Evaluating the Use of Bioenergy With Carbon Capture and Storage to Achieve Energy Transition and Decarbonization

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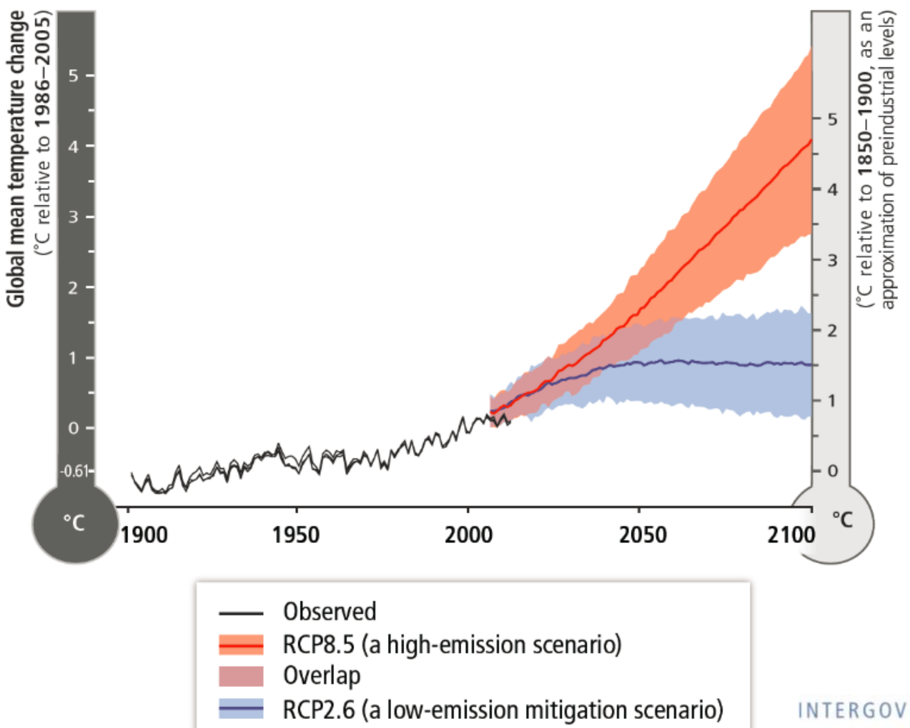
Long-term possible low carbon futures of the energy system

- **Climate constraints**
  - 2°C objective (emissions targets [Gt CO_2], radiative forcing [W/m²], atmospheric concentration [ppm])
  - Paris Agreement (NDCs)

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE



How to achieve a sustainable energy transition?

ipcc
INTERGOVERNMENTAL PANEL ON climate change

Modelling approach

TIAM-FR: ***French version of the TIMES Integrated Assessment Model***

$$NPV = \sum_{r=1}^{R} \sum_{y \in YEARS} (1 + d_{r,y})^{REFYR-y} * ANNCOST(r,y)$$

Where
NPV is the net present value of the total cost for all regions over the projected period;
ANNCOST (r,y) is the total annual cost in region r and year y;
dr,y is the discount rate;
REFYR is the reference year for discounting; YEARS is the set of years and R is the set of regions (15 regions)

Optimization, linear programming
Minimization of the total discounted cost of the system

Bottom-up

Long-term: **2010**-2100

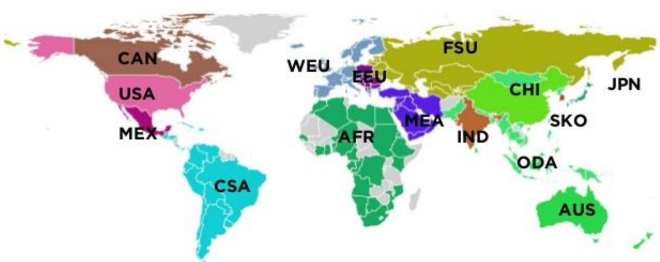
Multi-regional: 15 regions (+T-ALyC)

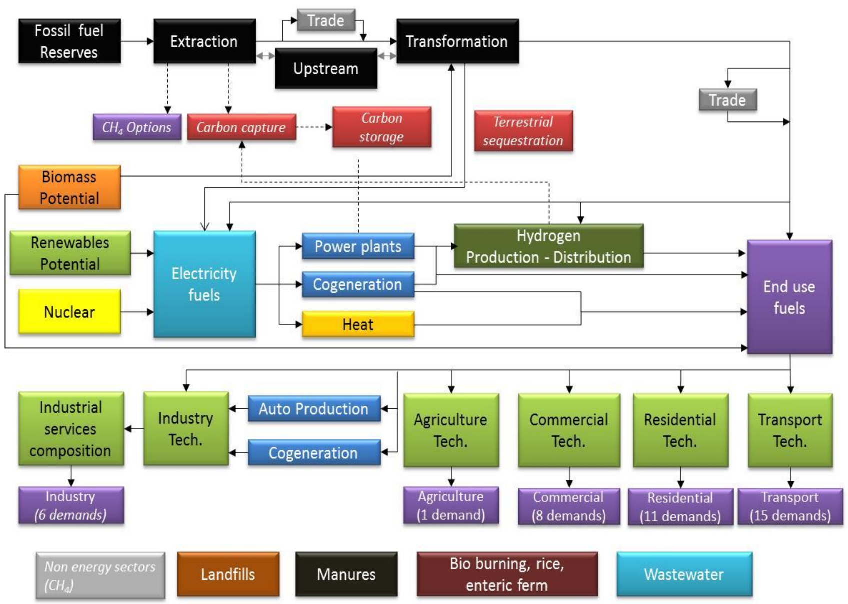
Multi-sectors: 6 sectors

42 demands

585 729 data

- 11 646 commodities (about 770/region)
- 39 817 technologies (about 2 500/region)





