



Questioning the use of median values in IPCC AR6 scenarios

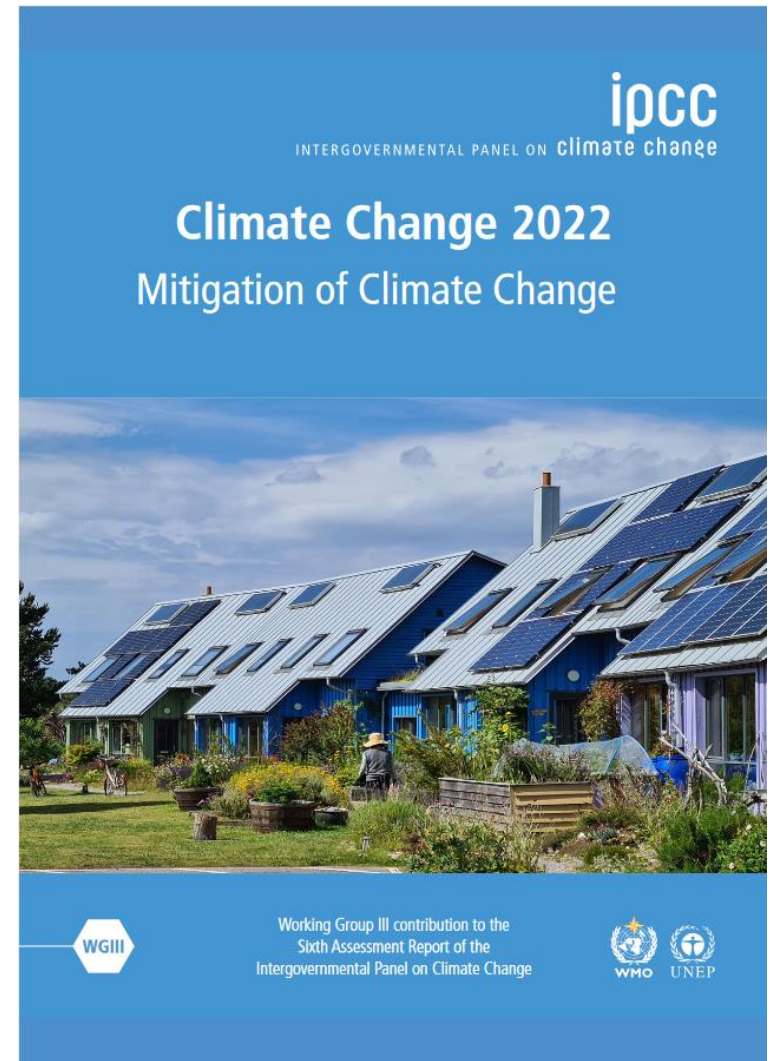
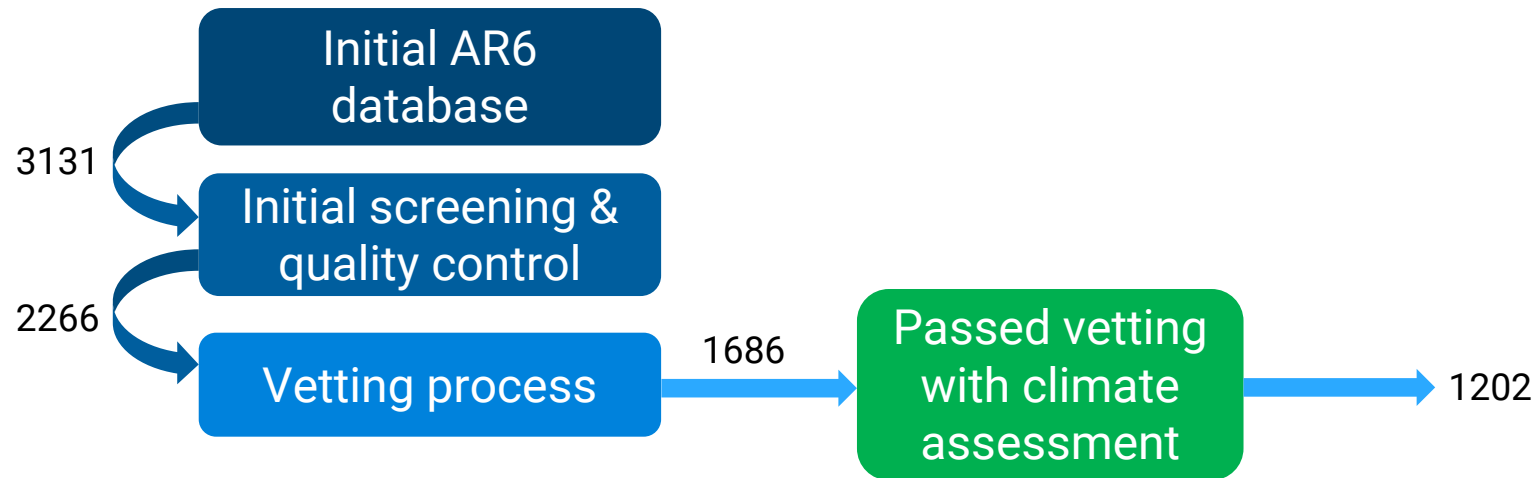
Lucas Desport¹, Naima Chabouni², Sandrine Selosse¹,
Nadia Maizi¹

