



# **Achieving energy transition with negative emissions: how carbon storage and biomass resource potentials can impact the development of Bioenergy with Carbon Capture and Storage**

Sandrine Selosse

MINES ParisTech, PSL Research University, Centre for Applied Mathematics  
Chair Modeling for Sustainable Development

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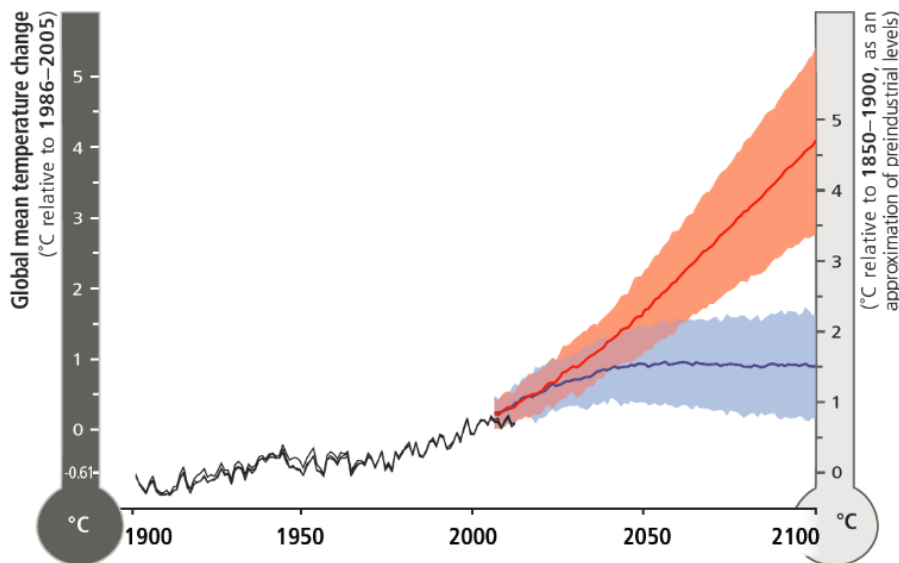
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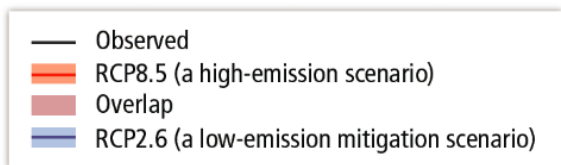
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## • Climate constraints

- 2°C objectives (emissions targets [Gt CO<sub>2</sub>], radiative forcing [W/m<sup>2</sup>], atmospheric concentration [ppm])
- Paris Agreement (NDCs)