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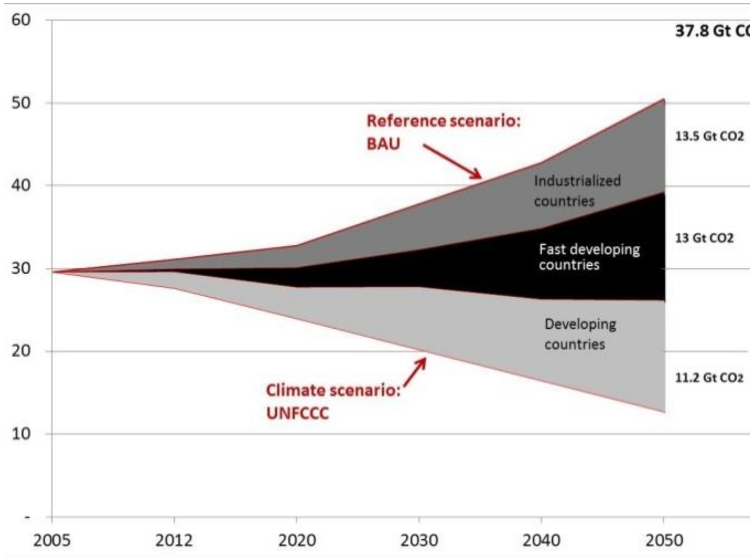
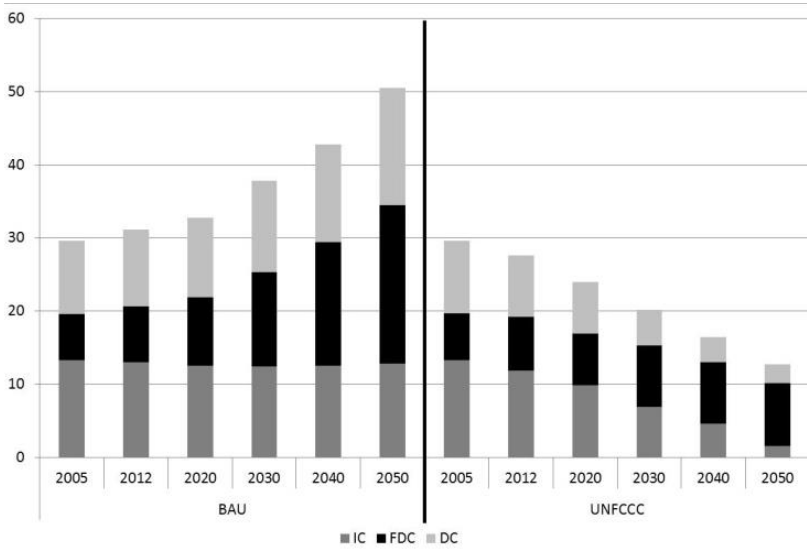
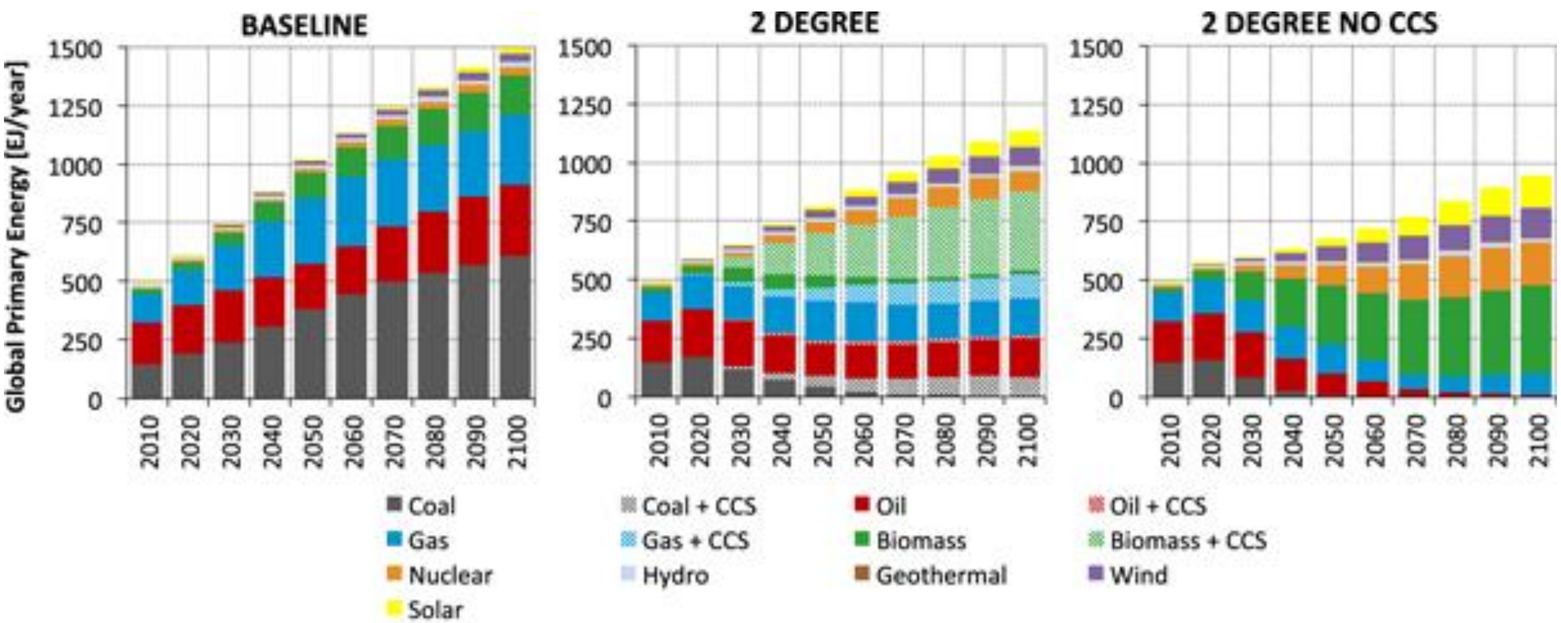




