Global energy demand in a warming climate

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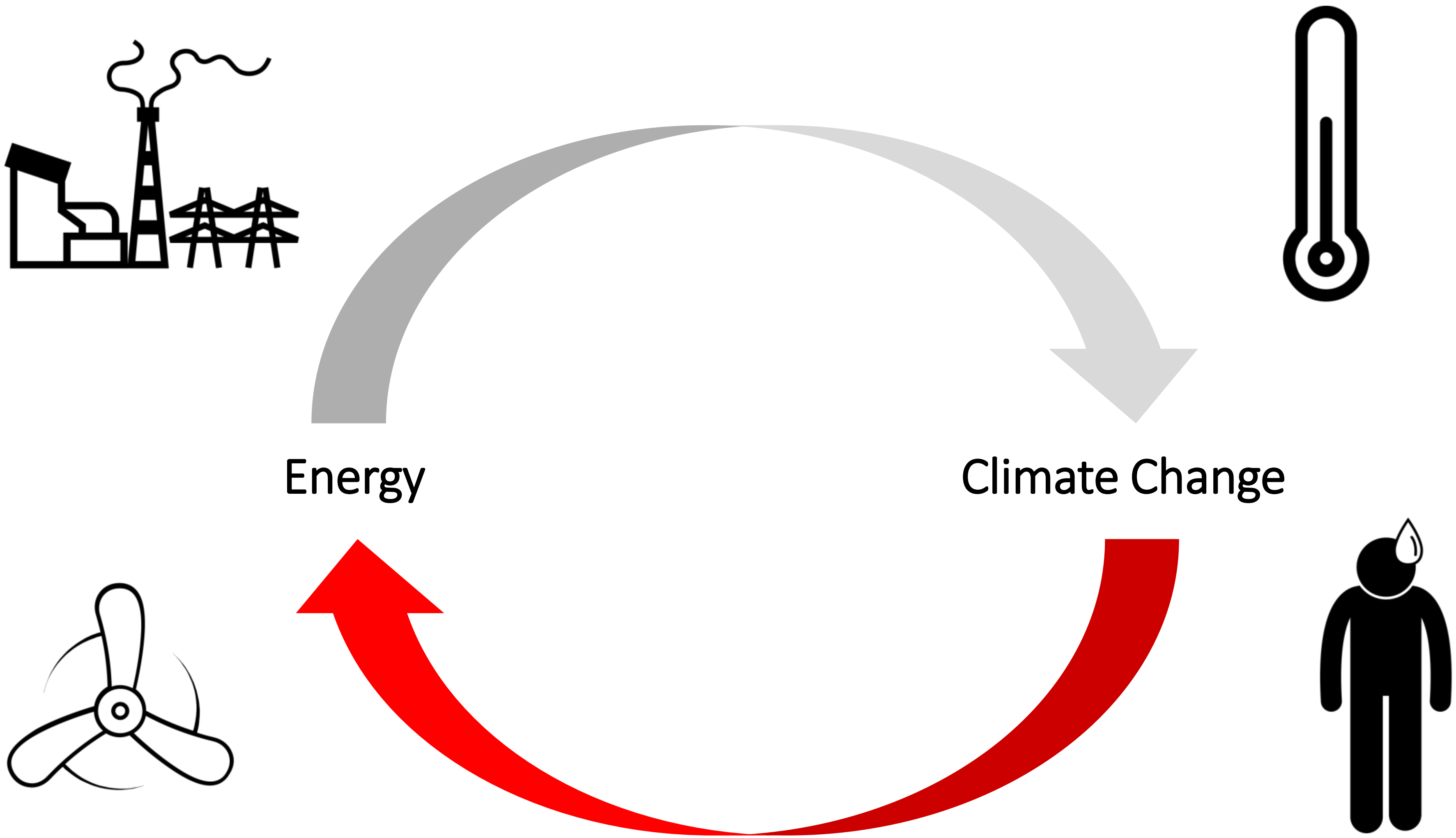
WholeSEM Annual Conference

