UCL Energy Institute

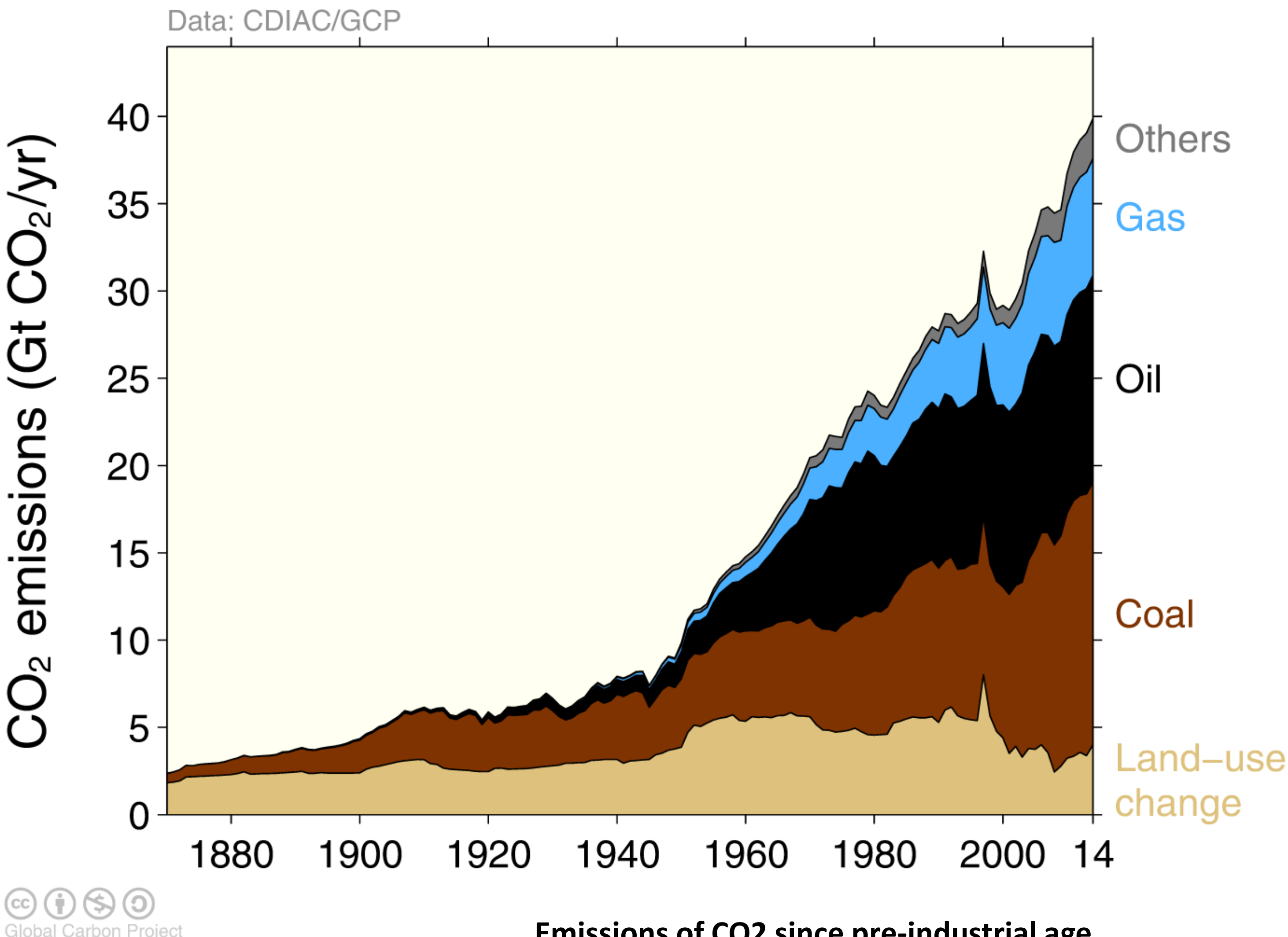
UCL

Fossil fuel production scenarios under carbon budget and equity considerations

Steve Pye, Paul Ekins, James Price

LCSRnet Conference, University of Warwick
September 13th, 2017

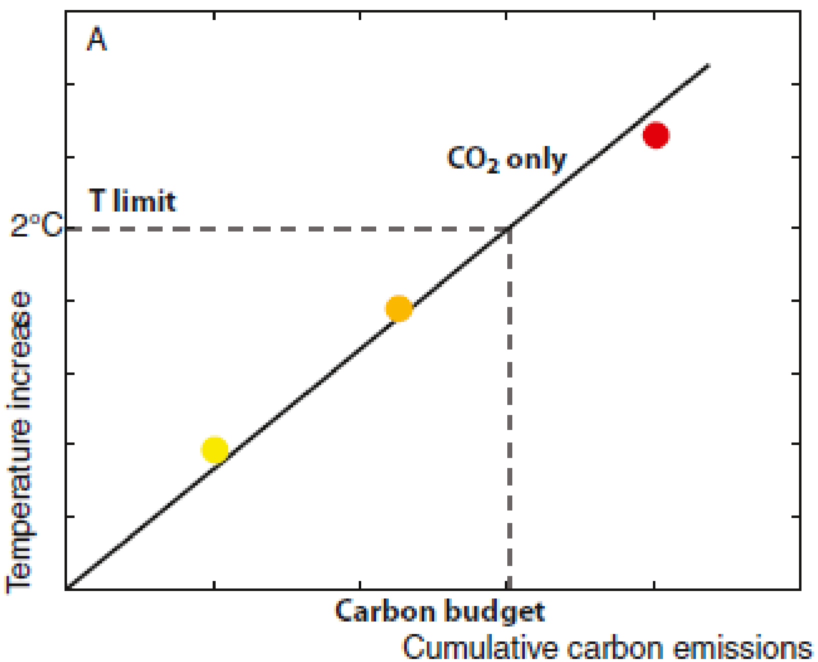
Significant growth of fossil fuel use……and emissions



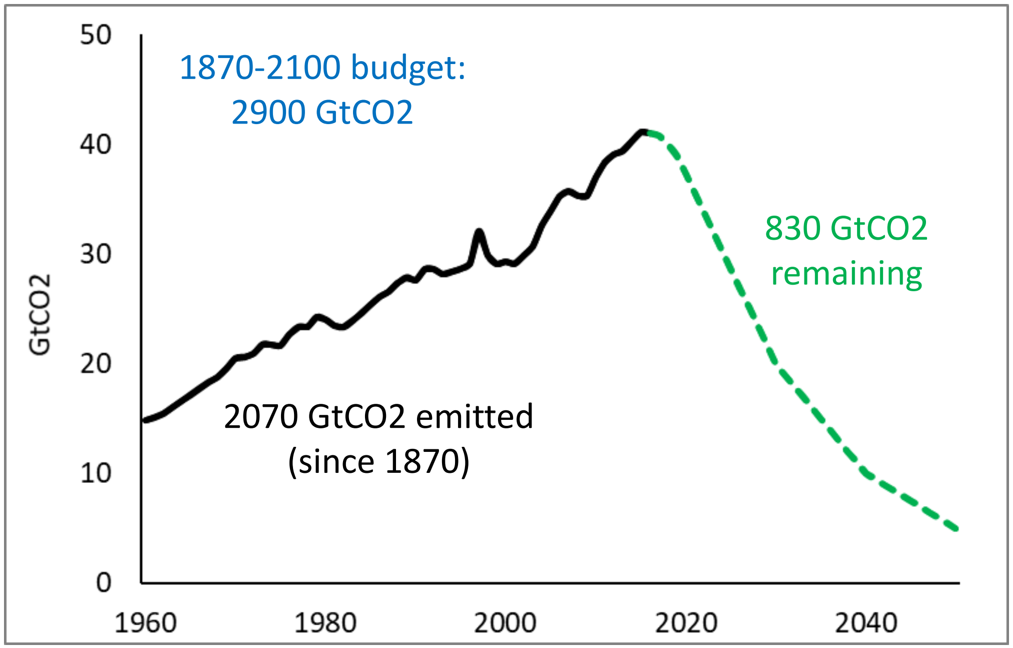
Emissions of CO2 since pre-industrial age
(Source: Global Carbon Project 2015)

Meeting Paris goals means remaining within a carbon budget

- Carbon budget based on known relationship between cumulative CO2 emissions and global temperature rise
- For 2 °C budget (at 66% prob.), central estimate of range at 830 GtCO2 (in 2017), or 20 years at current emission levels



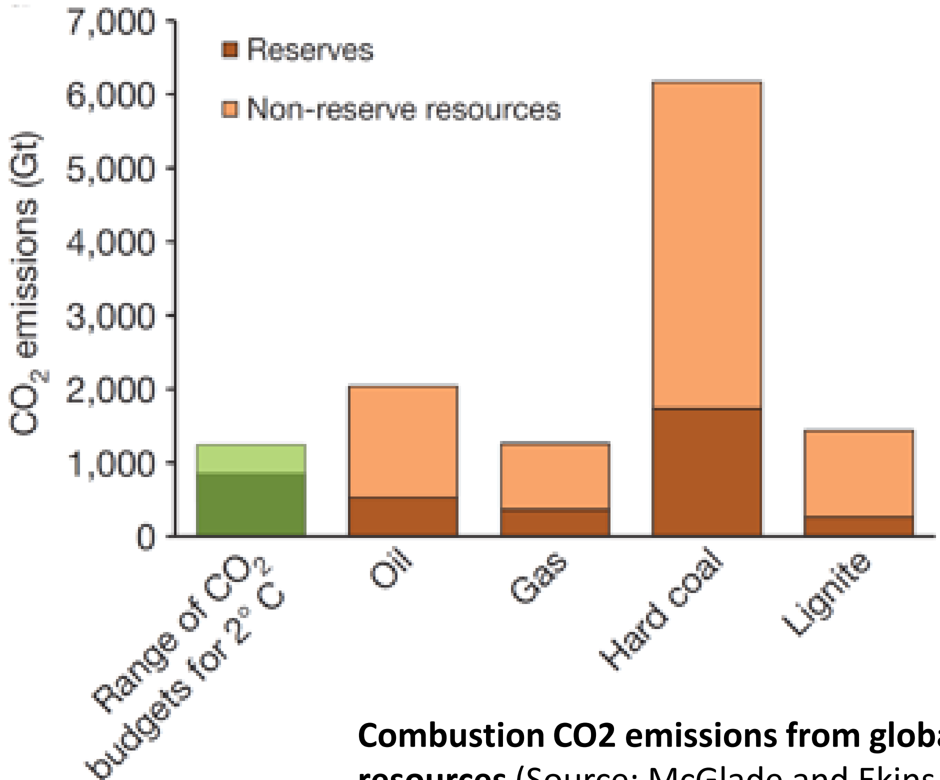
Relationship between temperature increase and cum. CO2 emissions (Source: Knutti & Rogelj, 2015)



Indicative CO2 reduction trajectory to remain within budget

Remaining within a carbon budget means reducing production and leaving a large share of resources unburned

- Using unabated fossil fuel reserves (2,900 $GtCO_2$) would exceed the remaining carbon budget by more than 3 times (resources = 11,000 Gt CO_2)
- Under the 2 °C case, 80% of coal, 50% of gas, and 33% of oil reserves globally should be classified as unburnable…….but crucial issues of **under what conditions**, and **which reserves**?



