Quelques éléments sur la modélisation prospective dans le 6ème rapport du groupe III du GIEC

Franck Lecocq – Journée de la chaire MPDD

10 Juin 2022

N’hésitez pas à vous plonger dans le rapport

- https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

- **Résumé pour décideurs**
  - https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf
- **Résumé technique**
  - https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_TechnicalSummary.pdf
- **Rapport complet**
  - https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf

1: Introduction and Framing
2: Recent trends and drivers
3: Long term mitigation goals and pathways
4: Mitigation and development pathways in the near- to mid-term
5: Demand, services and social aspects of transformation
6: Energy systems
7: AFOLU
8: Urban systems and other settlements
9: Buildings
10: Transport
11: Industry
12: Responses across and beyond sectors
13: National and sub-national policies and institutions
14: International cooperation
15: Mobilising finance
16: Innovation, technology development and technology transfer
17: Accelerating the transition in the context of sustainable development

Une utilisation plus mesurée des IAMs plus mesurée que dans l'AR5

- Critique de l'AR5 : survalorisation des modèles globaux (Ch6) par rapport au reste du rapport, notamment dans le SPM et la communication
- Volonté d'éviter cet écueil pour l'AR6
  - Pas de tentative de mise en cohérence des chapitres sectoriels et du chapitre sur les IAMs
  - Place plus périphérique des Illustrative Mitigation Pathways
  - Introduction d'une annexe très détaillée sur modèles et scénarios
- Au final
  - IAM = outil irremplaçable de mise en cohérence globale des images du futur
  - Une « line of evidence » parmi d'autres pour les autres chapitres
  - Une plus grande variété de narratifs … représentative de la littérature

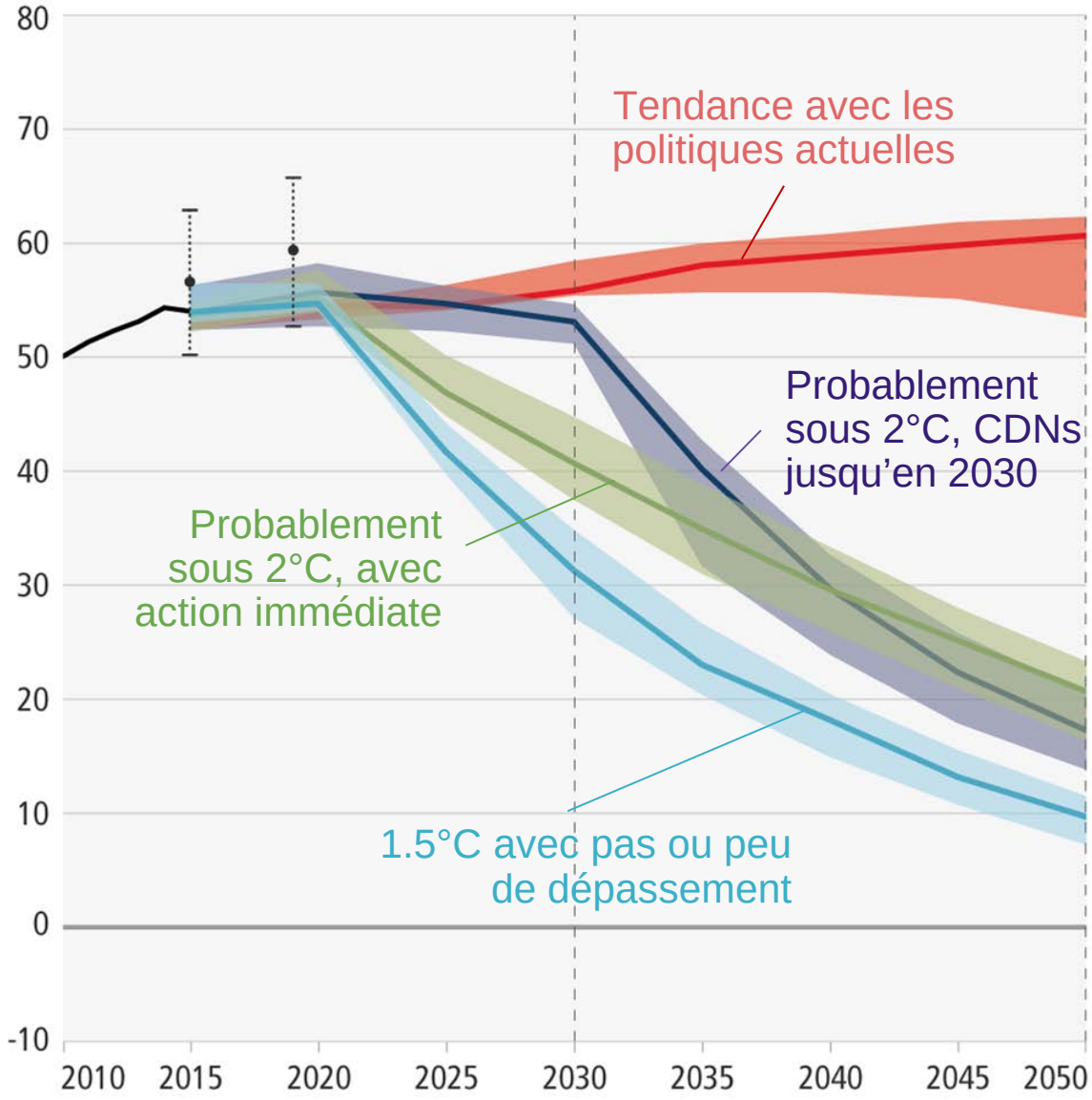
3 principales classes de modèles mobilisées