Regional contribution to the mitigation effort

Technological choices to a climate stabilization



Muratori et al. (2016) - http://iopscience.iop.org/article/10.1088/1748-9326/11/9/095004

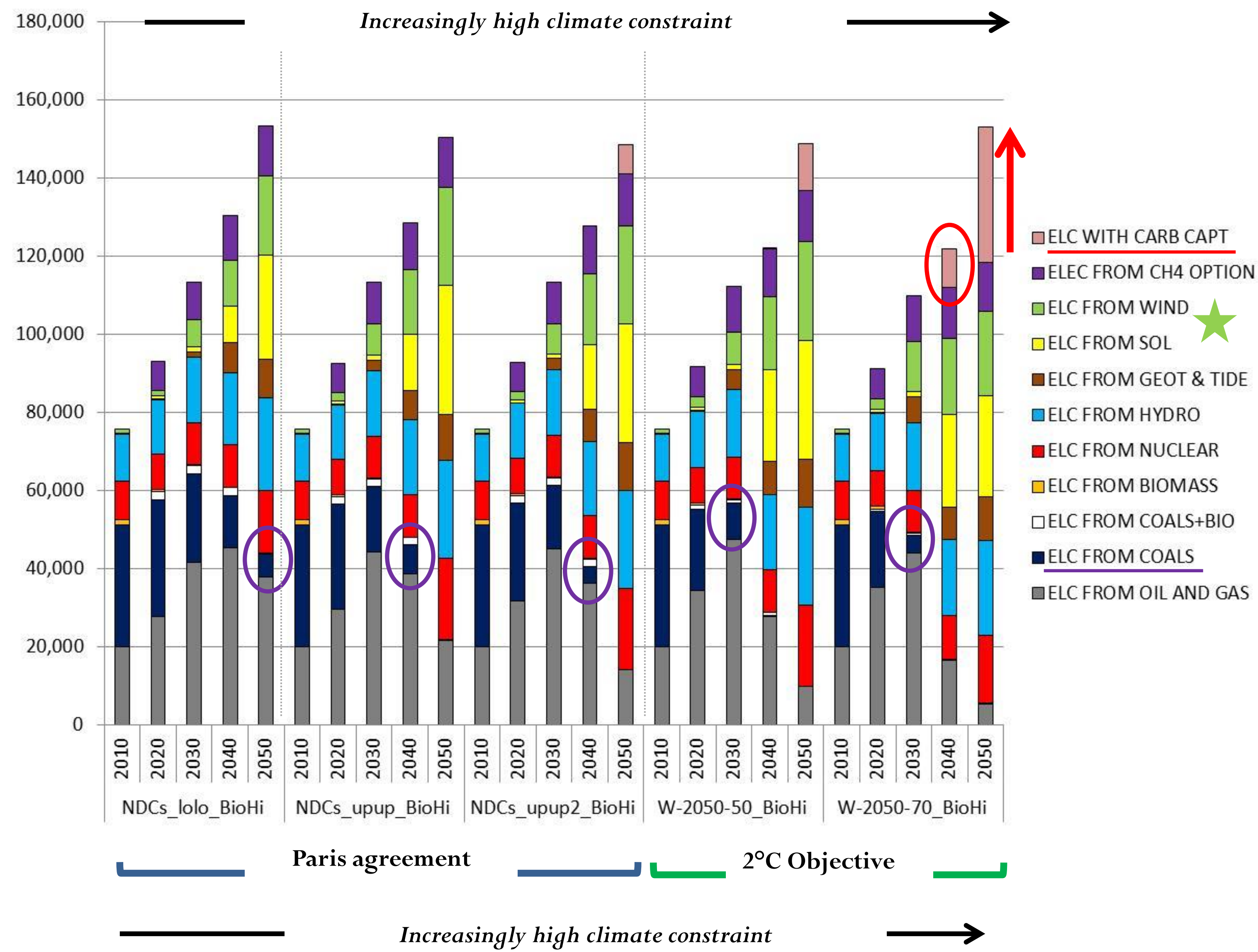
AR5 : 101 of the 116 scenarios with a limited atmospheric concentration at 430-480 ppm rely on BECCS

About 67% of these have a BECCS share in primary energy exceeding 20% in 2100

(Fuss et al. (2014), Nature Climate Change)

TIAM-FR

World electricity production (PJ)



What low carbon and sustainable energy future?