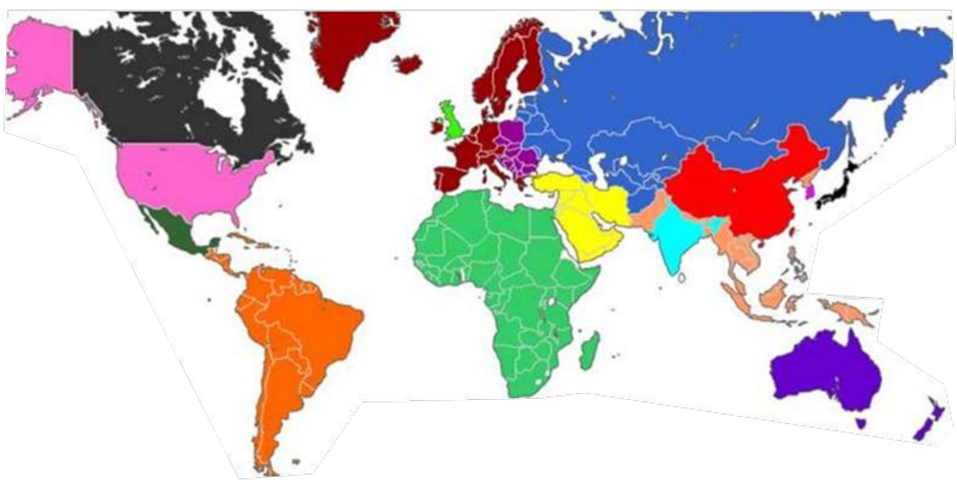
Combustion CO2 emissions from global fossil fuel resources (Source: McGlade and Ekins, 2015)

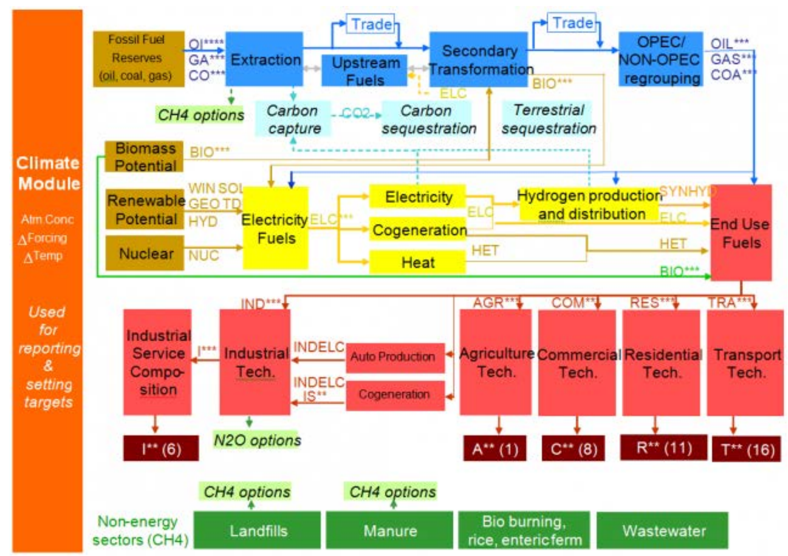
Level of demand for fossil fuels highly uncertain under climate constraints, with implications for established and new producing nations

- Global modelling undertaken to inform how future uncertainties might affect production levels and revenues
- For emerging producers in lower income countries, particularly important to identify the risks and opportunities. Outlook uncertainty from -
    - Climate policy ambition in different regions
    - Technologies that enable continued use of fossil fuels (CCS)
    - Rapid progress in energy technologies that directly reduce fossil fuel demand e.g. electric vehicles, solar generation
- Under a carbon budget, there are also important equity issues arising where limits on production emerge, in terms of who benefits or not

TIAM-UCL global model

- Energy systems model that assesses different cost-optimal ways of meeting current and future energy demand under climate constraints
- Model split into 16 different regions, each explicitly characterising fossil fuel resources and trade flows between regions out to 2100



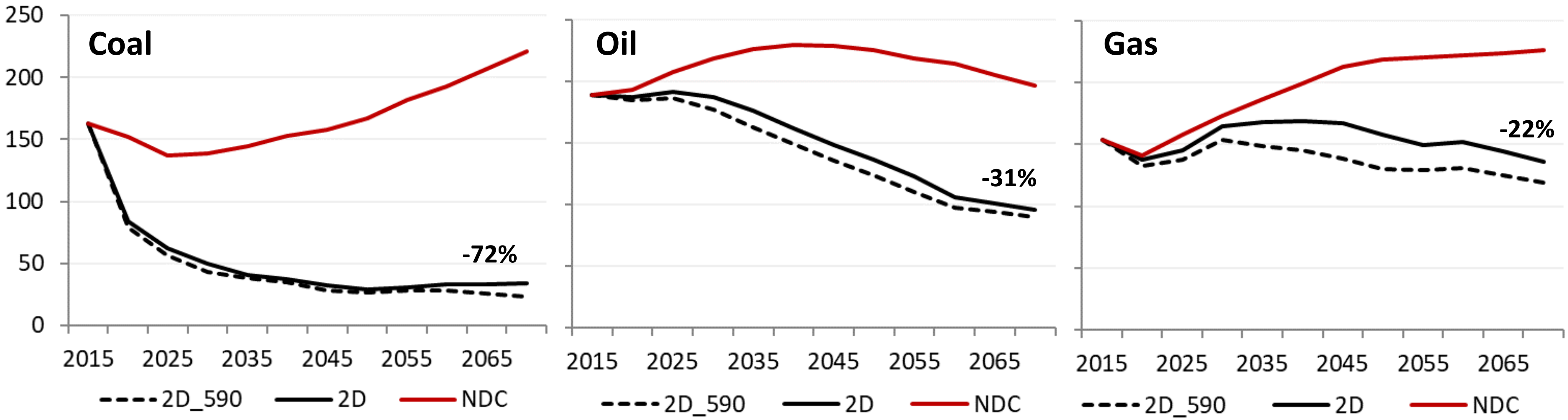


Sensitivities related to different fossil fuel outlooks

Scenario name	Sensitivity type	Description
2 degrees (2D)		Based on a carbon budget (of 915 GtCO2 from 2015) that provides a 66% probability that warming is limited to 2°C
'Well below' 2 degrees (2D_590)	Climate ambition	Based on a more stringent carbon budget of 590 GtCO2
Failure to Ratchet (NDC)		NDC ambition is maintained post-2030 but not ratcheted up
Delay CCS (2D_LowCCS)	Role of CCS / negative emissions	As for 2D, but with CCS deployment rates reduced by 25%
CCS but no BECCS (2D_NoBECCS)		As for 2D, but with no possibility of negative emission generation from bioenergy use with CCS
No CCS (2D_NoCCS)		As for 2D, but with zero prospects for CCS
CCS & higher bioenergy level (2D_TechAccel)	Technology acceleration	As for 2D, but with stronger progress on low carbon light duty vehicles, and renewables
High bioenergy resource (2D_HiBio)	High bioenergy resource	As for 2D, but with 2.5 times more bioenergy use in 2050
Lower demand (2D_SSP1)	Demand level	As for 2D, but with lower demands based on SSP1 framing

Higher climate ambition strongly reduces levels of production

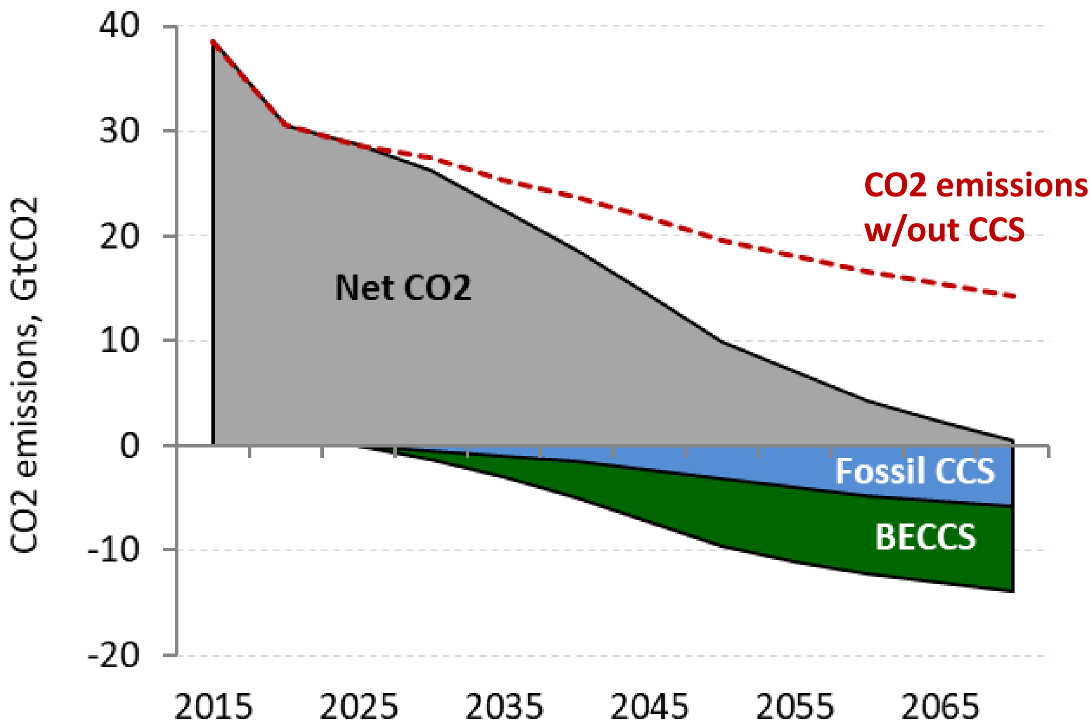
- 'NDC' represents COP21 pledges; hitting 3.5 °C in 2100, modest growth in fossil fuels
- Under a 2 °C target, rapid fall in coal production; oil at 50% of 2010 levels while gas at similar levels in 2070
- A more stringent budget (-30% CO_2) sees further reductions, albeit limited, due to increased CCS



Global production outlook under different climate ambition cases, EJ. *Labels show cum. reduction in 2D, compared to NDC* (Source: Own analysis with TIAM-UCL)

CCS plays a crucial role for remaining in carbon budget limits

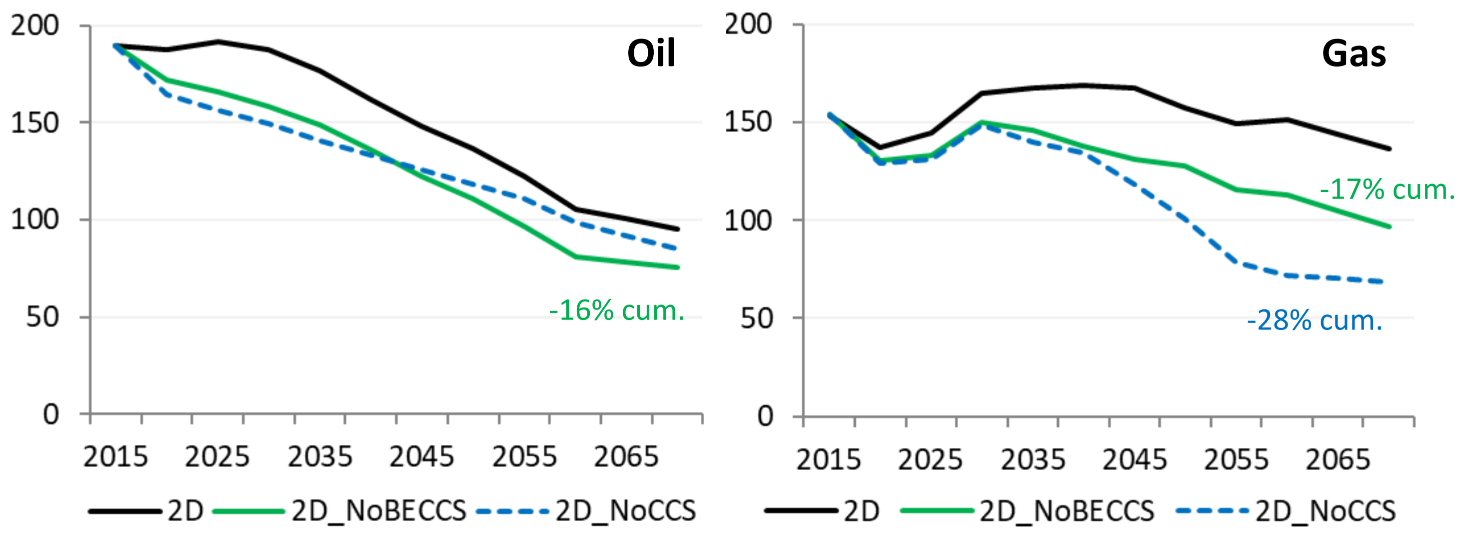
- Net CO2 trajectory (grey area) represents the cumulative CO2 emissions level consistent with the carbon budget
- CCS captures and stores CO2 (green-blue shaded area), without which emissions would be at a much higher level (red dashed line); helps to slow the rate of CO2 reductions and to deal with hard-to-mitigate sectors
- Uncertainty due to commercialisation in 2030s, and rapid scaling in subsequent decades



CO2 emissions outlook under 2D case (Source: own analysis with TIAM-UCL)

Production outlook declines in the absence of CCS & BECCS

- Without CCS (blue dash line), compared to 2D, we observe a quicker reduction in oil use, almost no coal by 2040, and 50% of the gas level in 2070
- But some form of CO2 removal from the atmosphere via negative emission technologies (NETs) is required for this level of fossil fuel use
  - Even if production levels were reduced to zero by 2100, emissions would still exceed the carbon budget by almost 20% (155 Gt)



Global production outlook under different CCS sensitivity cases, EJ
(Source: own analysis with TIAM-UCL)

Uncertain outlook for production in lower income regions

- For 2°C, production levels would need to decrease significantly below levels observed under NDC pledges
- However, opportunities remain for production (except for coal), the level of which is conditional on a range of factors
- Most notably, projected levels are underpinned by CCS, and in use with bioenergy (BECCS)
  - IAM scenarios project a significant role (Fuss et al., 2014) while on the ground few countries are planning for it (Peters and Geden, 2017)
- In the absence of CCS, the cumulative production level to 2070 sees large reduction, but even this implies some form of NETs
- Other key uncertainties, which reduce production levels, include more rapid deployment of low carbon technology (e.g. 45% reduction in cum. oil consumption in cars to 2070); lower growth & demand; higher non-CO2 GHGs

Regional distribution of reserves unburnable before 2050 to stay below 2^{o}C

Region	Oil		Gas		Coal	
	Gb	%	Tcm	%	Gt	%
Africa	23	21%	4.4	33%	28	85%
Canada	39	74%	0.3	24%	5.0	75%
China	9	28%	2.6	75%	116	61%
C & S America	58	39%	4.8	53%	8	51%
Europe	5.0	20%	0.6	11%	65	78%
FSU	27	18%	31	50%	203	94%
India	0.4	7%	0.3	27%	64	80%
Middle East	263	38%	46	61%	3.4	99%
OECD Pacific	2.1	37%	2.2	56%	83	93%
ODA	2.0	9%	2.2	24%	10	34%
United States	2.8	6%	0.3	4%	235	92%
Global	431	33%	95	49%	819	82%

Lower fossil fuel production compatible with Paris Agreement ambition raises questions of equity

- Equity concerns arise from reduced production under climate policy – who gets to extract?