¹Mines Paris – PSL, Centre for Applied Mathematics, France

²Paul Scherrer Institute, Laboratory for Energy System Analysis, Switzerland

CONTEXT

- 2022: AR6 is released (IPCC, 2022) detailing Mitigation Pathways Compatible with Long-term Goals (Riahi et al., 2022)
- Collection of long-term transition pathways through a voluntary submission process to be assessed, vetted, and classified
- Available in a database hosted by IIASA (Byers et al., 2022)



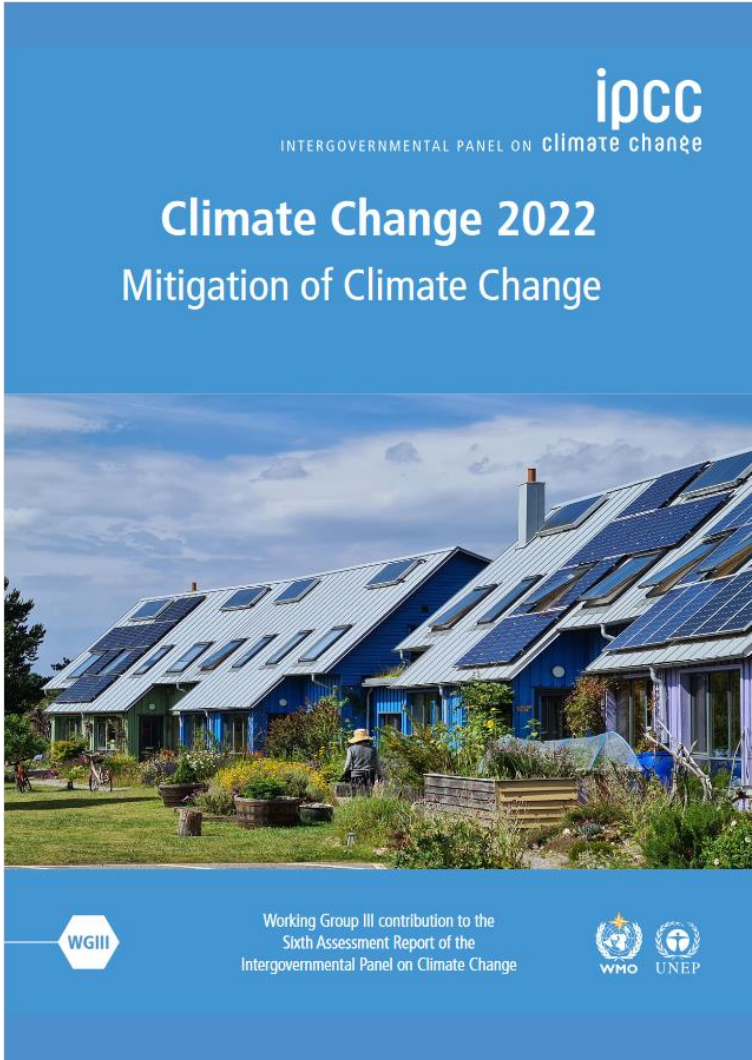
IPCC, 2022. Summary for Policymakers. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. doi.org/10.1017/9781009157926.001

Riahi, K., Schaeffer, R., Arango, J., Calvin, K., Guivarch, C., Hasegawa, Y., Jiang, K., Kriegler, E., Matthews, R., Peters, G.P., Rao, A., Roberston, S., Sebbit, A.M., Steinberger, J., Tavoni, M., van Vuuren, D.P., 2023. Mitigation Pathways Compatible with Long-term Goals, in: Climate Change 2022 - Mitigation of Climate Change. Cambridge University Press, pp. 295–408. <https://doi.org/10.1017/9781009157926.005>

Byers, E., Krey, V., Kriegler, E., Riahi, K., Schaeffer, R., Kikstra, J., Lamboll, R., Nicholls, Z., Sandstad, M., Smith, C., van der Wijst, K., Al-Khourdajie, A., Lecocq, F., Portugal-Pereira, J., Saheb, Y., Stromman, A., Winkler, H., Auer, C., Brutschin, E., Gidden, M., Hackstock, P., Harmsen, M., Huppmann, D., Kolp, P., Lepault, C., Lewis, J., Marangoni, G., Müller-Casseres, E., Skeie, R., Werning, M., Calvin, K., Forster, P., Guivarch, C., Hasegawa, T., Meinshausen, M., Peters, G., Rogelj, J., Samset, B., Steinberger, J., Tavoni, M., van Vuuren, D., 2022. AR6 Scenarios Database. <https://doi.org/10.5281/zenodo.7197970>

