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Technology and a Low Carbon Transformation

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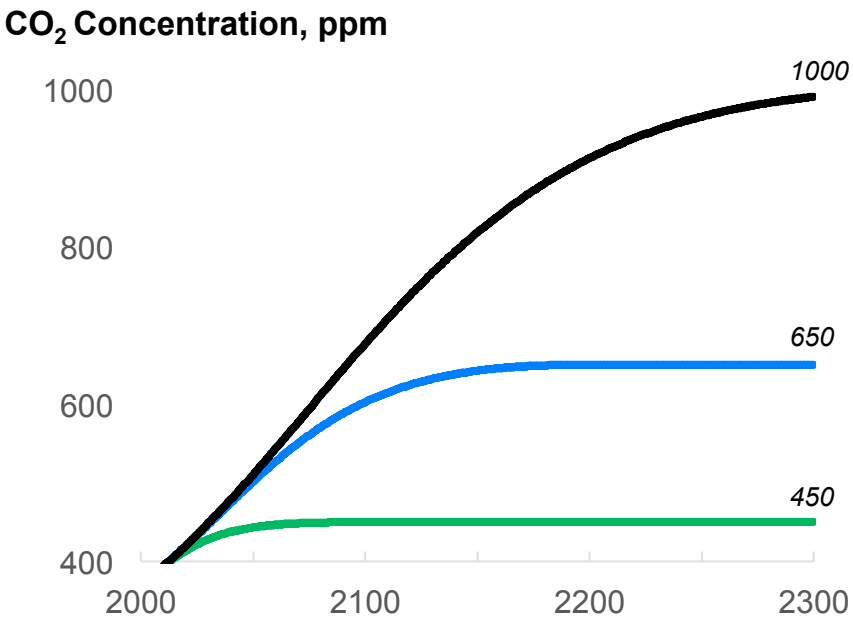
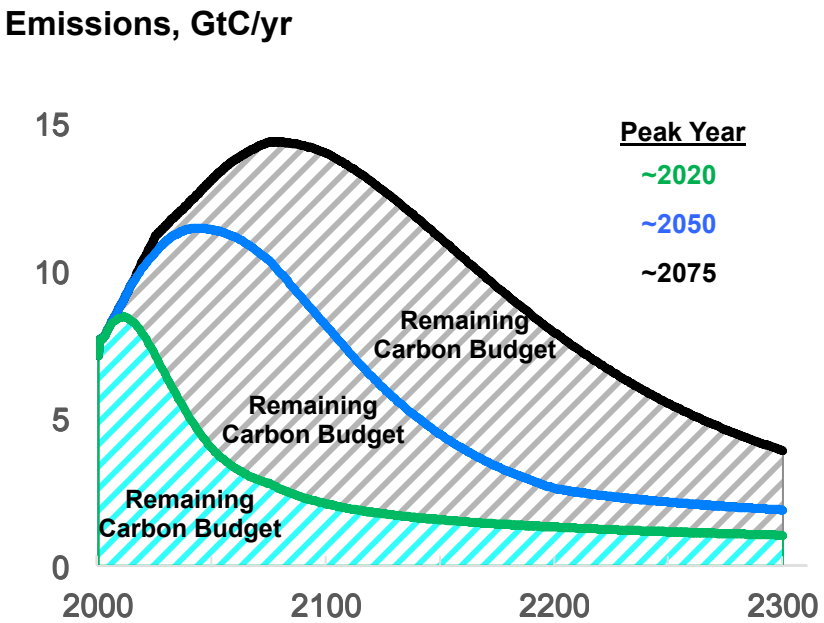
Outline

- CO_2 stabilization and the pace of transformation
- Transformation pathways
- Enabling environments for technology deployment
- Technology R&D portfolios

CO_2 Stabilization and the Pace of Transformation

Emissions Peak and Then Decline For Stabilization





Source: Kheshgi et al., Global Biogeochemical Cycles, 2003

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Long-Term Stabilization Requires Transformation

Efficiency / Reduce Demand → **Decarbonize Global Economy** → **Negative GHG Emissions**











