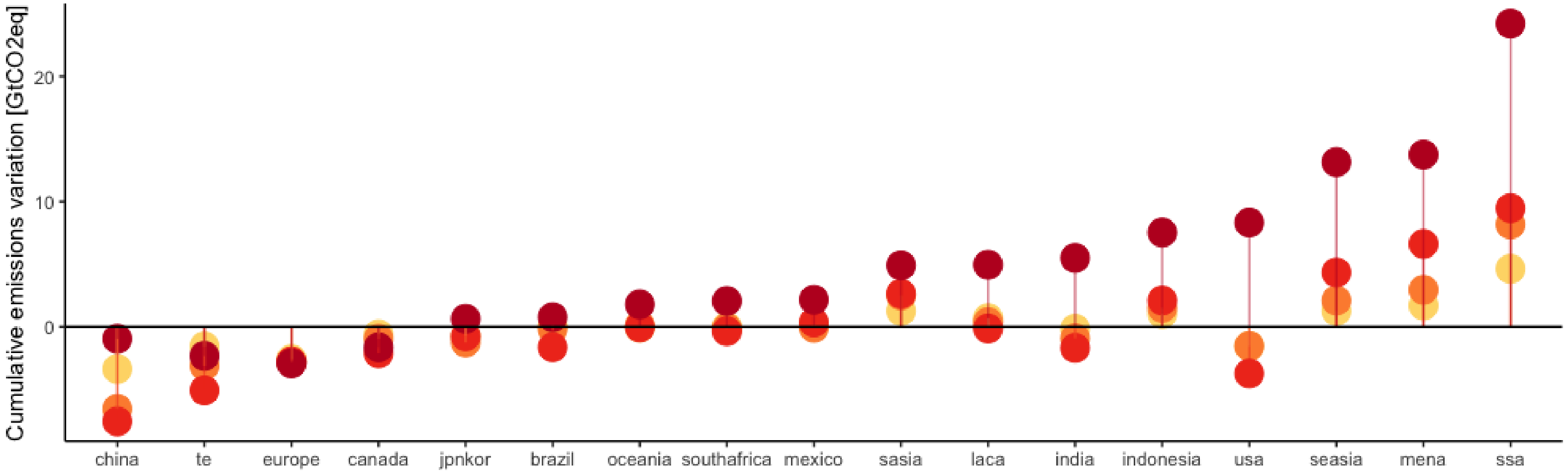
ref.

