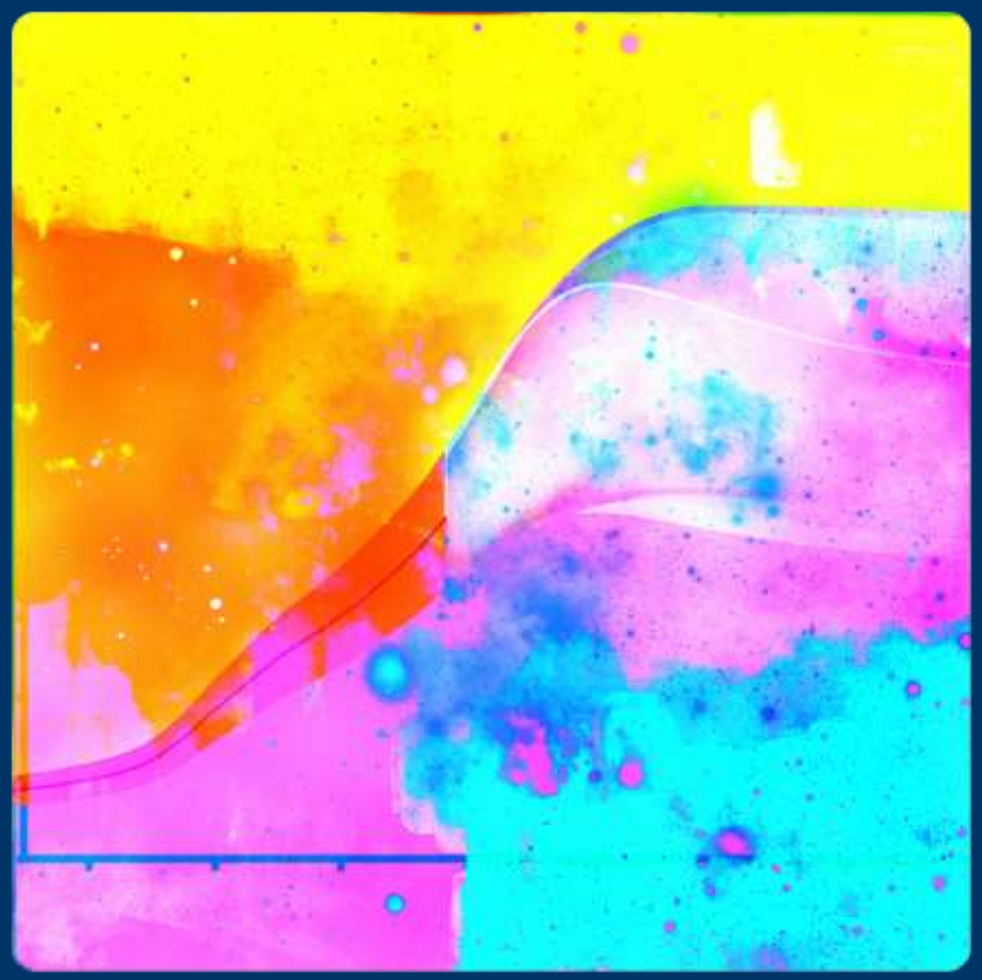

IPCC SR1.5

Chapter 4: Strengthening and implementing the global response

COP 24, IPCC Pavilion
December 6, 2018

Ashley Cooper / Aurora Photos

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Report’s key messages

Already 1°C of global warming, at current rate, would reach 1.5°C around 2040

Clear benefits to limiting warming to 1.5°C

We can still limit warming to 1.5°C

Unprecedented changes needed

Current action is insufficient

Limiting warming to 1.5°C would go hand in hand with achieving other societal goals

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Outline of the presentations

Starting points and approach of chapter 4

System transitions, options and CDR

Feasibility of selected mitigation and adaptation options

Enabling conditions for system transitions

Two deep dives:

- Adaptation: incremental or transformational?
- The finance and economics of the SR1.5

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Structure of chapter 4

4.1 Accelerating the global response to climate change

4.2 Pathways compatible with 1.5C: starting points

4.3 Systemic changes for 1.5C-consistent pathways

4.4 Implementing far-reaching and rapid change

4.5 Integration and enabling transformation

4.6 Knowledge gaps and key uncertainties

Structure of chapter 4

System transitions:

Energy, land & ecosystems, urban & infrastructure, industry

Mitigation and adaptation options, and their feasibility

Enabling conditions:

Policy

Finance

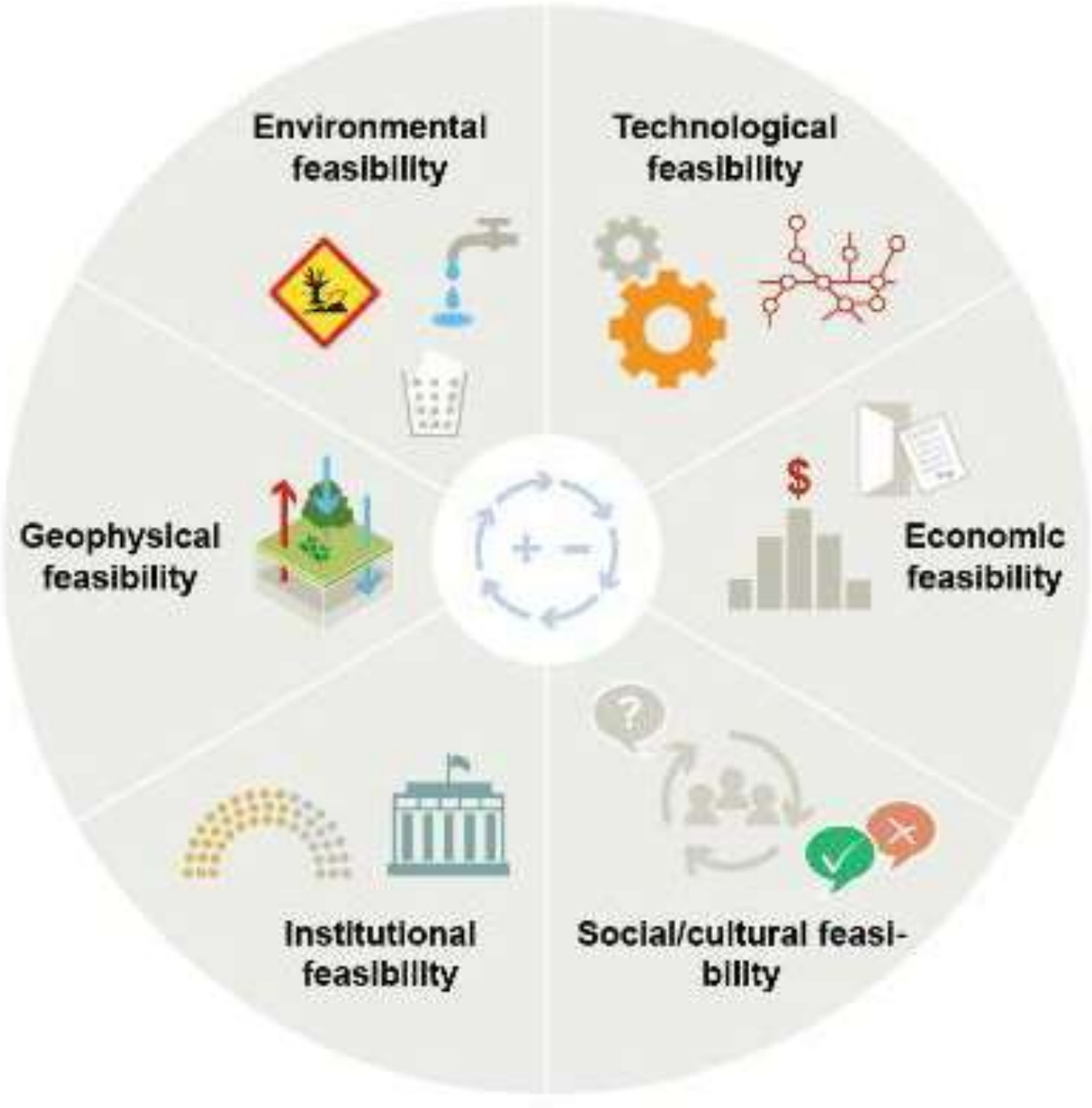
Innovation

Behaviour change

Institutional capacity

Multi-level governance

Feasibility of options in system transitions



Mitigation and adaptation options assessed along six dimensions

Result: where should a policymaker look first for quick wins? Where are gaps in knowledge? And what barriers need to be overcome?