**How to achieve a sustainable energy transition?**



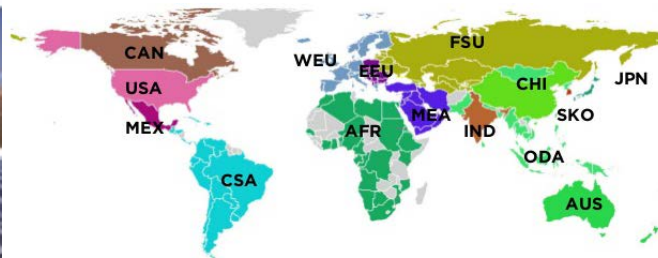


TIAM-FR: *French version of the TIMES Integrated Assessment Model*

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

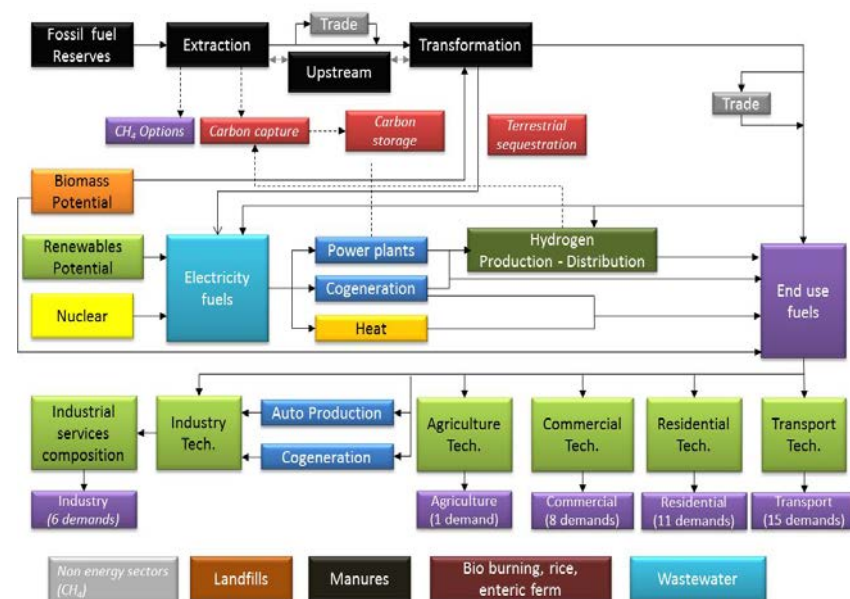
Bottom-up  
Long-term: **2010-2100**  
Multi-regional: 15 regions (+T-ALyC)  