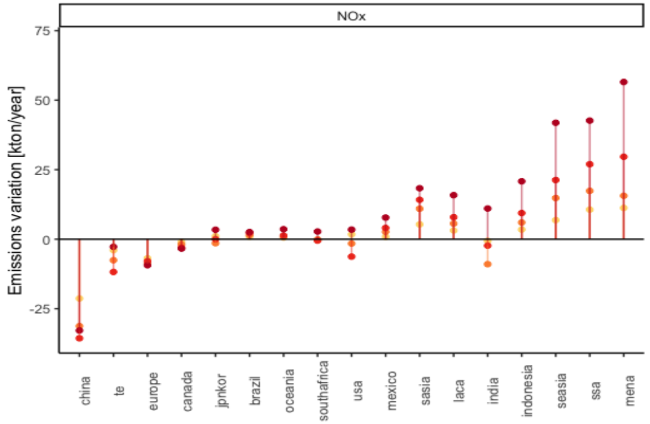
2.5°C

2°C

WB 2°C

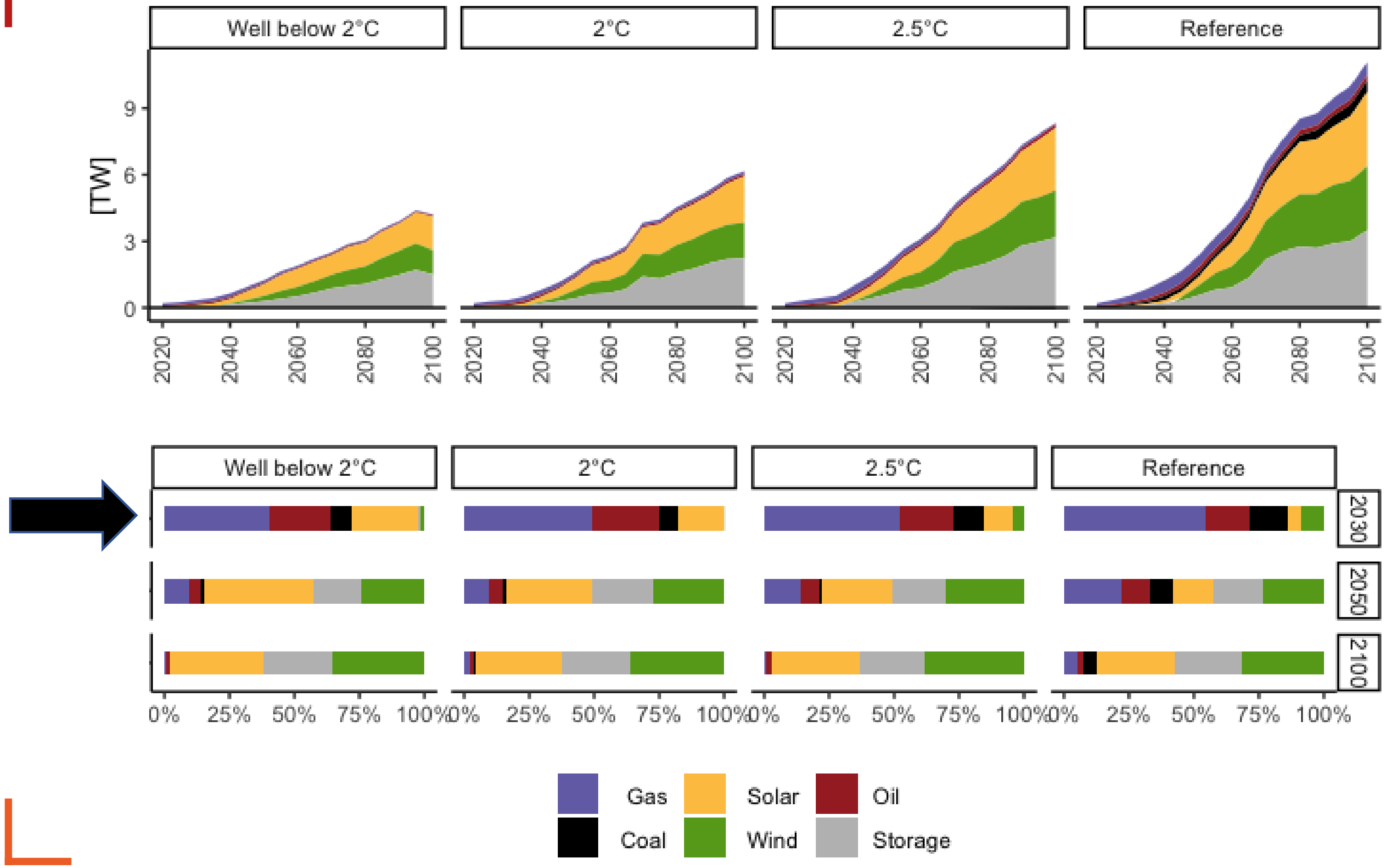
3. Results





3. Results

Additional generation capacity by technology



Share of coal, oil and gas on the **additional capacity mix**:

- 2030: from 85% (Reference) to 80%- 65% (Carbon tax scenarios)
- 2050: from 40% (Reference) to 20%-10% (Carbon tax scenarios)
- 2100: up to 10% in the Reference

4. Conclusions and policy implications

- We find that adaptation directly affects the **shape and the costs of mitigation pathways**.
- IAMs ignoring energy system costs and environmental implications of rising adaptation needs **underestimate the benefits of mitigation policies**.
- Failing to rapidly rise the ambition of mitigation policy means that adaptation will exacerbate the **lock-in into polluting fossil-fuel generation**.
- Climate adaptation interacts with the **co-benefits of mitigation**: as the new fossil-based generation would increase **air pollution**.
- Regional results have a bearing on **climate policy design** if a different policy instrument (emission trading schemes with initial allocations) is adopted.

Thank you!