- **Ambitious climate targets achieved if:**
  - Contribution of developing countries
  - Ambitious contribution of emerging countries
  - Early almost total decarbonization of the industrialized countries
  - Major deployment of the CCS
  - Use of negative emissions with BECCS

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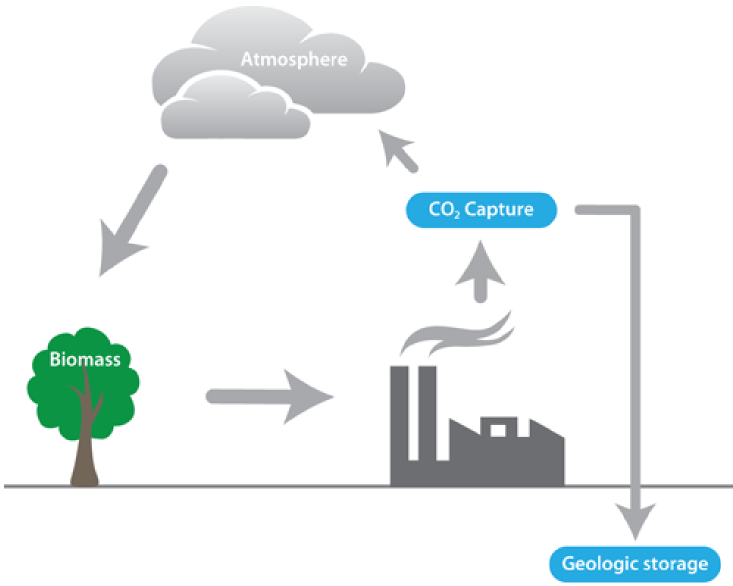
- **Technological and resource constraints**
  - Availability of technology
    - Carbon capture and storage (CCS)
    - Availability of onshore storage
  - Resource potential
    - Carbon storage
    - Biomass resources



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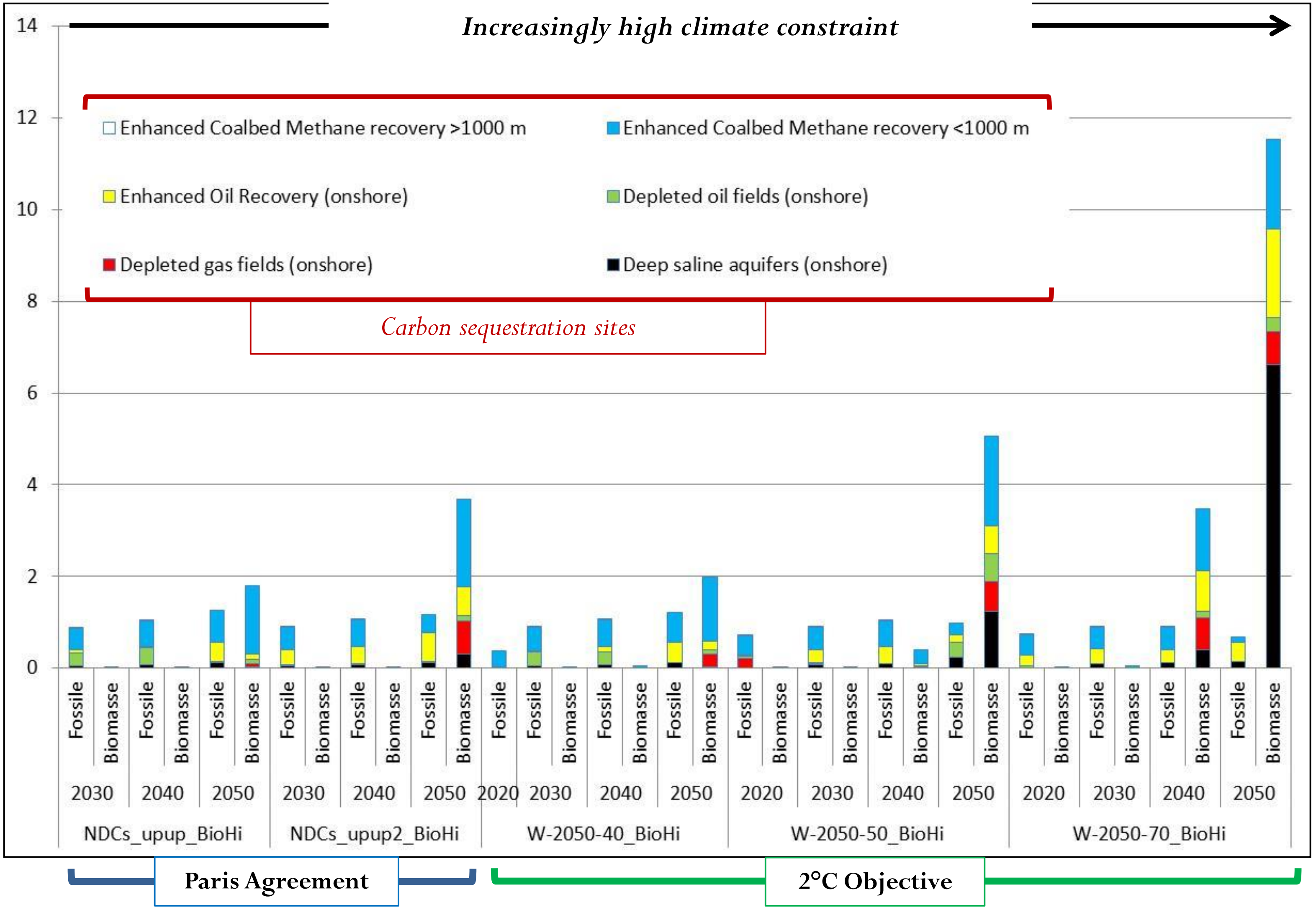
Achieving energy transition with negative emissions:
how carbon storage and biomass resource potentials can impact the development of BECCS