Feasibility Framework

- **Systematize the assessment of adaptation and mitigation options at the global level**

- **Feasibility: The degree to which climate goals and response options are considered possible and/or desirable (SR1.5 Glossary)**

- **Assess along six dimensions of feasibility**
  - Economic: Are necessary economic and financial conditions present?
  - Technological: Are the options mature/is there technical/technological capacity?
  - Institutional: Do institutional and political conditions support the option?
  - Socio-cultural: Is the option socially and culturally acceptable, and inclusive?
  - Environmental/ecological: Does the option increase ecosystem services or enhance resilience / adaptive capacity?
  - Geophysical: Does the capacity of physical systems to support the option?

- **Context-dependent: reflected per option**

- **Grounded in peer-reviewed literature**

Indicators for mitigation and adaptation differ slightly

Dimensions	Adaptation indicators	Mitigation indicators
Economic	Micro-economic viability Macro-economic viability Socio-economic vulnerability reduction potential Employment & productivity enhancement potential	Cost-effectiveness Absence of distributional effects Employment & productivity enhancement potential
Technological	Technical resource availability Risks mitigation potential	Technical scalability Maturity Simplicity Absence of risk
Institutional	Political acceptability Legal & regulatory feasibility Institutional capacity & administrative feasibility Transparency & accountability potential	Political acceptability Legal & administrative feasibility Institutional capacity Transparency & accountability potential
Socio-cultural	Social co-benefits (health, education) Socio-cultural acceptability Social & regional inclusiveness Intergenerational equity	Social co-benefits (health, education) Public acceptance Social & regional inclusiveness Intergenerational equity Human capabilities
Environmental / ecological	Ecological capacity Adaptive capacity/ resilience building potential	Reduction of air pollution Reduction of toxic waste Reduction of water use Improved biodiversity
Geophysical	Physical feasibility Land use change enhancement potential Hazard risk reduction potential	Physical feasibility (physical potentials) Limited use of land Limited use of scarce (geo)physical resources Global spread
	Total:19 indicators	**Total: 24 indicators**

Assessment Process

- Two rounds of internal review to select literature
- Each option's indicator-level assessment was validated by at least three experts
- If indicator-level assessment differed, it was discussed and reconciled
- This discussion also informed the "Context" column of Table 4.11 and 4.12
- Line of sight to specific articles relevant to each indicator (see Supplementary Material 4.D)

Supplementary Material: indicator-level assessment and line of sight

		Wind (on-shore & off-shore)	Solar PV	Bioenergy
	Evidence	Robust	Robust	Robust
	Agreement	Medium	High	Medium
Economic	Cost-effectiveness	(Silva Herran et al., 2016); (IRENA 2015); (IRENA, 2016); (WEC), 2016); (Shafiee et al., 2016); (Voormolen et al., 2016)	(Climate Council 2017b); (IRENA 2015); (IRENA, 2016); (Cengiz and Mamiş, 2015)	(Brown, 2015; Creutzig et al., 2015; Patel et al., 2016)
	Absence of distributional effects	(Greene and Geisken, 2013); (Corfee-Morlot et al., 2012)	(Toovey and Malin, 2016); (Corfee-Morlot et al., 2012)	(Arndt et al., 2011b; German and Schoneveld, 2012; Creutzig et al., 2013; Hunsberger et al., 2014; Buck, 2016; Robledo-Abad et al., 2017; Stevanović et al., 2017) (Popp et al., 2014; Persson, 2015; Kline et al., 2017; Searchinger et al., 2017), (German and Schoneveld, 2012) (Schoneveld et al., 2011)(Bernesson et al., 2004)(Grau et al., 2010) (Agoramoorthy et al., 2009)(Ewing and Msangi, 2009)
	Employment & productivity enhancement potential	(IEA 2017d); (IRENA 2017b); (Council, 2016); (Council, 2012)	(IEA) 2017d); (IRENA 2017b); (Council 2017b); (Council, 2016)	(Parcell and Westhoff, 2006; Gohin, 2008; Wicke et al., 2009; Arndt et al., 2011a)