Session 2: Energy, Economy and Technological Transitions

The context



The context

Energy connects development, adaptation, mitigation

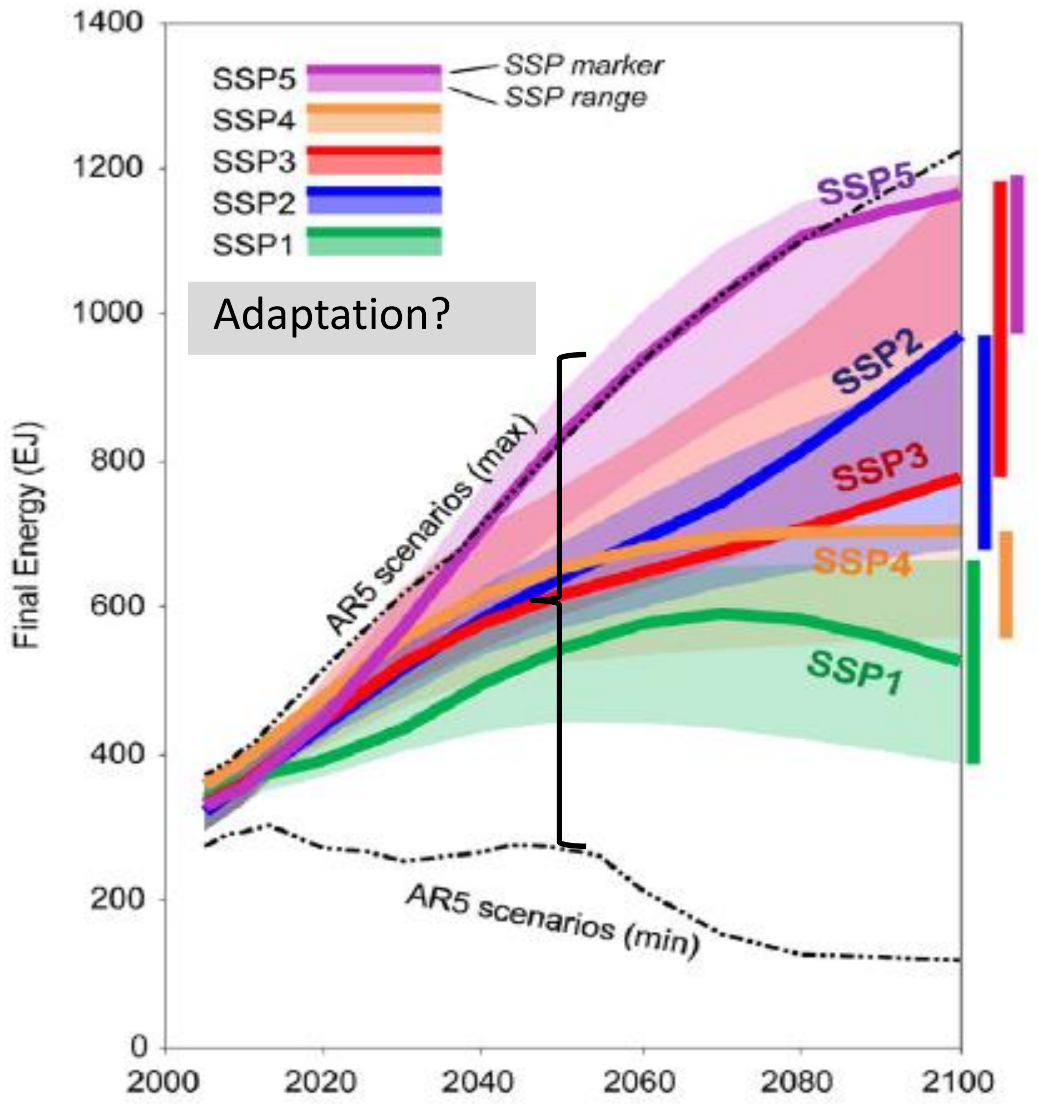
Adaptation-driven energy use as a **key driver** of future energy scenarios

Hinder progress towards SD and decarbonization?

Gaps in the transformation pathways lit.

Existing energy scenarios (BAU & mitigation) **do not include the feedback of climate change** on energy demand via adaptation (Fisher-Vanden et al. 2014, Riahi et al. 2017)

A major gap that could affect **transition dynamics** of decarbonization pathways (IPCC 5AR WGIII, e.g. Ch 6)



Gaps in the effort-sharing lit.