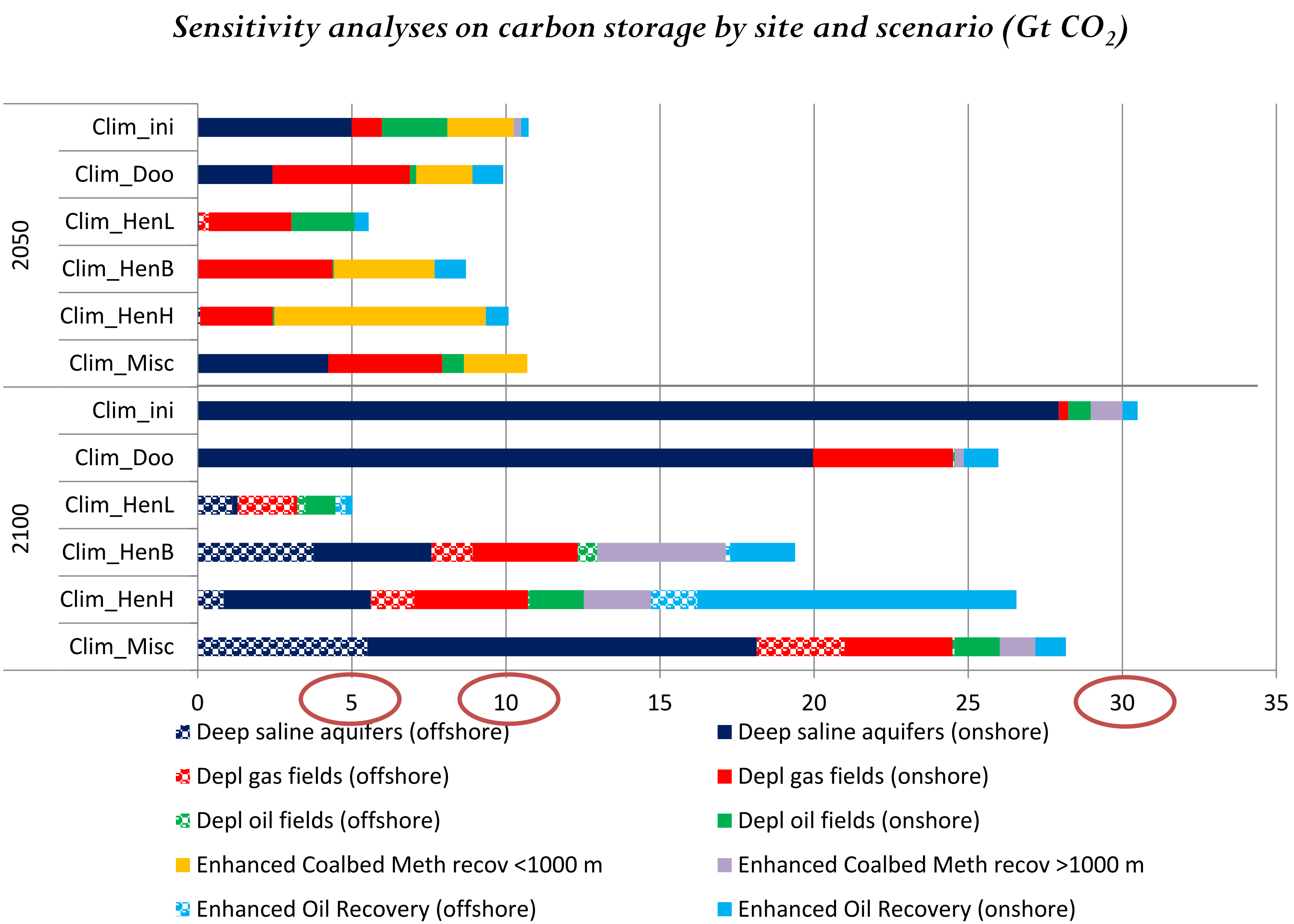
The question of carbon storage…. (Gt)