Feasibility assessment approach

MITIGATION OPTION ASSESSMENT FRAMEWORK		Energy system transitions						Land and ecosystem transitions				Urban and infrastructure system transitions									Industrial system transitions				Carbon dioxide removal				
	Mitigation option	Wind energy (on-shore & off-shore)	Solar PV	Bioenergy	Electricity storage	Power sector CCS	Nuclear energy	Reduced food wastage & efficient food	Dietary shifts	Sustainable intensification of agricultu	Ecosystems restoration	Land-use & urban planning	Electric cars and buses	Sharing schemes	Public transport	Non-motorised transport	Aviation & shipping	Smart Grids	Efficient appliances	Low/zero-energy buildings	Energy efficiency	Bio-based & circularity	Electrification & hydrogen	Industrial CCUS	BECCS	DACCS	Afforestation & reforestation	Soil carbon sequestration & biochar	Enhanced weathering
	Evidence	Robust	Robust	Robust	Robust	Robust	Robust	Robust	Medium	Medium	Medium	Robust	Medium	Limited	Robust	Robust	Medium	Medium	Medium	Medium	Robust	Medium	Medium	Robust	Robust	Medium	Robust	Robust	Medium
	Agreement	Medium	High	Medium	High	High	High	High	High	High	High	Medium	High	Medium	Medium	High	Medium	Medium	High	High	High	Medium	High	High	Medium	Medium	High	High	Low
Economic	Cost-effectiveness	B	C	B	B	B	B	C	LE	LE	C	C	B	C	C	C	A	B	C	C	C	B	A	B	A	A	C	C	A
	Absence of distributional effects	B	C	B	B	NE	NE	B	LE	LE	B	B	A	C	C	C	LE	B	B	C	LE	NE	LE	NE	B	NA	B	C	NE
	Employment & productivity enhancement potential	C	C	C	B	B	B	B	C	B	B	B	B	B	C	B	B	C	B	C	B	B	LE	B	NE	NA	B	C	NE
	OVERALL ECONOMIC FEASIBILITY	B	C	B	B	B	B	B	LE	LE	B	B	B	C	C	C	A	B	B	C	B	B	LE	B	A	A	B	C	LE
Technological	Technical scalability	C	C	C	C	C	C	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	B	C	B	B
	Maturity	C	C	C	B	B	C	NE	NE	LE	C	B	B	B	C	C	A	B	C	B	C	B	A	B	B	A	C	C	A
	Simplicity	B	C	C	B	LE	A	NE	NE	NE	C	A	B	B	B	C	LE	A	C	LE	B	A	NE	A	A	A	NE	NE	NE
	Absence of risk	C	C	C	C	B	B	C	C	B	C	LE	C	B	C	C	LE	B	NE	NE	NA	LE	NE	B	B	B	NE	NE	NE
	OVERALL TECHNOLOGICAL FEASIBILITY	C	C	C	B	B	B	B	B	B	C	B	B	B	C	C	B	B	C	B	C	B	B	B	B	A	C	B	A
Institutional	Political acceptability	B	B	B	B	B	B	C	NE	B	C	B	B	B	C	C	B	B	C	C	C	LE	C	B	A	NE	NE	NE	NE
	Legal & administrative feasibility	C	C	A	B	B	NE	NE	NE	B	B	B	C	A	C	C	A	B	C	B	C	A	NE	B	LE	B	NE	NE	NA
	Institutional capacity	B	B	LE	B	LE	A	C	NE	B	B	B	B	B	C	B	A	A	B	B	B	A	NE	B	B	NE	B	LE	LE
	Transparency & accountability potential	C	C	A	B	NE	A	C	NE	NE	B	C	C	C	LE	C	C	A	LE	LE	NA	LE	NA	NE	LE	LE	LE	B	NE
	OVERALL INSTITUTIONAL FEASIBILITY	B	B	A	B	B	A	C	NE	B	B	B	B	B	C	C	B	A	C	B	C	A	LE	B	A	LE	LE	LE	LE
Socio-cultural	Social co-benefits (health, education)	C	C	B	A	NE	B	C	B	C	C	C	C	C	C	C	LE	C	C	B	NA	NE	NA	NA	B	NA	C	NE	NE
	Public acceptance	B	C	A	B	A	A	B	B	C	C	B	B	B	B	B	B	B	C	NE	C	A	LE	A	A	A	B	C	LE
	Social & regional inclusiveness	C	B	B	C	NA	NE	B	B	B	B	B	LE	B	C	C	LE	C	B	NE	NA	B	NA	NE	LE	NE	B	NE	NE
	Intergenerational equity	C	C	NE	C	A	A	NE	LE	NE	C	LE	C	C	C	C	LE	C	NA	NA	NA	NE	NA	NE	NE	NE	LE	NE	NE
	Human capabilities	C	B	NE	B	A	NE	C	B	LE	LE	B	B	B	C	C	C	A	NA	NE	B	LE	NE	LE	LE	LE	NE	NE	NE
	OVERALL SOCIO-CULTURAL FEASIBILITY	C	C	B	B	A	A	B	B	C	C	B	B	B	C	C	LE	B	C	LE	B	LE	LE	LE	LE	LE	B	LE	LE
Environmental/ ecological	Reduction of air pollution	C	C	LE	B	C	C	LE	C	NE	NE	C	C	C	C	C	C	C	C	B	C	NE	NE	C	B	NA	NA	NA	B
	Reduction of toxic waste	C	B	NE	A	A	A	NE	NE	B	NE	LE	LE	C	LE	LE	C	B	C	C	NE	NE	NE	NE	NA	NA	NA	NE	LE
	Reduction of water use	C	C	A	B	A	B	C	C	LE	C	C	LE	B	LE	LE	B	C	C	C	B	NE	NE	A	A	NE	B	C	LE
	Improved biodiversity	C	C	B	NA	C	C	C	C	C	C	C	LE	C	C	LE	B	C	NA	NA	NE	NE	NE	LE	A	NA	B	NE	NA
	OVERALL ENVIRONMENTALFEASIBILITY	C	C	A	B	B	B	C	C	B	C	C	LE	C	C	LE	B	C	C	C	B	NE	NE	B	A	NE	B	LE	LE
Geophysical	Physical feasibility (physical potentials)	B	C	B	C	C	C	C	NE	NE	C	C	C	C	C	C	C	C	C	C	B	A	B	A	B	C	B	B	C
	Limited use of land	B	B	A	C	C	C	C	LE	B	B	C	A	C	C	C	LE	NA	NA	NA	NA	A	NE	NE	A	C	A	C	C
	Limited use of scarce (geo)physical resources	B	B	NA	A	B	C	NE	NE	C	NE	LE	A	C	C	C	B	B	LE	NA	C	NE	NE	NE	NE	NE	LE	NA	LE
	Global spread	C	B	B	C	C	C	LE	NE	LE	C	C	C	B	C	C	C	B	NA	NA	C	C	C	C	B	C	B	B	C
	OVERALL GEOPHYSICAL FEASIBILITY	B	B	B	B	C	C	C	NE	B	C	C	B	C	C	C	C	B	C	C	C	B	B	B	B	C	B	B	C

Legend	
A	Indicator could potentially block feasibility of option
B	Indicator has neither a positive, nor negative effect on feasibility of option, or evidence is mixed
C	Indicator does not pose barriers to feasbility of option
NA	Not applicable
NE	No evidence
LE	Limited evidence

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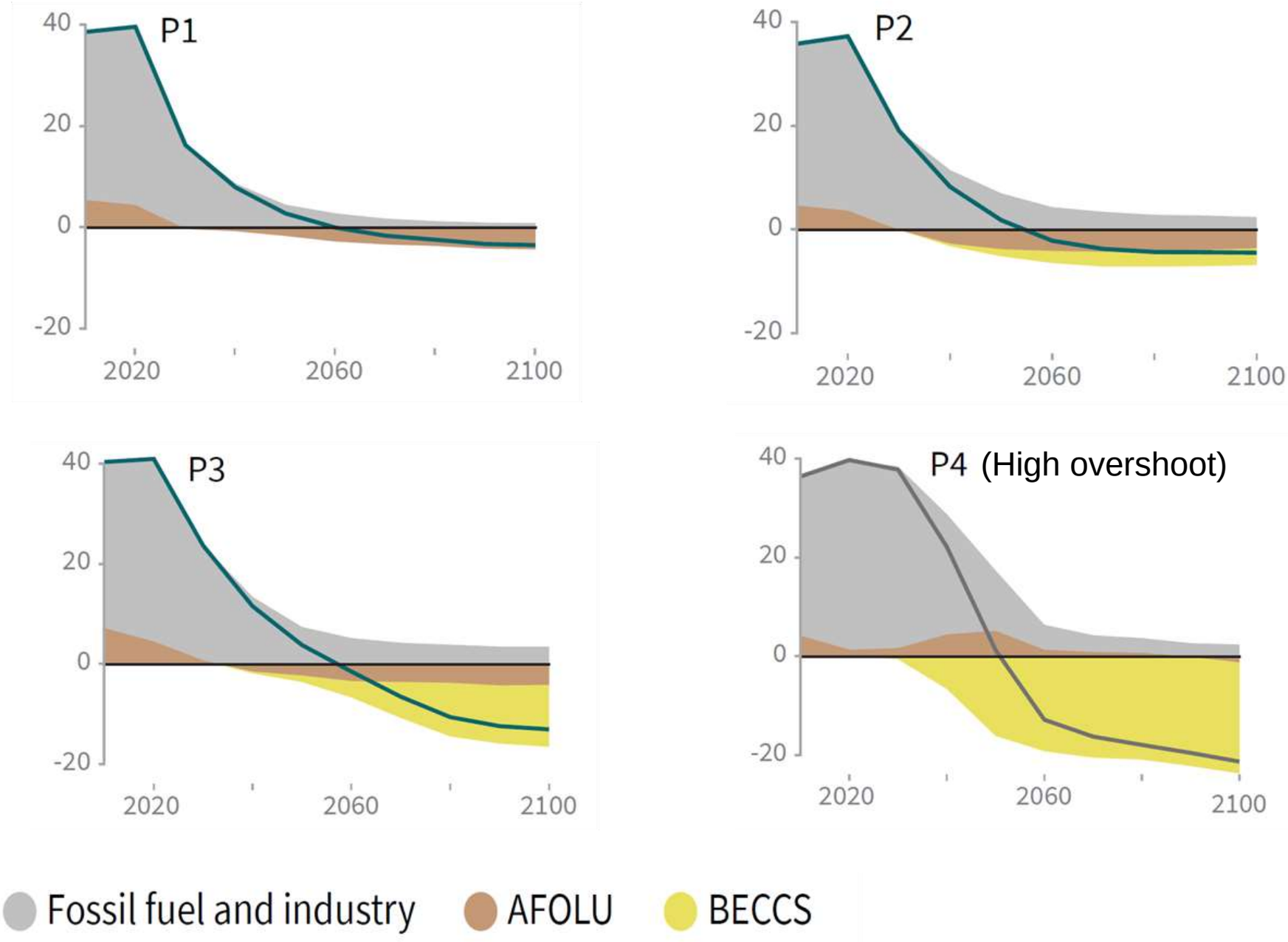
Sectoral indicators for 1.5°C-consistent pathways