Multi-sectors: 6 sectors  
42 demands

585 729 data  
11 646 commodities (about 770/region)  
39 817 technologies (about 2 500/region)



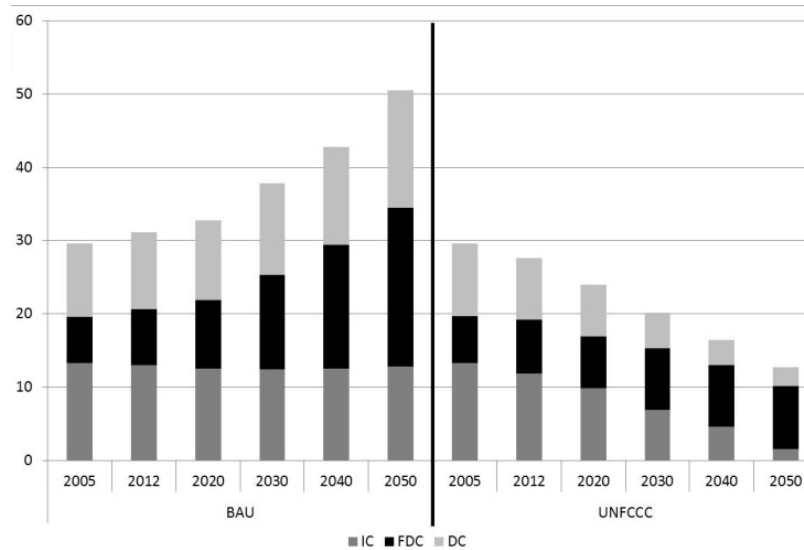
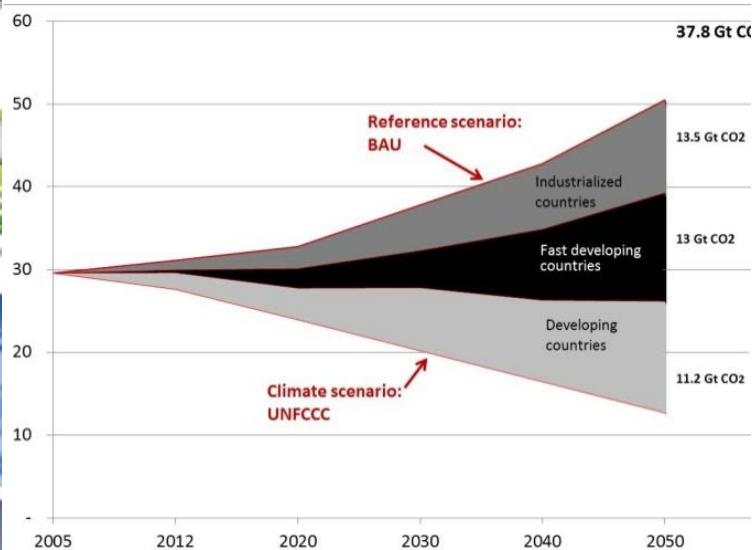
$$NPV = \sum_{r=1}^R \sum_{y \in YEARS} (1 + d_{r,y})^{REFYR-y} * ANNCOST(r,y)$$