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

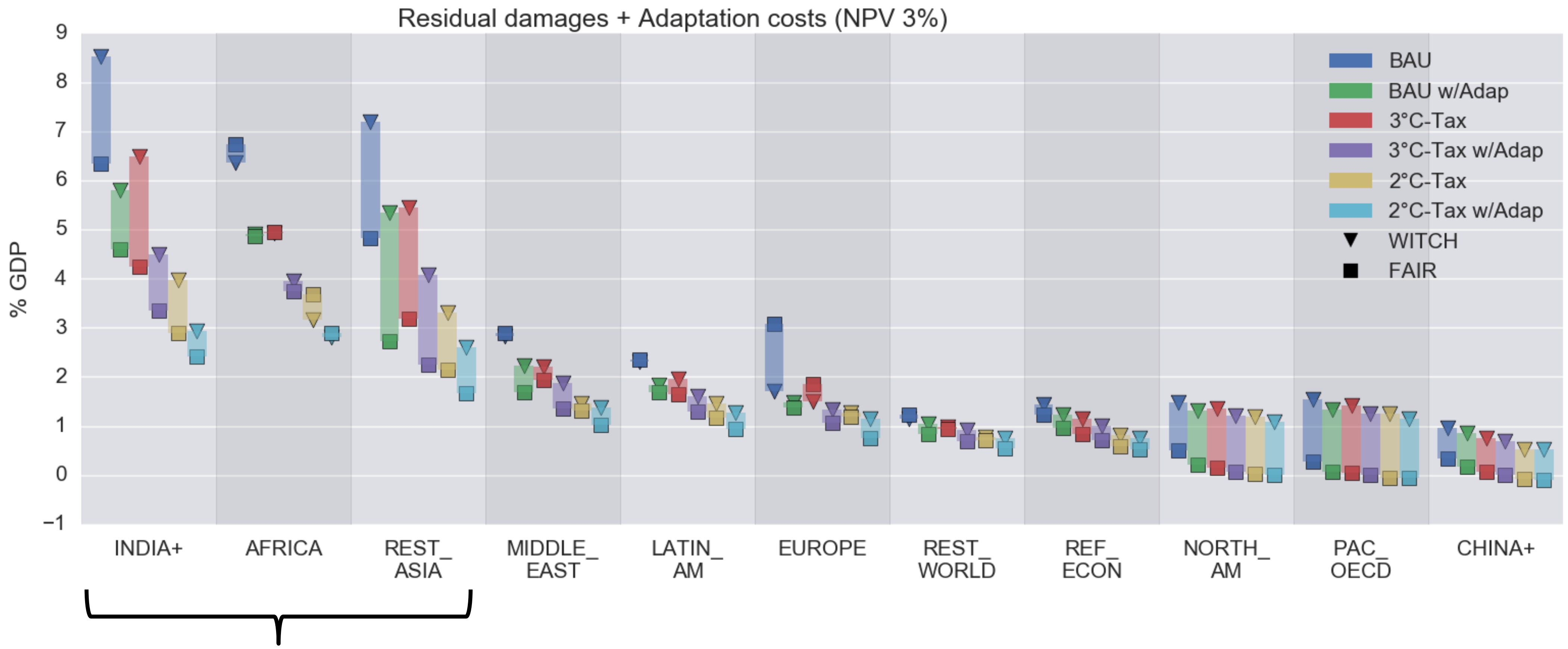
(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and

(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Gaps in the effort-sharing lit.



+$500 billion in 2050 to **high impact countries** to equalize total climate costs (mitigation + damages + adaptation costs), De Cian et al. 2016, ERL

Impact literature: the common framework

Process-based models

Engineering, bottom-up models:
e.g. IMAGE-TIMER, POLES

Subset of ESMsxRCPsxSSPs

➡

Future scenarios

Multiple scenarios

➡

Environmental & socio-economic Implications

IAMs/CGE

Examples: Isaac and van Vuuren 2009, Bosello et al. 2012, Dowling 2013, Hasegawa et al. 2016

Issues: expensive in terms of data and time requirements

Impact literature: a more flexible framework

Empirically-based response functions

ESMsxRCPsxSSPs

➡

Future scenarios

Multiple scenarios

➡

Environmental & socio-economic Implications

IAMs/CGE

Examples: Eboli et al. 2009, Roson and der Mensbrugghe (2010)

Issues: reduced-form response functions

Empirically-based response functions

Identify a **reduced-form relationship *F()*** while controlling for confounding factors (***Z***)

$$q_{i,t} = \mu_i + \tau_t + F\left[T_{i,t}, H_{i,t}\right] + \boldsymbol{Z}_{i,t}\boldsymbol{\gamma} + \varepsilon_{i,t}$$

i, t : observational units (e.g. country) and time over some historical period

Control for:

- time-invariant heterogeneity (μ_i)
- unspecified exogenous influences affecting all units (τ_t)
- confounding factors ($\boldsymbol{Z}_{i,t}$) – GDP, prices

Example: De Cian, Sue Wing, In prep

Empirical strategy (De Cian, Sue Wing, In prep.)

- Choose E to achieve a target of thermal performance
- Divergence between desired thermal performance and actual energy use
- Adjust E to min costs of adjustments + costs of not attaining the target

Short-run

$$\Delta q_{i,t} = \alpha_i + \left[\sum_{j=1}^{J} \beta_j^T \Delta \mathcal{E}_{j,i,t}^T + \sum_{k=1}^{K} \beta_k^H \Delta \mathcal{E}_{k,i,t}^H + \sum_{f} \beta_f^P \Delta p_{f,i,t} + \beta^Y \Delta y_{i,t} + \beta^X \Delta x_{i,t} \right]$$

$$+ \theta \left\{ q_{i,t-1} - \sum_{j=1}^{J} \gamma_j^T \mathcal{E}_{j,i,t-1}^T - \sum_{k=1}^{K} \gamma_k^H \mathcal{E}_{k,i,t-1}^H - \sum_{f} \gamma_f^P p_{f,i,t-1} - \gamma^Y y_{i,t-1} - \gamma^X x_{i,t-1} \right\} + \nu_{i,t}$$

Long-run

Future scenarios (De Cian, Sue Wing, In prep.)

