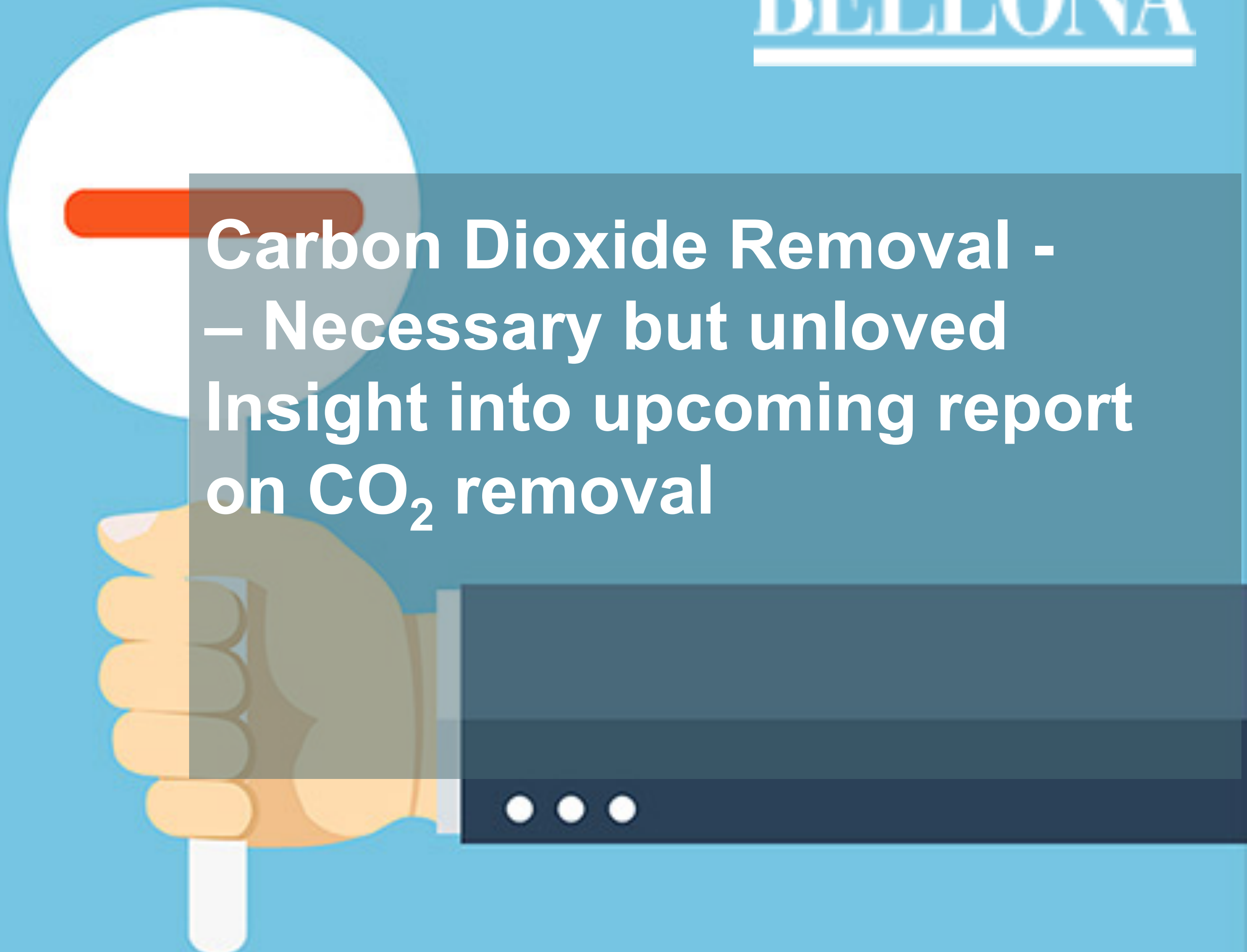
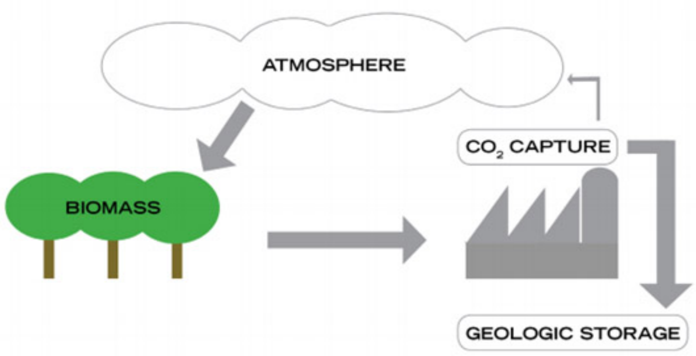
BELLONA



Carbon Dioxide Removal - – Necessary but unloved Insight into upcoming report on CO_2 removal

Carbon Dioxide Removal

2 major technologies:



Afforestation – planting of trees

Bio-Carbon Capture and Storage

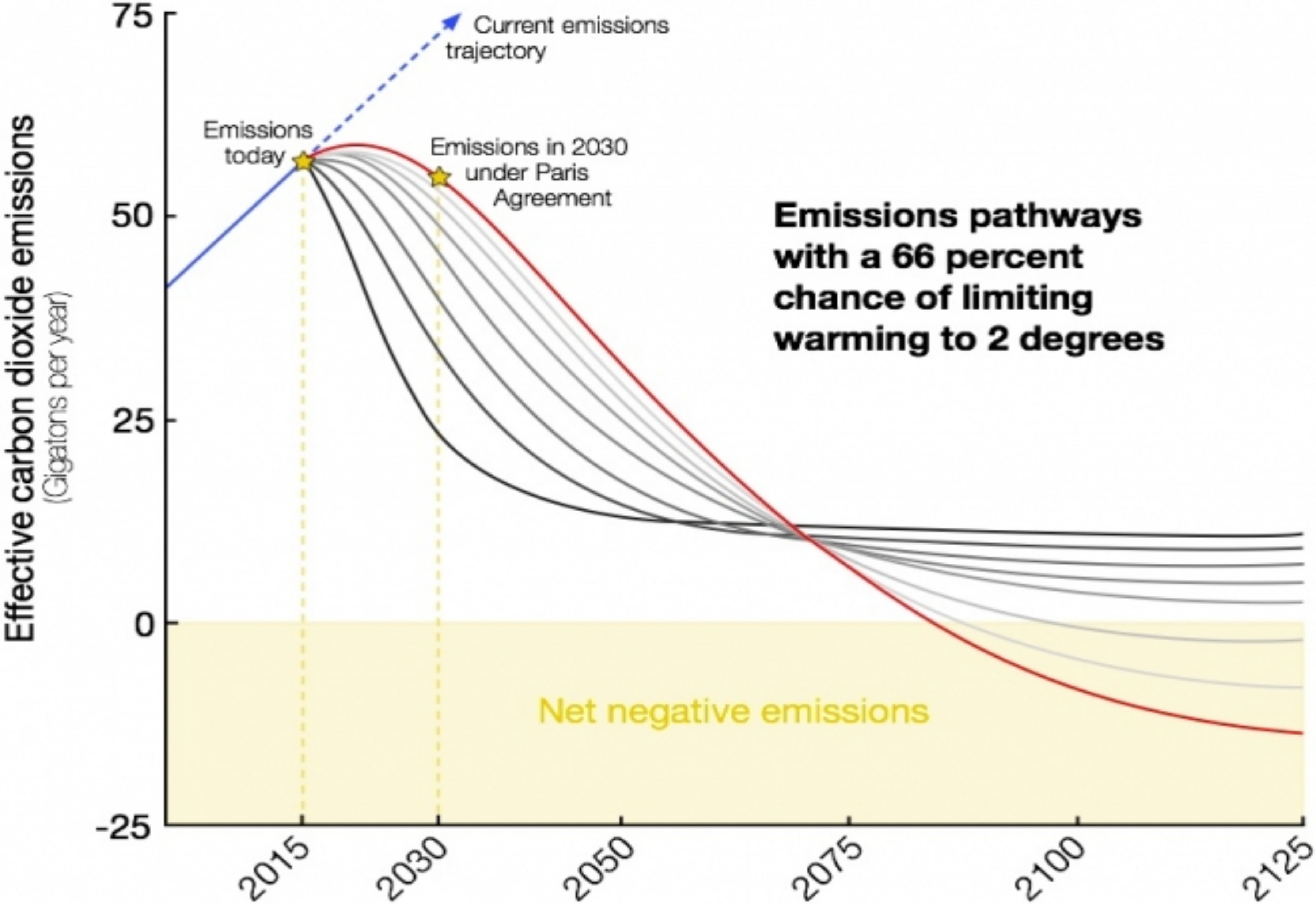
At the Bonn Climate Negotiations, Unexpected Drama Over 1.5 Degrees

Last week, negotiators met in Bonn to hash out the implementation of the Paris Agreement—while critics of negative emission technologies warned of the risk of land grabs.

"We have waited too long. Our options are reduced. We are facing fairly brutal carbon arithmetic now."

"This idea of negative emissions is a delaying tactic, it's smoke and mirrors to create the illusion that industrialized countries can maintain their standard of living, avoid sacrifice, and the world can still be saved," she says. "This is the elephant in the room. We must reduce consumption and we must do it now. It

https://psmag.com/at-the-bonn-climate-negotiations-unexpected-drama-over-1-5-degrees-eaf80e7b9983#.u41qn61y3



Current emissions trajectory
Emissions today
Emissions in 2030 under Paris Agreement
Emissions pathways with a 66 percent chance of limiting warming to 2 degrees
Effective carbon dioxide emissions
(Gigatons per year)
75
50
25
0
-25
Net negative emissions
2015
2030
2050
2075
2100
2125

Assessment of bio-CCS in 2°C compatible scenarios

Umwelt Bundesamt

German federal environmental agency

ECOFYS

Dutch Consultancy

Non-bio-CCS scenarios

- Emissions:
  - Emission reduction already by 2020 in most scenarios
  - Only 1 scenario in which emission increase for 2020
  - 5 out of 9 show negative emissions starting between 2070 and 2090
- Concentration:
  - Almost all scenarios show an overshoot in concentration of max. 450 ppm → C! = 430-480 in 2100, one scenario even below 390
  - For some overshoot is max about 410 ppm

BIO CCS

BIOENERGY WITH CARBON DIOXIDE CAPTURE & STORAGE

01

SUSTAINABLE BIOMASS GROWTH

Non-food biomass is grown, absorbing CO_2 from the atmosphere and energy from the sun.

02

BIOMASS TRANSFORMATION

Energy in Biomass is converted into, Heat, Electricity or Biofuels.

03

CO_2 CAPTURE & COMPRESSION

The CO_2 from biomass is captured and prevented from returning to the atmosphere. The CO_2 is compressed ready to transport.

04

CO_2 TRANSPORT

The CO_2 is transported via pipeline or ship.