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;  
d<sub>r,y</sub> 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)



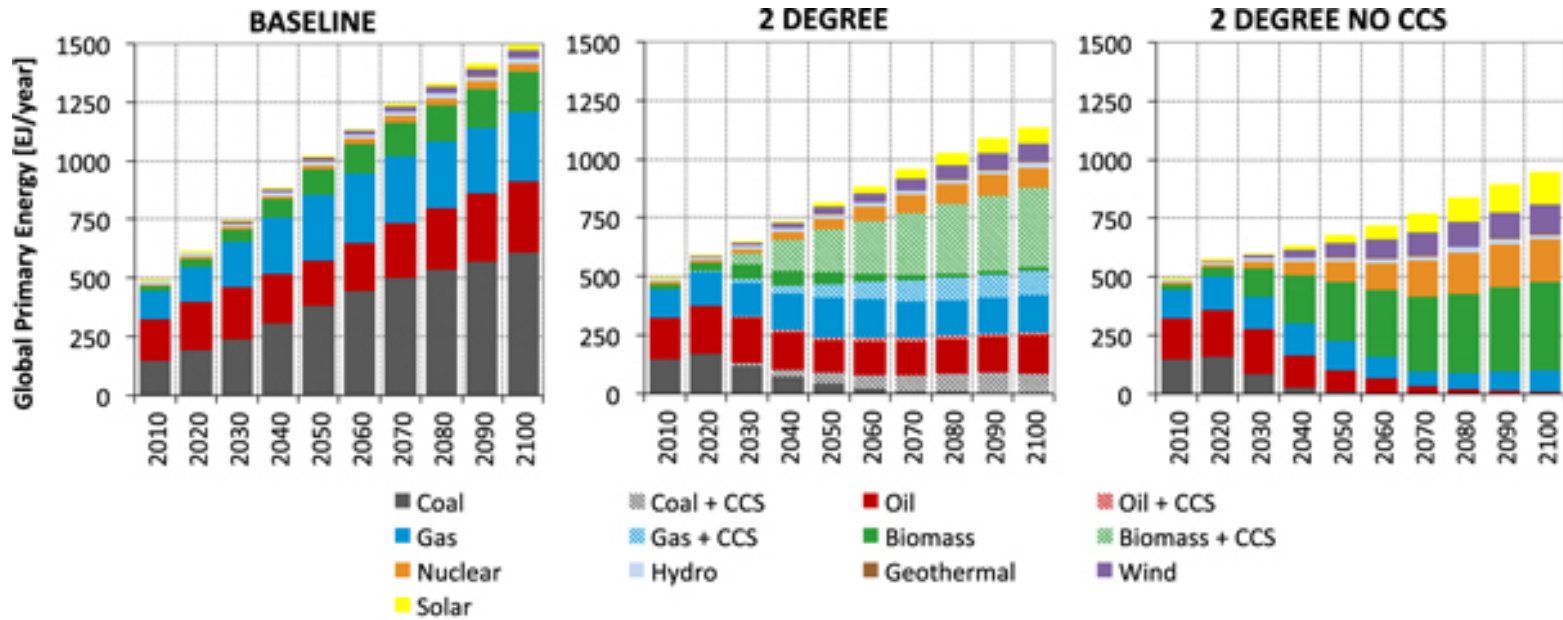
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*Regional contribution to the mitigation effort*