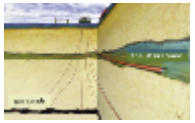

	Energy Intensity in 2050 (MJ per $ GDP)	Carbon per unit of Energy in 2050 (kg C per GJ)	Negative GHG Emissions (Year)	Mean °C Rise in 2100
Current	*12*	*18*	*-*	*0.8*
RCP 8.5	**9**	**18**	**-**	**4.3**
RCP 4.5	**7**	**14**	**-**	**2.4**
RCP 2.6	**5**	**5**	**2070**	**1.6**

Sources: van Vuuren *et al*., Climatic Change (2011); IPCC AR5 (2013)

Pace of Investment Inadequate

Reducing GHGs 50% below 2005 by 2050 requires <u>all</u> steps below:

Investment	Required Annual Additions 2005 – 2050	Annual Additions Since 2005	Required Annual Additions 2015 – 2050
Nuclear plants, 1,000 MW	30	< 1	~40
Coal and gas plants with CCS, 500 MW	55	< 1	~70
Wind turbines, 4 MW	15,600	8,100	~18,000
Solar PV, m^2 panels	325 million	370 million	~315 million

Source: IEA Energy Technology Perspectives 2010: Scenarios and Strategies to 2050

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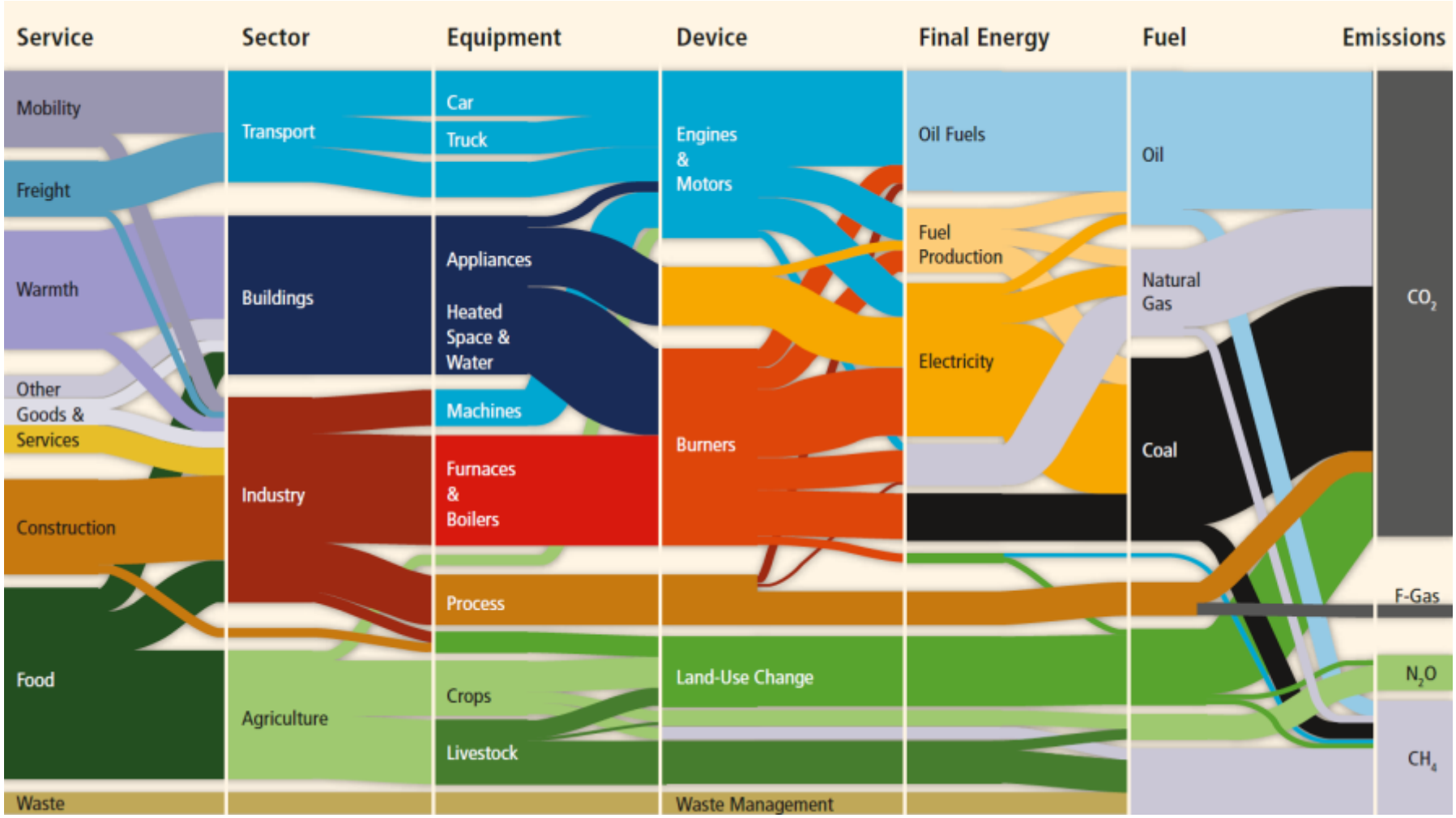
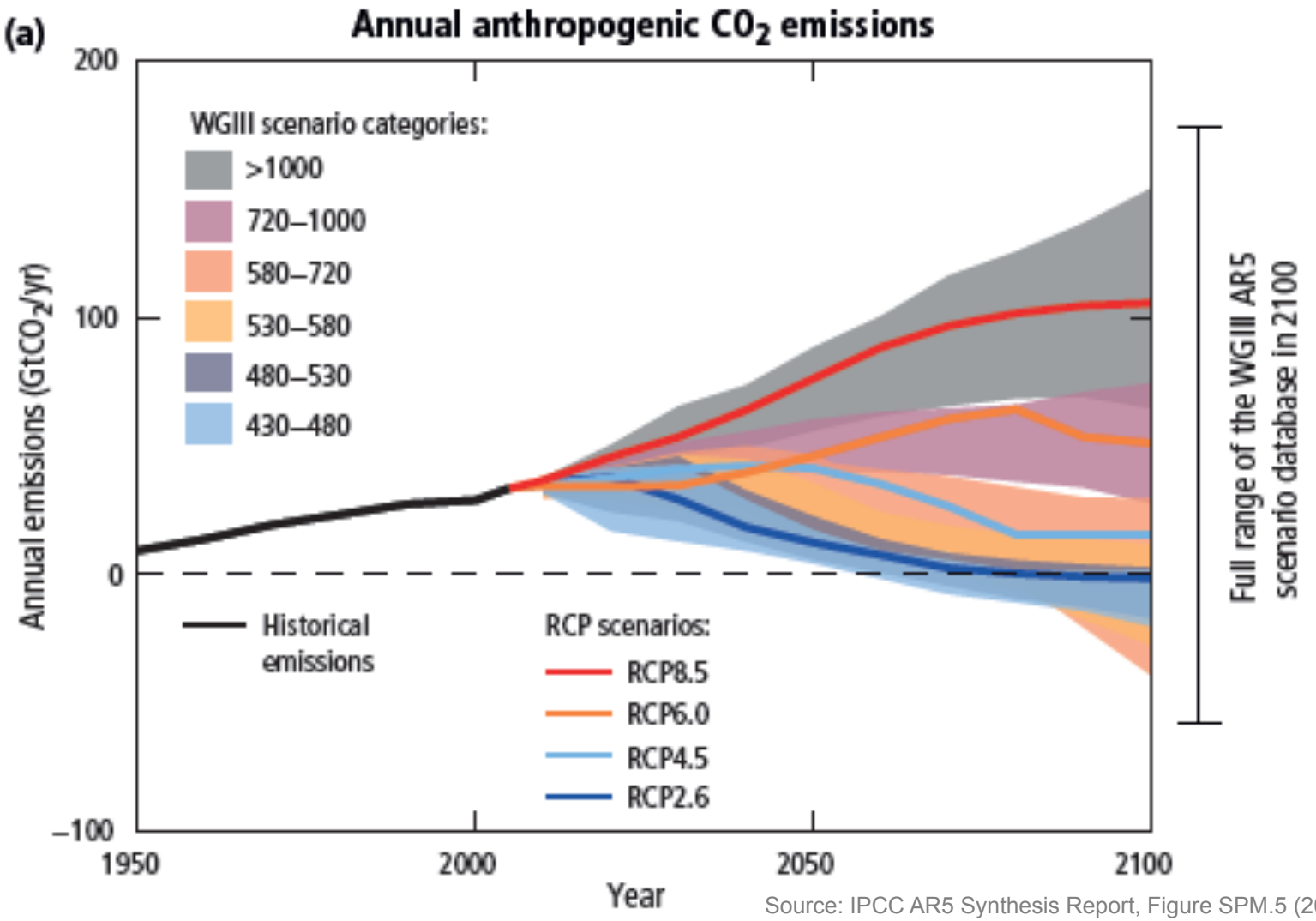
Transformation Spans the Economy