05

PERMANENT CO_2 STORAGE

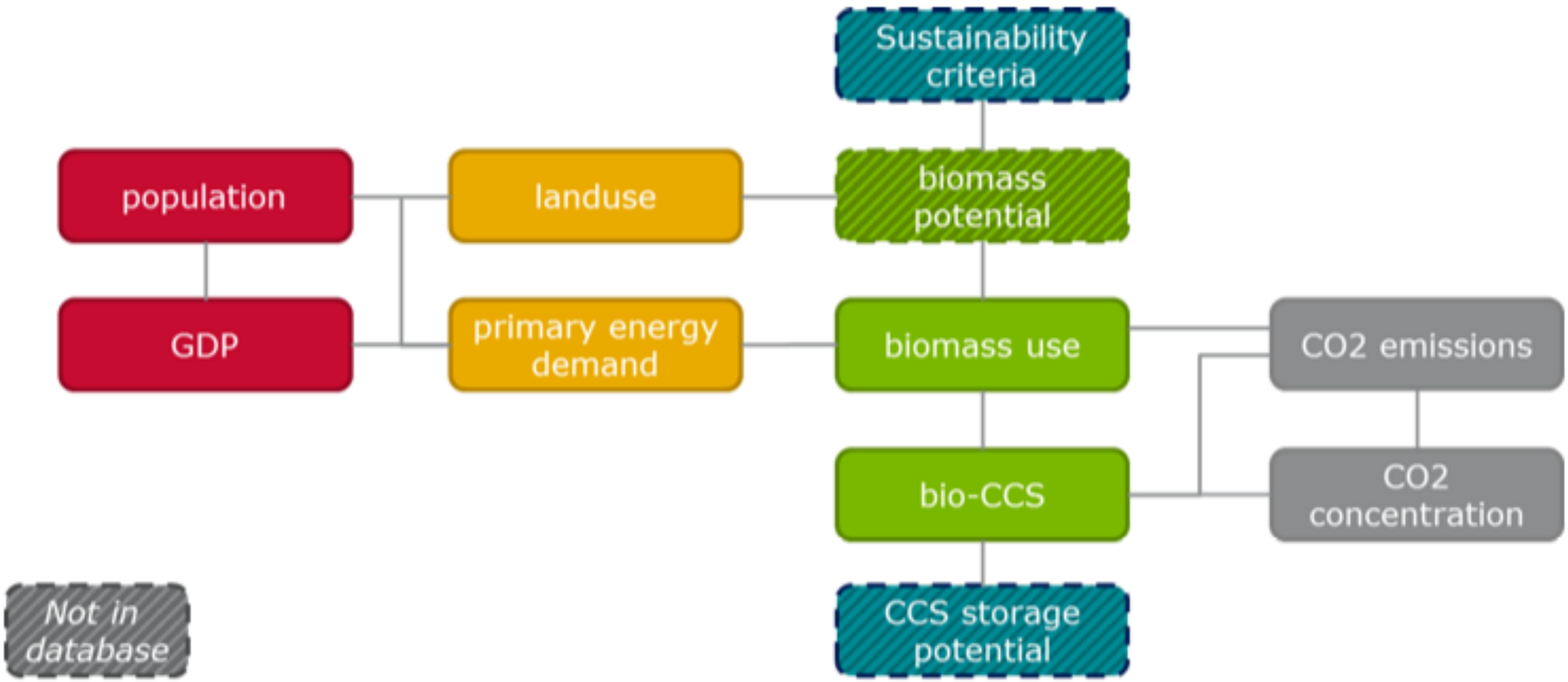
CO_2 is injected deep underground at specially selected and researched storage sites, trapped in microscopic pores in deep rocks.

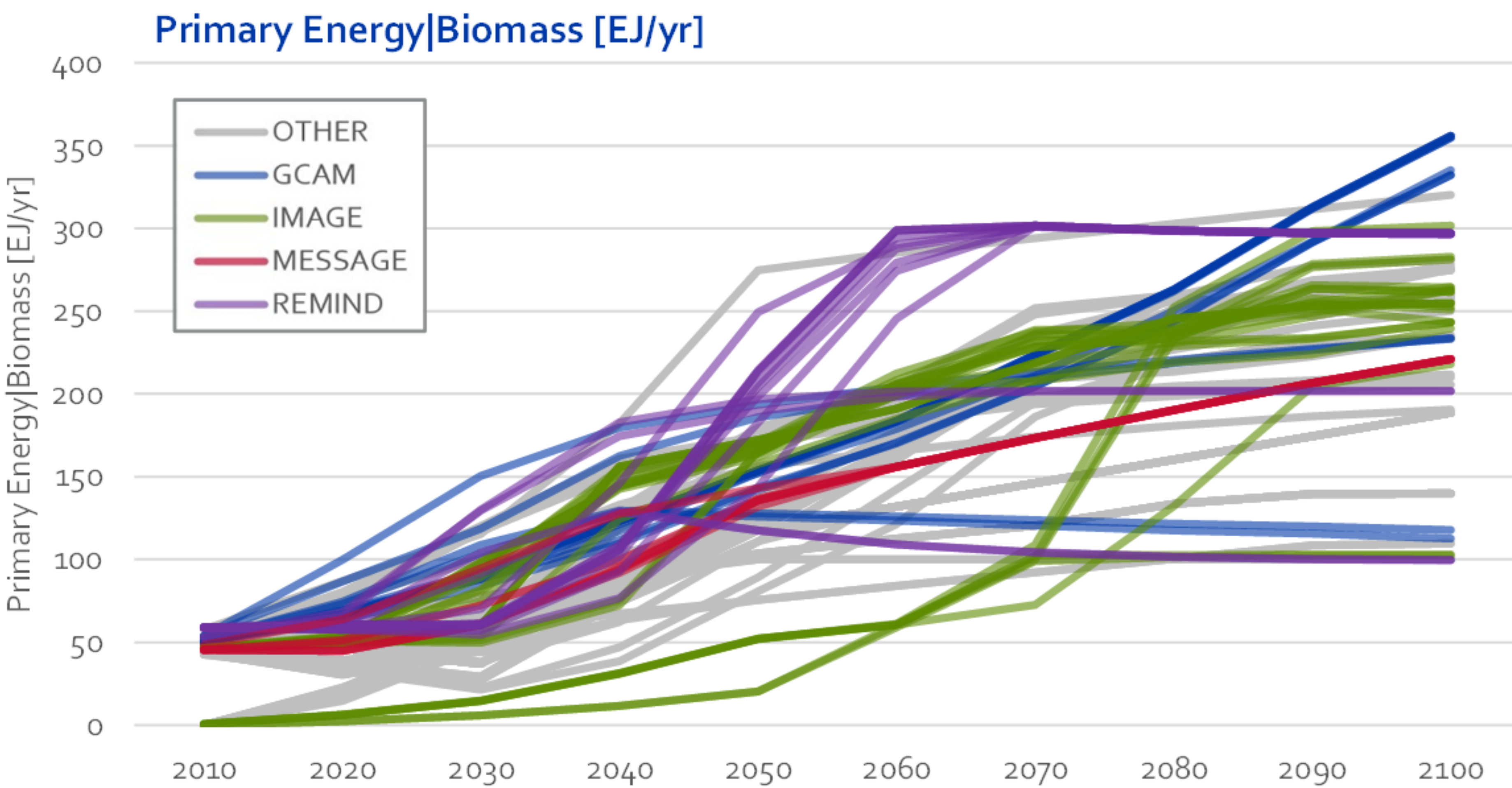
Table 1: Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters the 10th to 90th percentile of scenarios is shown.