# 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*)





# What low carbon and sustainable energy future?

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



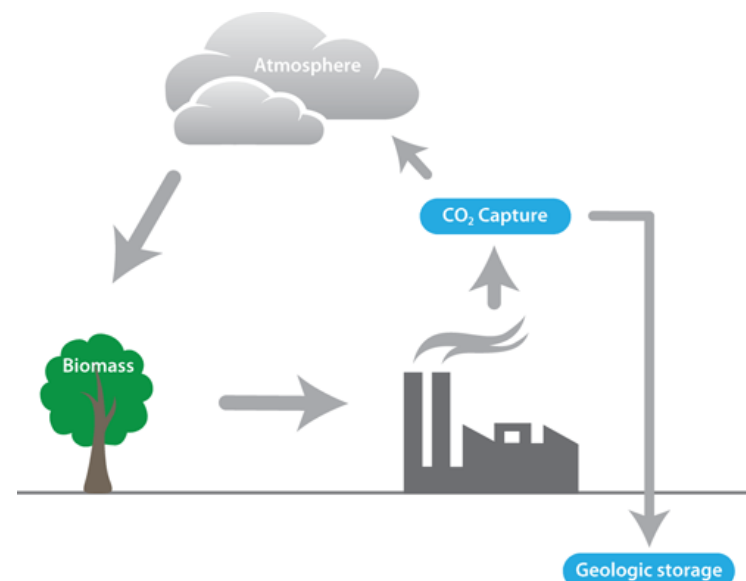
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- **Technological and resource constraints**

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





# What low carbon and sustainable energy future?



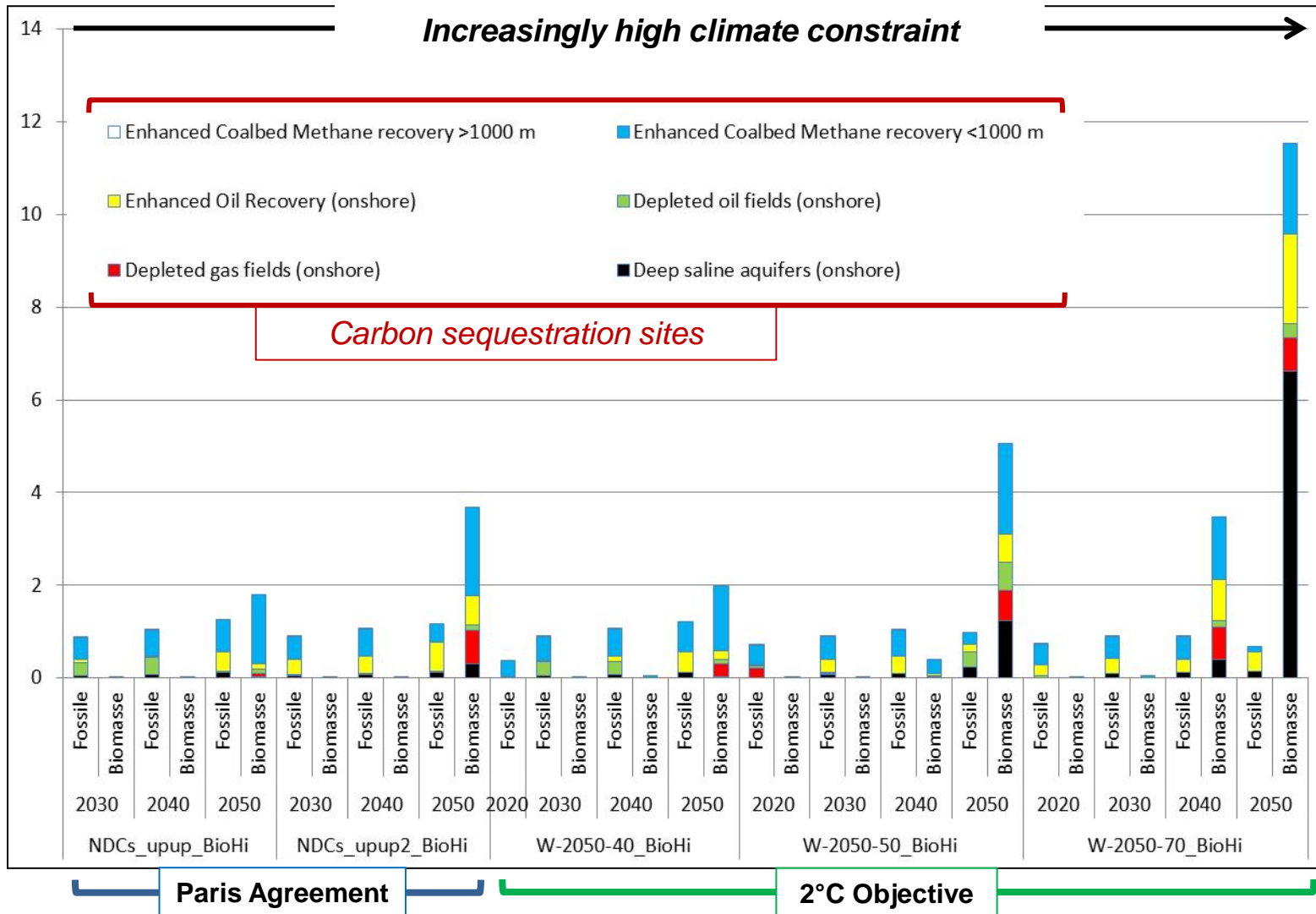
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**Achieving energy transition with negative emissions:**  
 how carbon storage and biomass resource potentials can impact the development of BECCS