- Change in exposure to the same **hot/cold days** used in the regressions from GCM temperature projections (RCPs 4.5 & 8.5) for each grid cell, ***c***, fuel, ***f***, sector, ***s***:

$$\phi_{c,f,s}^{\text{Climate}} = \exp\left\{ \underbrace{\sum_{j=1}^{J} \widehat{\gamma}_{j,f,s}^{T}}_{\text{Estimated semi-elasticities to hot/cold days}} \underbrace{\left(\widetilde{\varepsilon}_{j,c,\text{Future}}^{T} - \widetilde{\varepsilon}_{j,c,\text{Current}}^{T} \right)}_{\text{Change in 2050 exposure to hot/cold days}} \right\}$$

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- Change in per capita income (SSPs)

$$\phi^{\text{Economy}}_{i,f,s} = \exp\left\{ \underbrace{\widehat{\gamma}^{Y}_{f,s}}_{\text{Estimated per capita income elasticities}} \underbrace{\left(\widetilde{y}_{i,\text{Future}} - \widetilde{y}_{i,\text{Current}}\right)}_{\text{Change in 2050 exposure to hot/cold days}} \right\}$$

Data for the empirical analysis

- Unbalanced panel of tropical and temperate countries (1970-2014)
- 5 sectors: agr, com, ind, res, tra
- 3 fuels: electricity, natural gas, petr. prd
- 4 specifications leading to 5x3x2x4=**120** estimated equations
- Data sources: ENERDATA, PWT, GLDAS, GRUMPv1

	Electricity	Natural Gas	Petroleum	*Total*	Electricity	Natural Gas	Petroleum	*Total*
	Tropical				Temperate			
Agriculture	0.8	0	1.5	*2.3*	0.9	0.3	3.2	*4.4*
Industrial	4.5	6.8	4.6	*15.9*	21.6	12.9	8	*42.5*
Residential	3.5	2	3	*8.5*	14	15.9	5.4	*35.3*
Commercial	2.6	0.3	0.7	*3.6*	14.1	7.4	3.2	*24.7*
Transportation	0.1	0.6	19.4	*20.1*	0.8	0.6	60	*61.4*
Total	*11.5*	*9.7*	*29.2*	*50.4*	*51.4*	*37.1*	*79.8*	*168.3*

Empirical results

- High heterogeneity
- Positive temperature semi-elast. to hot days
- Some negative temperature semi-elast. to cold days in tropical regions
- LR responses are larger than SR

			Response to cold days ($T < 12.5°C$)	Response to hot days ($T > 27.5°C$)	Log real GDP per capita elasticity
					Temperate regions
Agriculture	Electricity	M4		0.008	0.645
	Natural gas	M1	-0.0195^{+}		1.320
	Petroleum				
Industrial	Electricity	M2		0.009	0.363
	Natural gas	M2		0.033	
	Petroleum	M2			-1.089
Residential	Electricity	M3		0.0146^{+}	0.366
	Natural gas	M1	0.023		1.433
	Petroleum	M4	0.0207^{+}		
Commercial	Electricity	M1	-0.006	0.047	0.864
	Natural gas	M1			0.970
	Petroleum	M3	0.012		-0.795
Transportation	Electricity	M1	-0.003^{+}		0.260
	Natural gas				
	Petroleum	M1			0.821
					Tropical regions
Agriculture	Electricity	M1	-0.008^{+}		-0.701
	Natural gas				
	Petroleum	M1	0.066		
Industrial	Electricity	M1	-0.028	0.008^{+}	0.478
	Natural gas	M2		0.010	
	Petroleum	M2		0.005	
Residential	Electricity	M2			1.287
	Natural gas				
	Petroleum				
Commercial	Electricity	M1		0.008	0.702
	Natural gas	M1			
	Petroleum	M3	-0.014	-0.017	
Transportation	Electricity	M3		-0.011	1.93
	Natural gas				
	Petroleum	M1	-0.009	0.004^{+}	0.678

Future scenarios: exposure

Illustrative – SSP5+RCP4.5 and RCP8.5, 1 GCM (CMCC-CM)