Echelle géographique **Couverture sectorielle**	**Globale**	**Régionale / Nationale**
Economie toute entière	**IAMs**	**Modèles de prospective nationaux**
Sectorielle	**Par exemple, modèles globaux d'usage du sol**	

Modèles et scénarios globaux

- Communauté bien organisée (IAMC)
- Appels à contribution pour scénarios globaux lancé par IIASA et IAMC
- 2266 scénarios reçus, 1686 sélectionnés
  - 1202 de 22 modèles scénarios avec assez d'information pour catégorisation en température
  - 484 scénarios de 26 modèles sans catégorisation en température (mais utilisés dans d'autres contextes)
- Couverture quasi exhaustive des modèles et scénarios globaux
- Se prête à traitement qualitatif et quantitatif

p50 [p5-p95] [1]			GHG emissions Gt CO_2-eq/yr [7]			GHG emissions reductions from 2019 % [8]			Emissions milestones [9,10]				Cumulative CO_2 emissions Gt CO_2 [13]		Cumulative net-negative CO_2 emissions Gt CO_2	Global mean temperature change 50% probability [14] °C		Likelihood of peak global warming staying below (%) [15]		
Category [2, 3, 4] [# pathways]	Category / subset label	WG I SSP & WG III IPs/IMPs alignment [5, 6]	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 [11, 12] (% 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	<2.0°C	<3.0°C
Modelled global emissions pathways categorised by projected global warming levels (GWL). Detailed likelihood definitions are provided in SPM Box1. The five illustrative scenarios (SSPx-y) considered by AR6 WGI and the Illustrative (Mitigation) Pathways assessed in WGIII are aligned with the temperature categories and are indicated in a separate column. Global emission pathways contain regionally differentiated information. This assessment focuses on their global characteristics.			*Projected median annual GHG emissions in the year across the scenarios, with the 5th-95th percentile in brackets. Modelled GHG emissions in 2019: 55 [53-58] Gt CO_2-eq*			*Projected median GHG emissions reductions of pathways in the year across the scenarios compared to modelled 2019, with the 5th-95th percentile in brackets. Negative numbers indicate increase in emissions compared to 2019*			*Median 5-year intervals at which projected CO_2 & GHG emissions peak, with the 5th-95th percentile interval in square brackets. Percentage of peaking pathways is denoted in round brackets. Three dots (...) denotes emissions peak in 2100 or beyond for that percentile.*		*Median 5-year intervals at which projected CO_2 & GHG emissions of pathways in this category reach net-zero, with the 5th-95th percentile interval in square brackets. Percentage of net zero pathways is denoted in round brackets. Three dots (...) denotes net zero not reached for that percentile.*		*Median cumulative net CO_2 emissions across the projected scenarios in this category until reaching net-zero or until 2100, with the 5th-95th percentile interval in square brackets.*		*Median cumulative net-negative CO_2 emissions between the year of net-zero CO_2 and 2100. More net-negative results in greater temperature declines after peak.*	*Projected temperature change of pathways in this category (50% probability across the range of climate uncertainties), relative to 1850-1900, at peak warming and in 2100, for the median value across the scenarios and the 5th-95th percentile interval in square brackets.*		*Median likelihood that the projected pathways in this category stay below a given global warming level, with the 5th-95th percentile interval in square brackets.*		