# The question of carbon storage.... (Gt)



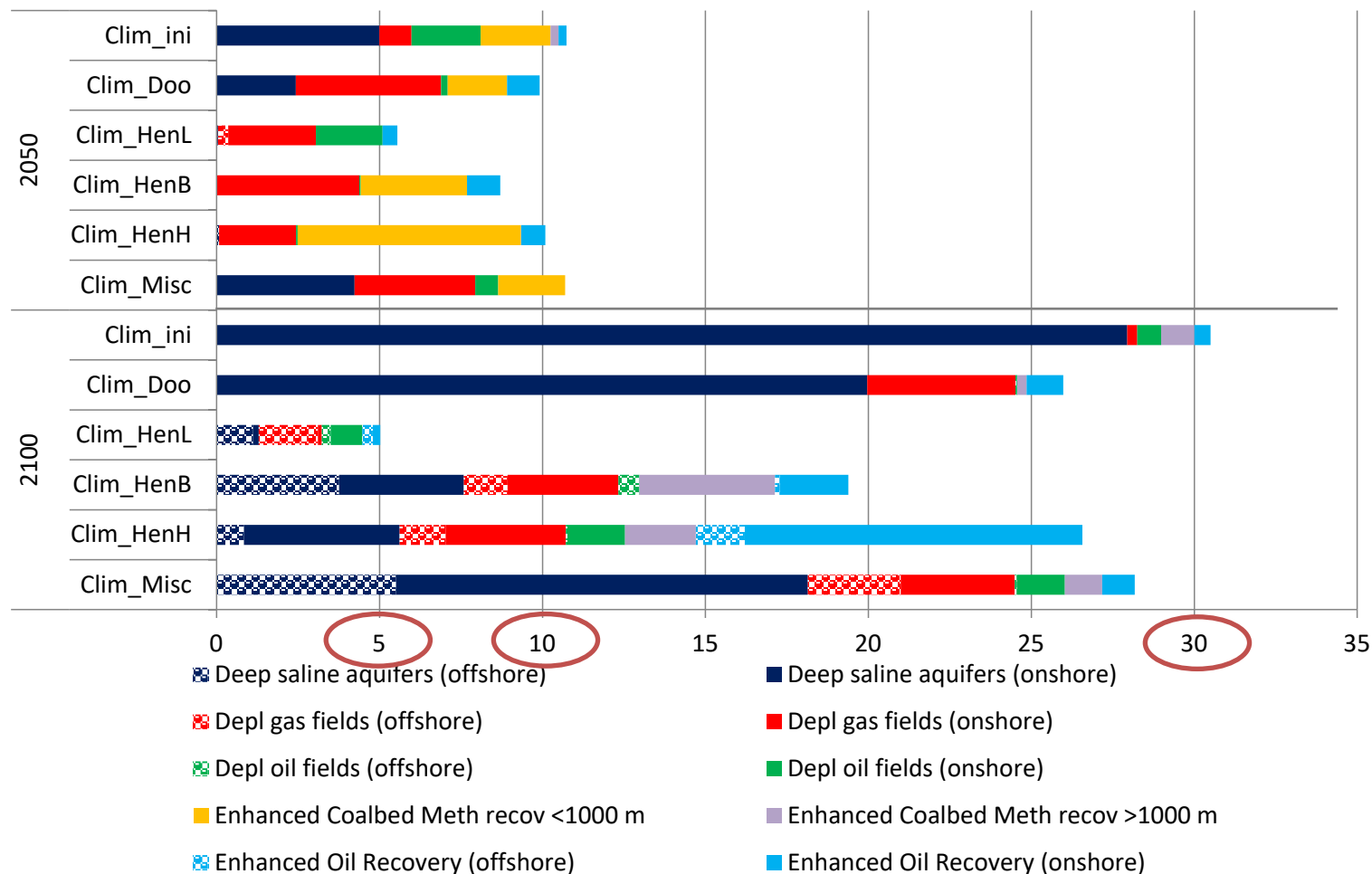


- **Scenario analysis** (under climate constraints)
  - Carbon storage potentials
    - Initial TIAM – 9,392 Gt
    - Collection of various databases, reports, etc. – 10,142 Gt
    - Ref. Dooley – 10,655 Gt
    - Ref. Hendriks – 572 Gt (Low)  
1,706 Gt (Best)  
5,864 Gt (High)
  - Onshore/offshore determination