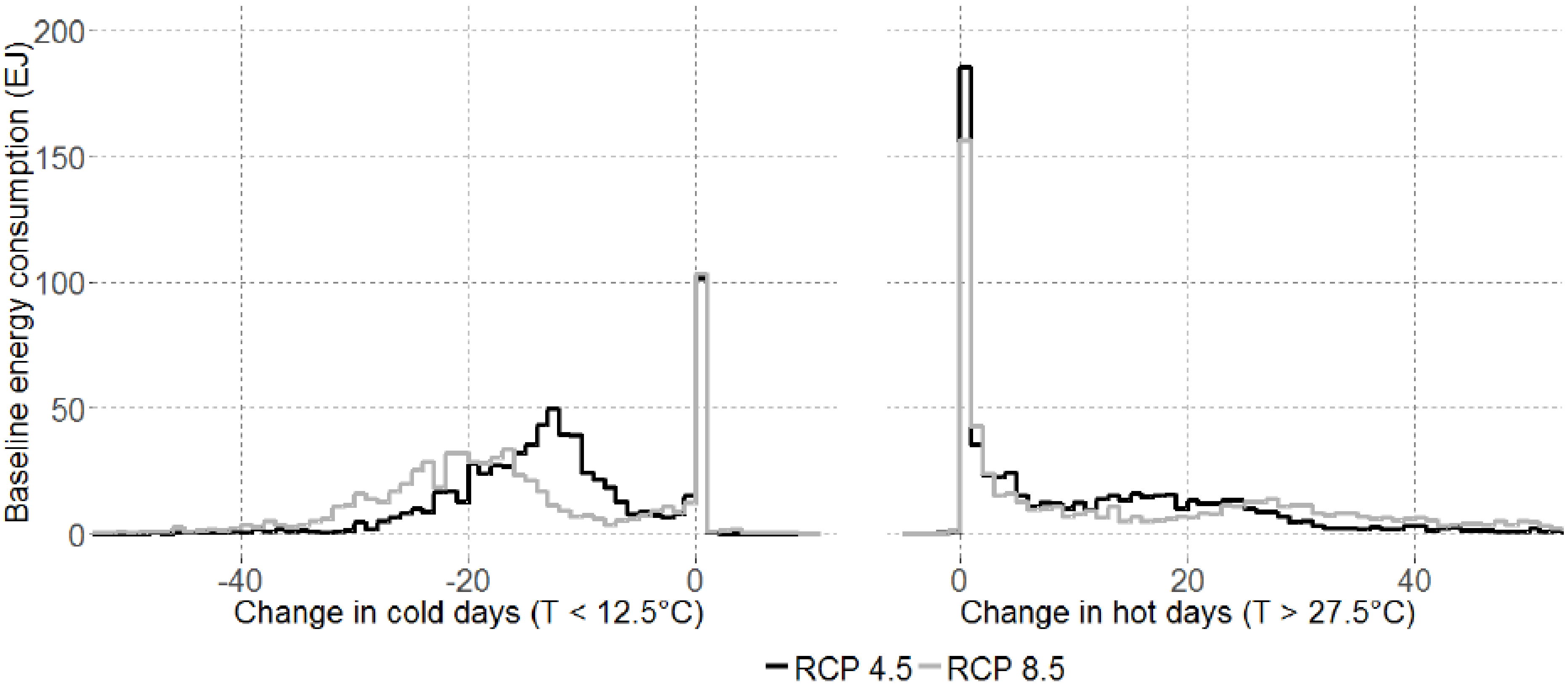
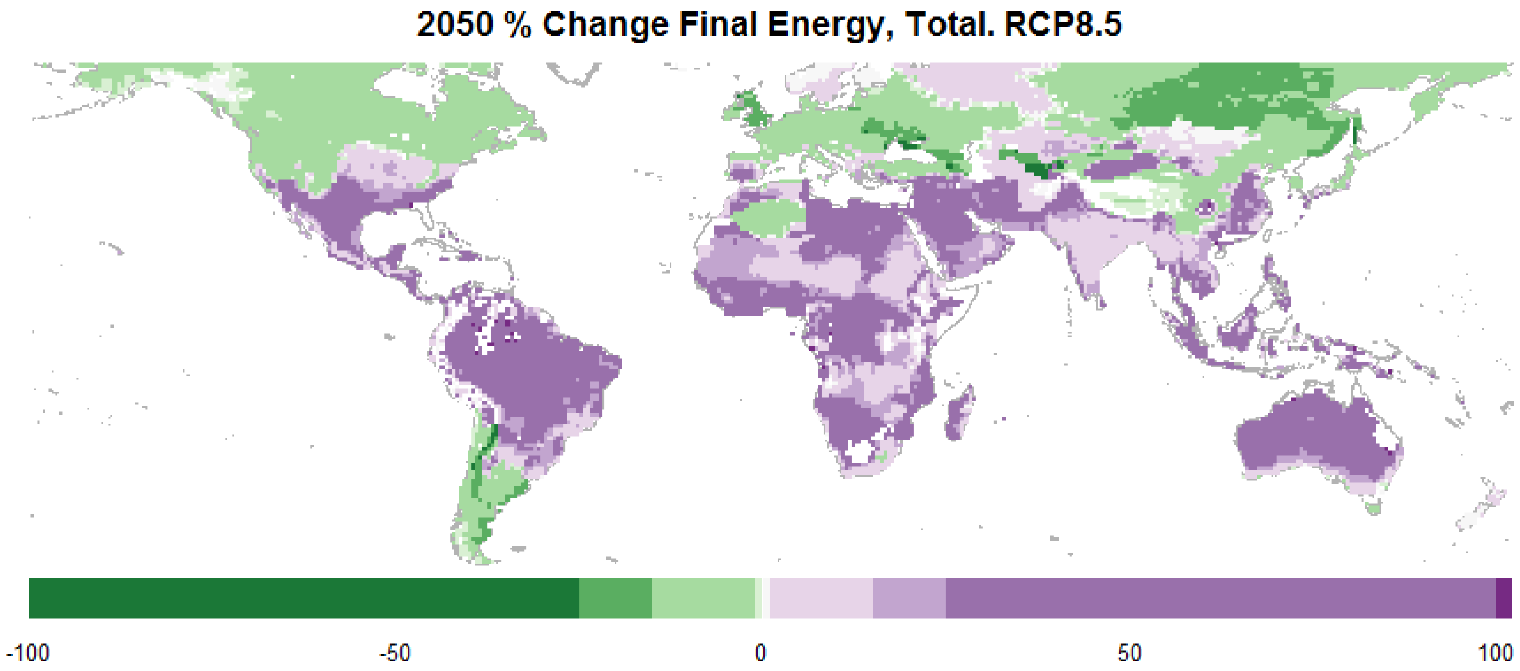