- Consideration of the equity dimension may inform –
  - how donors view funding into and provide advice on fossil fuel extraction
  - the formulation of domestic policy in developed countries, as it relates to extractives
  - strategies of new producing countries in relation to commitments made

- Caney (2016) outlines possible criteria for determining more equitable distribution of production
  - The need for development
  - Alternative means of development
  - Historical responsibility, or benefits accrued

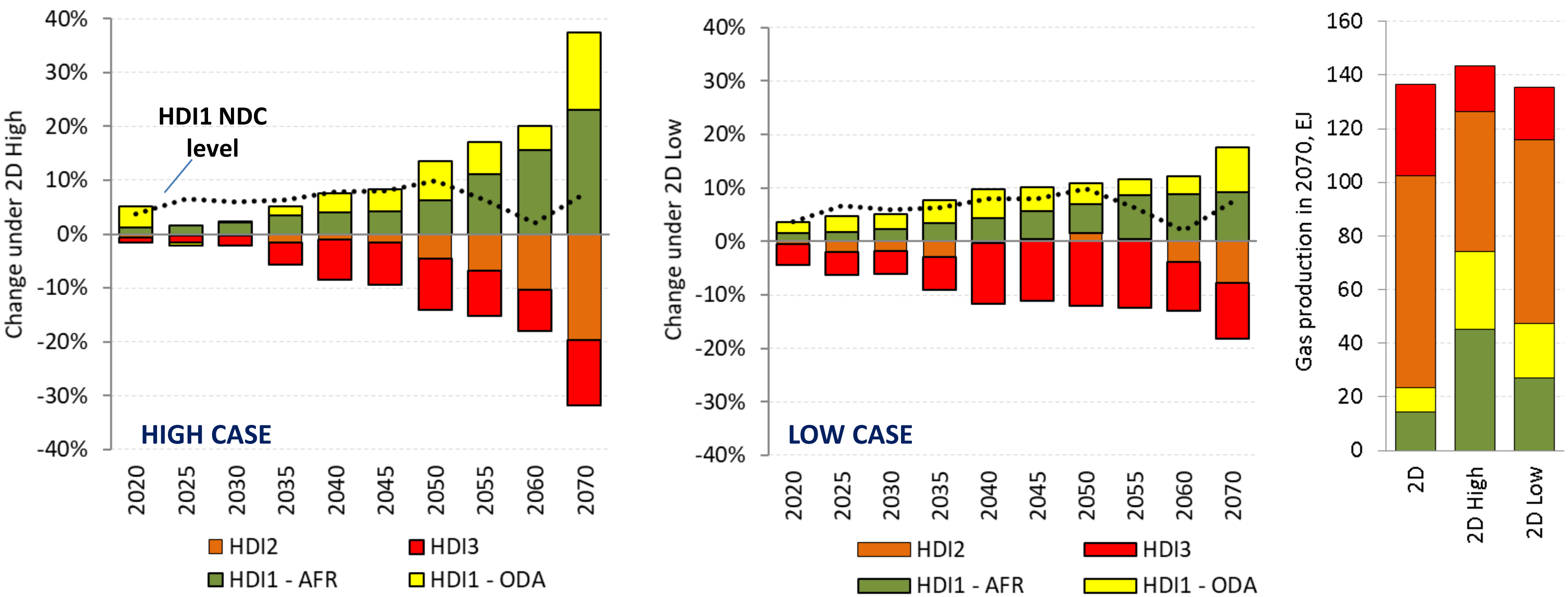
Modelling an equitable distribution of fossil fuel production

- Model regions grouped according to criteria ‘need for development’, using the Human Development Index (HDI)
- Increased production quota allocated to HDI1 & lower quota to HDI3, maintaining same global production levels as in 2D case
- A high and low re-distribution case was modelled; in the high case, HDI1 sees a larger increase in production share
- Quotas originally derived from earlier modelling analysis, which applied differentiated carbon pricing on extraction e.g. high price on HDI3, low on HDI1

HDI group ID	HDI group	HDI level	TIAM-UCL regions
1	Low-medium human development (LMHD)	<0.7	Africa, India, Other Developing Asia***
2	High human development (HHD)	0.7 – 0.8	Middle East**, Mexico, South and Central America, China, Former Soviet Union*
3	Very high human development (VHHD)	>0.8	Western Europe, Eastern Europe****, UK, Canada, USA, Australia, Japan, South Korea

Redistribution of 2D gas & oil production levels

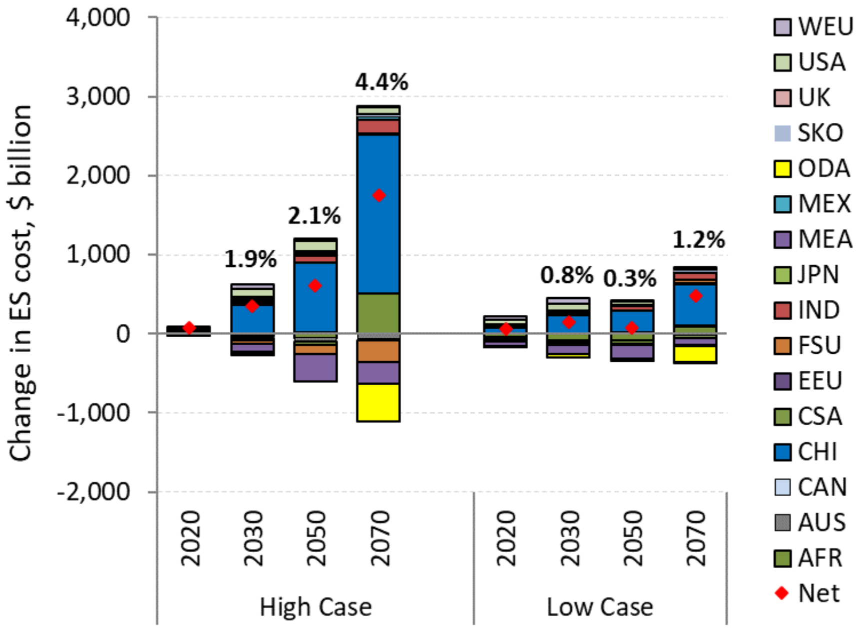
- Under high quota, limited near term benefits, but after 2040, growth above NDC levels as quota for HDI2 group tightens
- Under low quota, redistribution up to 10% per annum, mostly at expense of HDI3 (as cost-competitive large producers in HDI2 not impacted)



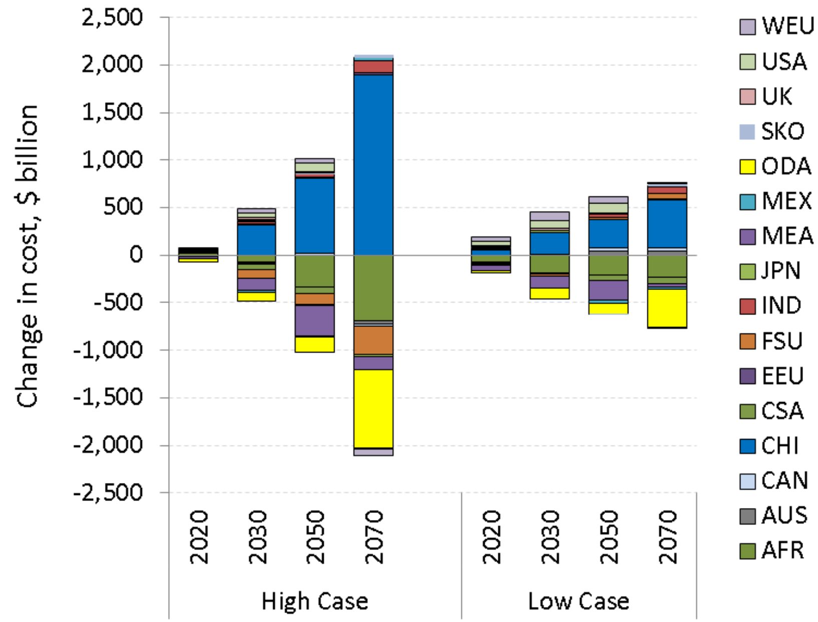
% change in gas production by HDI group relative to the total 2D production level (left), and total gas production in 2070 by HDI group (right). *Dashed line indicates NDC level relative to 2D, for HDI1.*

Growth in overall system costs, driven by increasing commodity costs

- By 2070, system costs are 4.4% higher under the high quota case (left); this is primarily driven by China's increased import cost (right)
- Increased export revenues in Africa do not necessarily outweigh the additional investment (as shown in 2070)



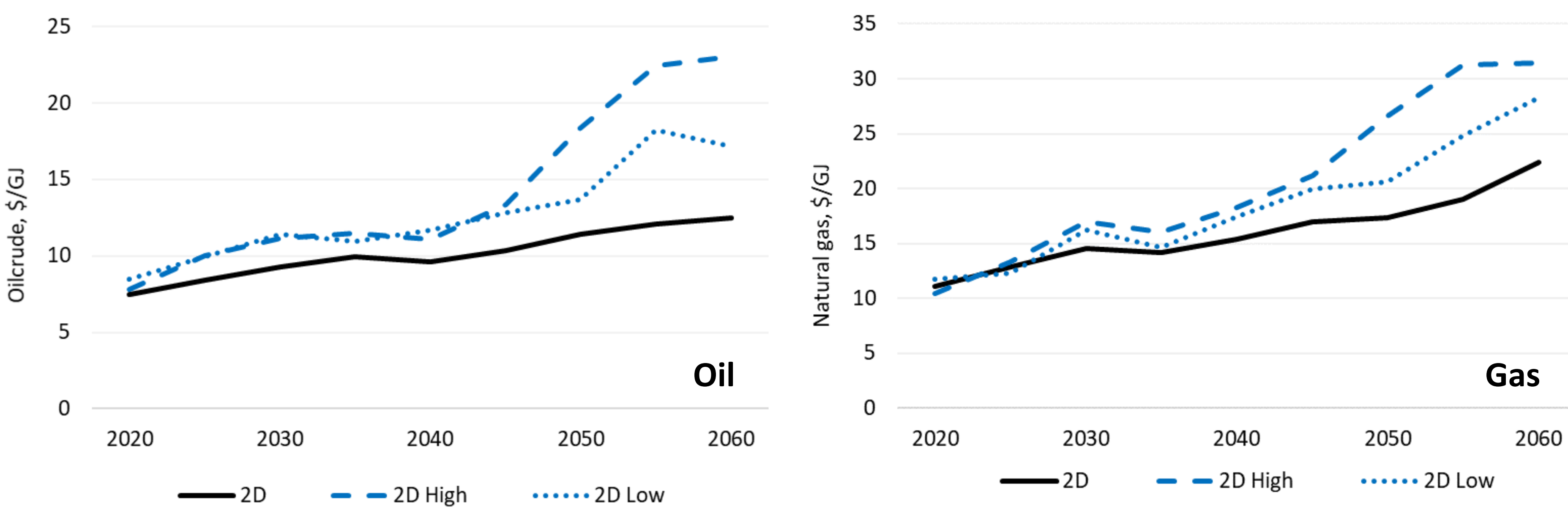
Change in system cost under equity cases compared to 2D optimal case, $billion



Change in commodity trade costs under equity cases compared to 2D optimal case, $billion

Higher costs of production arise from redistribution, impacting on net importers

- While benefits may accrue to producers, increase commodity costs are faced by net importers such as China
- There is therefore a trade-off between benefits to producers of redistribution and consumers, who may face higher prices



Marginal costs of oil and gas in China for 2D and equity cases, $/GJ

Equity concerns need to be considered in the climate & extractives discussion; however, an integrated approach is needed

- Increased production to the benefit of LIC producers requires commensurate reductions in other regions
- Redistribution inevitably results in higher net system costs; there is a clear trade off here between optimality and equity
- Some of the LIC reserves and resources may actually not yield a net benefit if indeed the costs of production are not recovered via the market price
- There is a question of whether this is an equitable approach from the perspective of non-producing regions and countries, as commodity prices (and import bills) go up

References

- Caney, S. (2016). Climate change, equity, and stranded assets. *Oxfam America Research Backgrounder. Washington, DC: Oxfam America*. https://www.oxfamamerica.org/static/media/files/climate_change_equity_and_stranded_assets_backgrounder.pdf

- Fuss, S., Canadell, J. G., Peters, G. P., Tavoni, M., Andrew, R. M., Ciais, P., ... & Le Quéré, C. (2014). Betting on negative emissions. *Nature Climate Change*, *4*(10), 850-853.