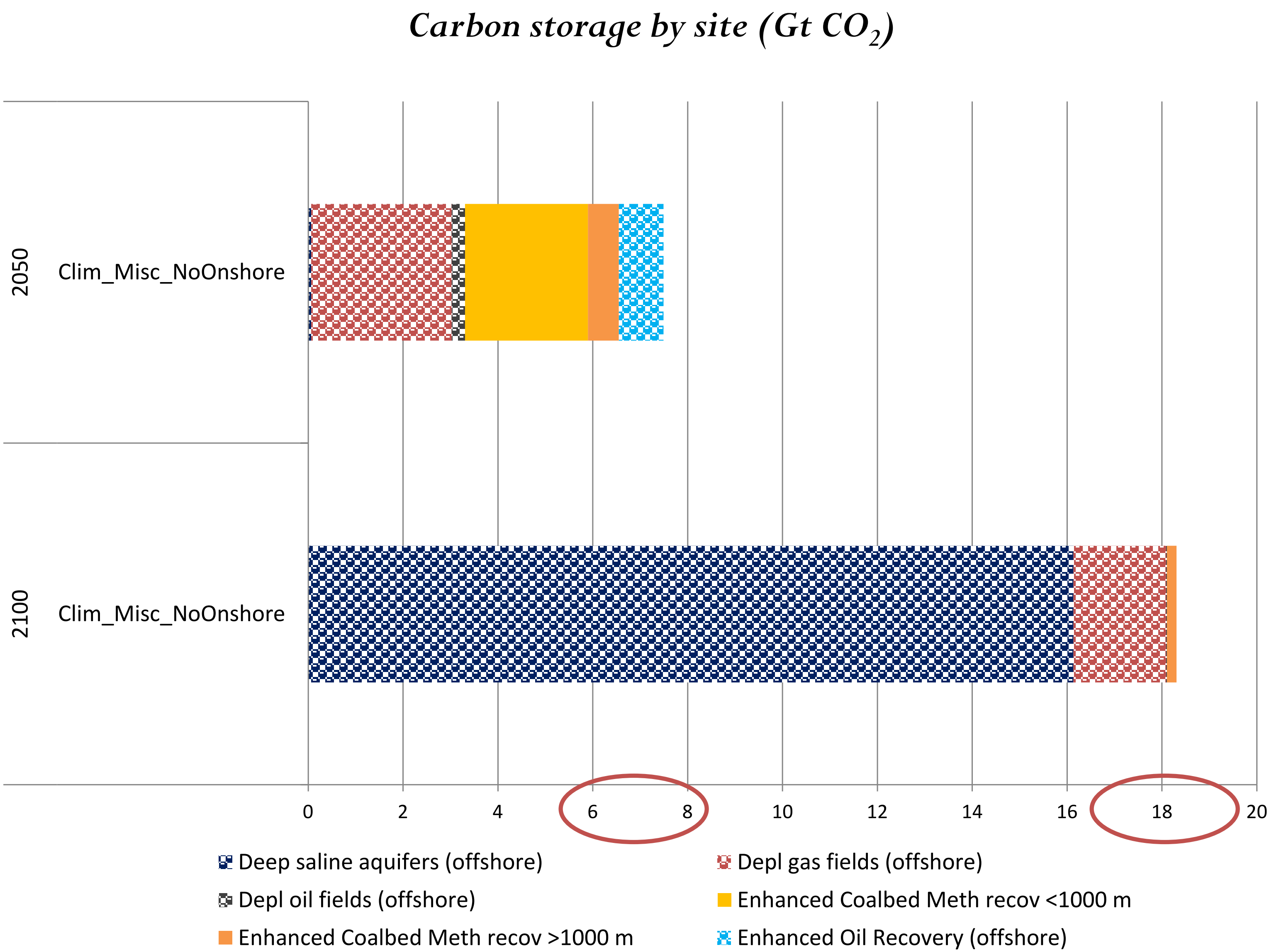
Analysis of the carbon storage potential

- **Scenario analysis** (under climate constraints)
  - Carbon storage potentials
    - Initial TIAM – *9,392 Gt*
    - Collection of various databases, reports, etc. – *10,142 Gt*
    - Ref. Dooley – *10,655 Gt*
    - Ref. Hendriks – *572 Gt (Low)*
      1,706 Gt (Best)
      5,864 Gt (High)
  - Onshore/offshore determination

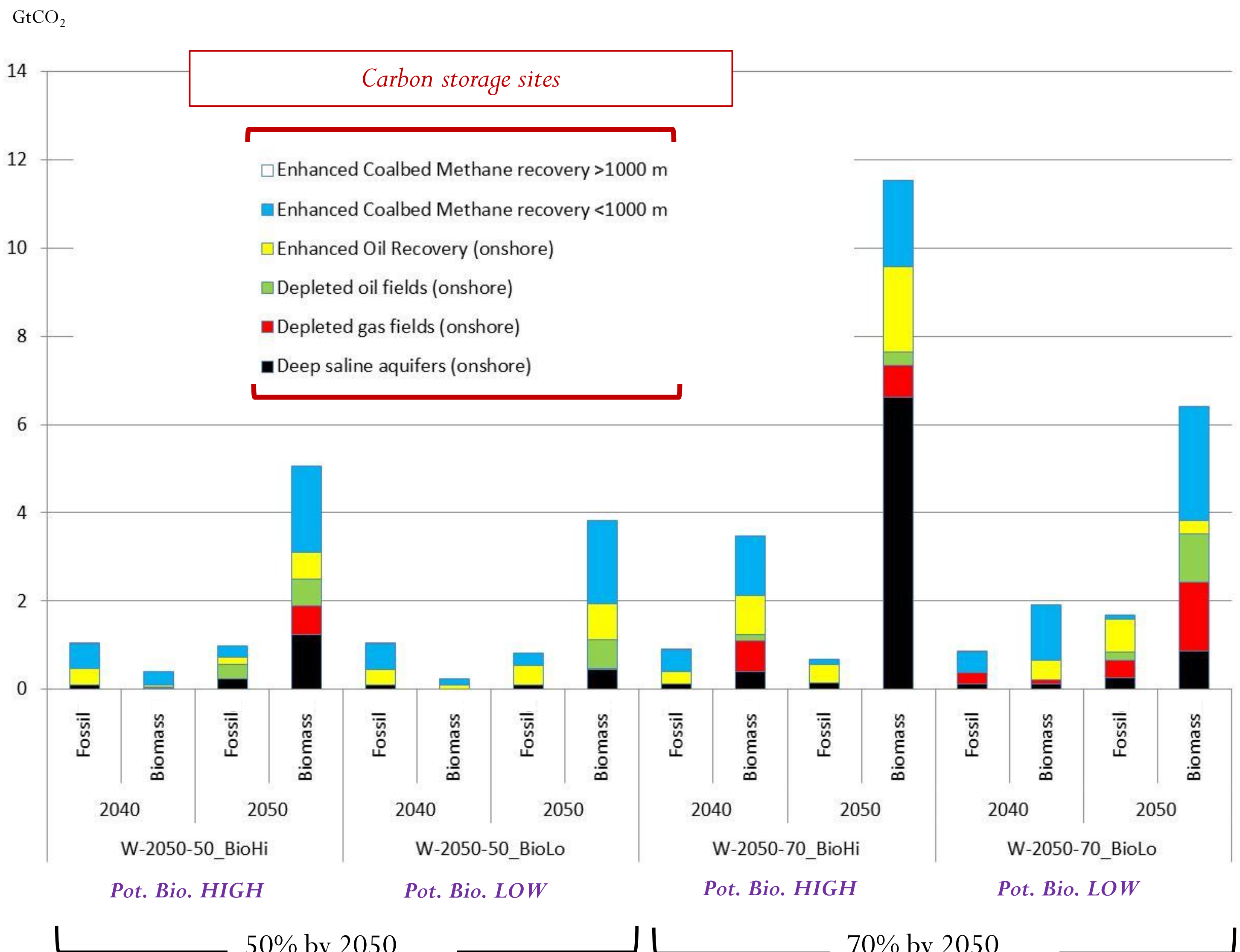
Carbon storage by year to achieve the 2°C objective
(radiative forcing at 2,6 W/m² by 2100)