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Category	Description	WGI SSP	WGIII IP/IMP	Scenarios
C1: Limit warming to 1.5°C (>50%) with no or limited overshoot	Reach or exceed 1.5°C during the 21st century with a likelihood of ≤67%, and limit warming to 1.5°C in 2100 with a likelihood >50%. Limited overshoot refers to exceeding 1.5°C by up to about 0.1°C and for up to several decades.	SSP1-1.9	IMP-SP, IMP-LD, IMP-Ren	97
C2: Return warming to 1.5°C (>50%) after a high overshoot	Exceed warming of 1.5°C during the 21st century with a likelihood of >67%, and limit warming to 1.5°C in 2100 with a likelihood of >50%. High overshoot refers to temporarily exceeding 1.5°C global warming by 0.1°C–0.3°C for up to several decades.		IMP-Neg ^a	133
C3: Limit warming to 2°C (>67%)	Limit peak warming to 2°C throughout the 21st century with a likelihood of >67%.	SSP1-2.6	IMP-GS	311
C4: Limit warming to 2°C (>50%)	Limit peak warming to 2°C throughout the 21st century with a likelihood of >50%.			159
C5: Limit warming to 2.5°C (>50%)	Limit peak warming to 2.5°C throughout the 21st century with a likelihood of >50%.			212
C6: Limit warming to 3°C (>50%)	Limit peak warming to 3°C throughout the 21st century with a likelihood of >50%.	SSP2-4.5	ModAct	97
C7: Limit warming to 4°C (>50%)	Limit peak warming to 4°C throughout the 21st century with a likelihood of >50%.	SSP3-7.0	CurPol	164
C8: Exceed warming of 4°C (≥50%)	Exceed warming of 4°C during the 21st century with a likelihood of ≥50%.	SSP5-8.5		29

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CONCERN

- In the report, Tables 3.2 and 3.4 of Chapter 3 (Riahi et al., 2022) respectively report quantitative insights of greenhouse gas (GHG) emissions and the energy system

Table 3.2 | GHG, CO₂ emissions and warming characteristics of different mitigation pathways submitted to the AR6 scenarios database and as categorised in the climate assessment.

p50 [p5–p95] ^a			GHG emissions Gt CO ₂ -eq/yr ^d			GHG emissions reductions from 2019 % ^h			Emissions milestones ^{ll}				Cumulative CO ₂ emissions Gt CO ₂ ^m		Cumulative net-negative CO ₂ emissions Gt CO ₂		Global mean temperature changes 50% probability ⁿ °C		Likelihood of peak global warming staying below (%) ^o			Time when specific global warming levels are reached (with a 50% probability)		
Category ^{b,c,d} [# pathways]	Category/subset label	WG I SSP & WG III IPs/IMPs alignment ^{e,f}	2030	2040	2050	2030	2040	2050	Peak CO ₂ emissions (% peak before 2100)	Peak GHG emissions (% peak before 2100)	Net-zero CO ₂ (% net-zero pathways)	Net-zero GHGs ^{k,l} (% net-zero pathways)	2020 to net-zero CO ₂	2020–2100	Year of net-zero CO ₂ to 2100	at peak warming	2100	<1.5°C	<2°C	<3°C	1.5°C	2°C	3°C	
C1 [97]	limit warming to 1.5°C (>50%) with no or limited overshoot		31 [21–36]	17 [6–23]	9 [1–15]	43 [34–60]	69 [58–90]	84 [73–98]				2095–2100 (52%) [2050–...]	510 [330–710]	320 [–210–570]	–220 [–660–20]	1.6 [1.4–1.6]	1.3 [1.1–1.5]	38 [33–58]	90 [86–97]	100 [99–100]	2030–2035 (91%) [2030–...]	... (0%) [...]	... (0%) [...]	

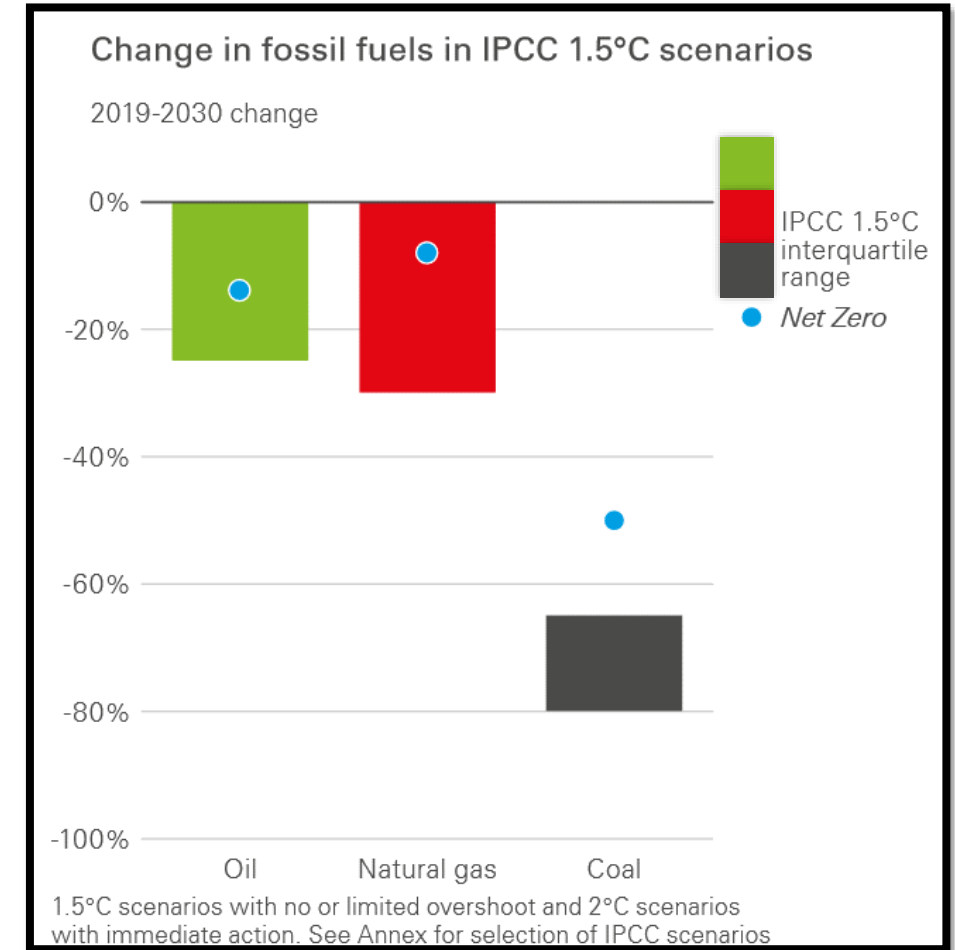
Table 3.4 | Energy and emissions characteristics of the pathways by climate category for 2030, 2050, 2100. Source: AR6 scenarios database.