Category	CO_2eq concentrations in 2100 [ppm CO_2eq]	Subcategories	Change in CO_2eq emissions compared to 2010 [in %]		Likelihood of staying within a specific temperature level over the 21st century (relative to 1850-1900)			
			2050	2100	1.5°C	2°C	3°C	4°C
1	430-480	Total range	-72 to -41	-118 to -78	More unlikely than likely	Likely	Likely	Likely
2 (a)	480-530	No overshoot of 530 ppm CO_2eq	-57 to -42	-107 to -73	Unlikely	More likely than not	Likely	Likely
2 (b)	480-530	Overshoot of 530 ppm CO_2eq	-55 to -25	-114 to -90	Unlikely	About as likely as not	Likely	Likely
3 (a)	530-580	No overshoot of 580 ppm CO_2eq	-47 to -19	-81 to -59	Unlikely	More unlikely than likely	Likely	Likely
3 (b)	530-580	Overshoot of 580 ppm CO_2eq	-16 to 7	-183 to -86	Unlikely	More unlikely than likely	Likely	Likely
4	580-650	Total range	-38 to 24	-134 to -50	Unlikely	More unlikely than likely	Likely	Likely
5	650-720	Total range	-11 to 17	-54 to -21	Unlikely	Unlikely	More likely than not	Likely
6	720-1000	Total range	18 to 54	-7 to 72	Unlikely	Unlikely	More unlikely than likely	Likely
7	>1000	Total range	52 to 95	74 to 178	Unlikely	Unlikely	Unlikely	More unlikely than likely

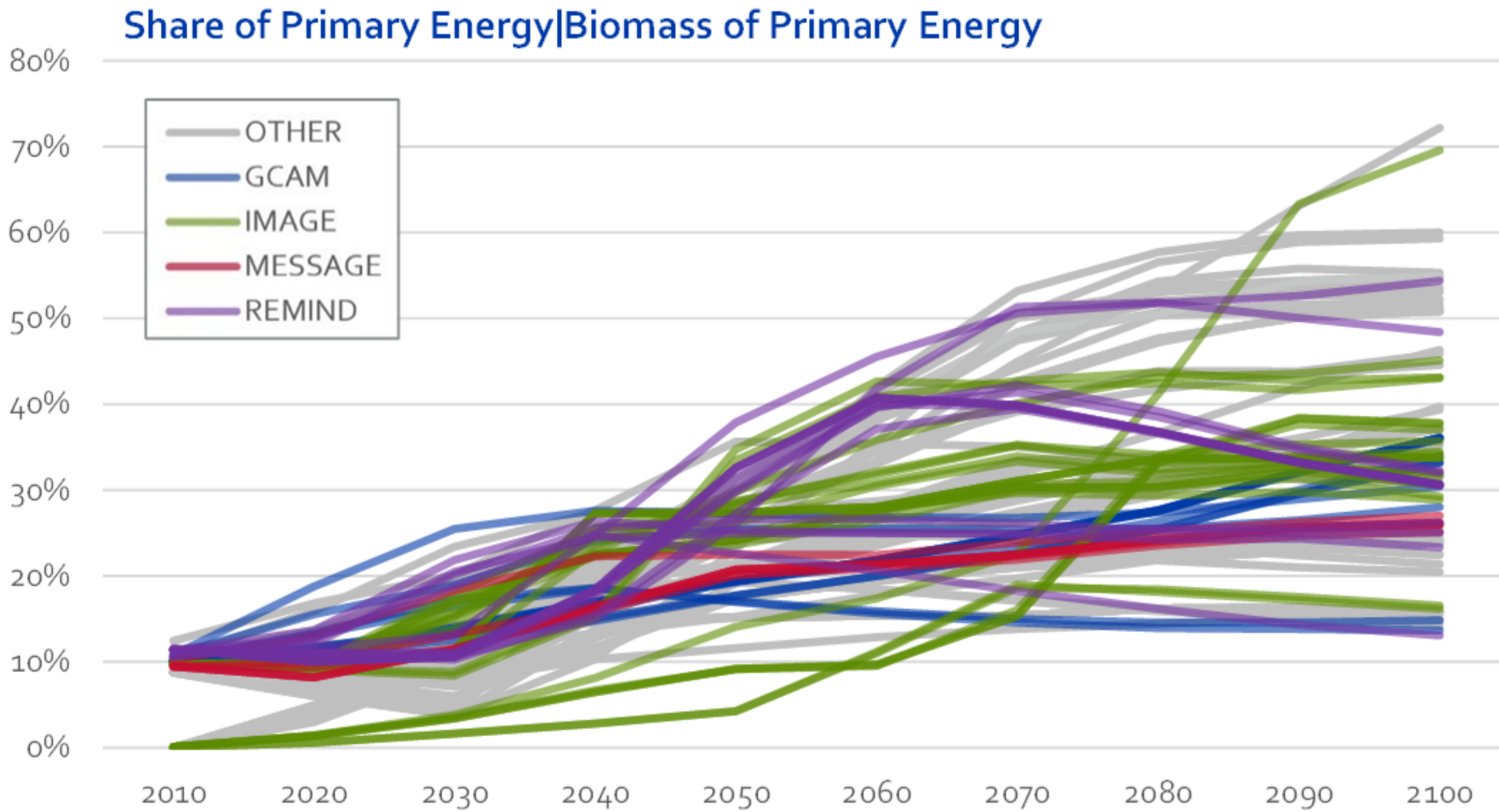
Source: Ecofys based on (IPCC, 2014a), table SPM.1, p.22

CO_2 Emissions must reduce as population and wealth grows!