Figure 3: Exposure of business as usual energy demand to temperature changes

Future scenarios: impacts



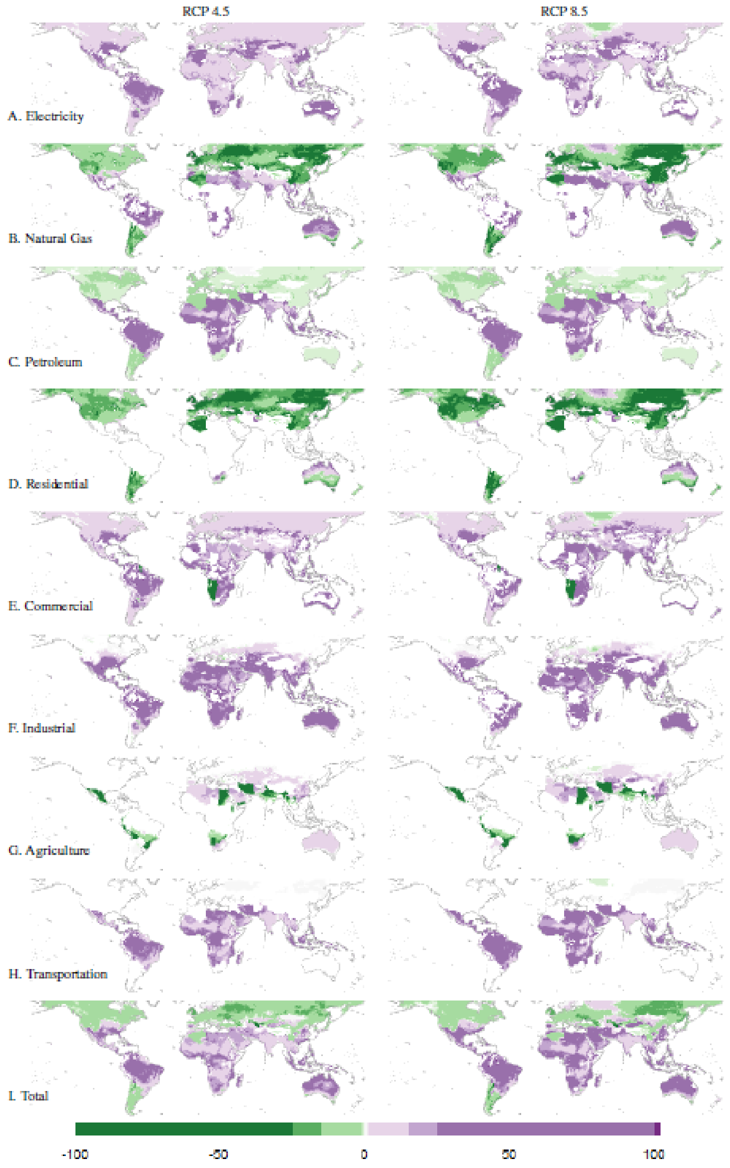


Figure 4: CMCC-CM simulated impacts on final energy demand circa 2050

Note: Spatial variation is driven by variation in EXPOSURE
SSP5, RCP4.5, RCP8.5, CMCC-CM GCM