p50 (p5–p95) ^a			Global Mean Surface Air Temperature change			Low-carbon share of Primary Energy ^{4,*} [%] 2020 = 16 (12–18)			Energy & Industrial Processes Index 2020 = 100			Final energy demand [EJ/yr] 2020 = 419 (367–458)			Final energy intensity of GDP Index 2020 = 100			Electricity share in final energy [%] 2020 = 20 (18–25)			CO ₂ intensity of electricity [Mt CO ₂ /TWh] 2020 = 469 (419–538)			Non-energy GHG emissions [Gt CO ₂ -eq] 2020 = 18 (15–21)			Fossil CCS (2100) [Gt CO ₂] 2020 = 0 (0–0)			
Category [# pathways] ^{b,c}	Category/subset	WG1 SSP & IPs alignment	2030	2050	2100	2030	2050	2100	2030	2050	2100	2030	2050	2100	2030	2050	2100	2030	2050	2100	2030	2050	2100	2030	2050	2100	2020–2100			
C1 [97]	limit warming to 1.5°C (>50%) with no or limited overshoot	IMP-SD, IMP-LD, IMP-Ren, SSP1-1.9	32 (17–48)	68 (25–86)	75 (19–98)	65 (49–75)	8 (–8–24)	–3 (–20–8)	399 (293–447)	410 (325–540)	612 (321–818)	71 (59–81)	46 (34–60)	26 (14–45)	27 (23–35)	52 (40–64)	66 (50–78)	99 (4–215)	–5 (–66–11)	–4 (–104–1)	10 (5–13)	5 (1–9)	2 (–2–9)	1 (0–5)	2 (0–13)	3 (0–16)	196 (3–882)			

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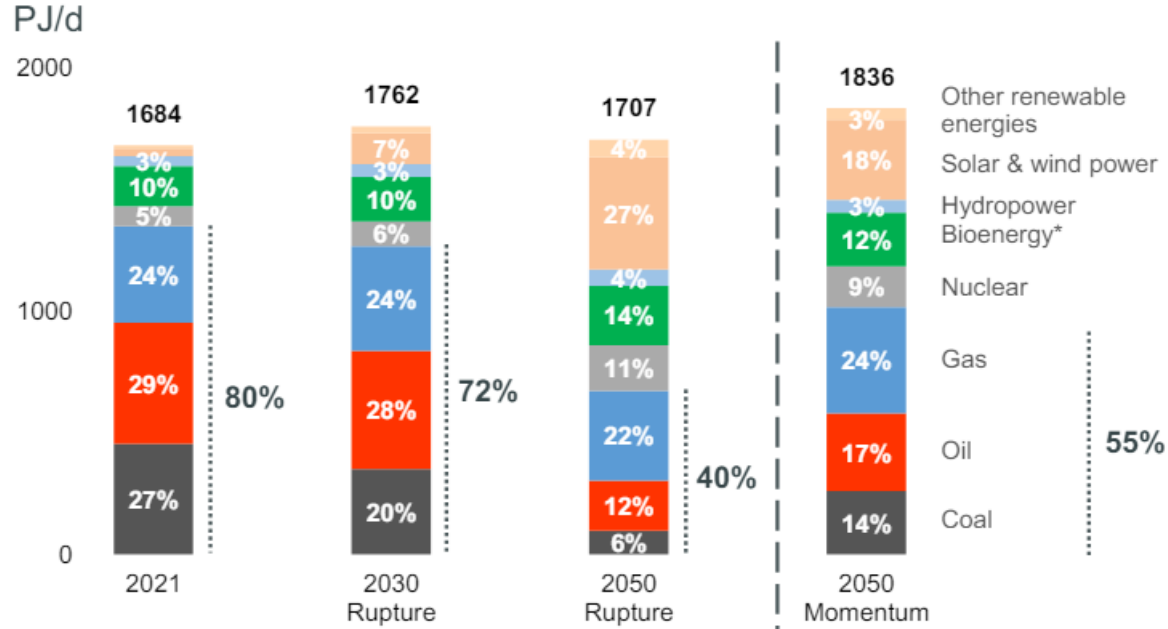
- In the meantime, we have been noticing questionable use of IPCC data by organizations
- Skea et al. (2021) analyze the methodology behind energy future exercises:
 - « Many organisations are starting to **blend** outlooks, exploratory and normative approaches »
 - « Organisations are increasingly **benchmarking** their scenario results against those of others »
 - « Scenarios are intended to be 'plausible descriptions of how the future may develop'. Given the wide range of energy sector outcomes [..], **it is fair to ask whether the full end of the range remains plausible.** »
- From our personal experience, we have noticed that some entities use IPCC median values in different manners