Primary Energy|Biomass [EJ/yr]
400
350
300
250
200
150
100
50
0
OTHER
GCAM
IMAGE
MESSAGE
REMIND
Primary Energy|Biomass [EJ/yr]
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

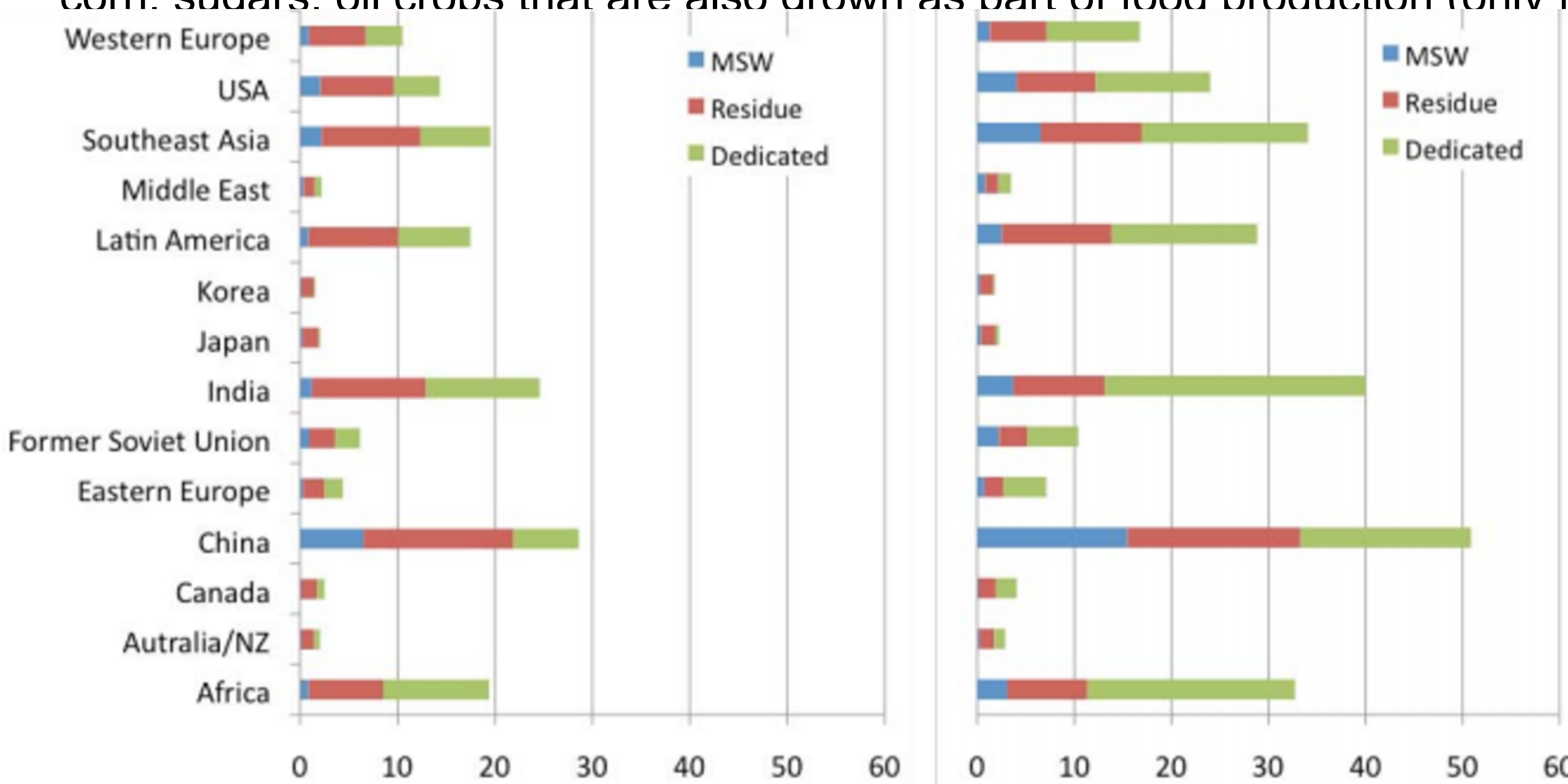

Share of Primary Energy|Biomass of Primary Energy
80%
70%
60%
50%
40%
30%
20%
10%
0%
OTHER
GCAM
IMAGE
MESSAGE
REMIND
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