Source: IPCC AR5 WG3, Ch 10 (2014)

Transformation Pathways

Future Emissions Scenarios Sketch Out Transformation Pathways



Source: IPCC AR5 Synthesis Report, Figure SPM.5 (2014)

Transformation Pathways to Inform Climate Change Risk Management

"*Given the inherent complexities of the climate system, and the many social, economic, technological, and other factors that affect the climate system, we can expect always to be learning more and to be facing uncertainties regarding future risks.*"

"…a valuable framework for making for making decisions about America's Climate Choices is ***iterative risk management****. This refers to an ongoing process of identifying risks and response options, advancing a portfolio of actions that emphasize risk reduction and are robust across a range of possible futures, and revising responses over time to take advantage of new knowledge."*

Americas Climate Choices (NRC 2011)

Mitigation Cost Increases in Scenarios with Limited Availability of Technologies

Table SPM.2 | Increase in global mitigation costs due to either limited availability of specific technologies or delays in additional mitigation [a] relative to cost-effective scenarios [b]. The increase in costs is given for the median estimate and the 16th to 84th percentile range of the scenarios (in parentheses) [c]. In addition, the sample size of each scenario set is provided in the coloured symbols. The colours of the symbols indicate the fraction of models from systematic model comparison exercises that could successfully reach the targeted concentration level. *{Table 3.2}*

	Mitigation cost increases in scenarios with limited availability of technologies [d] *[% increase in total discounted [e] mitigation costs (2015–2100) relative to default technology assumptions]*				**Mitigation cost increases due to delayed additional mitigation until 2030** *[% increase in mitigation costs relative to immediate mitigation]*	
2100 concentrations (ppm CO_2-eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy	medium term costs (2030–2050)	long term costs (2050–2100)
450 (430 to 480)	138% (29 to 297%) 4	7% (4 to 18%) 8	6% (2 to 29%) 8	64% (44 to 78%) 8	44% (2 to 78%) 29	37% (16 to 82%) 29
500 (480 to 530)	not available (n.a.)	n.a.	n.a.	n.a.		
550 (530 to 580)	39% (18 to 78%) 11	13% (2 to 23%) 10	8% (5 to 15%) 10	18% (4 to 66%) 12	15% (3 to 32%)	16% (5 to 24%)
580 to 650	n.a.	n.a.	n.a.	n.a.		

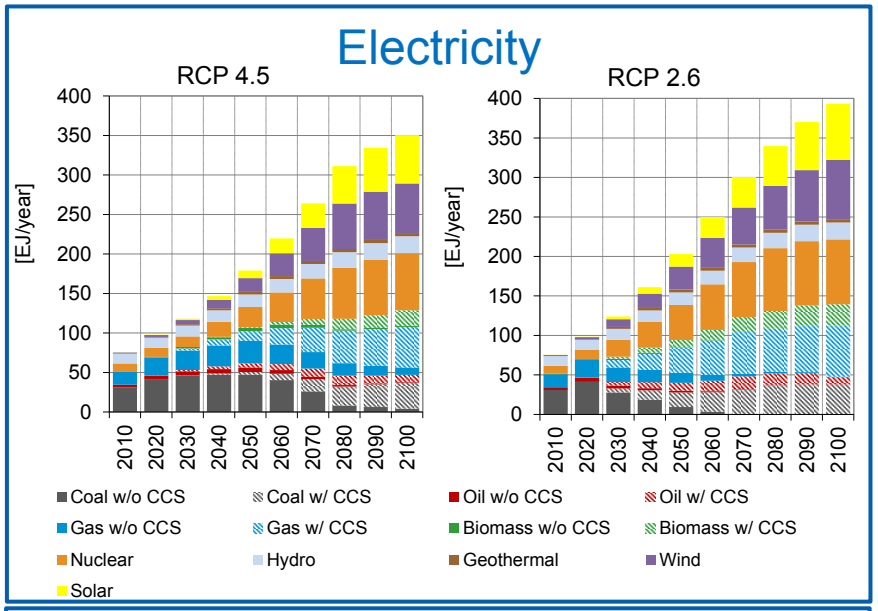
Symbol legend—fraction of models successful in producing scenarios (numbers indicate the number of successful models)