→ We are questioning the fact that these outlooks compare or employ statistical calculations from C1 IPCC scenarios to validate their results



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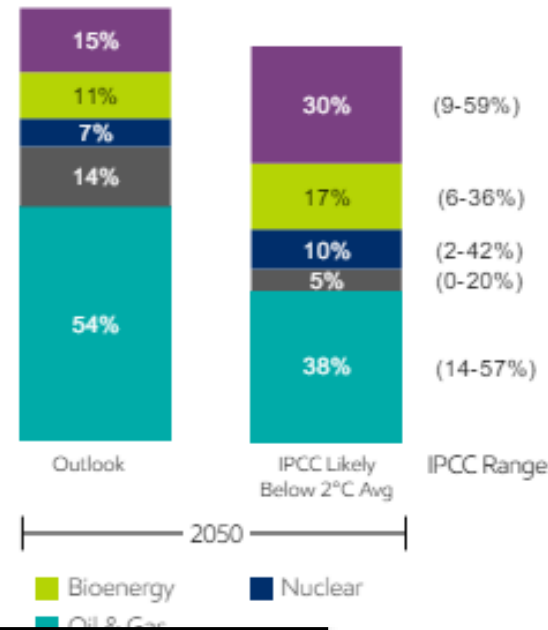
World Primary Energy Demand (projection)



Temperature increase by 2100 is ~1.7-1.8°C**

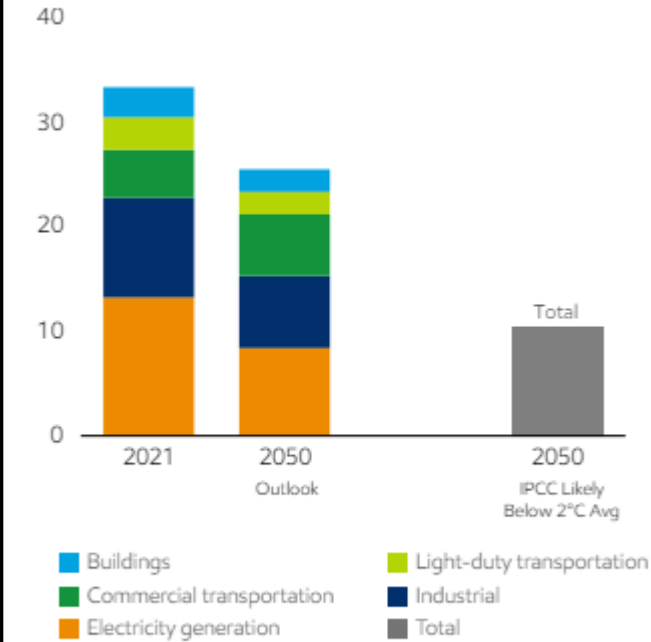
** Since pre-industrial era, comparing the energy-related CO₂ emission trajectories with the IPCC AR6 scenarios, at P66

Source: IPCC AR6 Scenarios Database hosted by IIASA release 1.0 average; IPCC C3: "Likely below 2°C" scenarios; ExxonMobil analysis



Energy-related emissions

CO₂ Billion metric tons



Source: IPCC: AR6 Scenarios Database hosted by IIASA release 1.0 average; IPCC C3: "Likely below 2°C" scenarios; ExxonMobil analysis

Emissions do not contain industry process emissions or land use and natural sinks

MOTIVATION & CONCEPT

→ From our perspective, building outlooks upon IPCC median scenarios could be a misleading approach for three reasons:

1. Sample size issue
2. Heterogeneity of the underlying models
3. Feasibility and plausibility issues

→ *Reductio ad absurdum* demonstration:

Let's assume that C1 median values based on:

- + Climate-related parameters
- + Energy-related parameters
- + Or a combination of these parameters