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]
C1a [50]	**... with net-zero GHGs**	SSP1-1.9, SP LD	33 [22-37]	18 [6-24]	8 [0-15]	41 [31-59]	66 [58-89]	85 [72-100]	2020-2025 (100%) [2020-2025]		2050-2055 (100%) [2035-2070]	2070-2075 (100%) [2050-2090]	550 [340-760]	160 [-220-620]	-360 [-680–140]	1.6 [1.4-1.6]	1.2 [1.1-1.4]	38 [34-60]	90 [85-98]	100 [99-100]
C1b [47]	**... without net-zero GHGs**	Ren	29 [21-36]	16 [7-21]	9 [4-13]	48 [35-61]	70 [62-87]	84 [76-93]				...-... [0%] [...-...]	460 [320-590]	360 [10-540]	-60 [-440-0]	1.6 [1.5-1.6]	1.4 [1.3-1.5]	37 [33-56]	89 [87-96]	100 [99-100]
C2 [133]	**return warming to 1.5°C (>50%) after a high overshoot**	Neg	42 [31-55]	25 [17-34]	14 [5-21]	23 [0-44]	55 [40-71]	75 [62-91]	2020-2025 (100%) [2020-2030]	[2020-2025]	2055-2060 (100%) [2045-2070]	2070-2075 (87%) [2055-...]	720 [530-930]	400 [-90-620]	-360 [-680–60]	1.7 [1.5-1.8]	1.4 [1.2-1.5]	24 [15-42]	82 [71-93]	100 [99-100]
C3 [311]	***limit warming to 2°C (>67%)***		44 [32-55]	29 [20-36]	20 [13-26]	21 [1-42]	46 [34-63]	64 [53-77]	2020-2025 (100%) [2020-2030]	[2020-2025]	2070-2075 (93%) [2055-...]	...-... (30%) [2075-...]	890 [640-1160]	800 [510-1140]	-40 [-290-0]	1.7 [1.6-1.8]	1.6 [1.5-1.8]	20 [13-41]	76 [68-91]	99 [98-100]
C3a [204]	**... with action starting in 2020**	SSP1-2.6	40 [30-49]	29 [21-36]	20 [14-27]	27 [13-45]	47 [35-63]	63 [52-76]	2020-2025 (100%) [2020-2025]		2070-2075 (91%) [2055-...]	...-... (24%) [2080-...]	860 [640-1180]	790 [480-1150]	-30 [-280-0]	1.7 [1.6-1.8]	1.6 [1.5-1.8]	21 [14-42]	78 [69-91]	100 [98-100]
C3b [97]	**... NDCs until 2030**	GS	52 [47-56]	29 [20-36]	18 [10-25]	5 [0-14]	46 [34-63]	68 [56-82]			2065-2070 (97%) [2055-2090]	...-... (41%) [2075-...]	910 [720-1150]	800 [560-1050]	-60 [-300-0]	1.8 [1.6-1.8]	1.6 [1.5-1.7]	17 [12-35]	73 [67-87]	99 [98-99]
C4 [159]	**limit warming to 2°C (>50%)**		50 [41-56]	38 [28-44]	28 [19-35]	10 [0-27]	31 [20-50]	49 [35-65]	2020-2025 (100%) [2020-2030]		2080-2085 (86%) [2065-...]	...-... (31%) [2075-...]	1210 [970-1490]	1160 [700-1490]	-30 [-390-0]	1.9 [1.7-2.0]	1.8 [1.5-2.0]	11 [7-22]	59 [50-77]	98 [95-99]
C5 [212]	**limit warming to 2.5°C (>50%)**		52 [46-56]	45 [37-53]	39 [30-49]	6 [-1-18]	18 [4-33]	29 [11-48]			...-... (41%) [2080-...]	...-... (12%) [2090-...]	1780 [1400-2360]	1780 [1260-2360]	0 [-160-0]	2.2 [1.9-2.5]	2.1 [1.9-2.5]	4 [0-10]	37 [18-59]	91 [83-98]
C6 [97]	**limit warming to 3°C (>50%)**	SSP2-4.5 Mod-Act	54 [50-62]	53 [48-61]	52 [45-57]	2 [-10-11]	3 [-14-14]	5 [-2-18]	2030-2035 (96%) [2020-2090]	2020-2025 (97%)	no net-zero		no net-zero	2790 [2440-3520]	no net-zero	temperature does not peak by 2100	2.7 [2.4-2.9]	0 [0-0]	8 [2-16]	71 [53-88]
C7 [164]	**limit warming to 4°C (>50%)**	SSP3-7.0 Cur-Pol	62 [53-69]	67 [56-76]	70 [58-83]	-11 [-18-3]	-19 [-31-1]	-24 [-41–2]	2085-2090 (57%) [2040-...]	2090-2095 (56%)				4220 [3160-5000]			3.5 [2.8-3.9]	0 [0-0]	0 [0-2]	22 [7-60]
C8 [29]	**exceed warming of 4°C (>=50%)**	SSP5-8.5	71 [69-81]	80 [78-96]	88 [82-112]	-20 [-34–17]	-35 [-65–29]	-46 [-92–36]	2080-2085 (90%) [2070-...]					5600 [4910-7450]			4.2 [3.7-5.0]	0 [0-0]	0 [0-0]	4 [0-11]



Limiter le réchauffement à 1,5 °C

- Pic des émissions mondiales de GES avant 2025, réduites de 43% d'ici 2030.
- Emissions de méthane réduites de 34% d'ici 2030.

Limiter le réchauffement à 2°C

- Emissions réduites de 27% d'ici 2030.