Type of biomass use

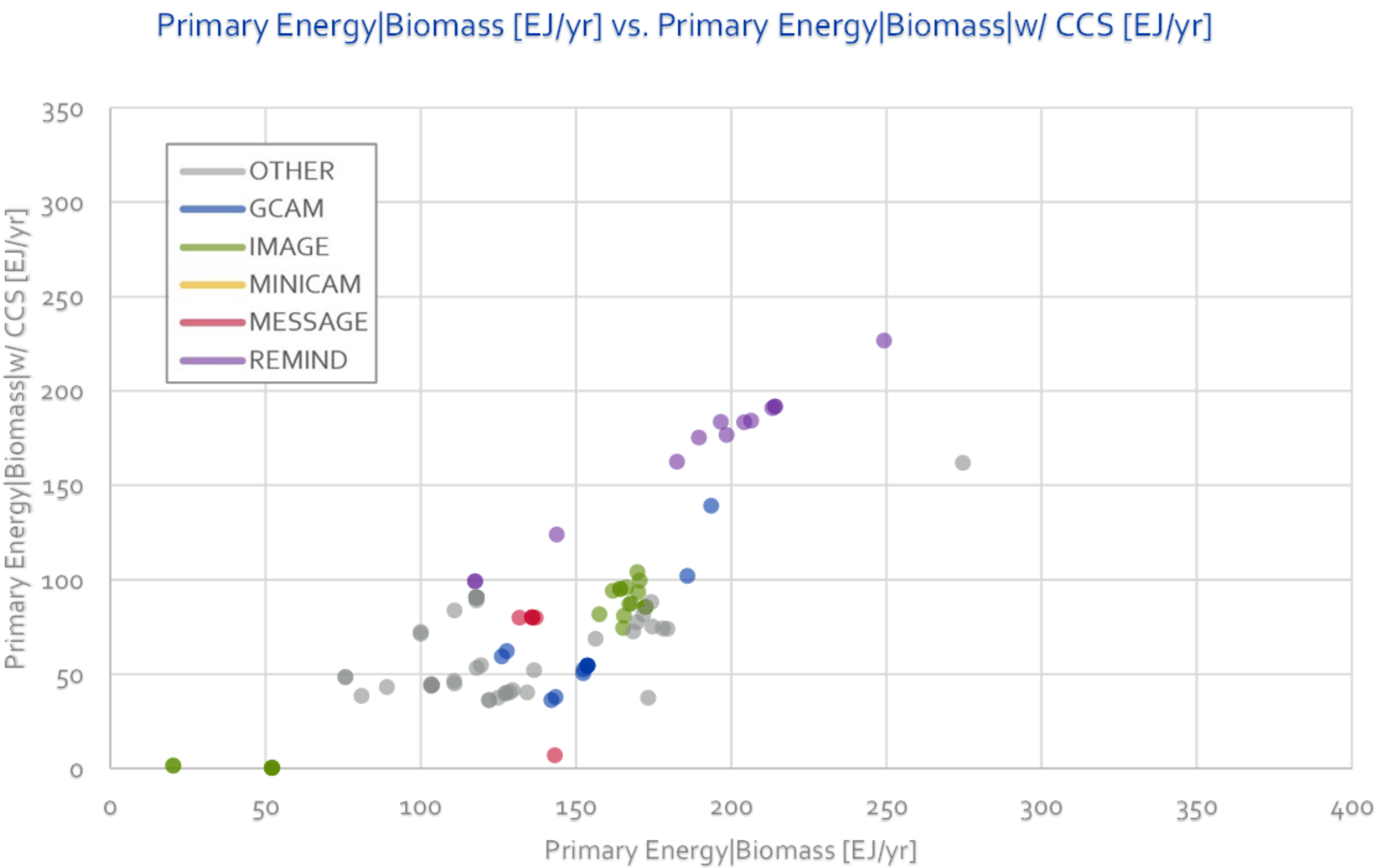
GCAM

In the GCAM model, the following biomass types are included (Wise, et al., 2014):

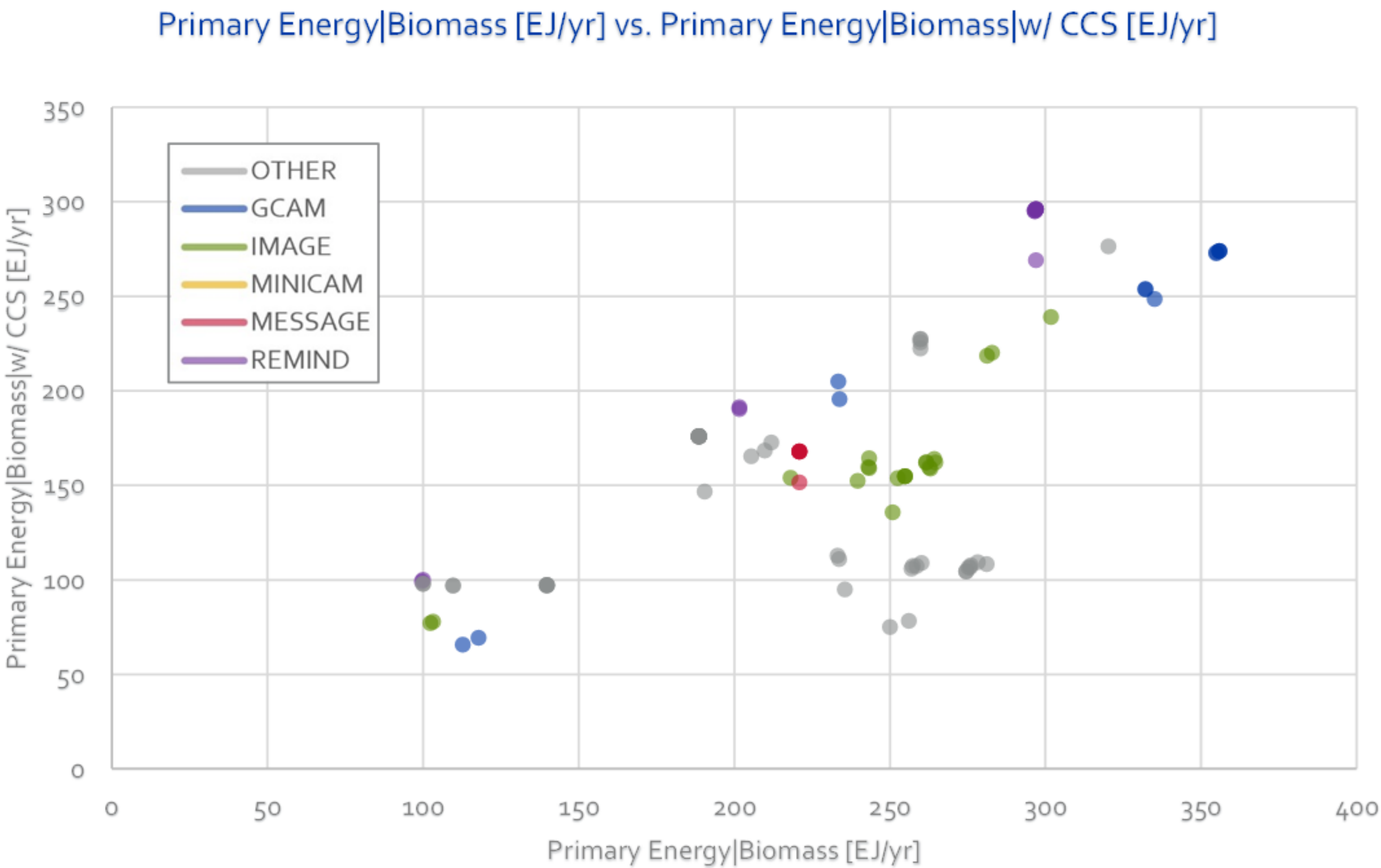
- **Bioenergy Crops:** Lignocellulosic sources such as perennial grasses and woody crops;
- **Biomass residues:** Agricultural and Forestry residues;
- **MSW:** Organic Municipal Solid Waste;
- **Conventional biofuels:** Conventional or first-generation biofuel sources such as corn, sugars, oil crops that are also grown as part of food production (only for