Pathways	Number of scenarios	Energy		Buildings	Transport		Industry
		Share of renewables in primary energy [%]	Share of renewables in electricity [%]				
IAM Pathways 2050	1.5C-no or low-OS	50	60 (67; 52)			77 (86; 69)	
	1.5C-high-OS	35	62 (68; 47)			82 (88; 64)	
Other Studies 2050	LED	73	77	45		59	91
	Löffler et al. (2017)	100	100				
	IEA (2017c) (ETP)	58	74	5	55	30	57
	IEA (2017g) (WEM)	47	69	–5	58	32	55

Table 4.1

Illustrative model pathways: we still have a choice



Greenhouse gas emissions pathways

- Limiting warming to 1.5°C would require systemic changes and CO_2 removal
  - → Energy systems transition
  - → Land and ecosystems transition
  - → Urban and infrastructure system transition
  - → Industrial system transition
  - → Carbon dioxide removal
- Mitigation and adaptation options within these systems transitions

Peter Essick / Aurora Photos

Peter Essick / Aurora Photos

Energy system transition

- In 1.5C-consistent pathways:
  - → Lower energy use to meet energy demand
  - → Fast electrification of energy end use
  - → Renewables make up 70-85% of electricity in 2050
  - → Coal makes up 0-2% of electricity in 2050
  - → Increasingly feasible options: solar, wind, electricity storage
  - → No similar improvement for options: nuclear, CCS

Peter Essick / Aurora Photos

Land and ecosystem transition

- In 1.5C-consistent pathways:
  - Large scale land-use and land cover transitions
  - Challenges for sustainable management of land demand
  - Mitigation options: ecosystems restoration, dietary shifts, efficient food production
  - Careful design and implementation of land-based mitigation options
  - Adaptation options: efficient livestock systems, efficient irrigation, conservation agriculture
  - Changing agricultural practices as adaptation strategy

Industrial system transition

- In 1.5C-consistent pathways:
  - → CO_2 emissions 65-90% lower in 2050 (w.r.t. 2010)
  - → Mitigation options: energy efficiency, electrification, hydrogen, bio-based feedstocks, CCUS
  - → Increasing energy & process efficiency insufficient
  - → Options technically proven at various scales but barriers to large-scale deployment to be overcome

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Urban and infrastructure system transition

- In 1.5C-consistent pathways:
  - Energy demand in buildings 55-75% electricity in 2050
  - Share of low-emission final energy in transport sector rises from <5% in 2020 to 35-65% in 2050
  - Mitigation options: electric vehicles, non-motorised transport, low/zero-energy buildings
  - Adaptation options: green infrastructure, resilient water and urban ecosystem services
  - Potential for synergies between adaptation and mitigation options

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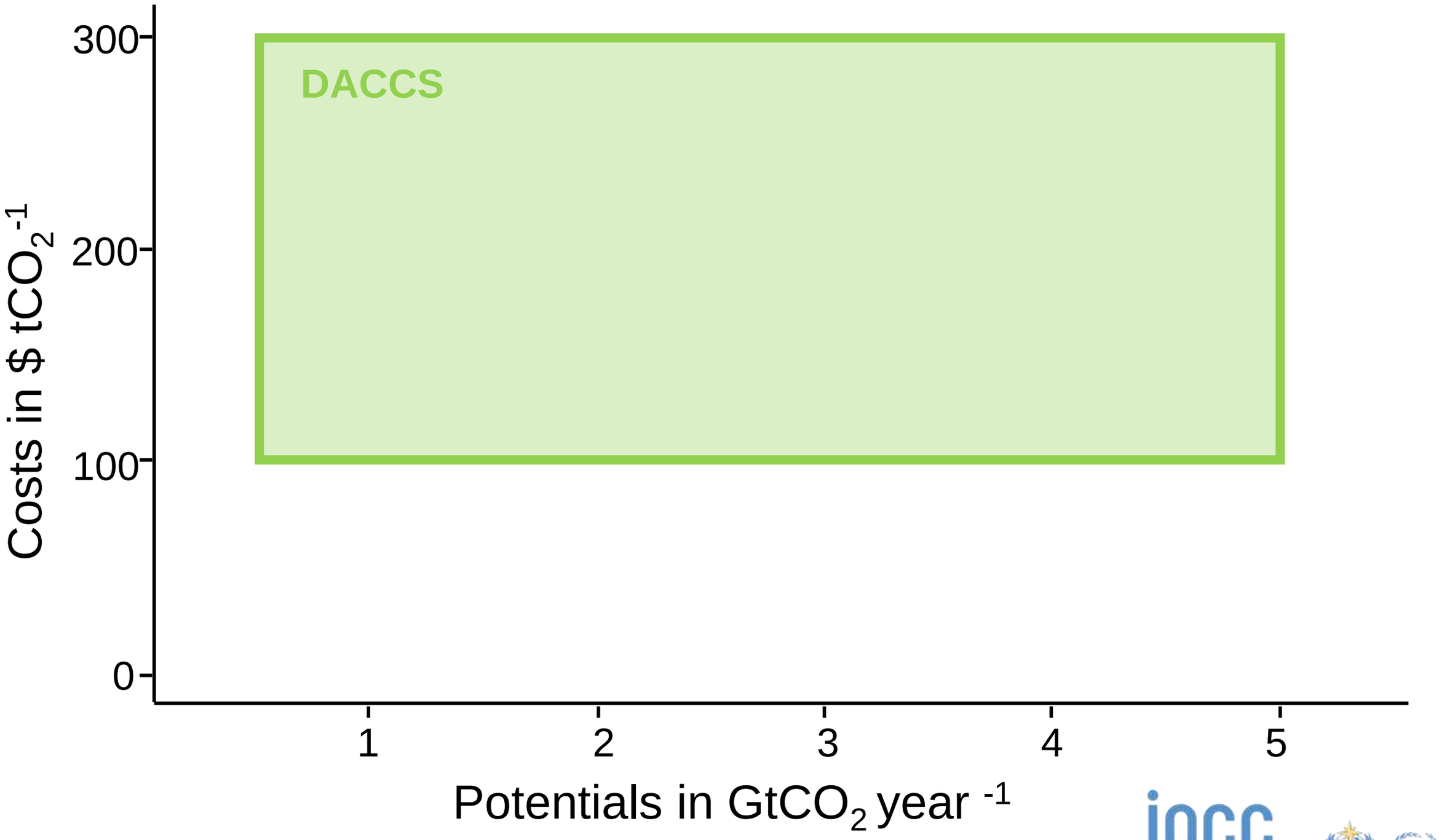
Carbon Dioxide Removal (CDR) options considered in the SR1.5

Natural	Natural & technological	Technological
Afforestation & reforestation	Bio-energy and CO_2 capture and storage (BECCS)	Enhanced Weathering
Biochar		Direct Air CO_2 Capture and Storage (DACCS)
Soil Carbon Sequestration		