- Kartha, S (2016). Fossil fuel production in a 2°C world: The equity implications of a diminishing carbon budget. Discussion brief. Stockholm Environment Institute. https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-DB-2016-Equity-fossil-fuel-production-rents.pdf

- Knutti, R., & Rogelj, J. (2015). The legacy of our CO2 emissions: a clash of scientific facts, politics and ethics. *Climatic Change*, *133*(3), 361-373.

- McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2 [deg] C. *Nature*, *517*(7533), 187-190.

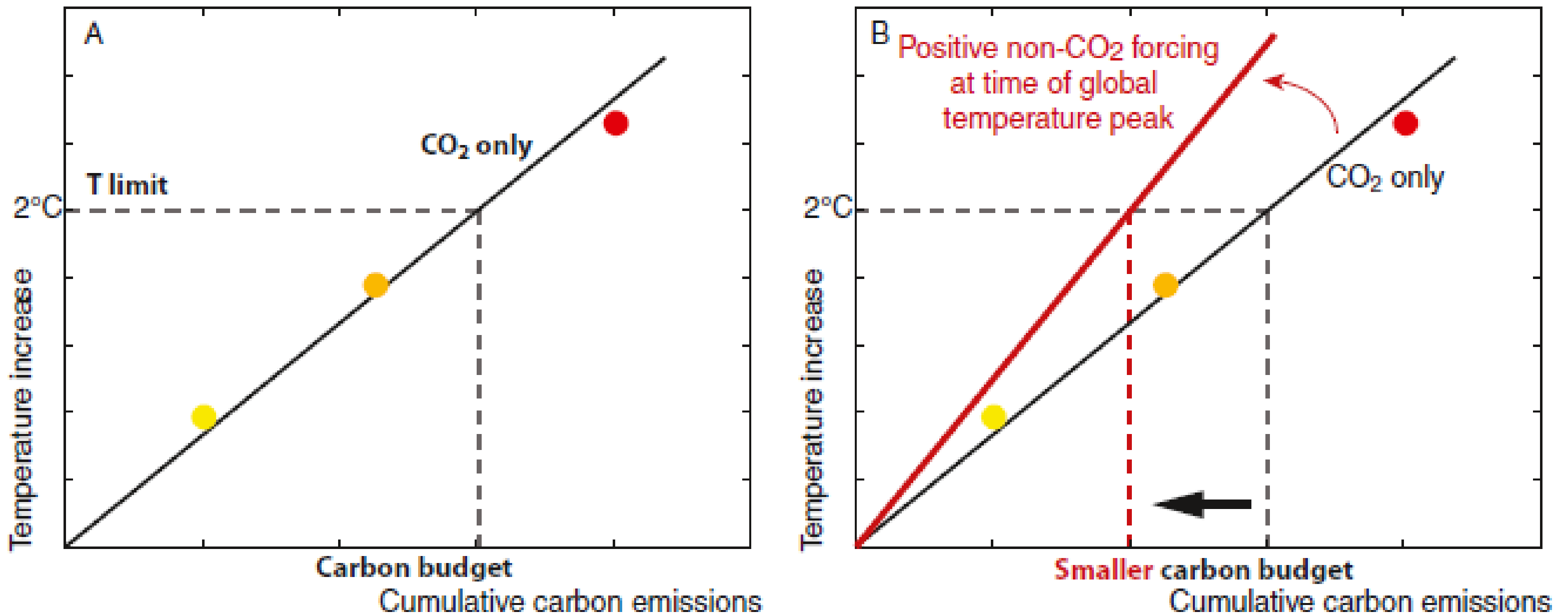
- Peters, G.P., Geden, O., 2017. Catalysing a political shift from low to negative carbon. Nat. Clim. Chang. advance online publication.

Thanks for listening

Paul Ekins	Steve Pye
p.ekins@ucl.ac.uk	s.pye@ucl.ac.uk

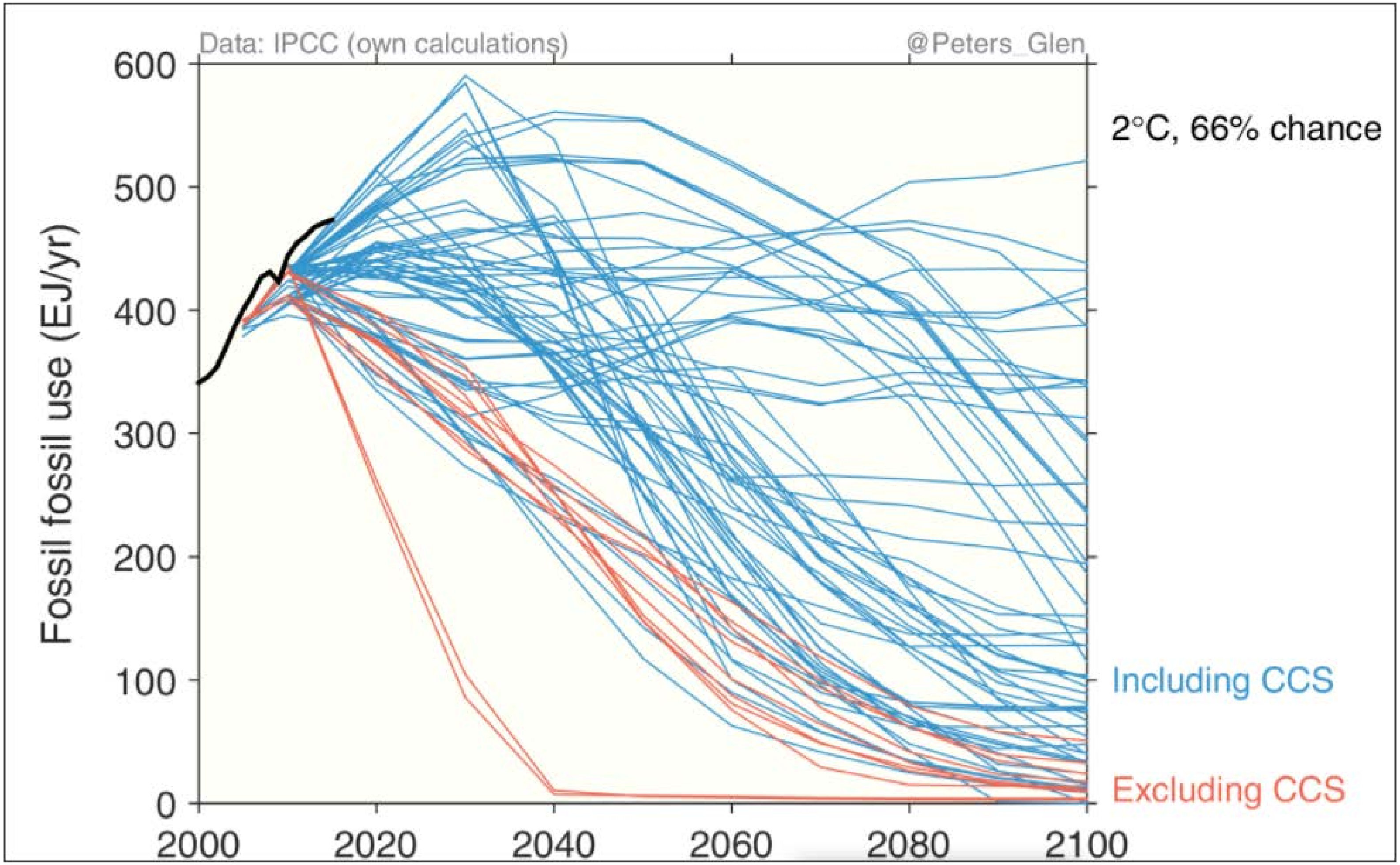
Prospects for fossil fuel producers under a carbon budget

- Carbon budget based on known relationship between cumulative CO2 emissions and global temperature rise
- Fossil fuel use will have to reduce significantly under 2°C compatible carbon budgets.
- ‘Room’ for fossil fuels uncertain; depends on non-CO2 GHGs, use with capture technology, offsetting through negative emissions, other fossil fuel prospects
- Not just level affected but timing and distribution of production



Source: Knutti & Rogelj (2015)

Fossil fuel use under a 2C limit, w/ and w/out CCS



Source: Glen Peters, http://www.cicero.uio.no/en/posts/klima/does-the-carbon-budget-mean-the-end-of-fossil-fuels

Headline findings of McGlade and Ekins 2015 paper

- Under the 2 ºC case, 80% of coal, 50% of gas, and 33% of oil **reserves** globally should be classified as unburnable

- Unburnable reserves are distributed unevenly (as per resource supply economics)
    - Majority of very large coal reserves in China, Russia and the United States
    - 60% of gas reserves in Middle East
    - Oil reserves in the Arctic region

- An even higher proportion of **resources** remain unburnable
    - 95% coal
    - 54% conv. and 100% unconv. oil
    - 69% conv. and 82% unconv. gas

- The absence of CCS does not significantly impact the level reserves remaining unburned in <u>2050</u>, due to late start date (now 2030) and deployment rate of technology

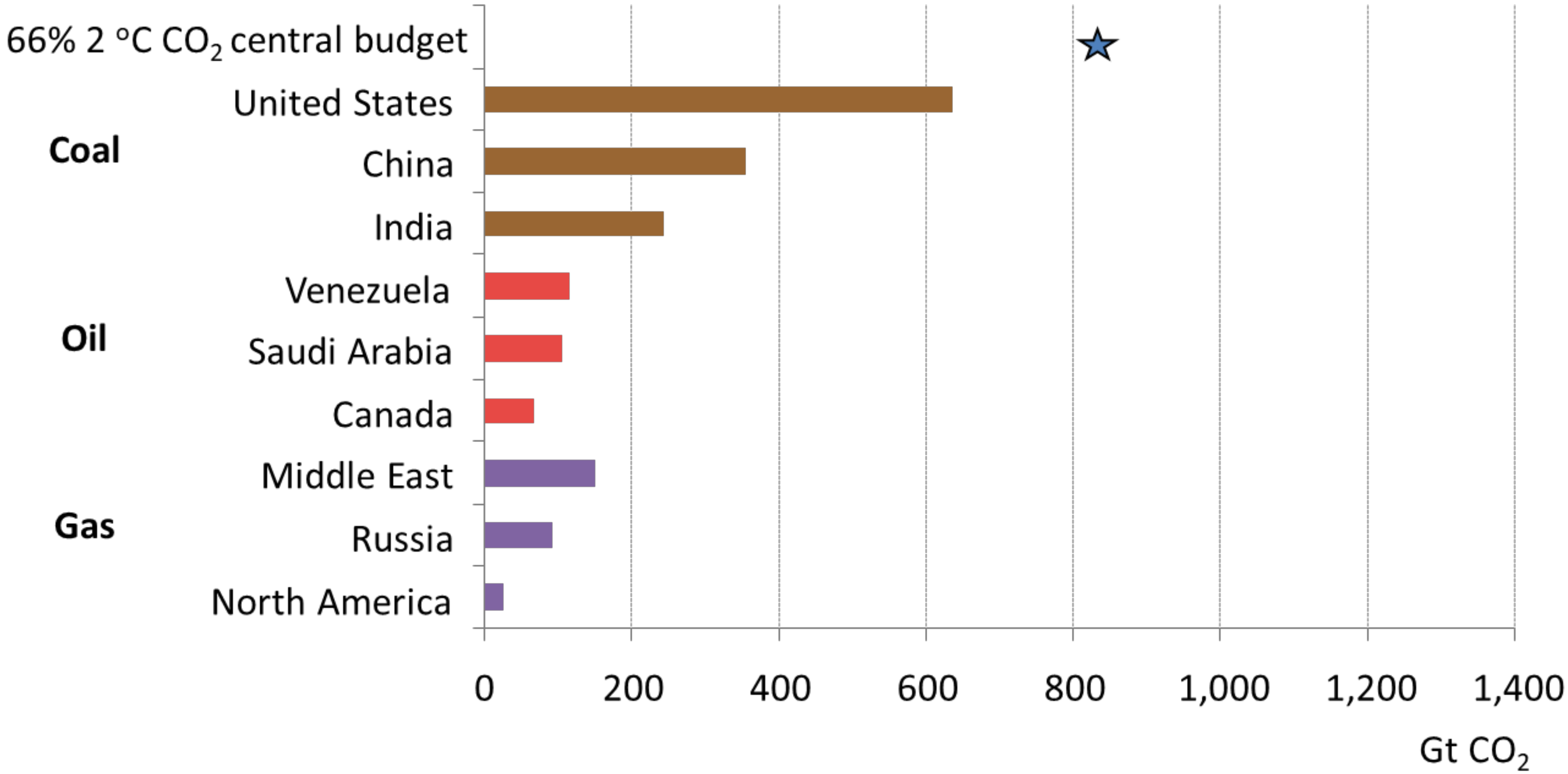
Regional distribution of reserves unburnable before 2050 to stay below 2°C