Primary energy from biomass (total vs. with CCS) in **2050**



Primary energy from biomass (total vs. with CCS) in **2100**



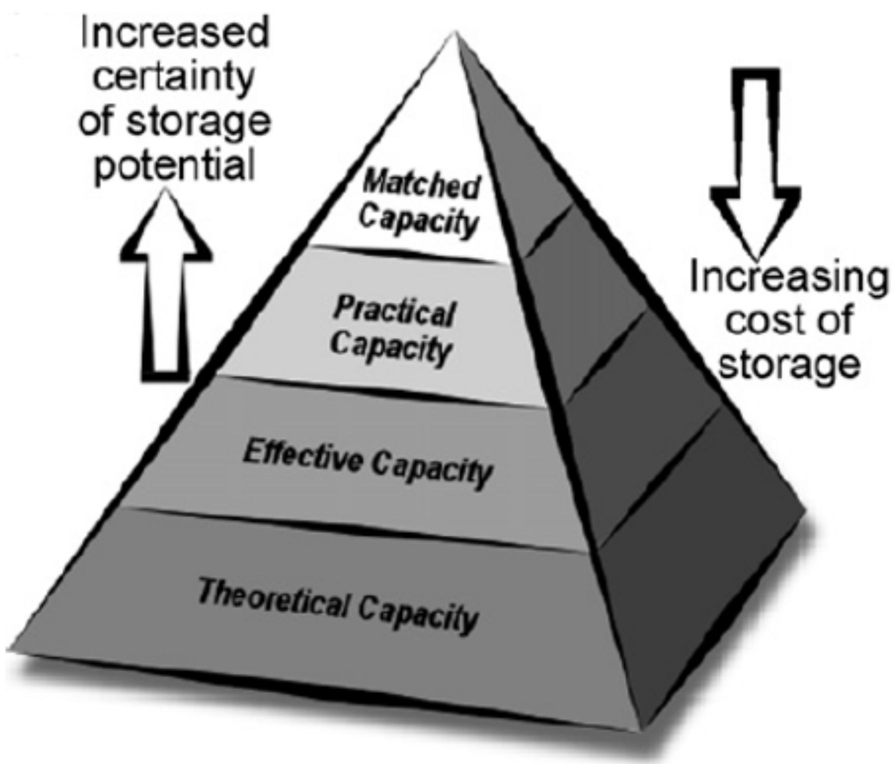
1.Conclusions from review of biomass assumptions

Based on the literature and expert review, there is no immediate reason to assume that the scenarios included in this study cannot be realised, but there are some concerns:

- On the **sustainability** criteria, it becomes clear that most of the scenarios exceed the 100 EJ/yr, which means that there is low agreement in literature whether this is feasible and it is uncertain whether these amount of primary energy from biomass can be realised within sustainable limits (100-300 EJ/yr);
- Several REMIND scenarios show **steep growth** rates between 2040 and 2060, while also a population growth of almost 1 billion people is assumed. This seems very challenging, if not unlikely;
- There are some scenarios that come close to **the 300 EJ/yr or even exceed this.** For these scenarios (e.g. several GCAM and REMIND scenarios) it is unlikely whether the biomass potential can be realised within sustainable limits, which would be an undesired situation.

What about storing the CO2 from Biomass?

An assessment of the scale of CO2 storage capacity required through Bio-CCS is given in 5.2.2. A range of **~300 to ~1000Gt** of biogenic CO2 to be stored by 2100. This is equivalent **to ~3% to ~9% of total global CO2 storage capacity**.