(sur la base des scenarios évalués par le Groupe III du GIEC)

Les modèles globaux comme outil de cohérence d'ensemble

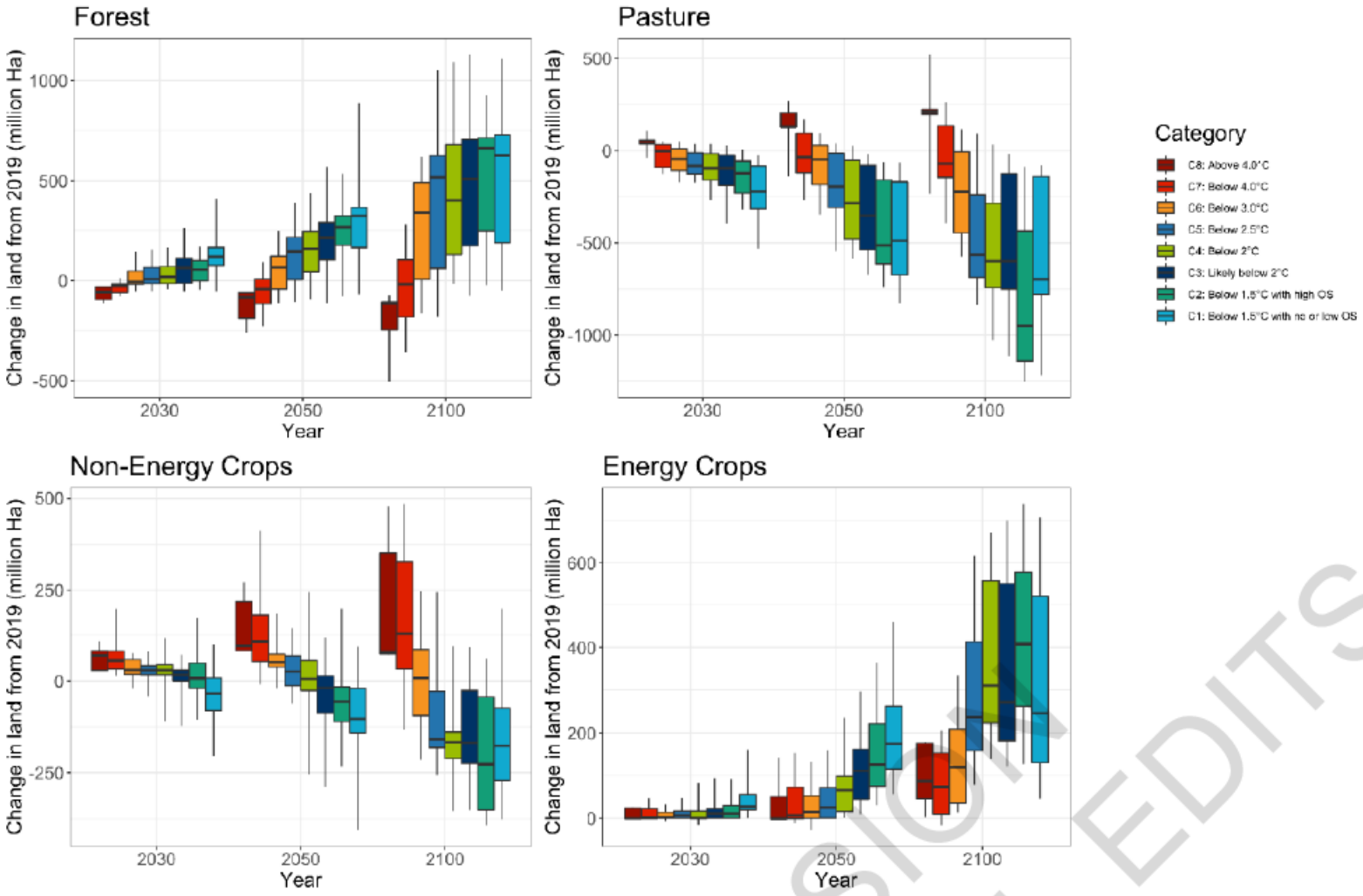
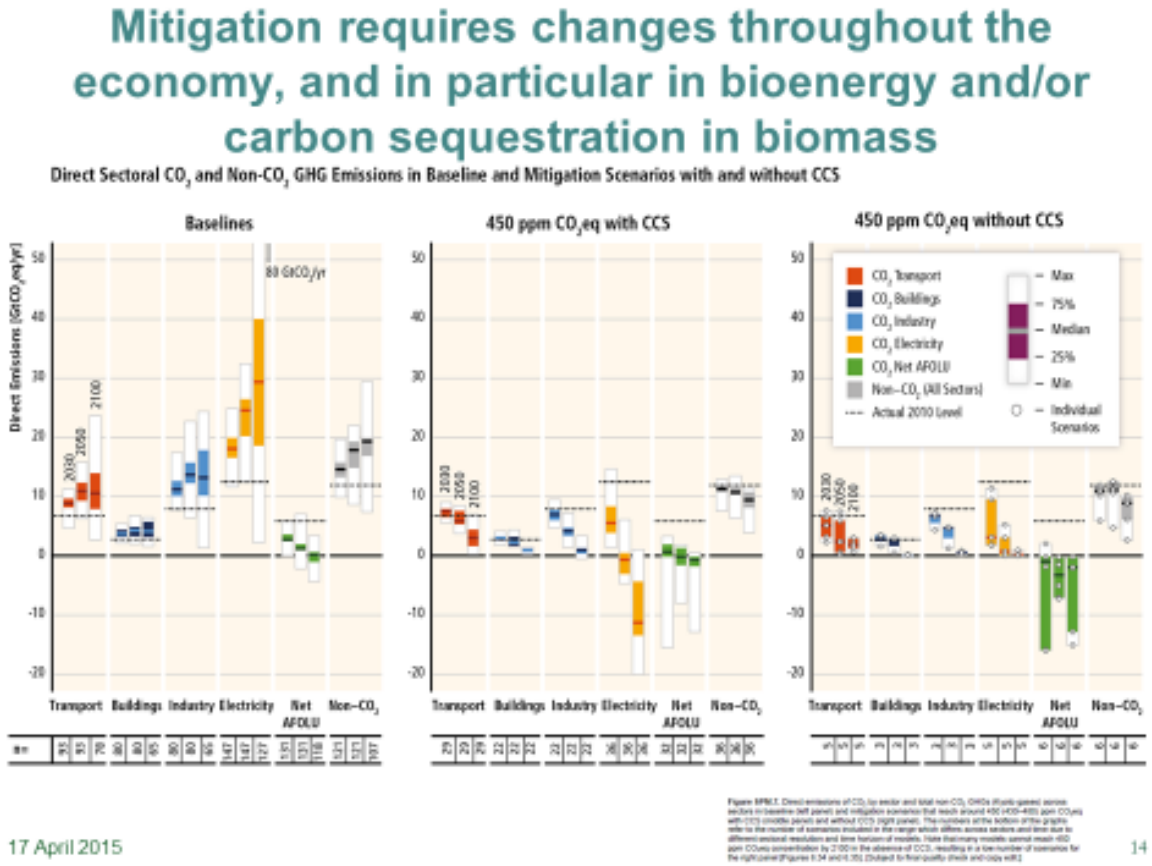
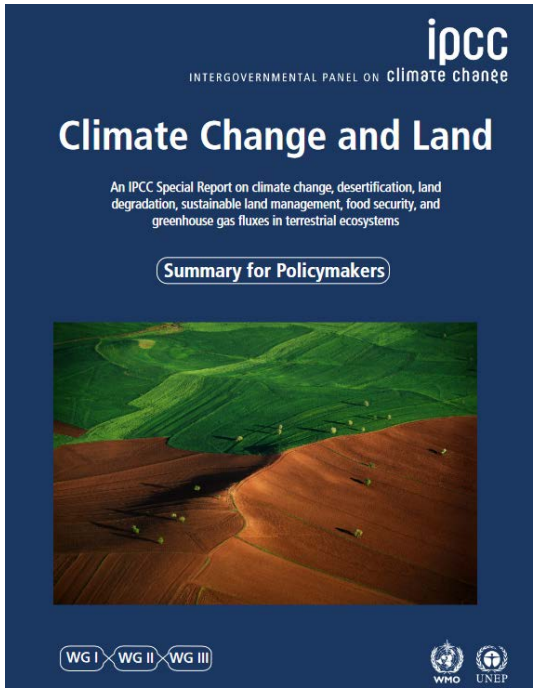