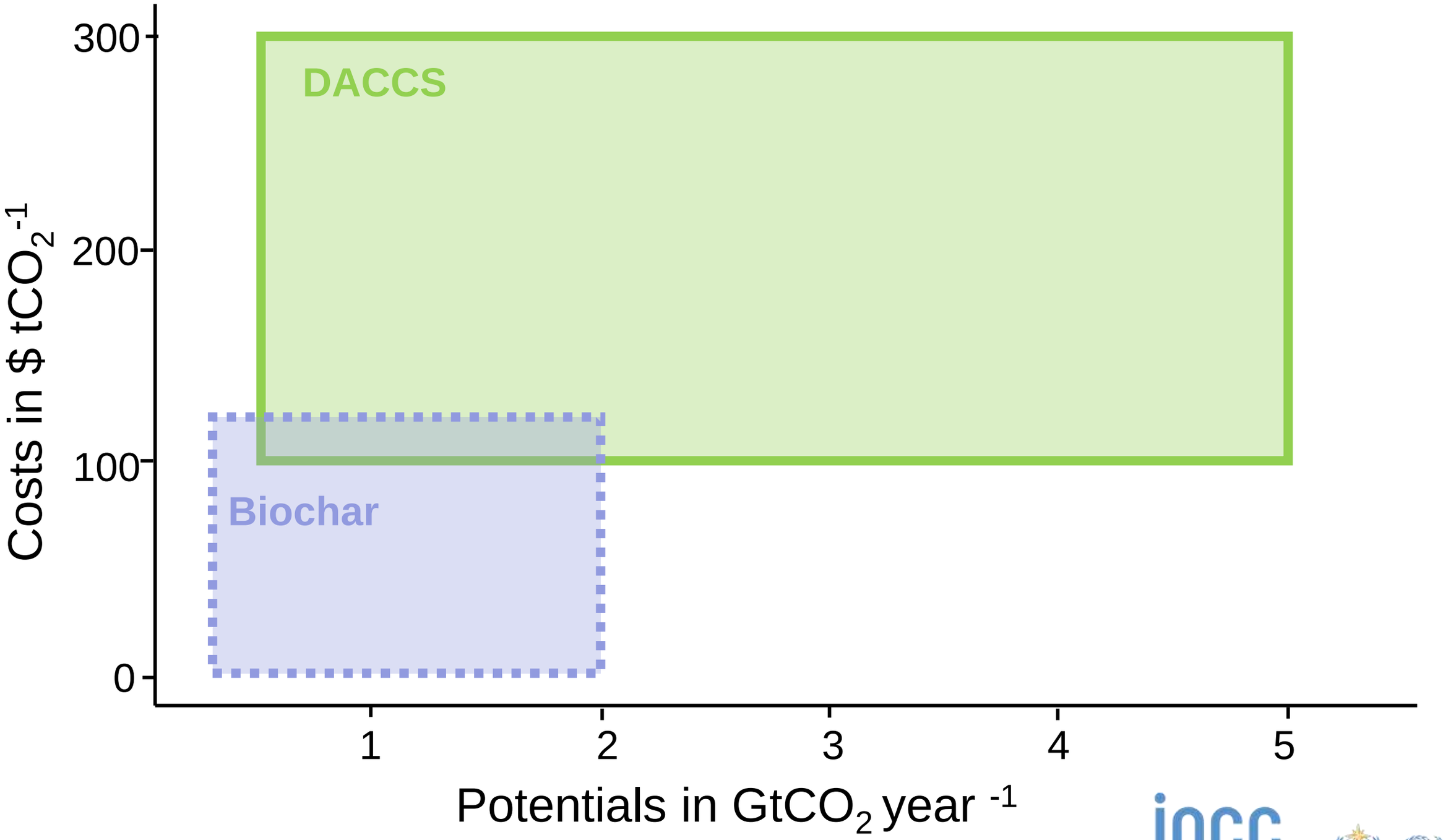
BECCS and afforestation/reforestation included in modelled pathways