Region	Oil		Gas		Coal	
	Gb	%	Tcm	%	Gt	%
Africa	**23**	**21%**	**4.4**	**33%**	**28**	**85%**
Canada	39	74%	0.3	24%	5.0	75%
China	9	28%	2.6	75%	116	61%
C & S America	**58**	**39%**	**4.8**	**53%**	**8**	**51%**
Europe	5.0	20%	0.6	11%	65	78%
FSU	27	18%	31	50%	203	94%
India	**0.4**	**7%**	**0.3**	**27%**	**64**	**80%**
Middle East	263	38%	46	61%	3.4	99%
OECD Pacific	2.1	37%	2.2	56%	83	93%
ODA	**2.0**	**9%**	**2.2**	**24%**	**10**	**34%**
United States	2.8	6%	0.3	4%	235	92%
Global	**431**	**33%**	**95**	**49%**	**819**	**82%**

Source: McGlade and Ekins, 2015

In isolation, single countries and regions don't exceed carbon budget

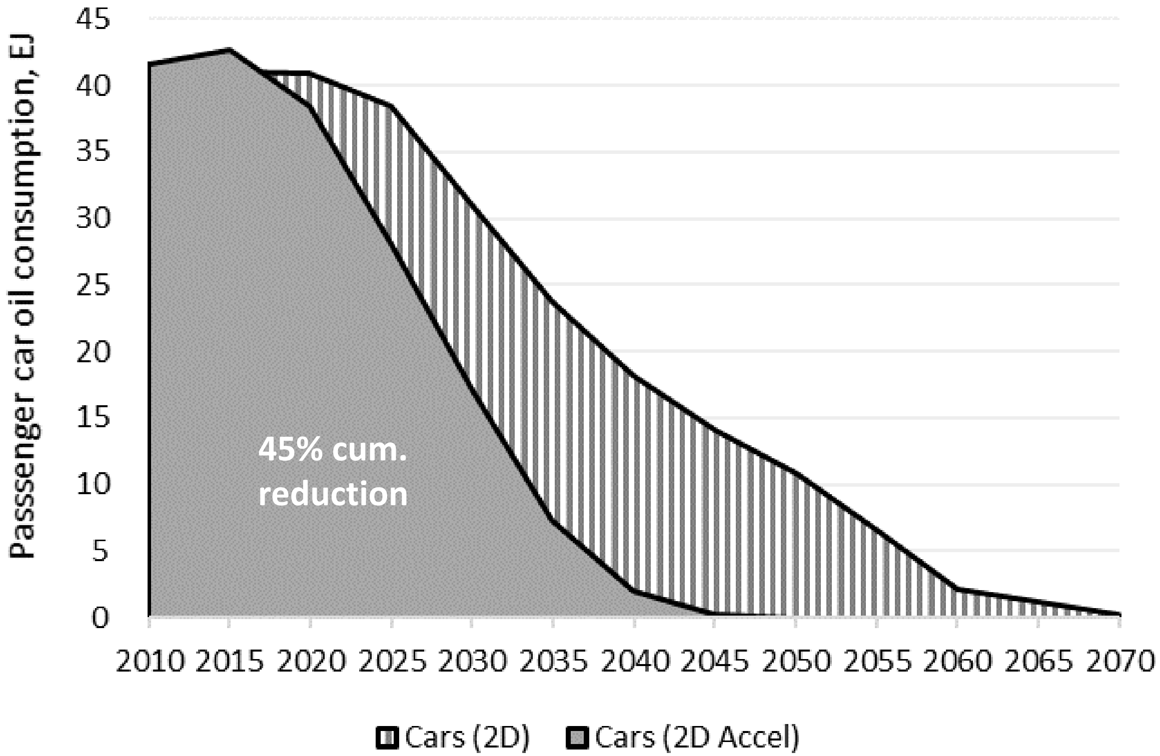
Increases in one country or region implies constraints on production elsewhere; there is a real tension between national sovereign rights, equity considerations (e.g. Caney, 2016) and global limits



Source of reserve estimates: WEO 2016

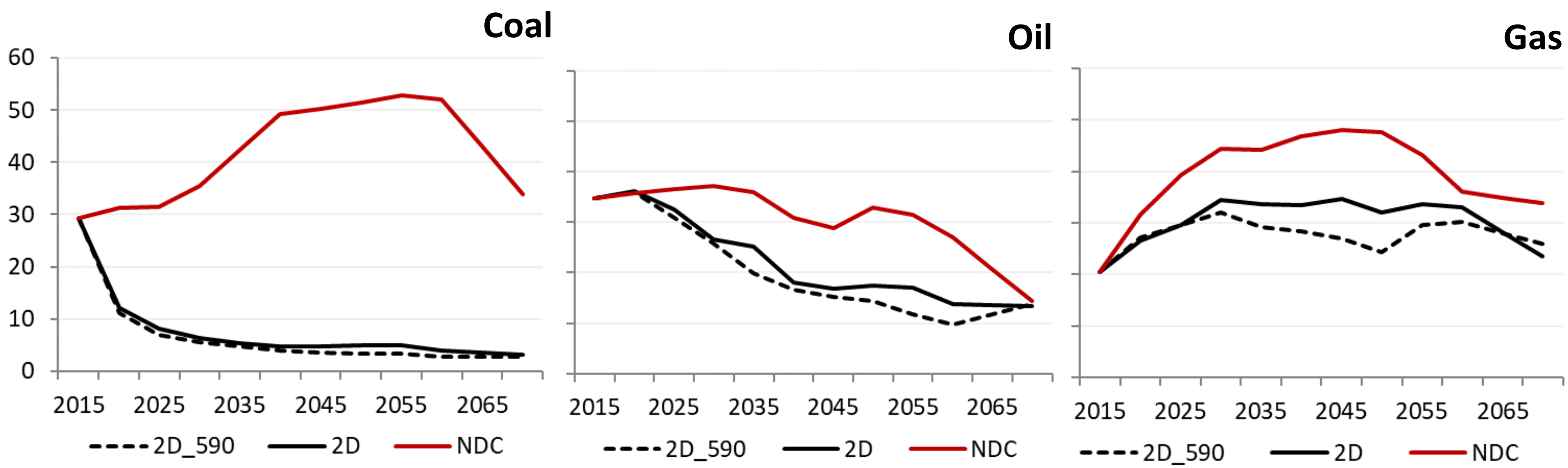
Outlook under technology acceleration case

- Difference in oil product consumption between 2D and 2D w/ technology acceleration



Global consumption outlook for passenger cars, EJ
(Source: own analysis with TIAM-UCL)

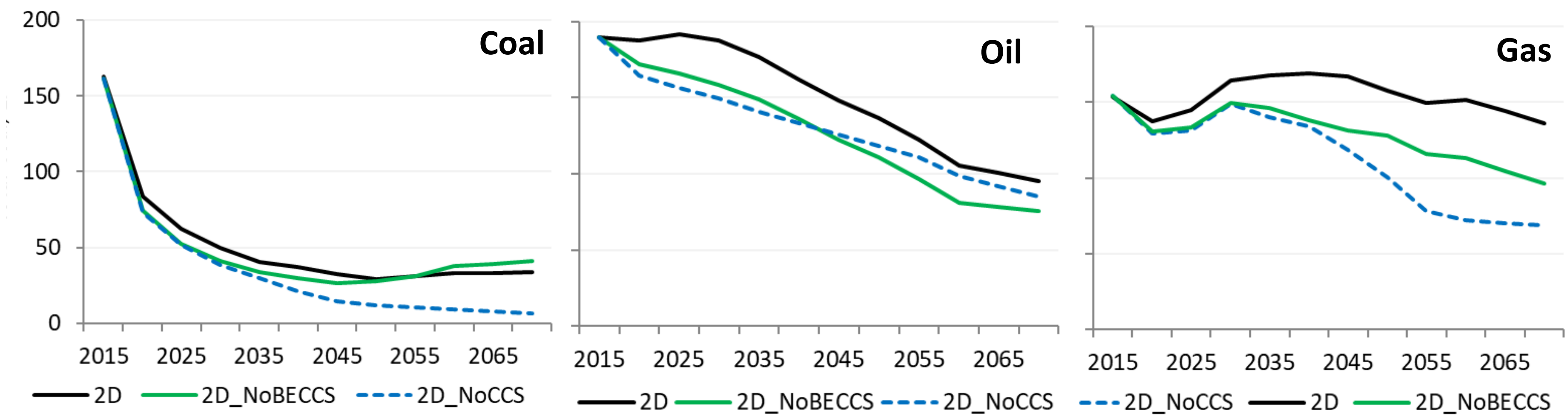
Higher climate ambition strongly impacts level of production: HDI1



HDI1 production outlook under different climate ambition cases, EJ
(Source: own analysis with TIAM-UCL)

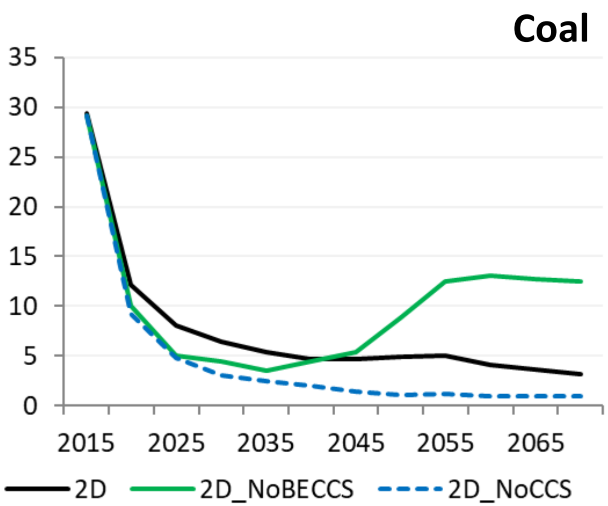
Production outlook in the absence of CCS & BECCS

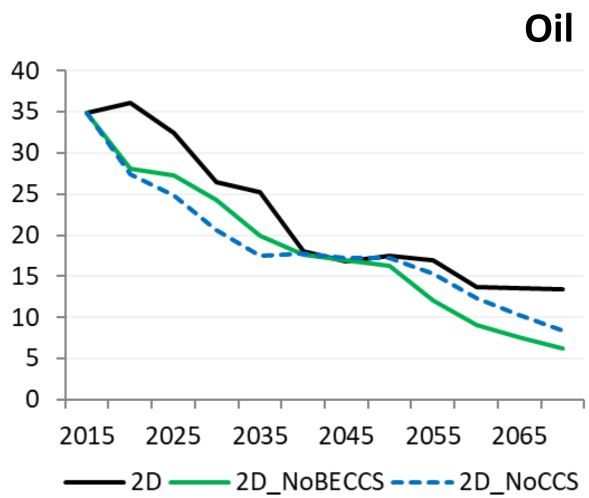
- NoCCS (blue dash line) sees a quicker reduction in oil use, almost no coal by 2040, and 50% of gas level in 2070
- NoBECCS (green line) also results in bigger reductions than under 2D for gas and oil; gas level higher than NoCCS due to more fossil CCS deployment

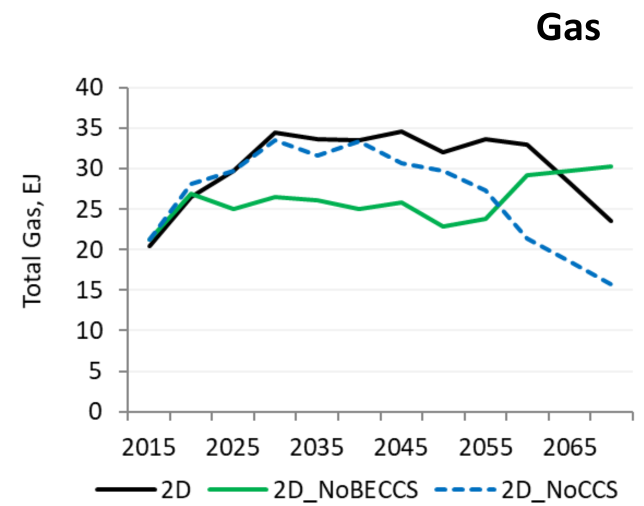


Global production outlook under different CCS sensitivity cases, EJ
(Source: own analysis with TIAM-UCL)