Exploration Permitting and licencing

Characterisation of a CO_2 Storage Site

Environmental Impact Assessment

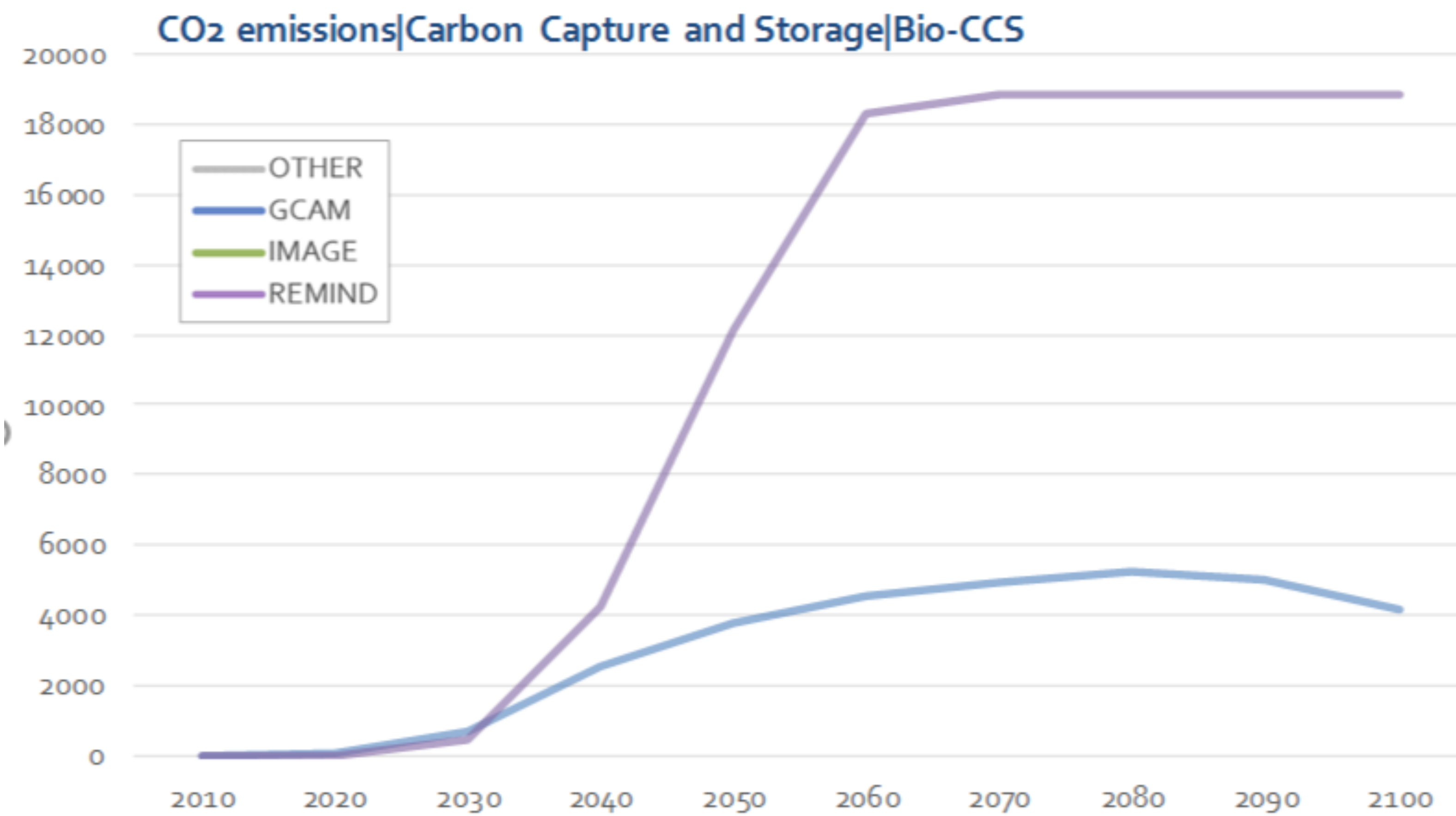
Development permitting and licencing

Development of a CO_2 Storage Site

Operation of a CO_2 Storage Site

Closure and post-closure of a CO_2 Storage Site

How much Bio-CO2 will need to be stored?



How many CO2 storage sites will be needed?

Assumptions used for representative CO_2 storage sites and primary biomass energy to illustrated CO_2 storage development

Energy Density of Biomass	20J/g (Field, 2008)
CO_2 storage site capacity	100 Mt CO_2 (IEAGHG, 2011)
CO_2 storage site injection rate	4 Mt CO_2/yr (IEAGHG, 2011)
CO_2 injection rate per injection well	1 Mt CO_2/yr
CO_2 storage site operational life	25 years (ZEP, 2011)
Length of time to characterise CO_2 storage site	7 years (IEAGHG, 2011)
Conversion, capture, transport and storage efficiency of carbon content of biomass	70% (Caldecott et al., 2015)

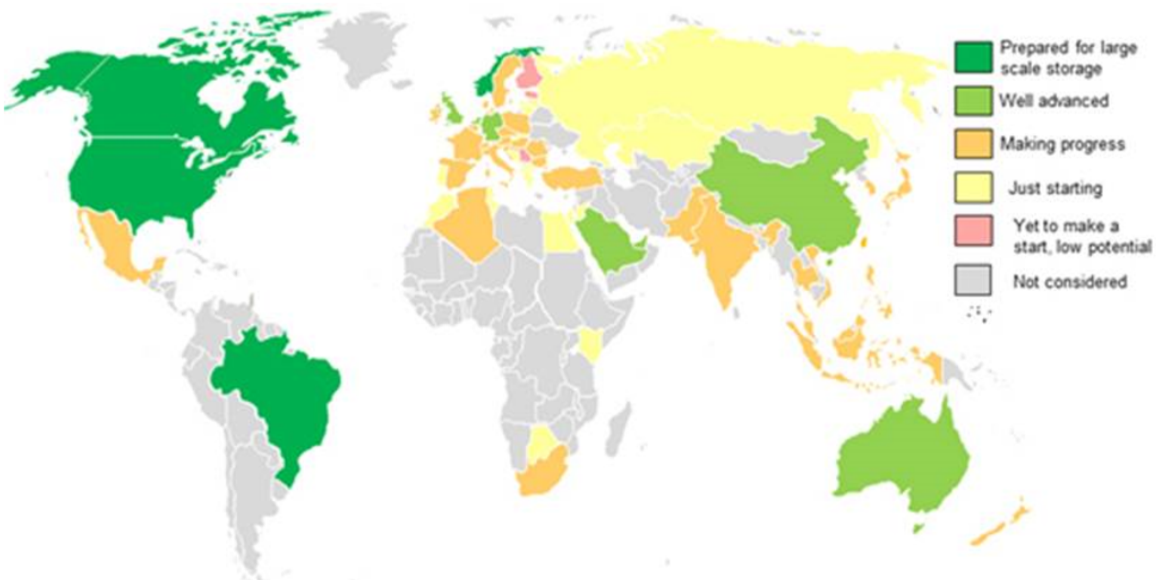
The very high Bio-CCS scenario

REMIND-scenario	2010	2020	2030	2040	2050	2060	2070	2080	Aggregated 2010-2100
Sights Developed	0	1	13	93	212	248	213	154	~ 9,500
Sights Decommissioned	0	0	0	0	-13	-93	-199	-155	~ 4,700
Number of Wells Drilled	0	4	52	372	848	992	852	616	~ 38,000
Number of wells decommissioned	0	0	0	0	-52	-372	-796	-620	~ 17,000

The low to moderate Bio-CCS scenario

GCAM-scenario	2010	2020	2030	2040	2050	2060	2070	2080	Aggregated 2010-2100
Sights Developed	0	12	16	46	48	65	44	26	~ 2,500
Sights Decommissioned	0	0	0	0	-16	-46	-32	-19	~ 1,400
Number of Wells Drilled	0	48	64	184	192	260	176	104	10,000
Number of wells decommissioned	0	0	0	0	-64	-184	-128	-76	~5,500

World map showing countries colour coded by storage readiness from (GCCSI, 2014)



Industrial capacity for CO_2 storage development and operation

Industrial capacity for CO_2 transport deployment and operation

Public acceptance

Institutional capacity

Hypothesis of general conclusion lines:

- In 104 out of the 116 category 1 scenarios bio-CCS is used.
- Many bio-CCS scenarios apply very unlikely, because of several factors, e.g.
  - Land use requirements and unrealistic emissions balance (also trade-off food security for increasing population)
  - Steep growth rates of CCS storage sites
  - High shares of bio-CCS of biomass (up to 100%)
  - site appropriateness (EIA) / conflict of goals
  - Industrial and administrative capacity for overseeing/permitting storage and transport
  - Decentralised small-scale bioenergy / infrastructure
  - Etc.
- Maybe a conclusion could be what range of the scenarios seem to be likely/ unlikely due to several factors
- Non-bio-CCS scenarios become unlikely because RES share must be much higher already; only reasonable if efforts to deploy RES and EE are increased

Modelling should take the above mentioned limiting factors into account to better present a realistic use of bio-CCS. Resulting trade-offs e.g. for food security and biodiversity must be given more thought in public debate.

"We have waited too long. Our options are reduced. We are facing fairly brutal carbon arithmetic now."