Future scenarios: incidence

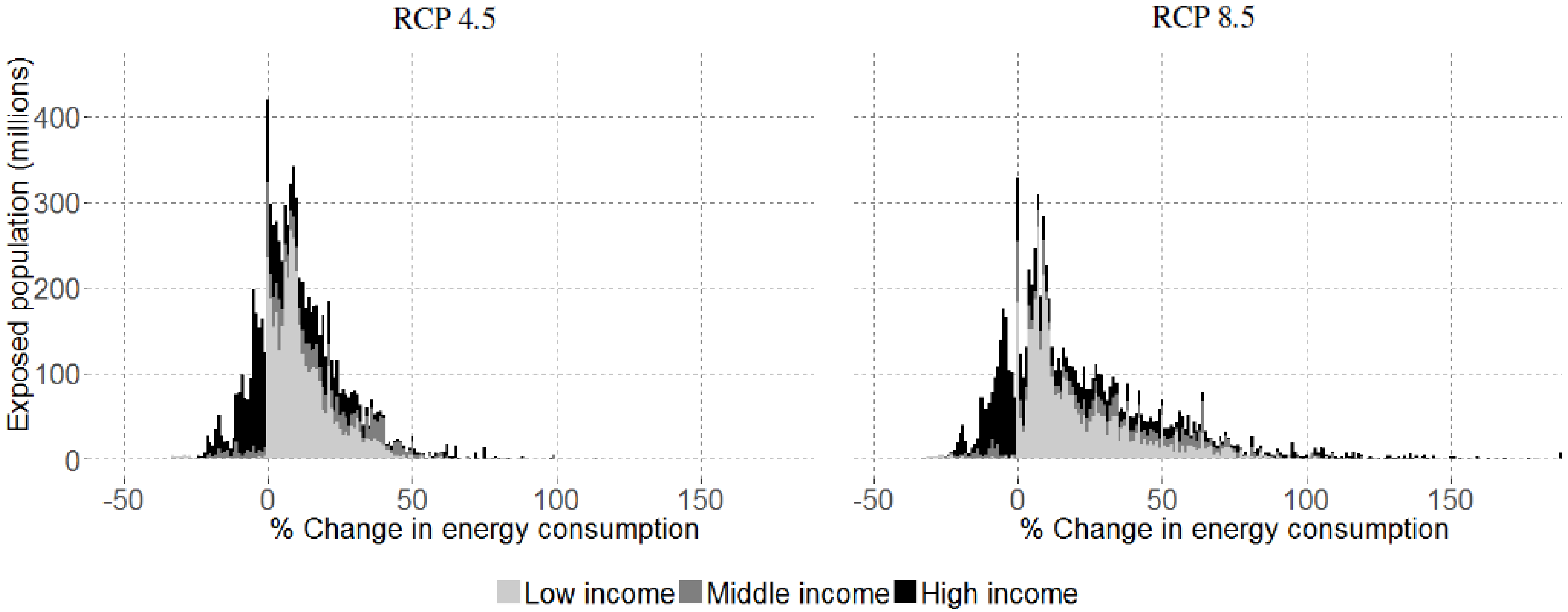
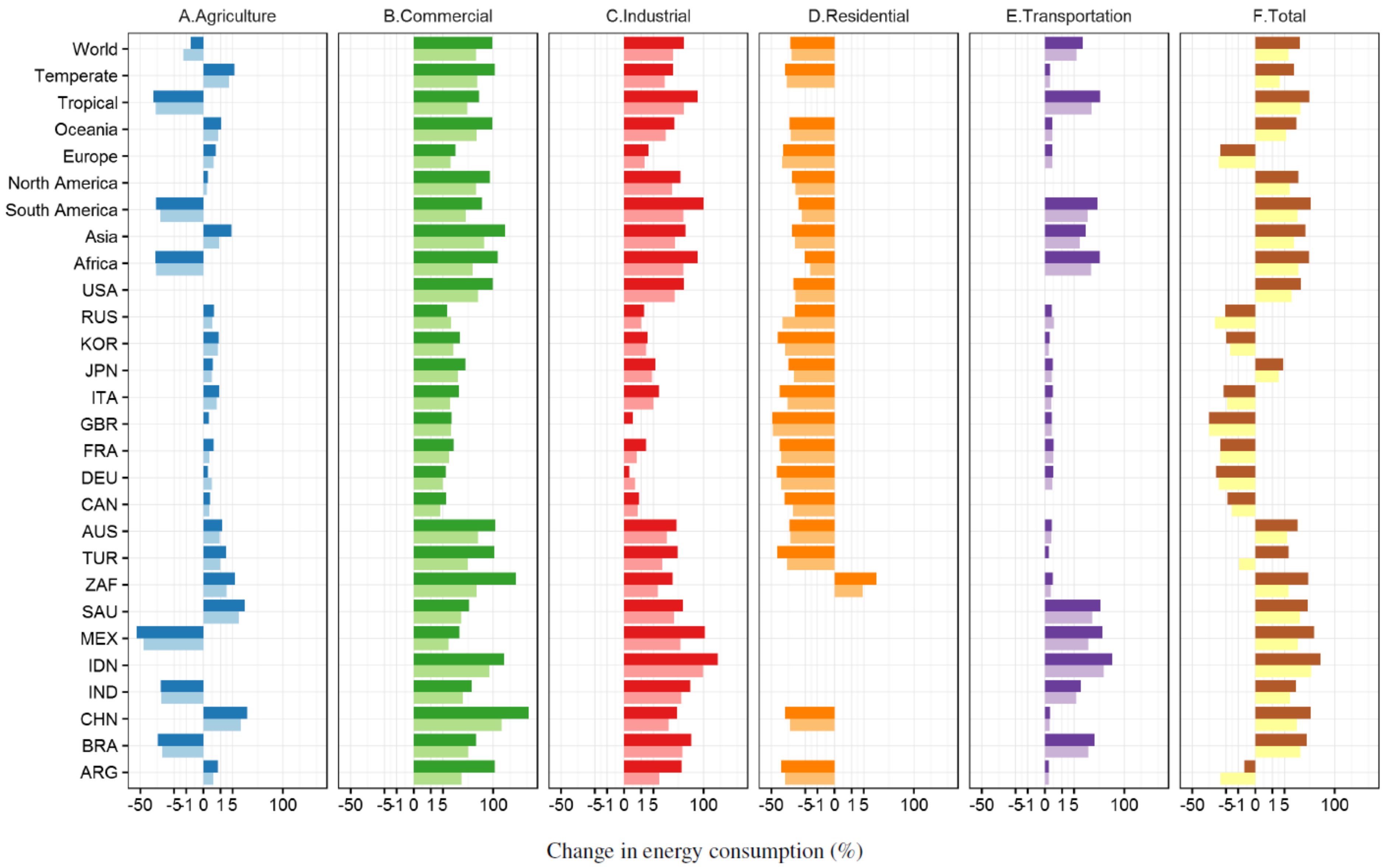