Production outlook in the absence of CCS & BECCS: HDI1



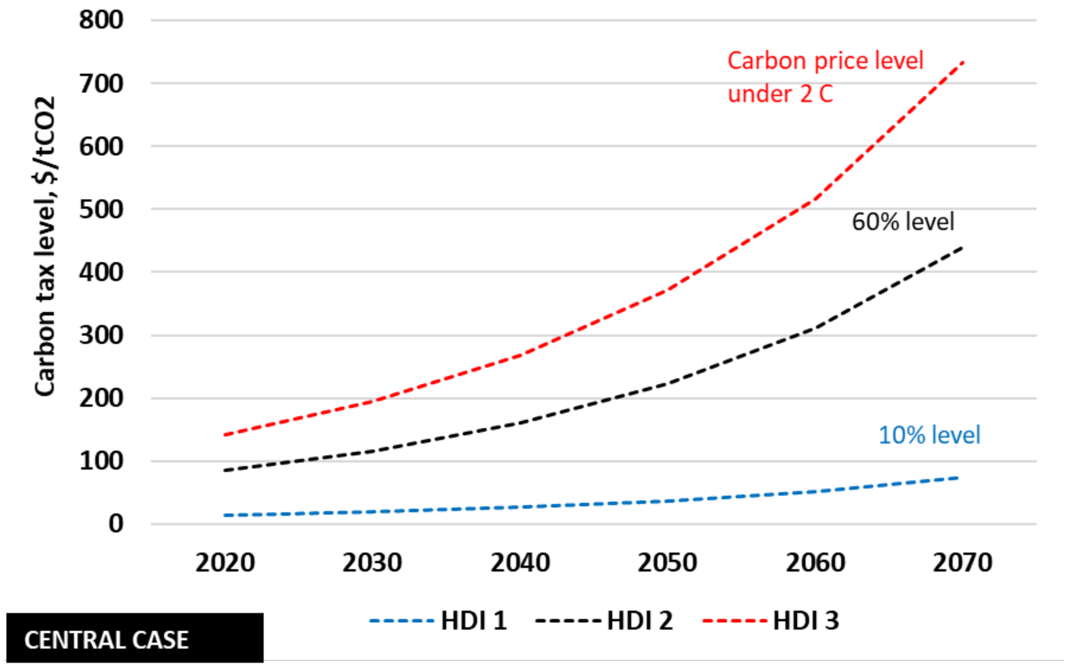




HDI1 production outlook under different CCS sensitivity cases, EJ
(Source: own analysis with TIAM-UCL)

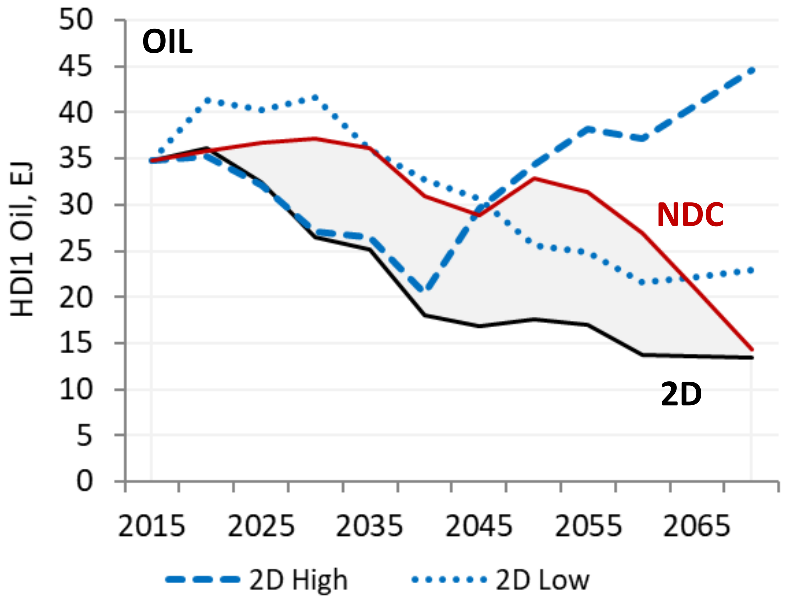
Determining equitable production allocation

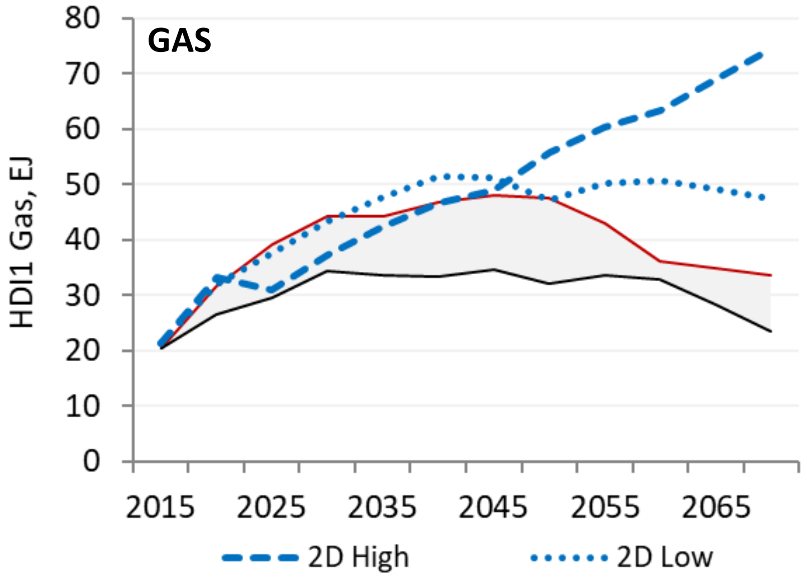
- Differentiated carbon tax applied to all fossil production in different regions
- For the central case, a higher tax was applied to HDI group 3 (VHHD) production, and a much lower tax level to HDI group 1 (LMHD) as shown below
- All three trajectories increased / decreased by effectively doubling / halving 2070 carbon price [to provide a high - low allocation range]



Increase in oil and gas production in lower income regions under redistribution

- The low quota case sees production around the NDC level
- Under the high quota, production drops as per 2D, before growth around 2040 starts to rapidly exceed NDC level
  - Production only increases later, as quota level starts to impact HDI2 producers

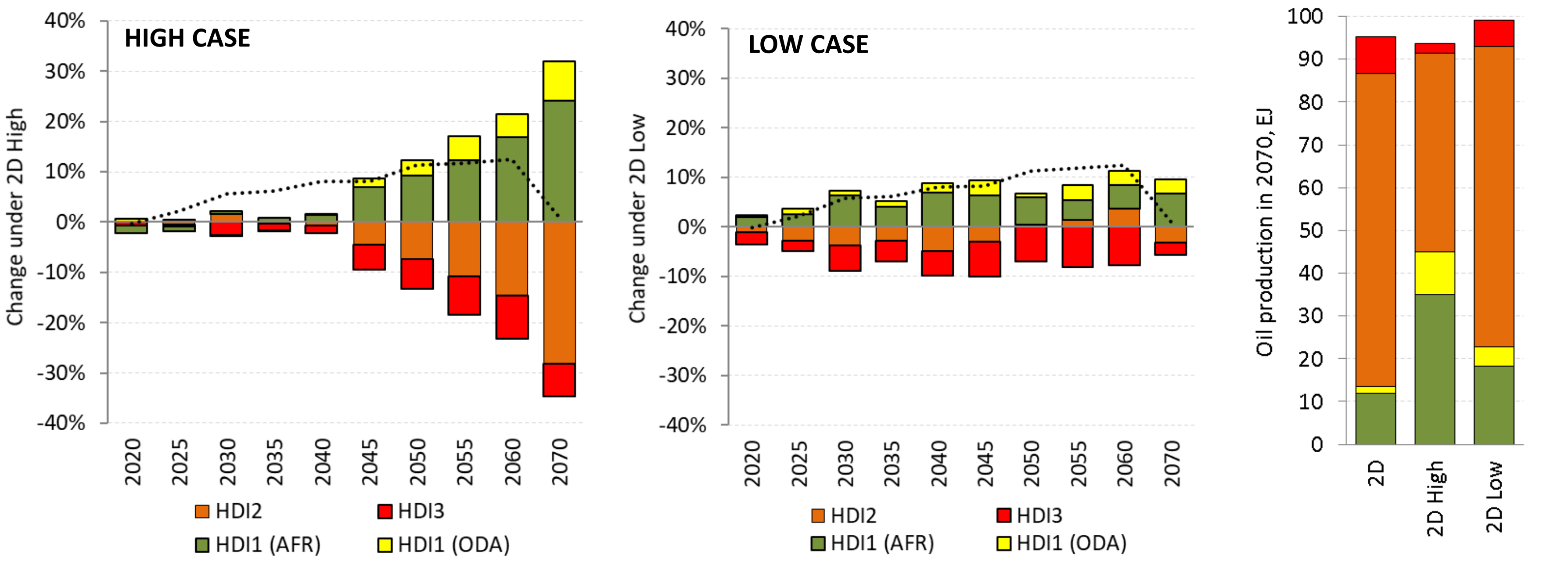




Production outlook for oil and gas in lower income regions under equity reallocation, EJ
(Source: own analysis with TIAM-UCL)

Change in oil production under equity cases

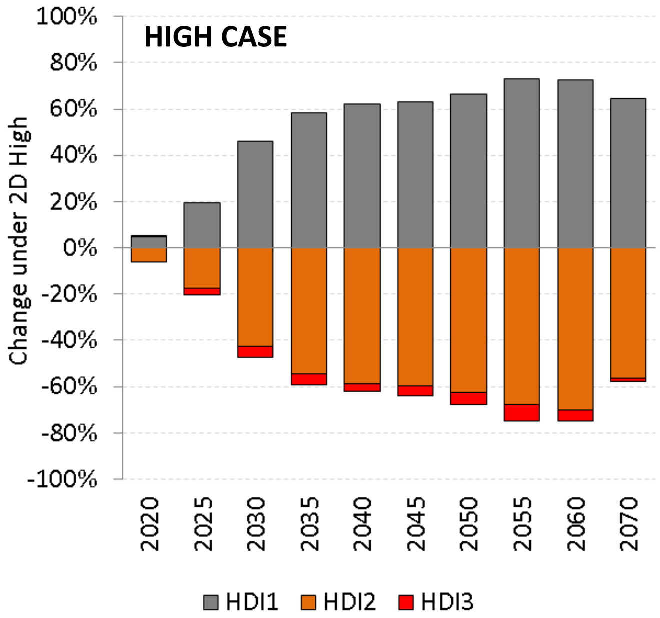
- Under high quota, no immediate benefits; strong redistribution only after 2040, due to relative cost competitiveness of HDI2 region
- Under low quota, redistribution up to 10% per annum, mostly at expense of HDI3 (as cost-competitive large producers not impacted)

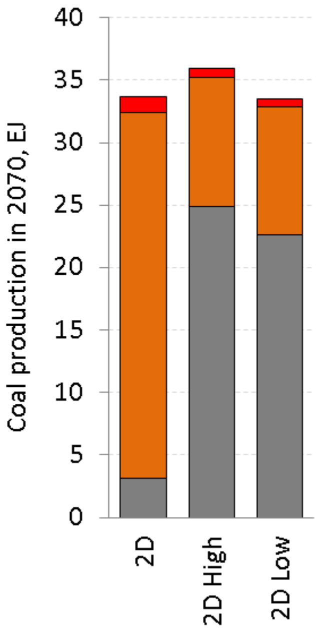


% change in oil production by HDI group relative to the total 2D production level (left), and total oil production in 2070 by HDI group (right)

Coal production redistribution under 2D equity cases

- All cases lead to similar change, due to strong sensitivity to cost increases, with the redistributive effect between HDI2 (China) and HDI1
- Changes are relatively small (compared to today's production) as the level under 2D has already dropped significantly by 2030