ENERGYA

www.energy-a.eu

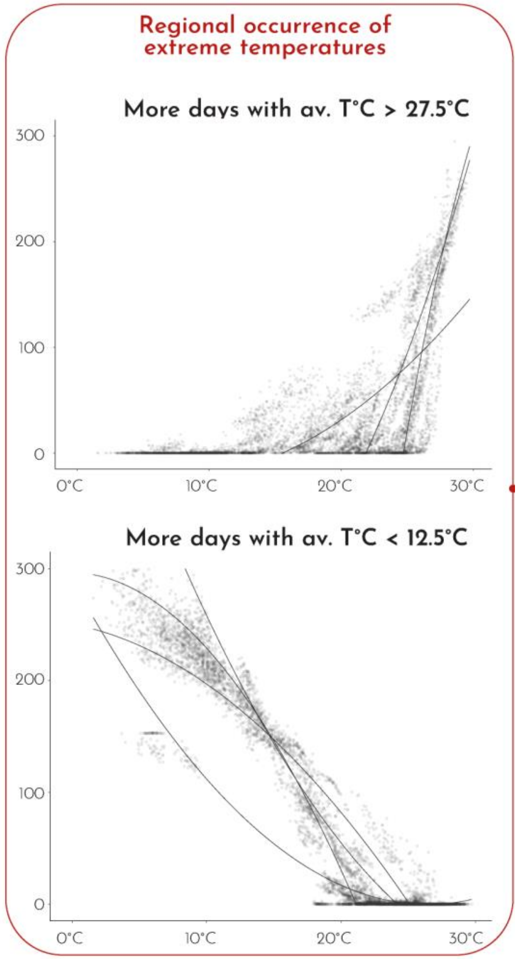
Ca' Foscari University of Venice

European Research Council
Established by the European Commission

Centro Euro-Mediterraneo sui Cambiamenti Climatici

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 756194.

3. WITCH adaptation-energy feedback loop



Extreme temperature indicators (ETI)

- Empirically estimated reduced-form relationship between ETIs and annual average temperature (country-year panel).
- WITCH projects regional ETIs from the future regional temperature level.

$$y_{i,t} ={}_1^{(k)} \, temp_{i,t} d_i^{(k)} + \ldots +_m^{(k)} \, temp_{i,t}^{(m)} d_i^{(k)} +_{m+1} c_i + \epsilon_{i,t}$$

where

y climate extreme indices

$temp$ mean temperature

c fixed effects

d cluster dummy variable

m maximum degree of the polynomial

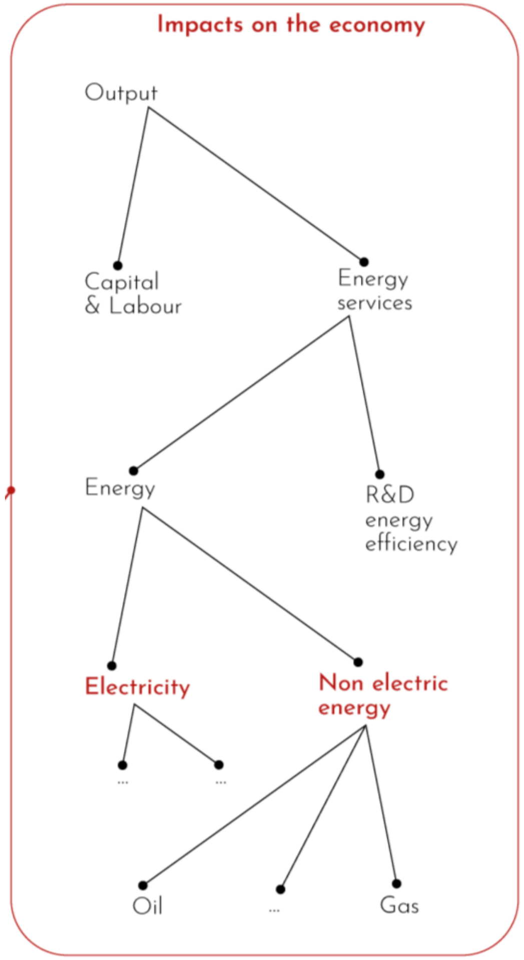
k cluster number (1...n; with n maximum number of clusters)

ϵ random errors

i countries

t time

3. WITCH adaptation-energy feedback loop



Energy demand shocks (implementation)

The energy (EN) shocks are implemented through changes in electricity (EL) and fuels' (NEL) productivity in the production tree:

$$EN_{i,t} = [\tilde{\alpha}_{EL,i} EL_{i,t}^{\rho_{EN}} + \tilde{\alpha}_{NEL,i} NEL_{i,t}^{\rho_{EN}}]^{\frac{1}{\rho_{EN}}}$$

$$\tilde{\alpha}_{EL,i,t} = \alpha_{EL,i} \frac{\Phi_{EL,i,t} Q_{EL,i,t}}{\sum_f Q_{f,i,t}}$$

$$\tilde{\alpha}_{NEL,i,t} = \alpha_{NEL,i} \left[\frac{\Phi_{GAS,i,t} Q_{GAS,i,t}}{\sum_f Q_{f,i,t}} + \frac{\Phi_{OIL,i,t} Q_{OIL,i,t}}{\sum_f Q_{f,i,t}} \right]$$