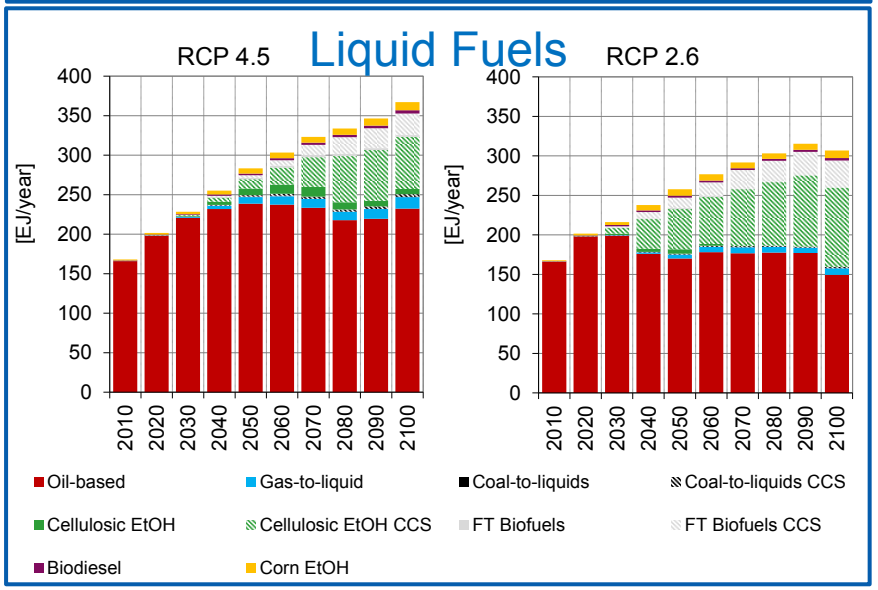
- : all models successful
- : between 80 and 100% of models successful
- : between 50 and 80% of models successful
- : less than 50% of models successful

Source: IPCC AR5 Synthesis Report, Table SPM.2 (2014)

Important Roles for CCS Across Sectors/Fuels

- Research part of an ongoing collaboration with PNNL's integrated assessment group
- Greater mitigation in electricity generation than in liquid fuels
- Modeled least-cost pathways to GHG stabilization deployed CCS in both electricity and liquid fuels (biofuels)
- Bioenergy with CCS (BECCS) competitive due to combination of carbon price and assumed net negative emissions, while bioenergy without CCS is not