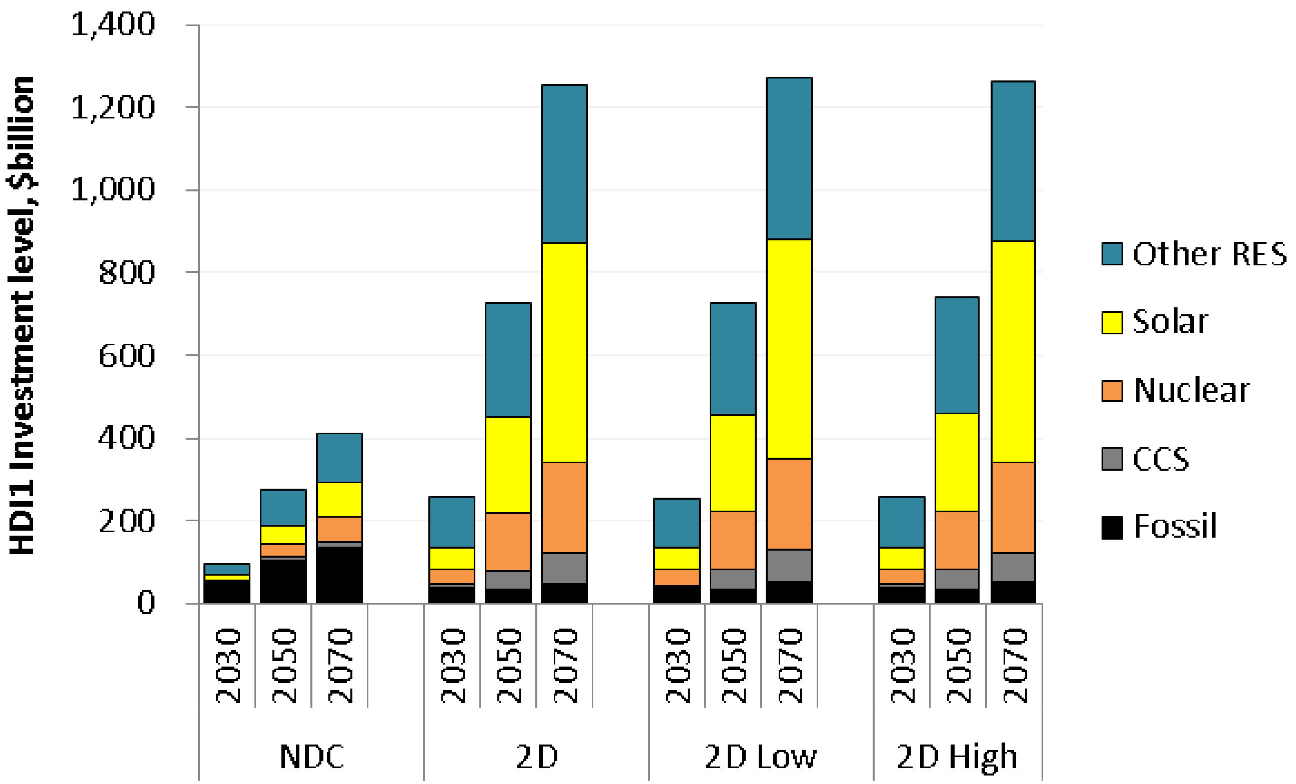




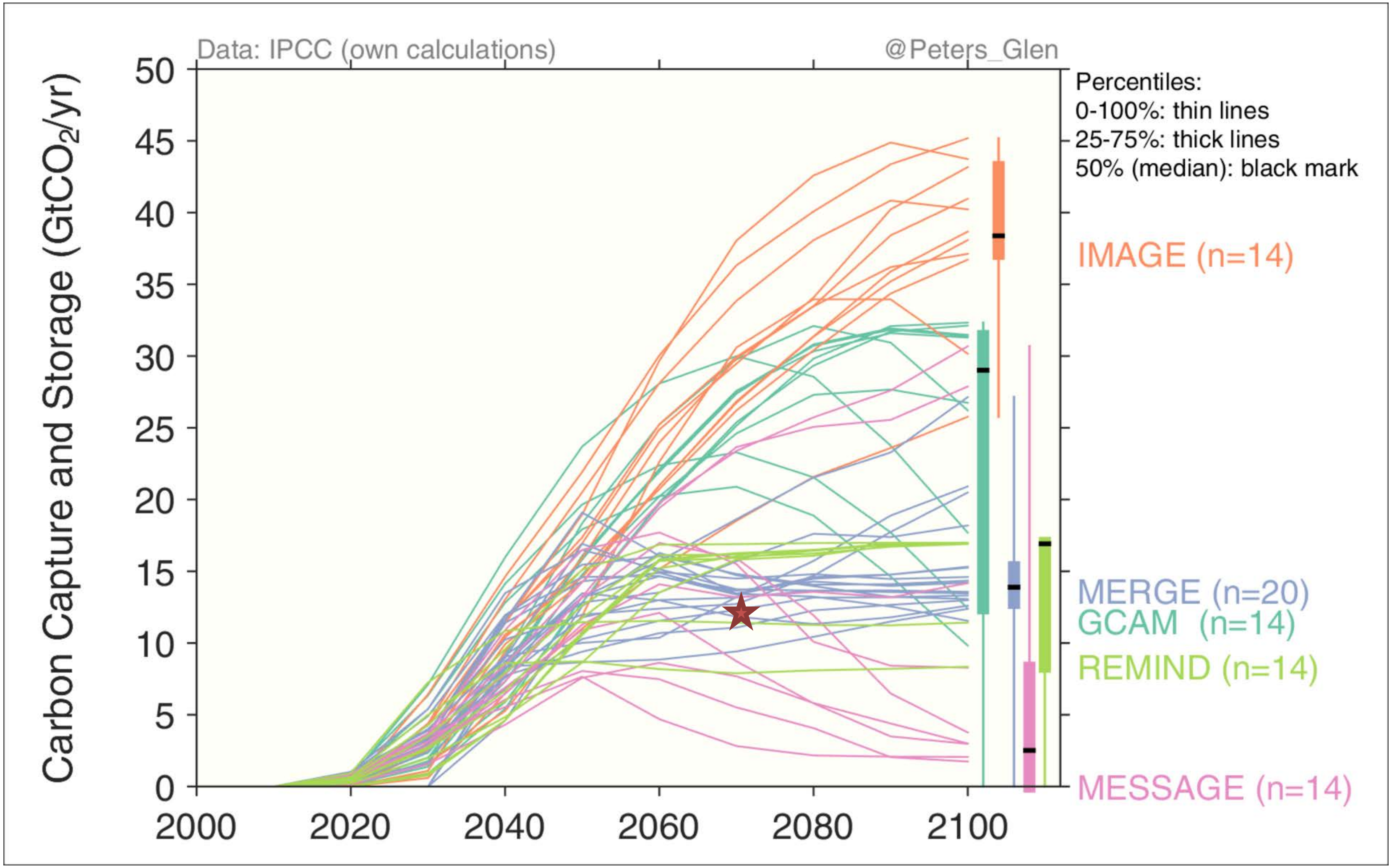
% change in coal production by HDI group relative to the total 2D production level (left), and total coal production in 2070 by HDI group (right)

Investment levels in the power generation sector are not impacted by increased production

- The strong push towards low carbon generation continues under equity cases
- Most additional production is exported rather than used in region