Figure 5: Incidence of climate change impacts on energy demand relative to future baseline

Future scenarios: aggregate results



Gaps & future research

- **Empirical evidence**: improved, but still poor socio-economic and geographic heterogeneity

- **Future scenarios**: explore uncertainty in the new scenario framework (Riahi et al. 2017)

- **Implications**: on the economy, environment, but also distributional impacts (e.g. on poverty)

- A new **MIP**?

Thank you for your attention

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Fondazione Eni Enrico Mattei

Future scenarios (De Cian, Sue Wing, In prep.)

- Change in exposure to **hot/cold days** (RCPs) using **delta method**
- Change in per capita income (SSPs)

$$\phi^{\text{Climate}}_{c,f,s} = \exp\left\{ \sum_{j=1}^{J} \widehat{\gamma}^{T}_{j,f,s} \left(\widetilde{\varepsilon}^{T}_{j,c,\text{Future}} - \widetilde{\varepsilon}^{T}_{j,c,\text{Current}} \right) \right\}$$

$$\Phi_{i,\text{Future}} = \frac{\sum_f \sum_s \left\{ \sum_{c \in i} \overline{w}_{c,i,\text{Future}} \phi^{\text{Climate}}_{c,f,s} \right\} \widetilde{Q}_{i,f,s,\text{BaU}}}{\sum_f \sum_s \widetilde{Q}_{i,f,s,\text{BaU}}}$$

Future energy demand @ country *i*, fuel *f*, sector *s*

$$Q_{i,f,s,\text{BaU}} = \phi^{\text{Economy}}_{i,f,s} \widetilde{Q}_{i,f,s,\text{Current}}$$

$$\phi^{\text{Economy}}_{i,f,s} = \exp\left\{ \widehat{\gamma}^{Y}_{f,s} \left(\widetilde{y}_{i,\text{Future}} - \widetilde{y}_{i,\text{Current}} \right) \right\}$$