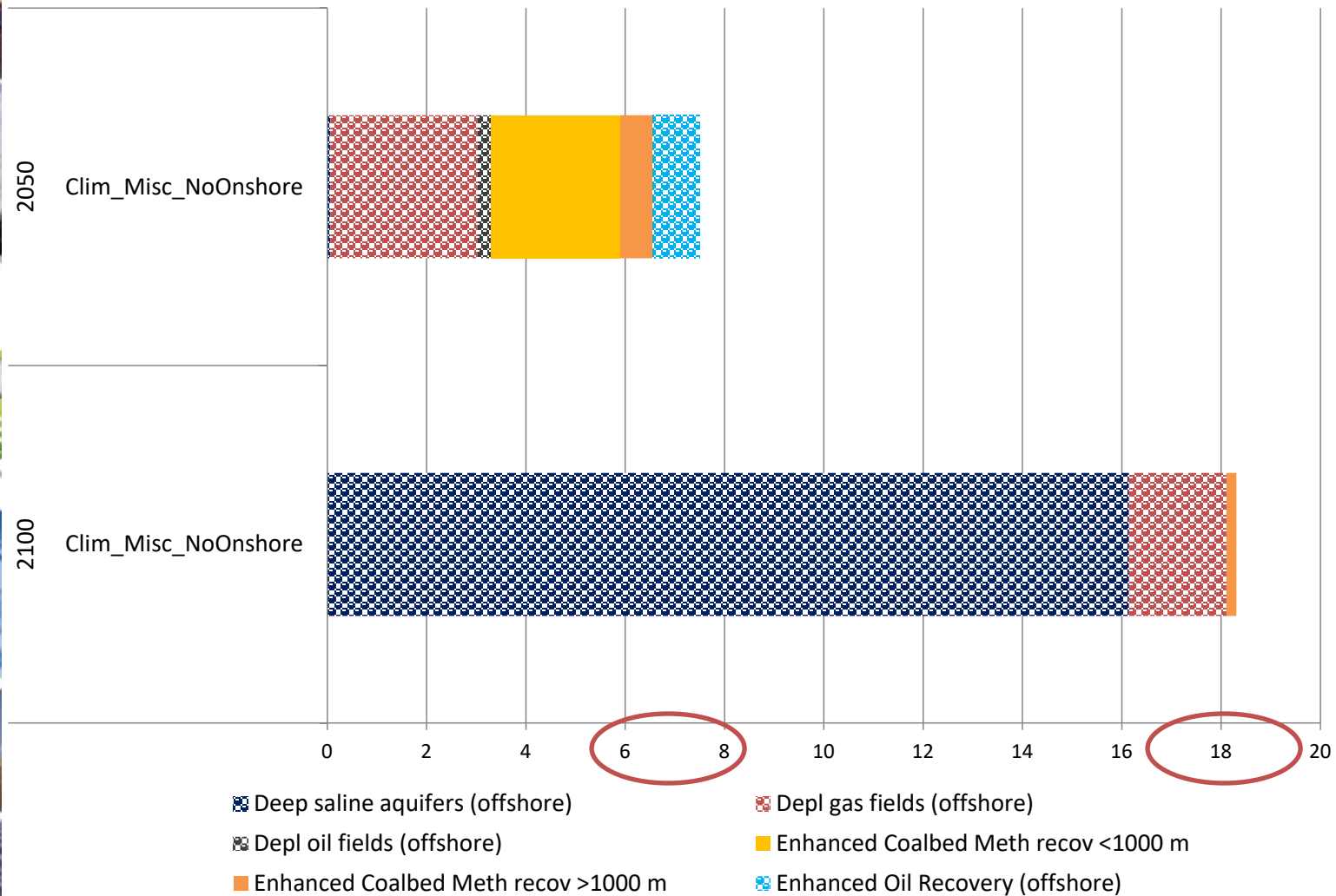
# Carbon storage by year to achieve the 2° C objective (radiative forcing at 2,6 W/m<sup>2</sup> by 2100)