...yield feasible, plausible pathways falling into C1

METHODOLOGY

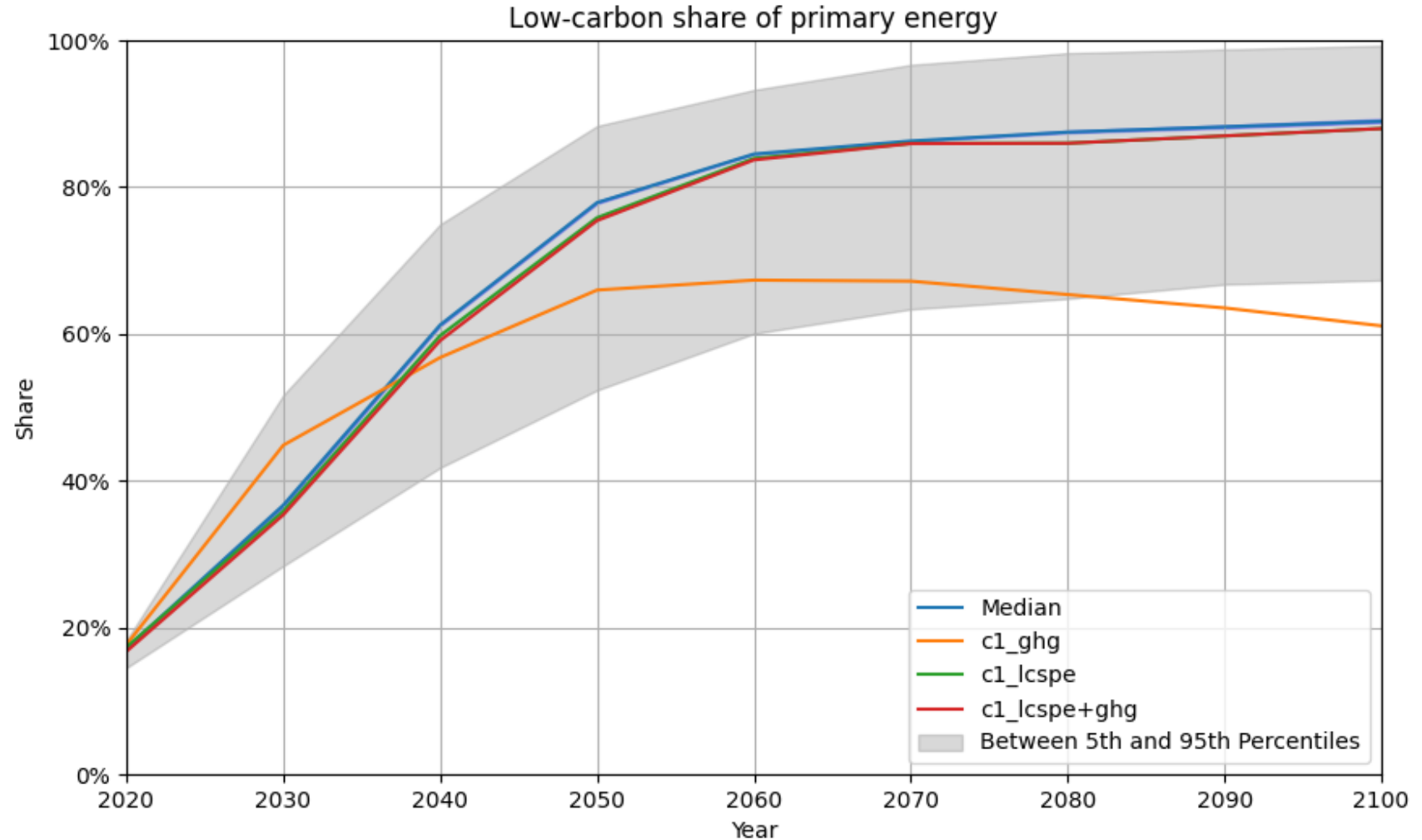
- We employ an Integrated Assessment Model – TIAM-FR developed in CMA, an offspring of the ETSAP-TIAM model (Loulou and Labriet, 2008)
- We extract global median values of C1 scenarios over the horizon
 - The GHG emission pathway
 - The low-carbon share of primary energy (LCSPE)
 - Final energy demand
 - Electricity share in final energy demand
 - The amount of fossil CCS
- For consistency with C1, the model is ran with SSP1-1.9 socio-economic assumptions

RESULTS

C1_ghg: scenario bounded to global median GHG emission pathway

C1_lcspe: scenario bounded to global median Low-Carbon Share of Primary Energy (LCSPE)