Source: Muratori et al., submitted

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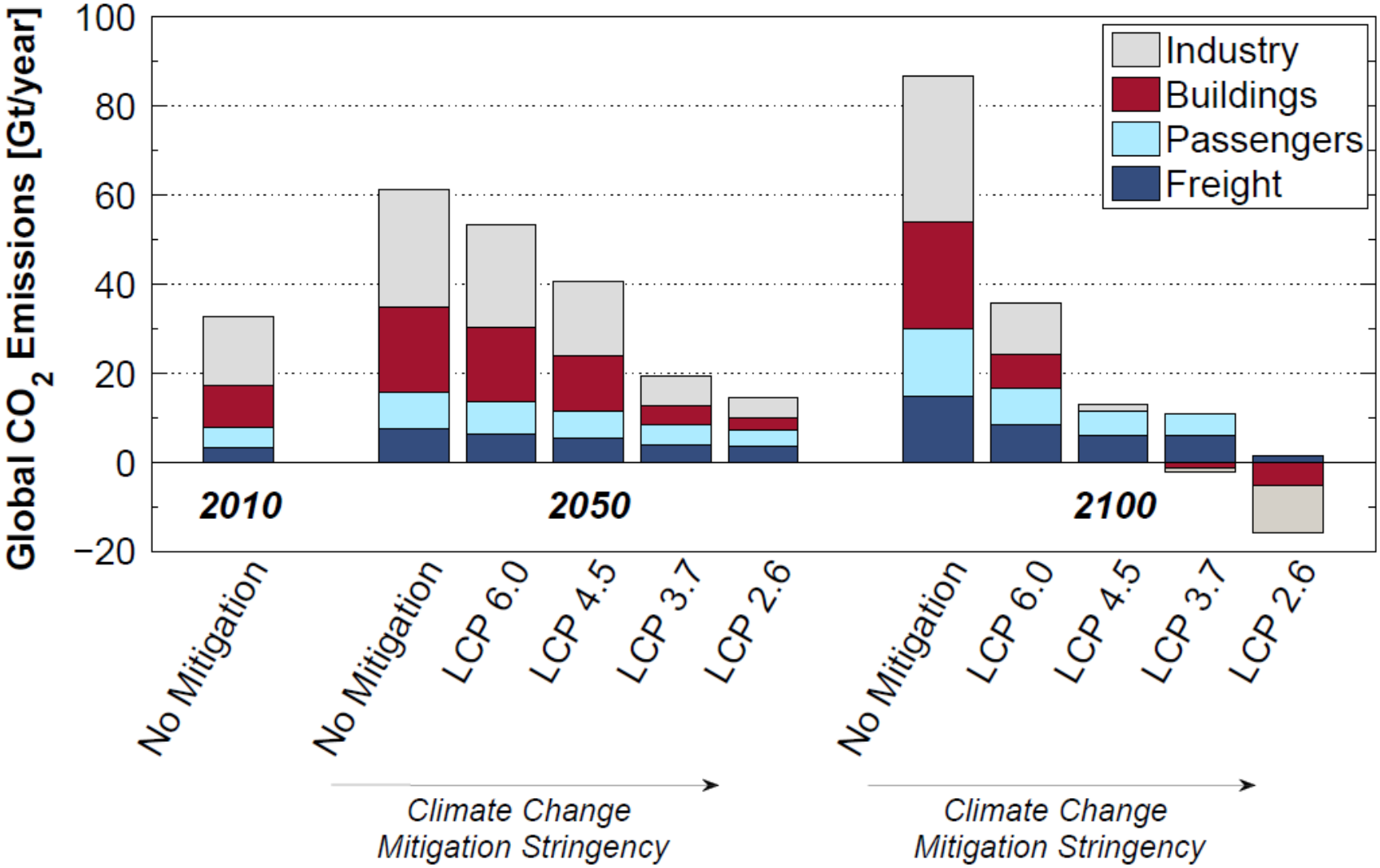
Pace of Least-Cost Decarbonization Projected to Differ Between End-Use Sectors



Source: Muratori et al., submitted

Enabling Environments for Technology Deployment

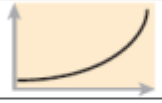
CCS: Recommendations Advanced Initiated by Gleneagles G8 (2005)

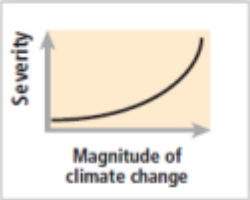
- Demonstrating CO_2 capture and storage
- Taking concerted international action
- Bridging the financial gap for demonstration
- Creating value for CO_2 for commercialisation of CCS
- Establishing legal and regulatory frameworks
- Communicating with the public
- Infrastructure
- Retrofit with CCS capture

Source: IEA/CSLF Report to the Muskoka 2010 G8 Summit

Climate Impacts in the Context of Other Drivers

Table 10-10 | Summary of findings.