Additional results

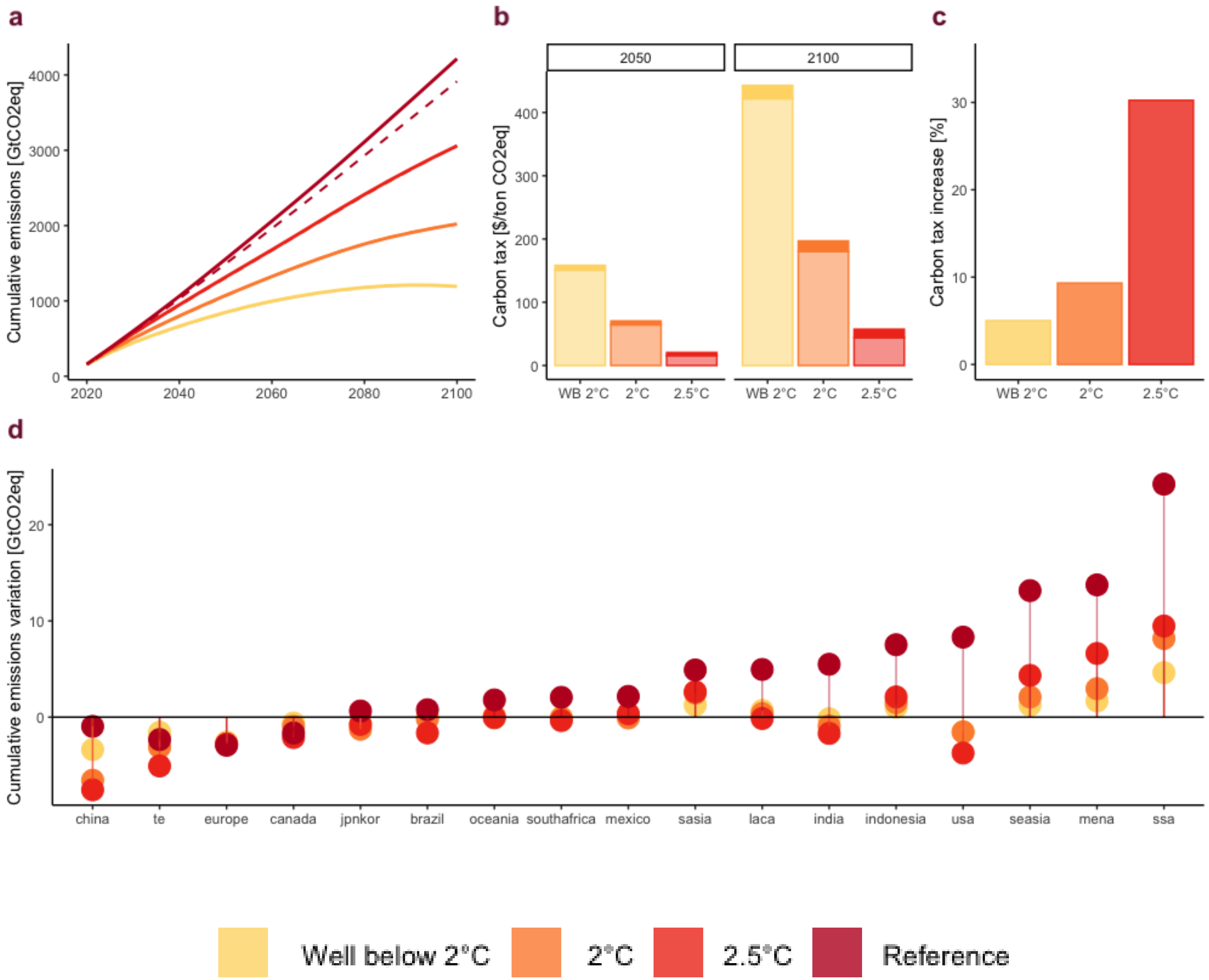
Adaptation to future climate change will need more energy

Electricity

Gas & Liquids

Additional results

Adaptation directly affects emissions and carbon prices



Additional results

Adaptation affects power generation costs