Figure 3.28: Change in Land Cover from 2019 in million hectares. Positive values indicate an increase in area.

Les modèles comme révélateurs des hypothèses sur le futur





Modèles et scénarios nationaux, économies toute entière

- Une communauté beaucoup plus large et moins structurée
- Appel à contribution pour les scénarios nationaux
  - 534 scénarios reçus, 47 modèles
  - Une fraction seulement de la communauté a répondu
- Importance des familles de modèles (TIMES, AIM en particulier)
- Distribution d'ensemble très inégale selon les pays

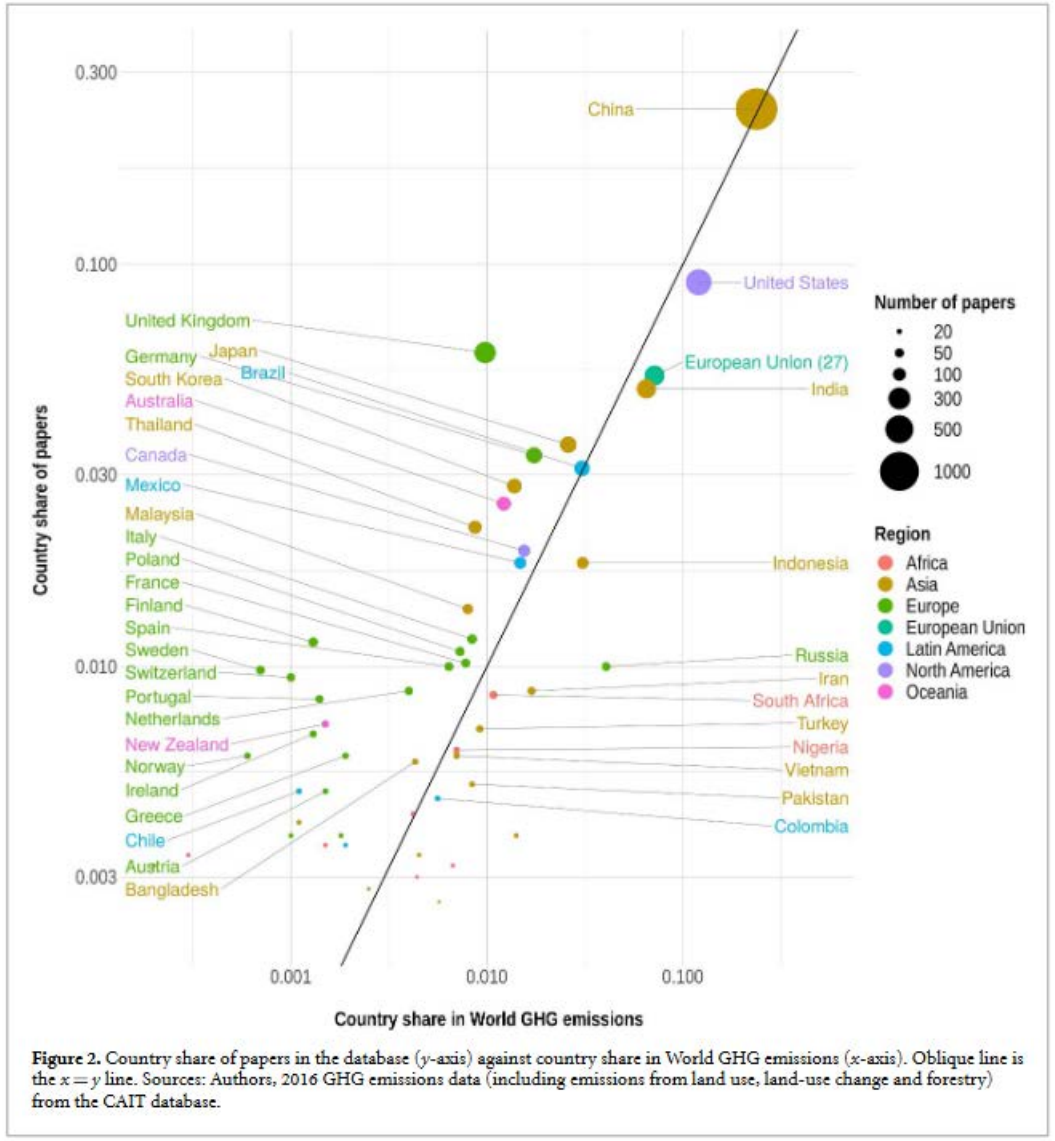


Figure 2. Country share of papers in the database (y-axis) against country share in World GHG emissions (x-axis). Oblique line is the $x = y$ line. Sources: Authors, 2016 GHG emissions data (including emissions from land use, land-use change and forestry) from the CAIT database.

Lepault et Lecocq, ERL, 2021

Une utilisation plus parcimonieuse des modèles nationaux (Ch4)