Sector	Climate change drivers	Sensitivity to climate change	Sign	Other drivers	Relative impact of climate change to other drivers
Winter tourism	• Temperature • Snow		Negative	• Population • Lifestyle • Income • Aging	Much less
Summer tourism	• Temperature • Rainfall • Cloudiness		Negative for suppliers in low altitudes and latitudes Positive for suppliers in high altitudes and latitudes Neutral for tourists	• Population • Income • Lifestyle • Aging	Much less
Cooling demand	• Temperature • Humidity • Hot spells		Positive for suppliers Negative for consumers	• Population • Income • Energy prices • Technology change	Less
Heating demand	• Temperature • Humidity • Cold spells		Negative for suppliers Positive for consumers	• Population • Income • Energy prices • Technology change	Less
Health services	• Temperature • Precipitation		Positive for suppliers Negative for consumers	• Aging • Income • Diet/lifestyle	Less
Water infrastructure and services	• Temperature • Precipitation • Storm Intensity • Seasonal Variability		Negative for water users Positive for suppliers Spatially heterogeneous	• Population • Income • Urbanization • Regulation	Less in developing countries Equal in developed countries
Transportation	• Temperature • Precipitation • Storm intensity • Seasonal variability • Freeze/thaw cycles		Negative for all users Positive for transport construction industry	• Population • Income • Urbanization • Regulation • Mode shifting • Consumer and commuter behavior	Much less in developing countries Less in developed countries
Insurance	• Temperature • Precipitation • Storm intensity • Seasonal variability • Freeze/thaw cycles		Negative for consumers Neutral for suppliers	• Population • Income • Regulation • Product innovation	Less or equal in developing countries Equal or more in developed countries



Source: AR5 WG2 Ch10, Arent et al. 2014

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Barriers to GHG Reduction Options: Industry

Table 10.6 | Barriers (–) and opportunities (+) for GHG emission reduction options in industry. References and discussion appear in respective sub-sections of 10.9.

	Energy efficiency for reducing energy requirements	Emissions efficiency, fuel switching and CCS	Material efficiency	Product demand reduction	Non-CO_2 GHGs
Technological Aspects: Technology	+ many options available – technical risk + cogeneration mature in heavy industry – non-transparent and technically demanding interconnection procedures for cogeneration	+ fuels and technologies readily available – retrofit challenges + large potential scope for CCS in cement production, iron and steel, and petrochemicals – limited CCS technology development, demonstration and maturity for industry applications	+ options available	– slower technology turnover can slow technology improvement and operational emission reduction	+/– approaches and technologies available for some sources – lack of lower cost technology for PFC emission reduction in existing aluminium production plants
Technological Aspects: Physical	+ less energy and fuel use, lower cooling needs, smaller size – concentrating suitable heat loads for cogeneration – retrofit constraints on cogeneration	– lack of sufficient feedstock to meet demand – CCS retrofit constraints – lack of CO_2 pipeline infrastructure – limited scope and lifetime for industrial CO_2 utilization	+ reduction in raw and waste materials – transport infrastructure and industry proximity for material/waste reuse	+ reduction in raw materials and disposed products	– lack of control of HFC leakage in refrigeration systems
Institutional and Legal	– impact of non-energy policies + energy efficiency policies (10.11) – market barriers – regulatory, tax/tariff and permitting of cogeneration +/– grid access for cogeneration		– fragmented and weak institutions	– regulatory and legal instruments generally do not take account of externalities	– lack of certification of refrigeration systems – regulatory barriers to HFC alternatives in aerosols
Cultural	– lack of trained personnel +/– attention to energy efficiency – lack of acceptance of unconventional manufacturing processes – cogeneration outside core business – lack of consumer and policymaker knowledge of cogeneration	– social acceptance of CCS	+/– public participation – human capacity for management decisions	+/– user preferences drive demand	– lack of information/education about solvent replacements – lack of awareness of alternative refrigerants
Financial	– access to capital and short investment payback requirements – high overhead costs for small or less energy intensive industries +/– factoring in efficiency into investment decisions (e.g., energy management) + cogeneration economic in many cases +/– market value of grid power for cogeneration – high capital cost for cogeneration	– lack of sufficient financial incentive for widespread CCS deployment – liability risk for CCS – high CCS capital cost and long project development times	– upfront cost and potentially longer payback period + reduced production costs	– businesses, governments, and labour favour increased production	– recycled HFCs not cost competitive with new HFCs – cost of HFC incineration