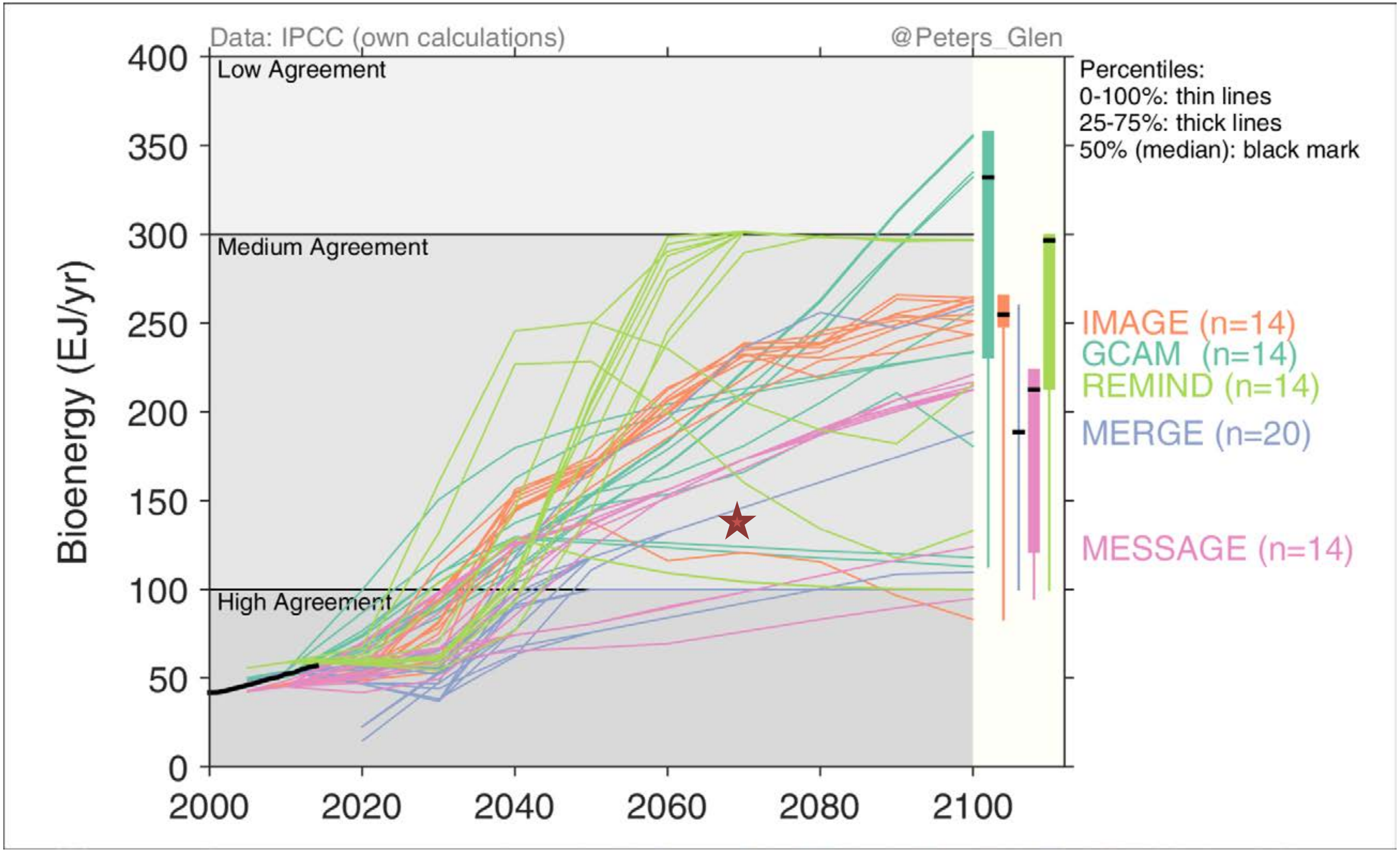


CCS in other IAMs



★ TIAM-UCL

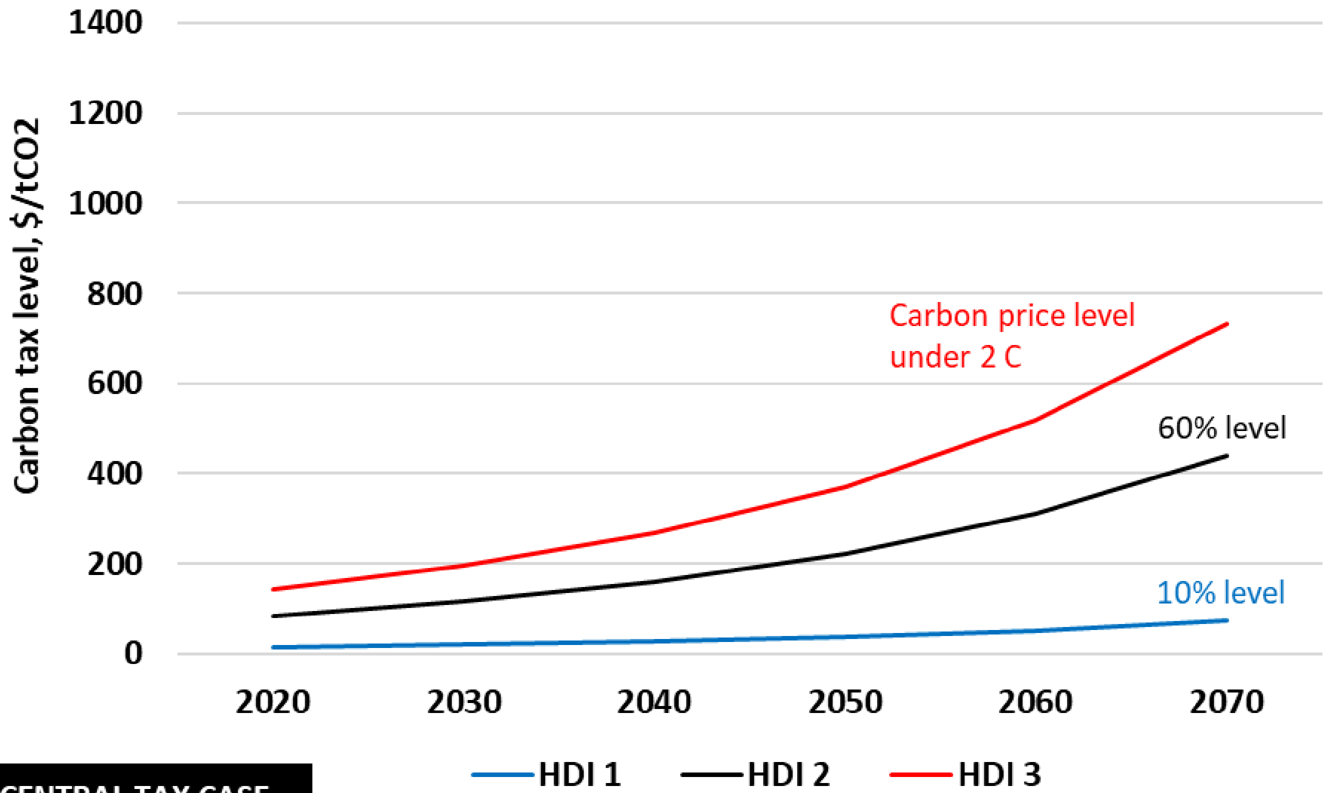
Bioenergy in other IAMs



★ TIAM-UCL

Use of differentiated carbon tax as mechanism for equity-based production

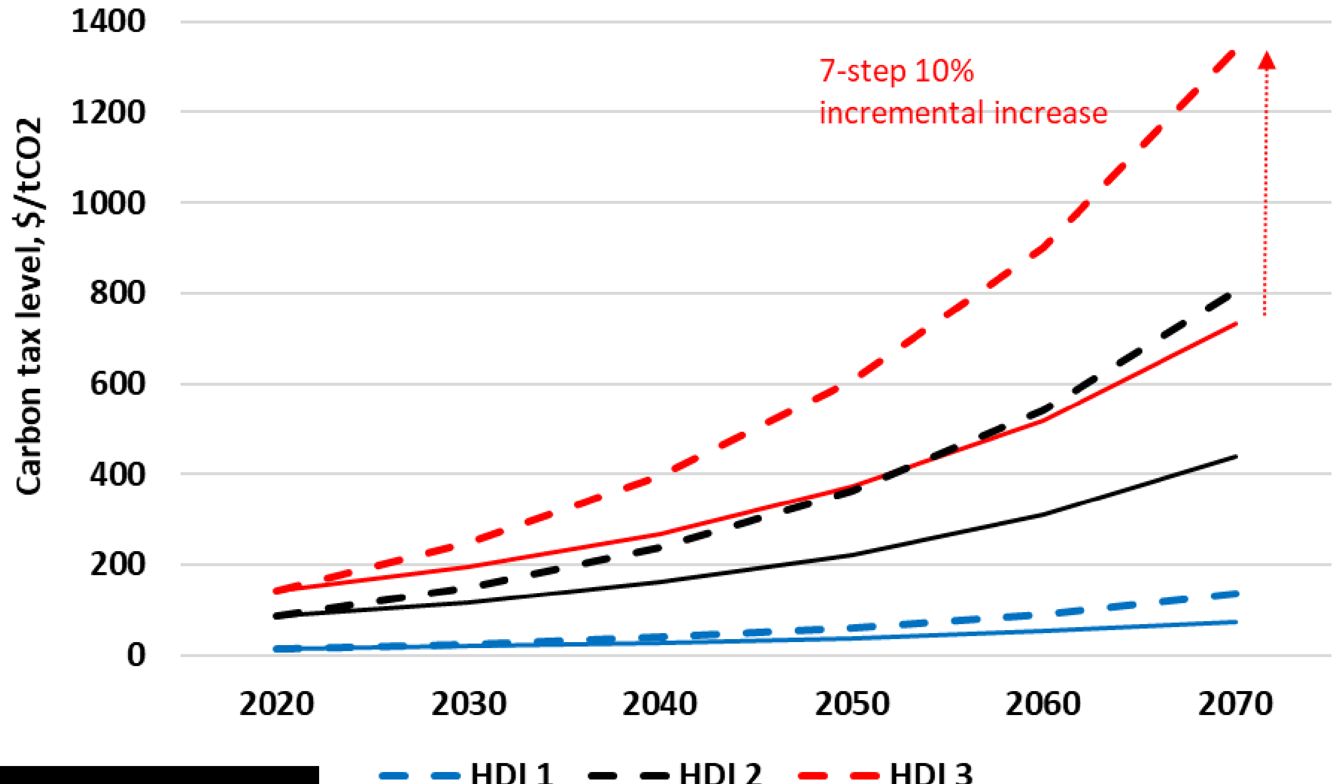
- Tax is applied to production, based on the carbon content of energy extracted
- Differentiated across the three HDI groups, to disincentivise production most in HDI group 3 (VHHD) and least in HDI group 1 (LMHD)



CENTRAL TAX CASE

Use of differentiated carbon tax on production across regions

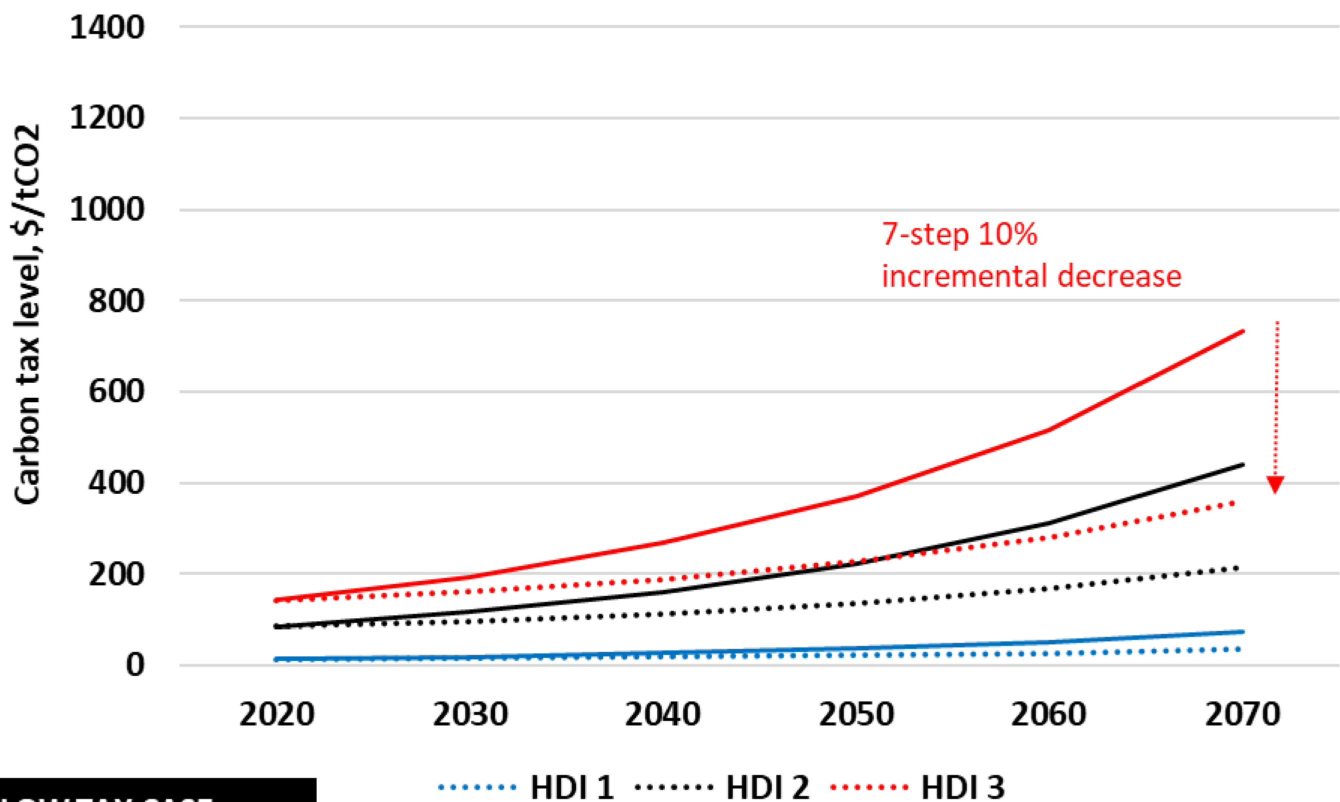
- The spread of carbon taxes is increased / decreased to explore impact on production; level of disincentive needed for redistribution?



HIGH TAX CASE

Use of differentiated carbon tax on production across regions

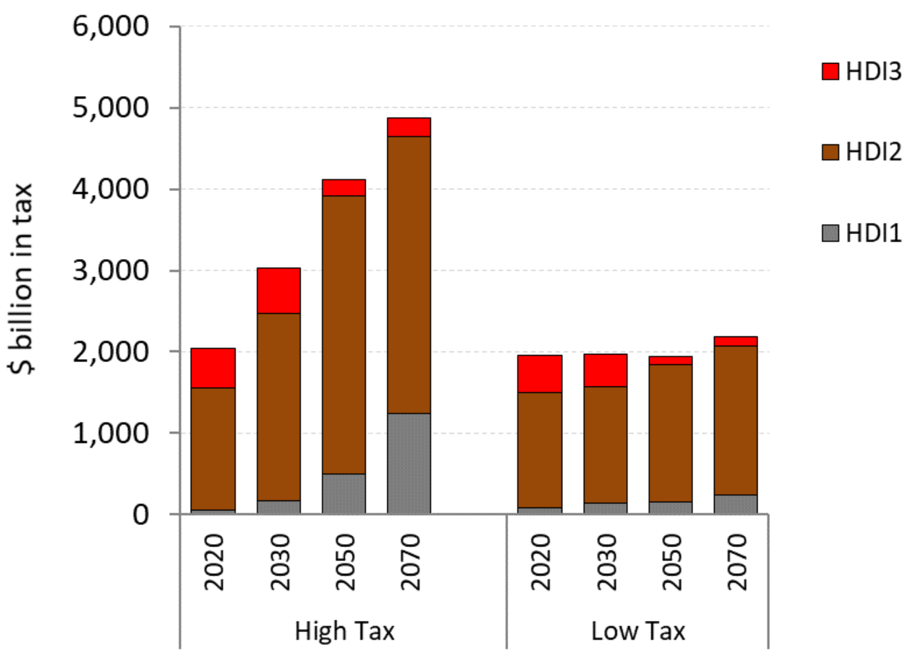
- The spread of carbon taxes is increased / decreased to explore impact on production; level of disincentive needed for redistribution?

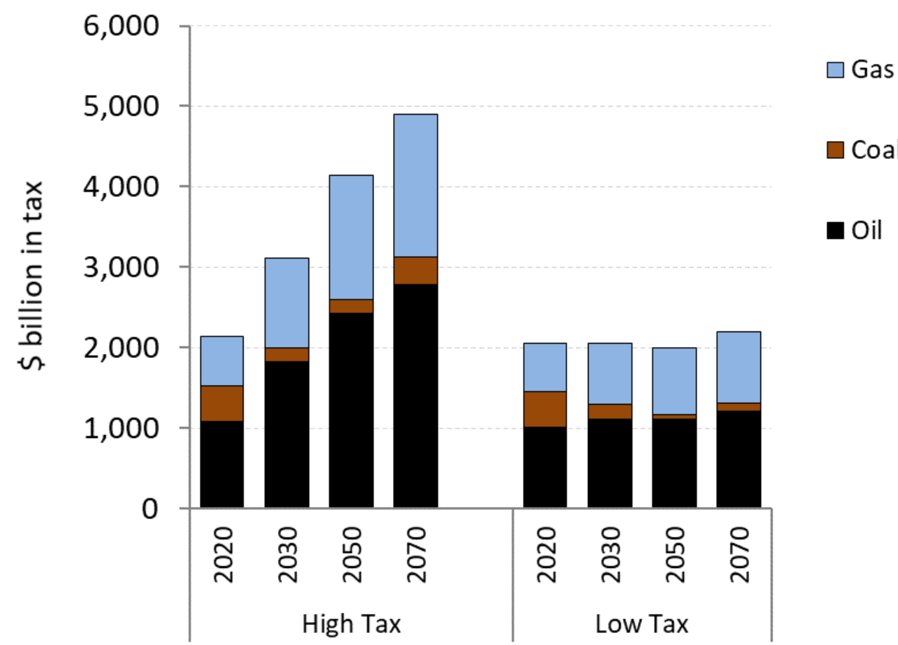


LOW TAX CASE

Tax revenue levels

- Revenue levels help identify which regions pay to continue producing, and for what commodities
  - Where production remains relatively cost-effective, and what fossil fuels continue to be needed (oil and gas from large producing HDI2 countries)





Tax revenue levels by HDI region, and fossil fuel type, $billion