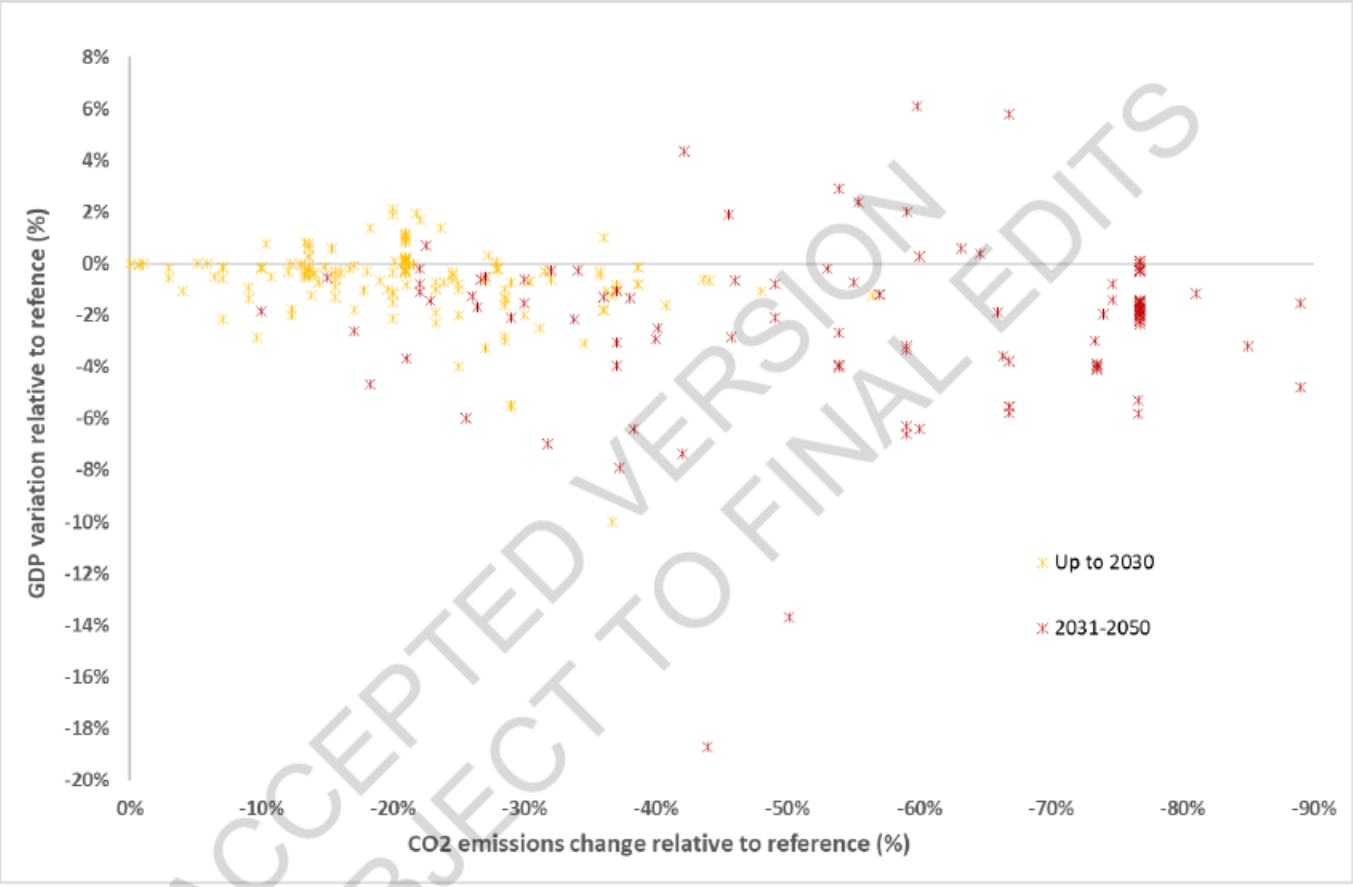
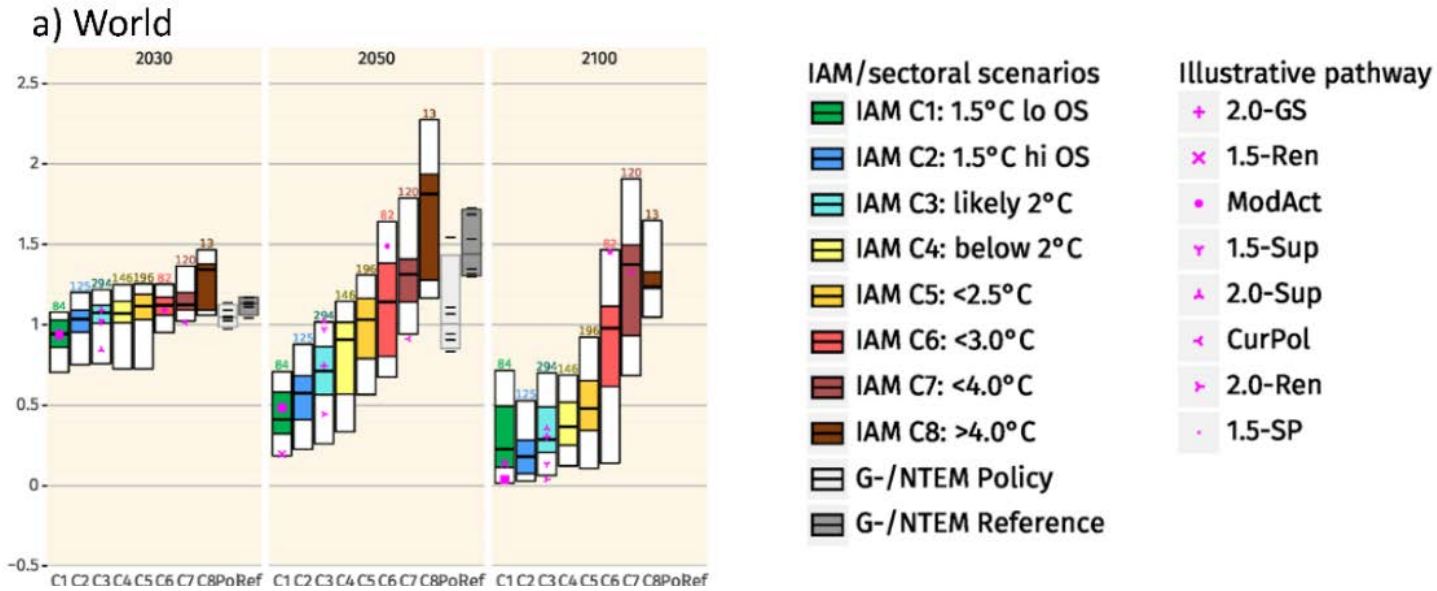