C1_lcspe+ghg: combination of c1_lcspe and c1_ghg

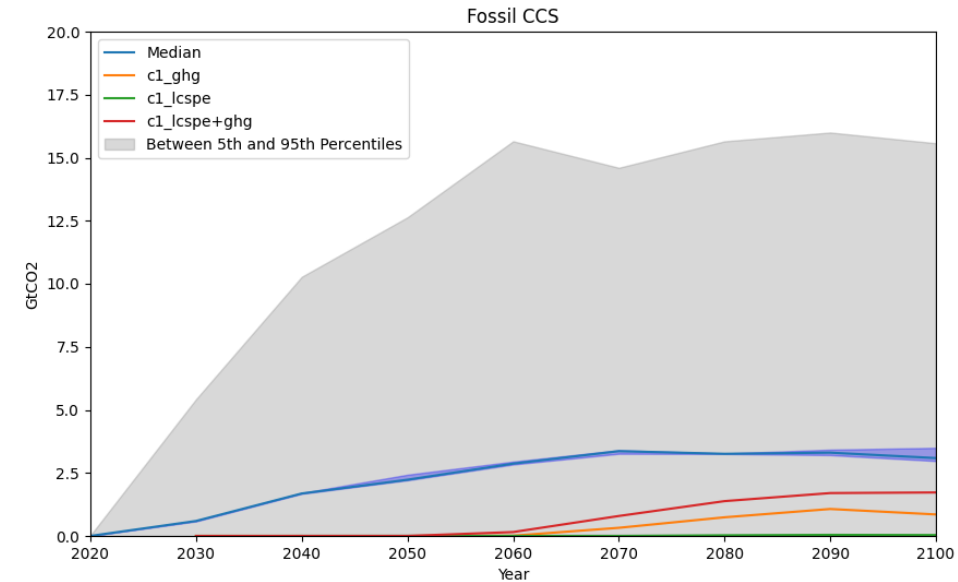
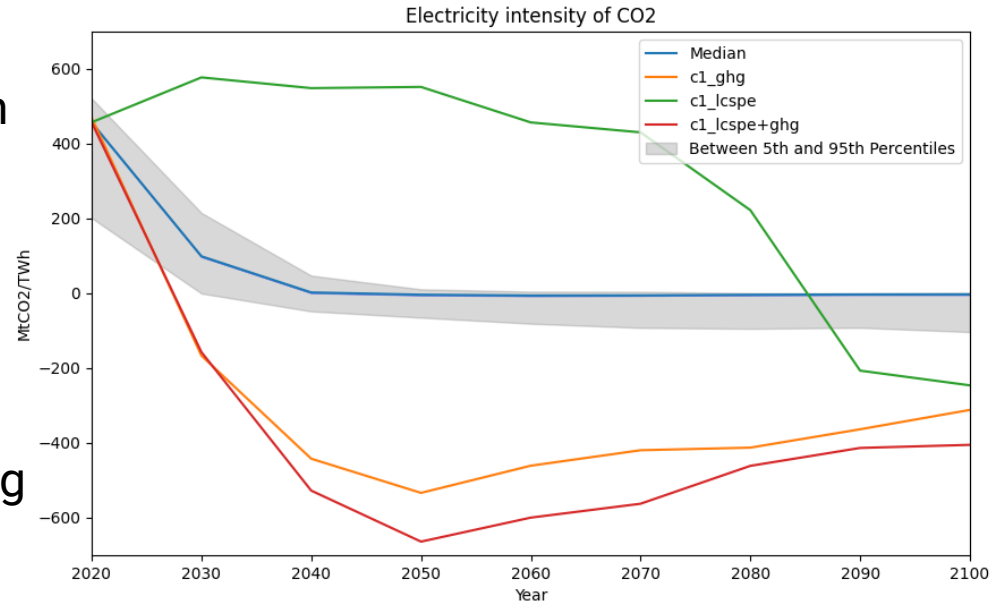
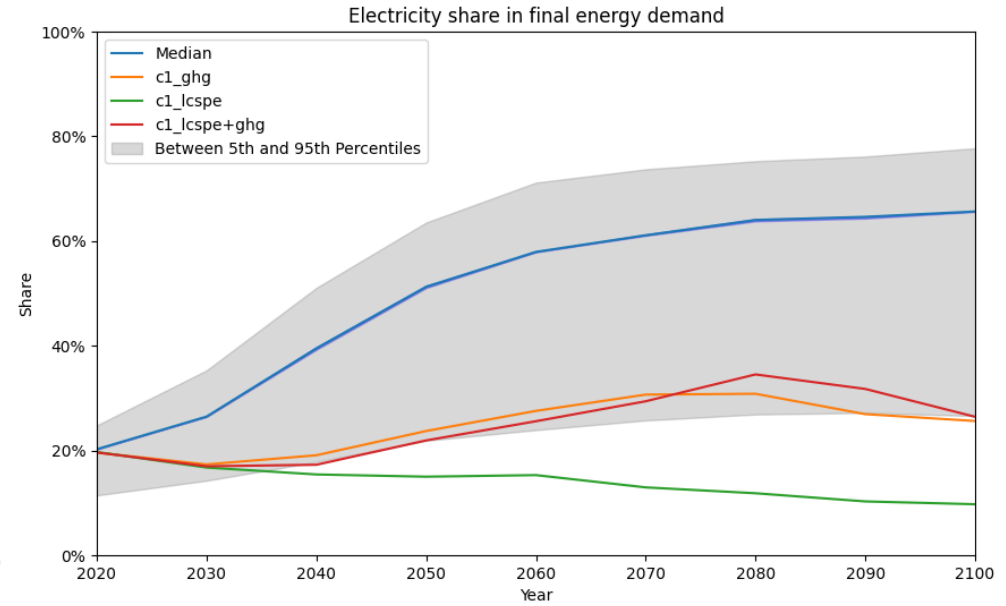
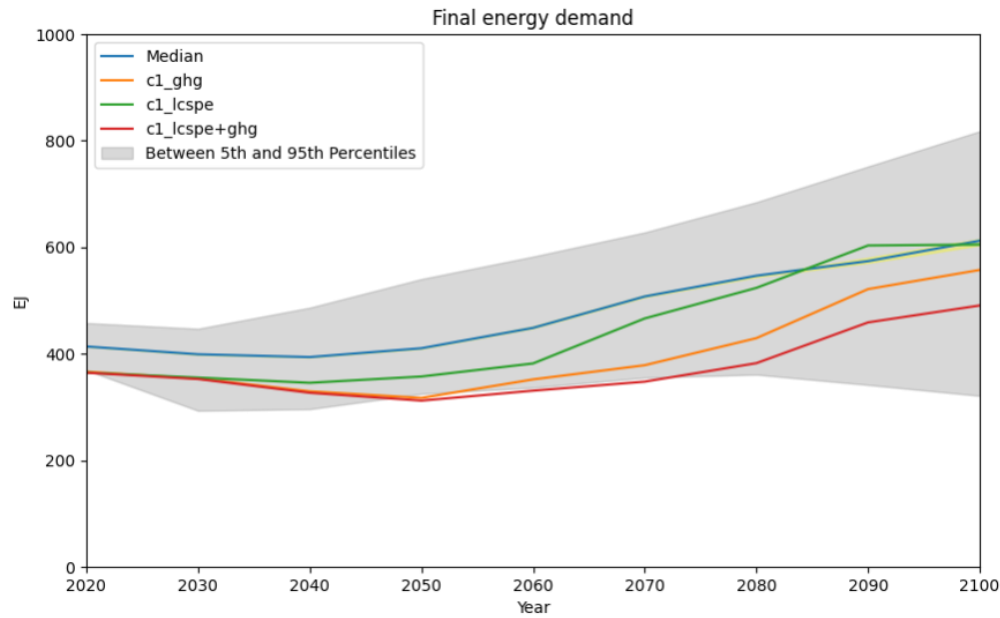