Source: AR5 WG3 Ch10, Fischedick et al. 2014

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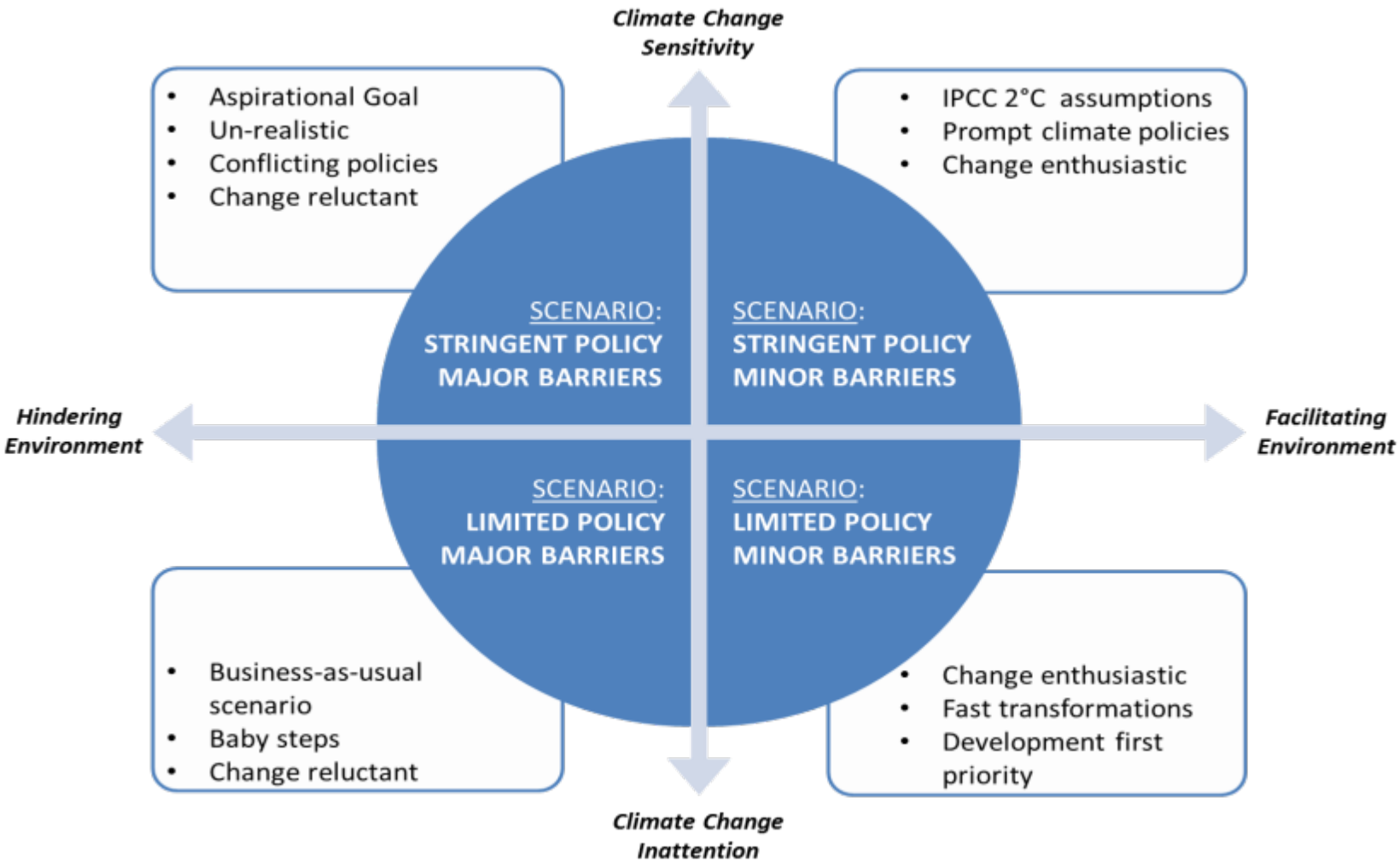
Transformation is Subject to Practical Barriers



Source: Muratori et al. 2016

Technology R&D Portfolios

Emerging Energy Technology

Investing to meet growing energy demand and manage climate change risks

Increase Supply

- Advanced biofuels and algae
- Natural gas to products

Expand Energy Access

- Hydrocarbon and renewable energy systems
- Power generation technologies

Improve Efficiency

- Internal combustion engine efficiency
- Light-weighting and packaging reduction

Mitigate Emissions

- Carbon capture and sequestration
- Methane emissions reduction

Good Science for Sound Policy

- Climate science, economics, and policy
- Resilience and preparedness

Source: Exxon Mobil Annual Shareholders Meeting, May 2016

Thank You