Inspired by UNEP EGR 2017

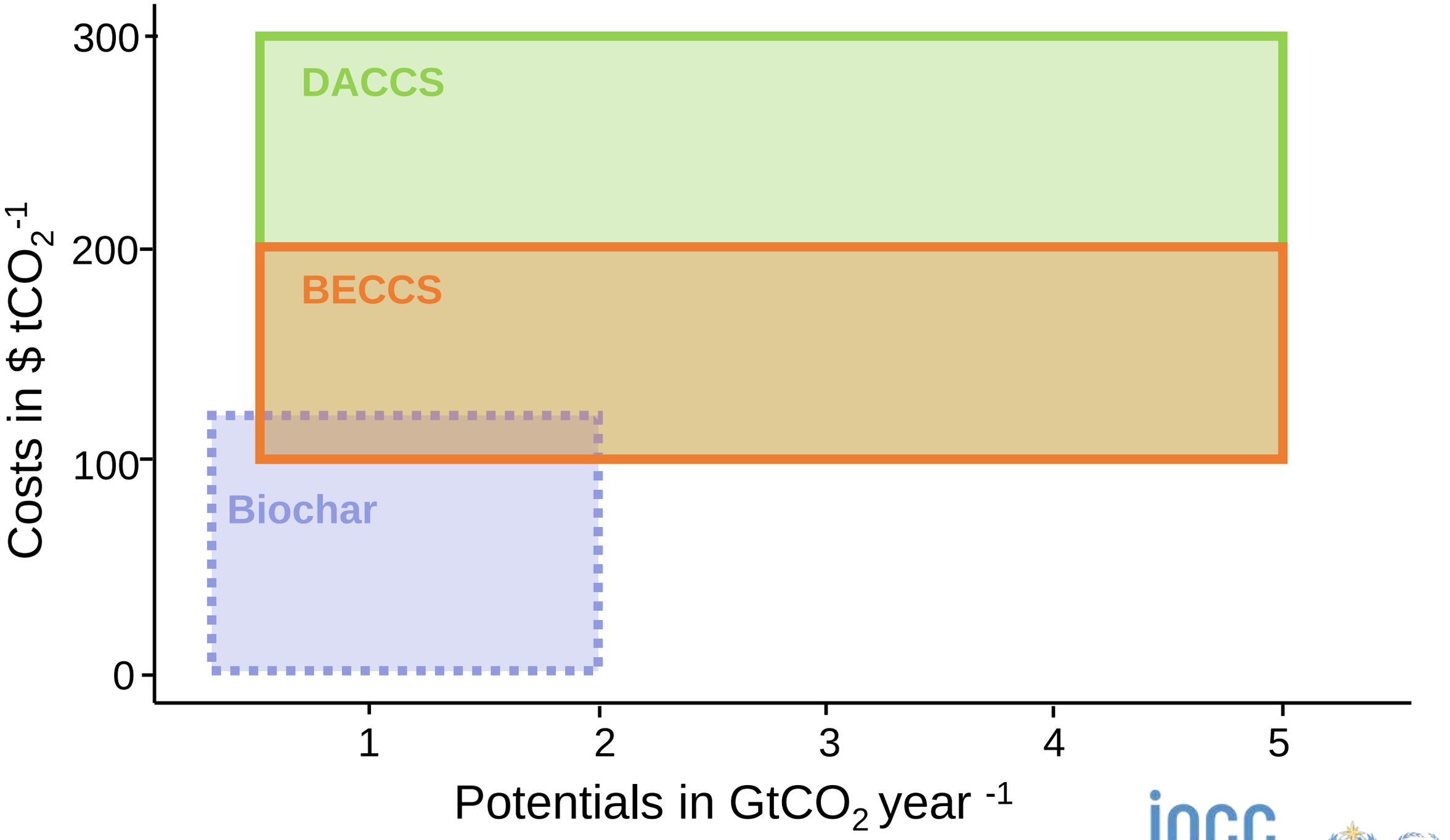
CDR in SR1.5: Costs and 2050 potentials



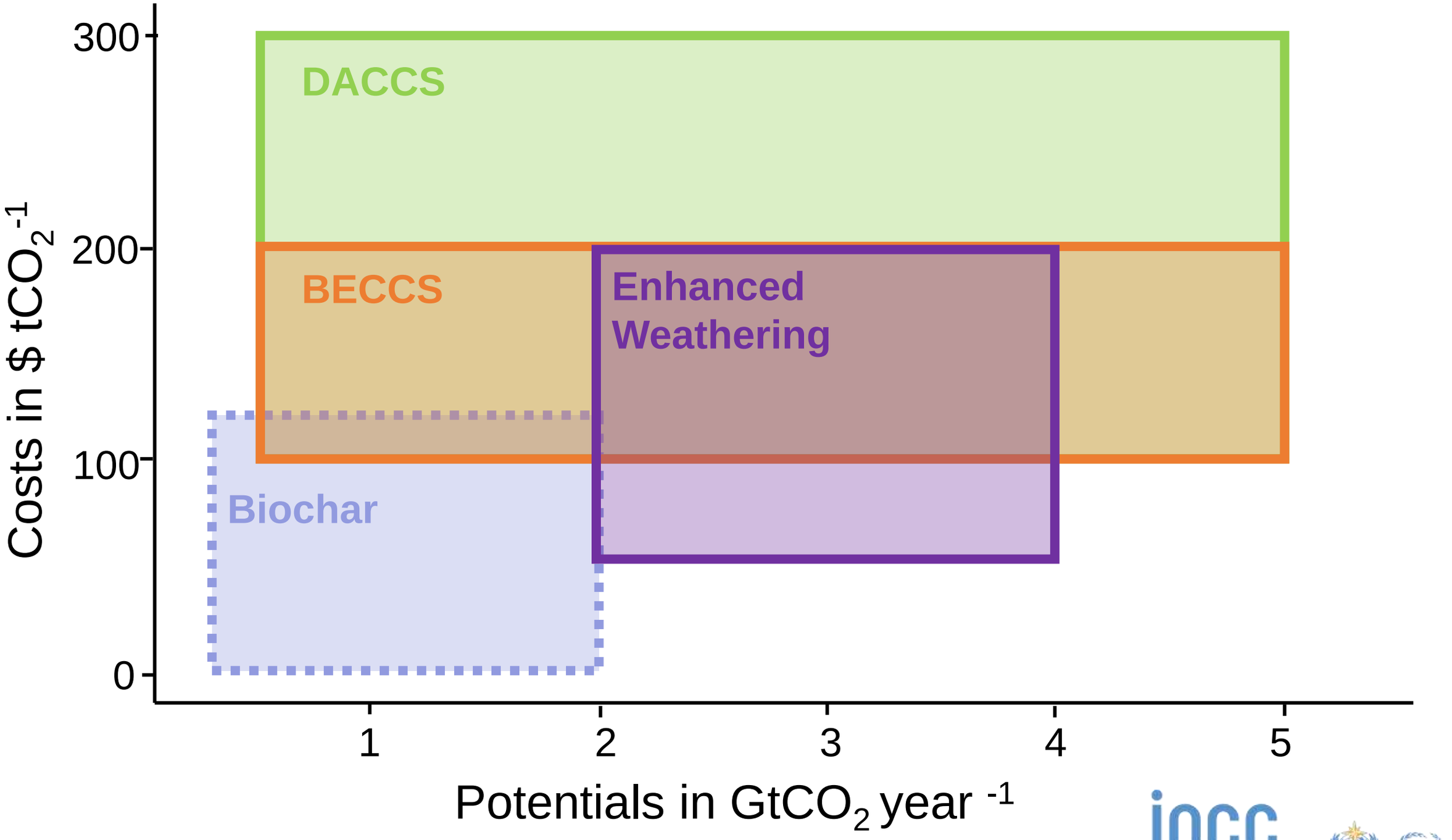
CDR in SR1.5: Costs and 2050 potentials



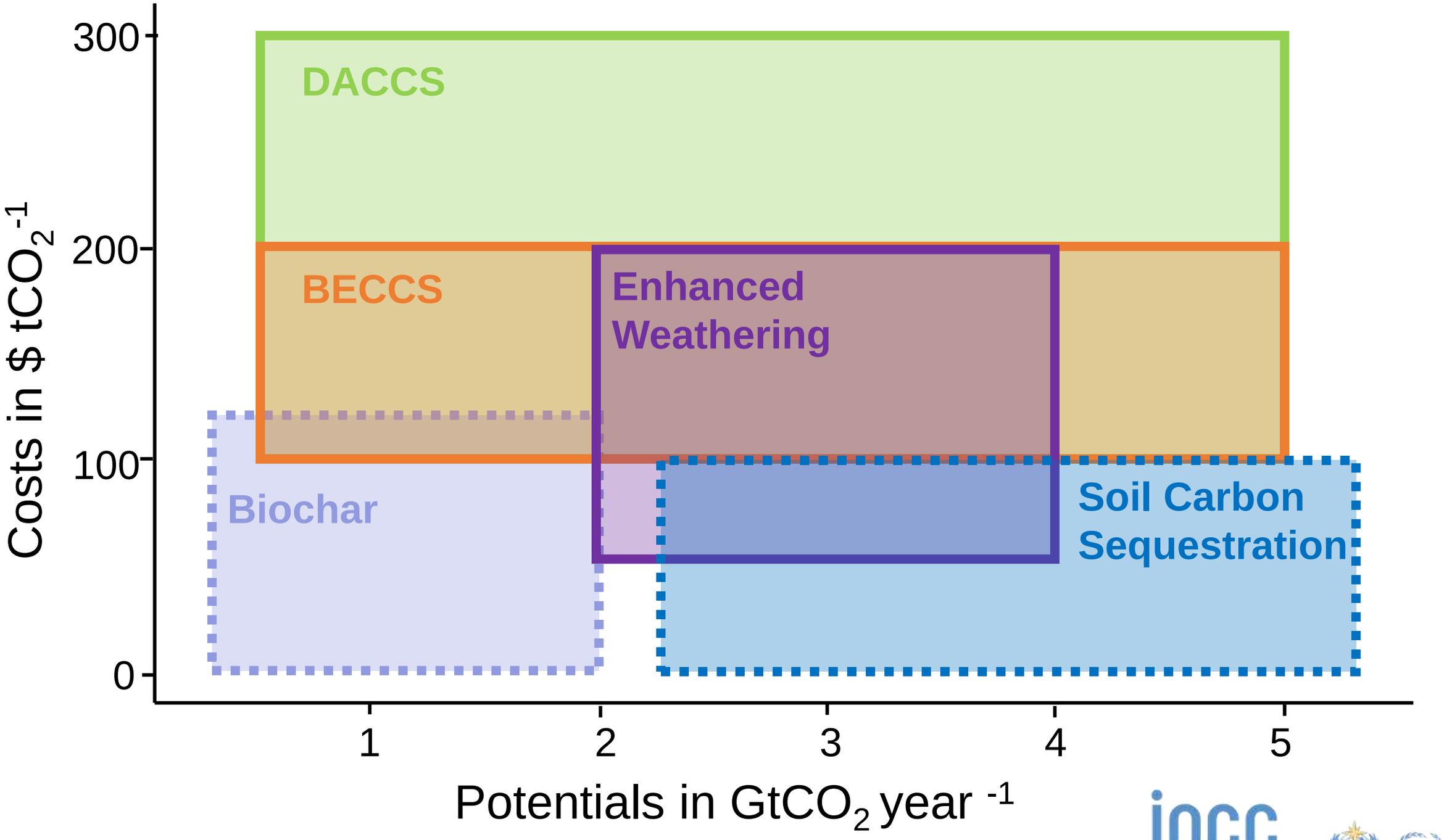
CDR in SR1.5: Costs and 2050 potentials



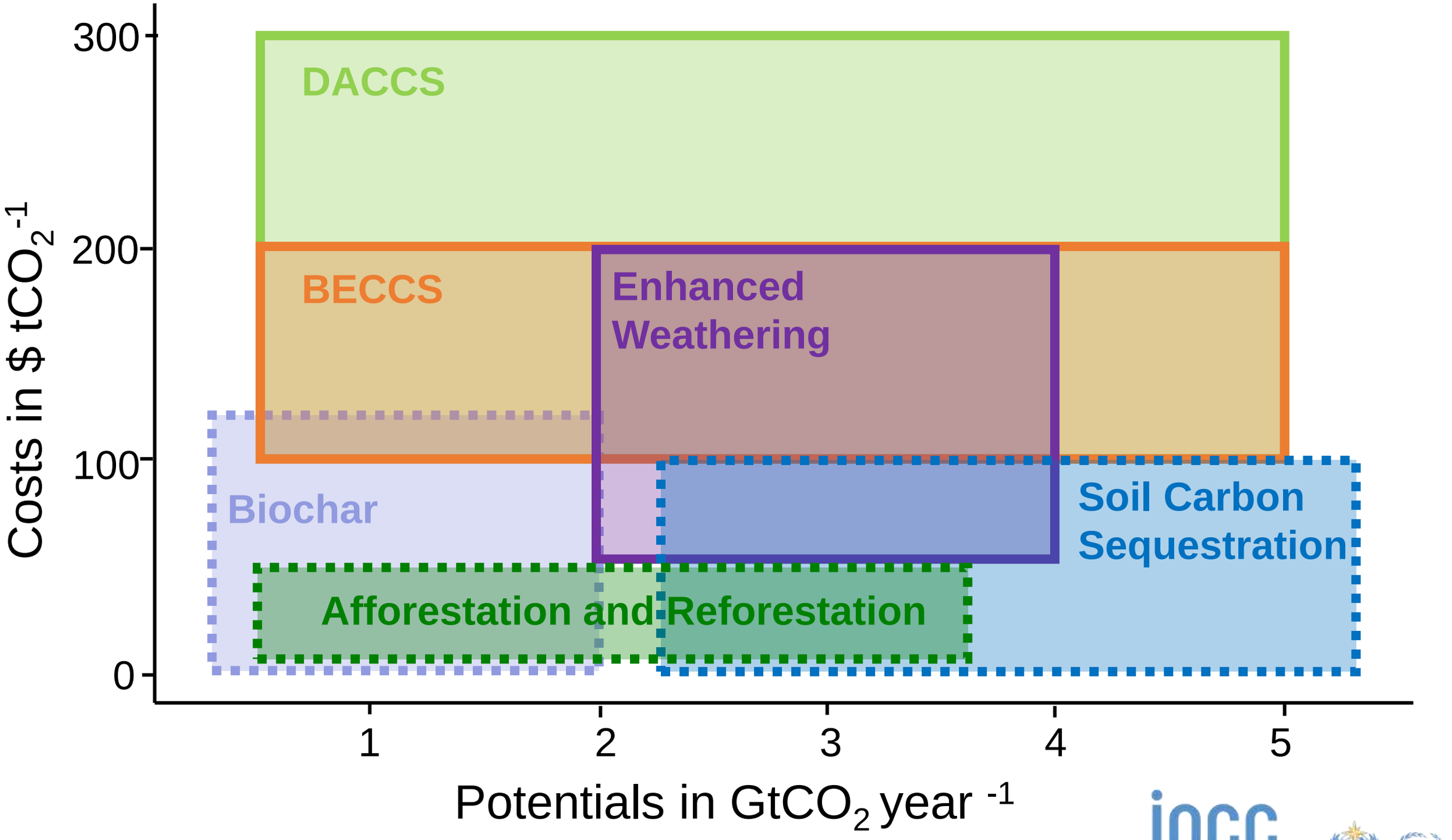
CDR in SR1.5: Costs and 2050 potentials

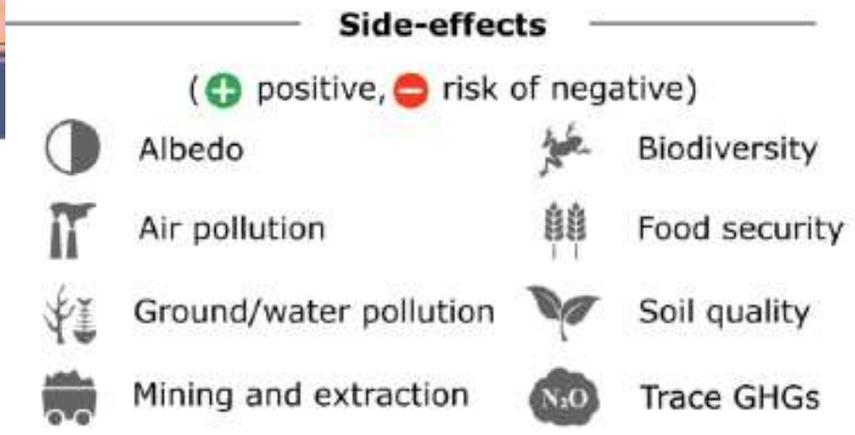


CDR in SR1.5: Costs and 2050 potentials



CDR in SR1.5: Costs and 2050 potentials





CDR in SR1.5: Side-effects

Included in pathways:

- Bio-energy and CCS
- Afforestation & reforestation

Other CDR:

- Direct Air Capture & Storage
- Enhanced Weathering
- Biochar
- Soil Carbon Sequestration

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Illustrative Adaptation Feasibility Assessment

Selection of 9 examples of options based on confidence level

In Table 4.12:

- 23 adaptation options
- Based on 19 indicators in six dimensions

Total of 603 unique references underpin the adaptation options feasibility assessment

Out of 437 indicator-level assessments

- 37 NA; 36 LE; 36 NE

	Adaptation option	Confidence	Economic	Technological	Institutional	Socio-cultural	Environmental-ecological	Geophysical	Context
Land and Ecosystem Transitions	Conservation agriculture	Medium							Depends on irrigated/rain-fed system, ecosystem characteristics, crop type, other farming practices
	Efficient irrigation	Medium							Depends on agricultural system, technology used, regional institutional and biophysical context
	Efficient livestock systems	Medium							Dependent on livestock breeds, feed practices, and biophysical context (e.g. carrying capacity)
	Community-based adaptation	Medium							Focus on rural areas and combined with ecosystems-based adaptation, does not include urban settings
	Ecosystem restoration & avoided deforestation	High							Mostly focused on existing and evaluated Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects
	Coastal defence & hardening	High							Depends on locations that require it as a first adaptation option
Urban and Infrastructure System Transitions	Sustainable land-use & urban planning	Medium							Depends on nature of planning systems and enforcement mechanisms
	Sustainable water management	High							Balancing sustainable water supply and rising demand especially
	Green infrastructure & ecosystem services	High							Depends on reconciliation of urban development with green infrastructure

Illustrative Mitigation Feasibility Assessment

Selection of 10 examples of options based on confidence level and relevance to illustrative pathways

In Table 4.11:

- 28 mitigation options
- Based on 24 indicators in six dimensions

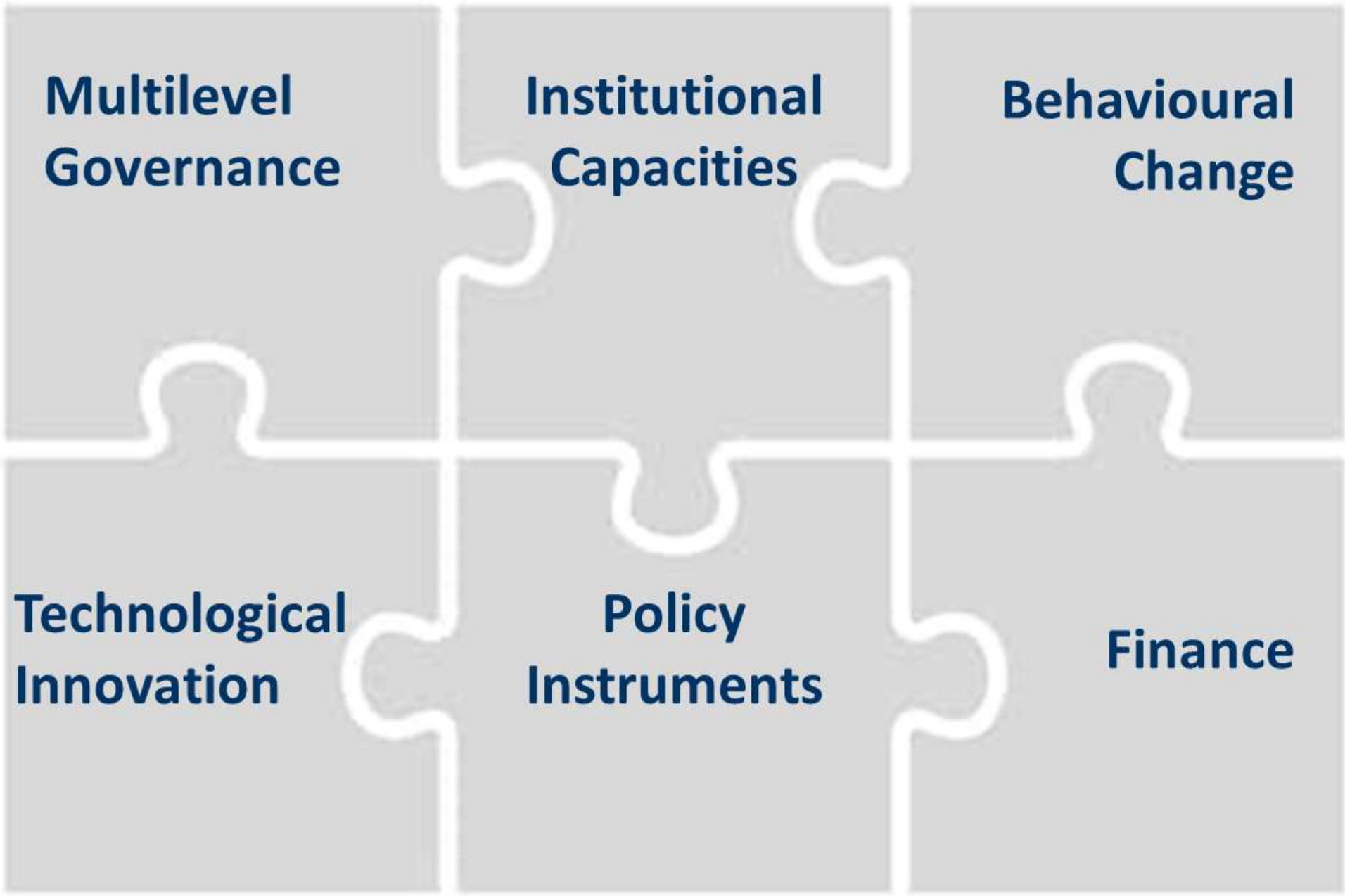
Total of 763 unique references underpin the mitigation options feasibility assessment

Out of 672 indicator-level assessments:

- 38 NA; 67 LE; 101 NE

	Mitigation Option	Confidence	Economic	Technological	Institutional	Socio-cultural	Environmental-ecological	Geophysical	Context
Energy System Transitions	Solar PV	High							Cost-effectiveness affected by solar irradiation and incentive regime. Also enhanced by legal framework for independent power producers, which affects uptake.
	Power sector CCS	High							Varies with local CO_2 storage capacity, presence of legal framework, level of development and quality of public engagement
Land and Ecosystem Transitions	Ecosystems restoration	High							Depends on location and institutional factors
Urban and Infrastructure System Transitions	Electric cars and buses	Medium							Varies with degree of government intervention; requires capacity to retrofit "fuelling" stations
	Non-motorized transport	High							Viability rests on linkages with public transport, cultural factors, climate and geography
	Low/zero-energy buildings	High							Depends on size of existing building stock and growth of building stock
Industrial System Transitions	Energy efficiency	High							Potential and adoption depend on existing efficiency, energy prices and interest rates, as well as government incentives.
	Industrial CCUS	High							High concentration of CO_2 in exhaust gas improve economic and technical feasibility of CCUS in industry. CO_2 storage or reuse possibilities.
Carbon Dioxide Removal	BECCS	Medium							Depends on biomass availability, CO_2 storage capacity, legal framework, economic status and social acceptance
	Afforestation & reforestation	High							Depends on location, mode of implementation, and economic and institutional factors

Enabling conditions



Enabling conditions

Technological Innovation

Widespread adoption of new technologies

National innovation policies and international cooperation

Technological innovation capabilities (industry, finance)

Combination of public support for R&D with policy mixes incentivizing technology diffusion

Ashley Cooper / Aurora Photos

Enabling conditions

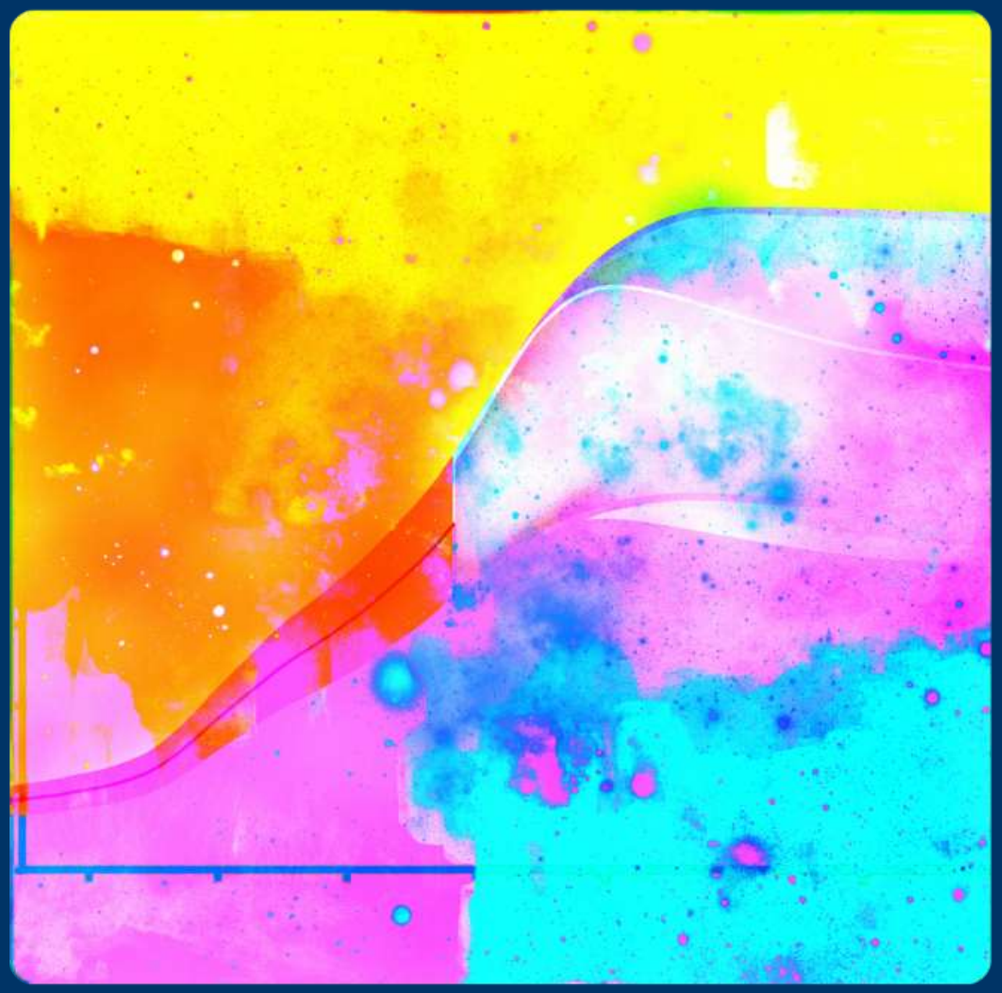
First time full assessment in an IPCC report

Tailored to motivations, capabilities and resources

Public support and acceptability

Perceived fairness of the distribution of consequences and procedures

Ashley Cooper / Aurora Photos



Questions?