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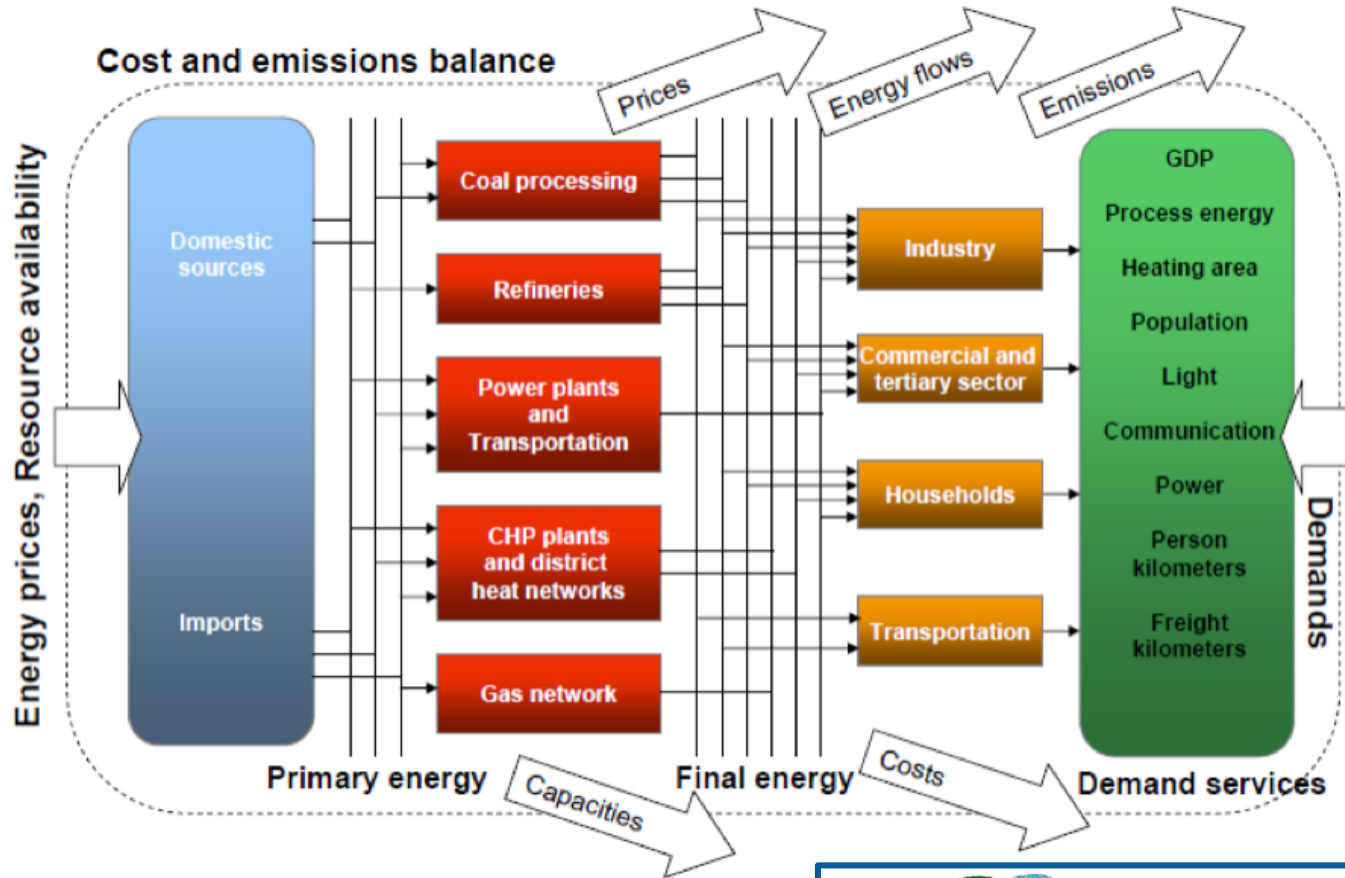
CONCLUSION

- These preliminary results support our initial intuition.
- In further works, all parameters are to be constrained altogether to assess both feasibility and plausibility of hypothetical median pathways and extend it to other categories
- Some combination of medians – and medians themselves – yield to infeasibilities

THANK YOU

LUCAS.DESPORT@MINESPARIS.PSL.EU

TIAM-FR (BOTTOM-UP)



$$NPV = \sum_{r=1}^R \sum_{t \in T} (1 + d_{r,t})^{t_0-t} AC_{r,t}$$

$$AC_{r,t} = c \cdot X_{r,t}$$

min NPV

c : constraints

$X_{r,t}$: investment choices