Figure 4.4 GDP against emissions in country-level modelling studies, in variations relative to reference

- Modèles d'économie nationaux = une ligne d'évidence parmi d'autres
- Discussions plus qualitatives
- Scénarios comme illustrations
- Utilisation de scénarios hors BDD
- Manque cruel de publication des scénarios nationaux pertinents
- Importance des *cross-country studies*
- Expérience accumulée … pour l'AR7

Un usage important des modèles sectoriels

- Appel lancé via l'IIASA
- Réponses limitées, communautés très éclatées
- Utilisation conjointe des résultats sectoriels des modèles globaux, et de modèles sectoriels spécifiques (AFOLU, Transport, Energie, Industrie, bâtiment)
- Pas de référence aux modèles (Urban systems)



Les illustrative mitigation pathways

- Des narratifs pour illustrer la variété des stratégies possibles pour atteindre 2°C/1.5°C
- Souvent repris partiellement, et sous formes de narratifs (4, 6, 7, 8 sous forme de narratifs, 10)
- Basés sur tout ou partie des IMPs

		General char.	Policy	Innovation	Energy	Land use, food biodiversity	Lifestyle
Cur-Pol		Continuation of current policies and trends;	Implementation of current climate policies and neglect of stated goals and objectives; Grey Covid recovery)	Business-as-usual; slow progress in low-carbon technologies	Fossil fuels remain important; lock-in	Further expansion of western diets; further slow expansion of agriculture area	Demand will continue to grow; no significant changes in current habits
Mod-Act		NDCs in 2030; as announced in 2020, fragmentated policy landscape; post-2030 action consistent with modest action until 2030	Strengthening of policies to implement NDCs; some further >2030 strengthening and mixed Covid recovery	Modest change compared to CurPol	Mostly moving away from coal; growth of renewables; some lock-in in fossil investments	Afforestation/reforestation policies as in NDcs	Modest change compared to CurPol
IMP	Neg	Mitigation in all sectors also includes a heavy reliance on net negative emissions (supply-side)	Successful international climate policy regime with a focus on a long-term temperature goal	Further development of CDR options;	CDR, transport H2/Elec based on negative emissions	Afforestation/reforestation, BECCS, increased competition for land	Not critical – some induced via price increases
	Ren	Rapid deployment and technology development of renewables; electrification;	Successful international climate policy regime; policies and financial incentives favouring renewable energy	Rapid further development of innovative electricity technologies and policy regimes	Renewable energy, electrification; sector coupling; storage or power-to-X technologies; better interconnections		Service provisioning and demand changes to better adapt to high RE supply
	LD	Reduced demand leads to early emission reductions		Social innovation; efficiency; across all sectors	Demand reduction; modal shifts in transport; rapid diffusion of BAT in buildings and industry	Lower food and agricultural waste; less meat-intensive lifestyles	Service provisioning and demand changes; behavioural changes
	GS	Mitigation action is gradually strengthened until 2030 compared to NDCs,	Until 2030, primarily current NDCs are implemented – but move towards strong, universal regime > 2030		Similar to Sup, but with some delay.	Similar to Sup, but with some delay.	
	SP	*Shifting pathways.* Major transformations shift development towards sustainability and reduced inequality, including deep GHG emissions reduction	SDG policies in addition to climate policy (poverty reduction; environmental protection		Demand reduction; renewable energy	Lower food and agricultural waste; less meat-intensive lifestyles; afforestation.	Service provisioning and demand changes

Annex III: Scenarios and Modelling Methods

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Part I. Modelling methods

- Overview
- Economic frameworks
- Energy system models
- Building sector models
- Transport models
- Industry sector models
- Land use modeling
- Reduced complexity climate modeling
- IAMs

Part II. Scenarios

- Overview on cc scenarios
- Use of scenarios in the assessment
- Scenario database

Un impact significatif de la production soutenue par la chaire MPDD sur l'AR6

Echantillon de papiers soutenus par la chaire et référencés dans l'AR6

1. Bataille et al 2020
2. Cayla et al 2011
3. Cluet et al 2020
4. Creutzig F. et al. 2021
5. Daioglou et al 2020a
6. Daioglou et al 2020b
7. Fisch-Romito V. 2020
8. Fish-Romero et al 2021
9. Harmsen, et al 2021
10. Hourcade J-C et al 2021a
11. Hourcade et al 2021b
12. Le Treut G et al 2021.
13. Lefevre J., et al 2021.
14. Lepault C., Lecocq F. 2021.
15. Maizi and Mazauric 2019
16. Maizi et al 2017
17. Millot et al 2018
18. Millot et al 2020
19. Prudhomme et al 2020
20. Saujot et Lefèvre 2020
21. Selosse and Ricci 2017
22. Taconet et al 2020
23. Wills et al. 2021

- Etc., etc.