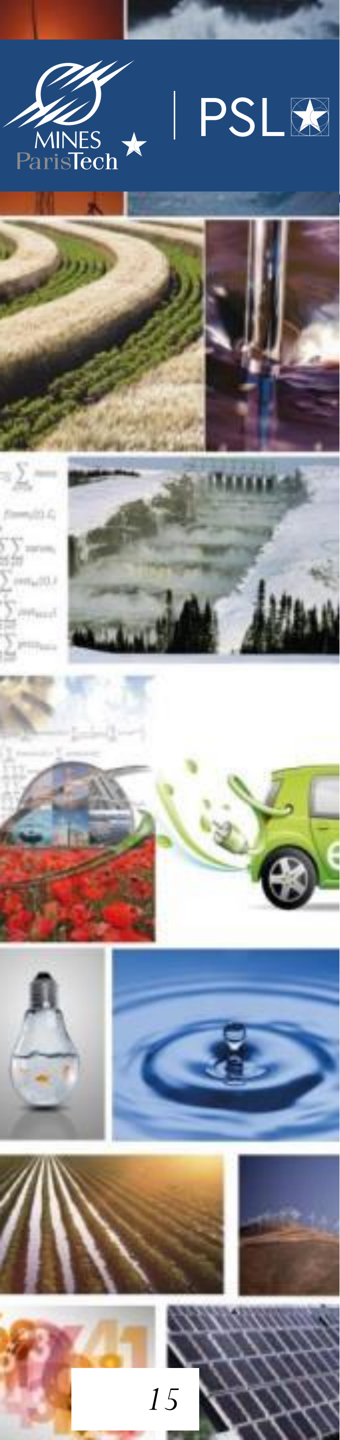


Impact of an onshore storage ban on carbon storage an CCS deployment



Sensitivity analysis on biomass potential and impact on carbon storage





Alternatives low carbon pathways:

A joint impact analyzis of carbon storage and biomass potentials

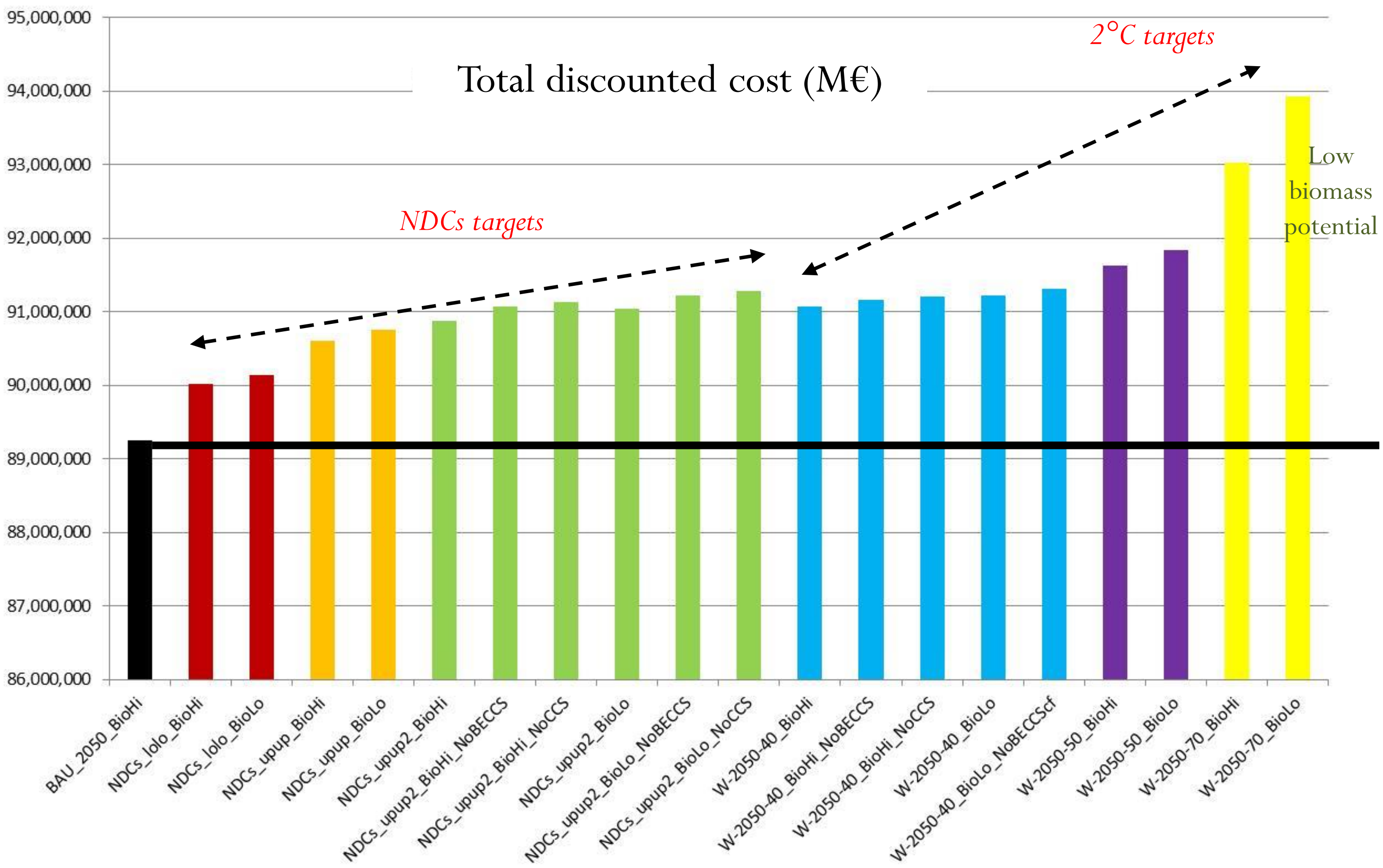
Scenario	Targeted year	Climate constraint	Carbon storage	Biomass 2050 potential
2050-70-ccsHi-BioMid	2050	70% GHG mitigation	10,142 Gt	215 EJ
2050-70-ccsHi-BioHi				328 EJ
2050-70-ccsHi-BioLo				70 EJ
2050-70-ccsMid-BioMid			1,706 Gt	215 EJ
2050-70-ccsMid-BioHi				328 EJ
2050-70-ccsMid-BioLo				70 EJ
2050-70-ccsLo-BioMid			572 Gt	215 EJ
2050-70-ccsLo-BioHi				328 EJ
2050-70-ccsLo-BioLo				70 EJ
2100-2D-ccsHi-BioMid	2100	2°C temperature increase limit	10,142 Gt	215 EJ
2100-2D-ccsHi-BioHi				328 EJ
2100-2D-ccsHi-BioLo				70 EJ
2100-2D-ccsMid-BioMid			1,706 Gt	215 EJ
2100-2D-ccsMid-BioHi				328 EJ
2100-2D-ccsMid-BioLo				70 EJ
2100-2D-ccsLo-BioMid			572 Gt	215 EJ
2100-2D-ccsLo-BioMHi				328 EJ
2100-2D-ccsLo-BioLo				70 EJ

The influence of carbon storage and biomass potentials in the future development of BECCS

Share of CCS in the world production of electricity in 2050				
Ambitious climate scenario - 70% GHG mitigation target		**Biomass potential**		
		High	Medium	Low
Carbon storage potential	High	**45% (BECCS: 70%)**	39% (BECCS: 55.9%)	27% (BECCS: 18.1%)
	Medium	45% (BECCS: 69.8%)	39% (BECCS: 56.3%)	27% (BECCS: 18.2%)
	Low	33% (BECCS: 93.9%)	28% (BECCS: 76.7%)	**15% (BECCS: 33.5%)**

Gt of negative emissions (CO2 sequestrated in 2050 from BECCS)				
Ambitious climate scenario – 70% GHG mitigation target		**Biomass potential**		
		High	Medium	Low
Carbon storage potential	High	**12 Gt**	8.8 Gt	2.8 Gt
	Medium	12 Gt	8.9 Gt	2.8 Gt
	Low	11 Gt	7.7 Gt	**2.2 Gt**

Cost analysis of constraints



Carbon marginal cost ($/tCO2)

Scenario	Year	Carbon marginal cost
NDCs_lolo_BioHi	2030	20
NDCs_lolo_BioLo		
NDCs_upup2_BioHi	2030	25
NDCs_upup2_BioLo		
NDCs_upup_BioHi		
NDCs_upup_BioLo		
W-2050-40_BioHi	2030	30
W-2050-40_BioLo		
NDCs_lolo_BioHi	2050	35
NDCs_lolo_BioLo		
W-2050-50_BioHi	2030	
W-2050-50_BioLo		
W-2050-70_BioLo	2030	40
W-2050-70_BioHi	2030	50
NDCs_upup_BioHi	2050	75
NDCs_upup_BioLo		
W-2050-40_BioHi	2050	90
W-2050-40_BioLo		
NDCs_upup2_BioHi	2050	95
W-2050-50_BioHi	2050	100
NDCs_upup2_BioLo	2050	120
W-2050-70_BioHi		
W-2050-50_BioLo	2050	150
W-2050-70_BioLo	2050	420

To conclude...

- A key measure of success is how far and how fast the Paris Agreement will encourage more ambitious actions

- Models like TIAM-FR constitute crucial tools to help policy-makers as regards long-term low carbon pathways but there is a need for:
  - Position of the envisioned future
  - Connect the proposed trajectories to the real
  - Anticipation and vision, based on short and long term consideration (and without disconnect them)

- Among the low-carbon technology options, CCS technologies are widely presented as a solution for achieving ambitious climate goals, particularly when associated with biomass
  - Deploying these technologies at this scale for mitigation purposes requires the implementation of incentive and regulation policies
  - Carbon storage capacities and particularly biomass potential can be a limiting factor for (BE)CCS deployment

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Thank you for your attention!

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