## Sensitivity analyses on carbon storage by site and scenario (Gt CO<sub>2</sub>)

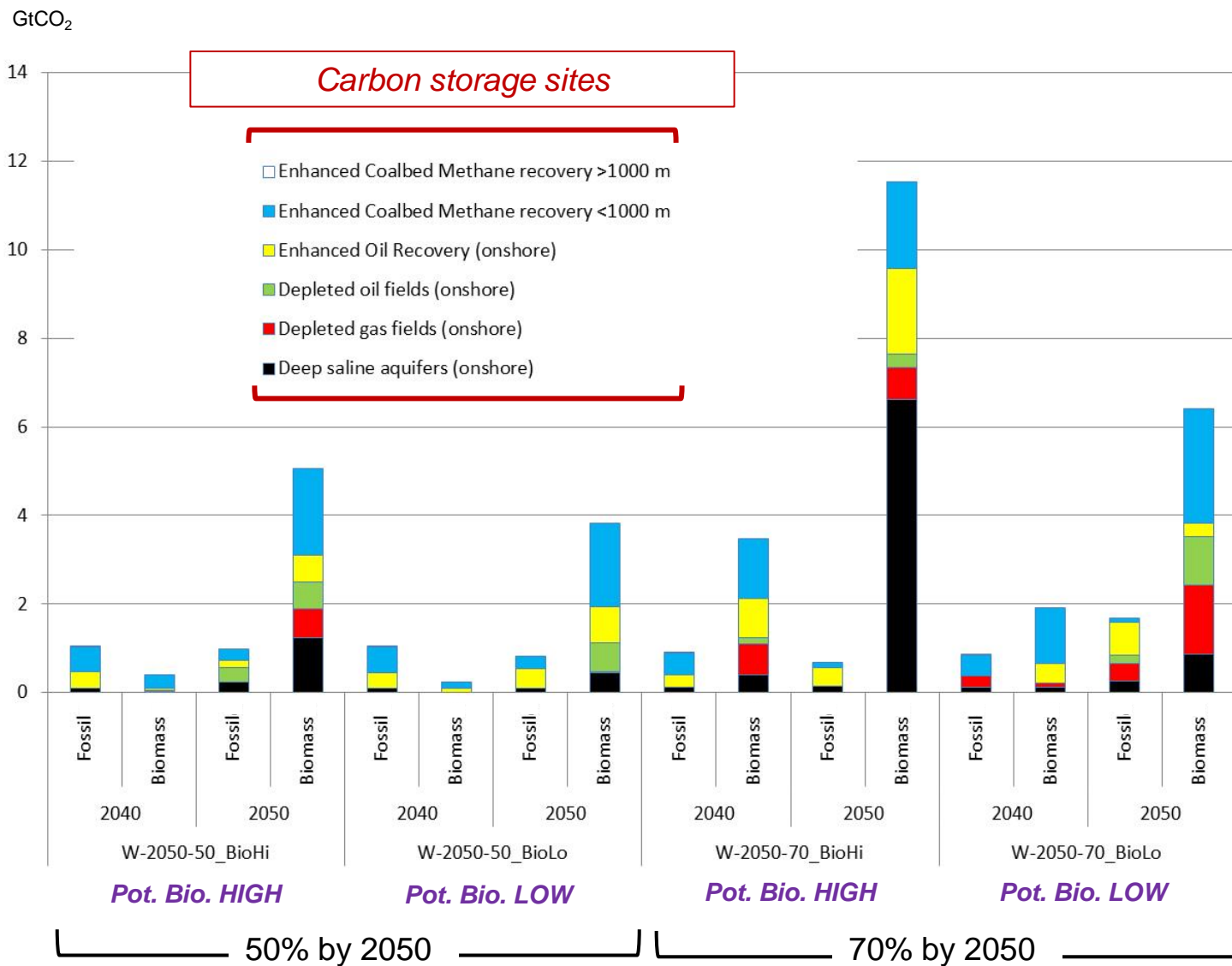


# Impact of an onshore storage ban on carbon storage an CCS deployment

## Carbon storage by site (Gt CO<sub>2</sub>)



# Sensitivity analysis on biomass potential and impact on carbon storage



# Alternatives low carbon pathways:

A joint impact analysis 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	70% GHG mitigation	70 EJ	215 EJ
2050-70-ccsMid-BioHi						328 EJ
2050-70-ccsMid-BioLo						70 EJ
2050-70-ccsLo-BioMid			572 Gt	70% GHG mitigation	70 EJ	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	2°C temperature increase limit	70 EJ	215 EJ
2100-2D-ccsMid-BioHi						328 EJ
2100-2D-ccsMid-BioLo						70 EJ
2100-2D-ccsLo-BioMid			572 Gt	2°C temperature increase limit	70 EJ	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	<b>45% (BECCS: 70%)</b>	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%)	<b>15% (BECCS: 33.5%)</b>

## Gt of negative emissions (CO2 sequestered in 2050 from BECCS)

Ambitious climate scenario - 70% GHG mitigation target		Biomass potential		
		High	Medium	Low
Carbon storage potential	High	<b>12 Gt</b>	8.8 Gt	2.8 Gt
	Medium	12 Gt	8.9 Gt	2.8 Gt
	Low	11 Gt	7.7 Gt	<b>2.2 Gt</b>





## 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
  - Carbon storage capacities and particularly biomass potential can be a limiting factor for (BE)CCS deployment
  - Deploying these technologies at this scale for mitigation purposes requires the implementation of incentive and regulation policies



# Thank you for your attention!

[sandrine.selosse@mines-paristech.fr](mailto:sandrine.selosse@mines-paristech.fr)

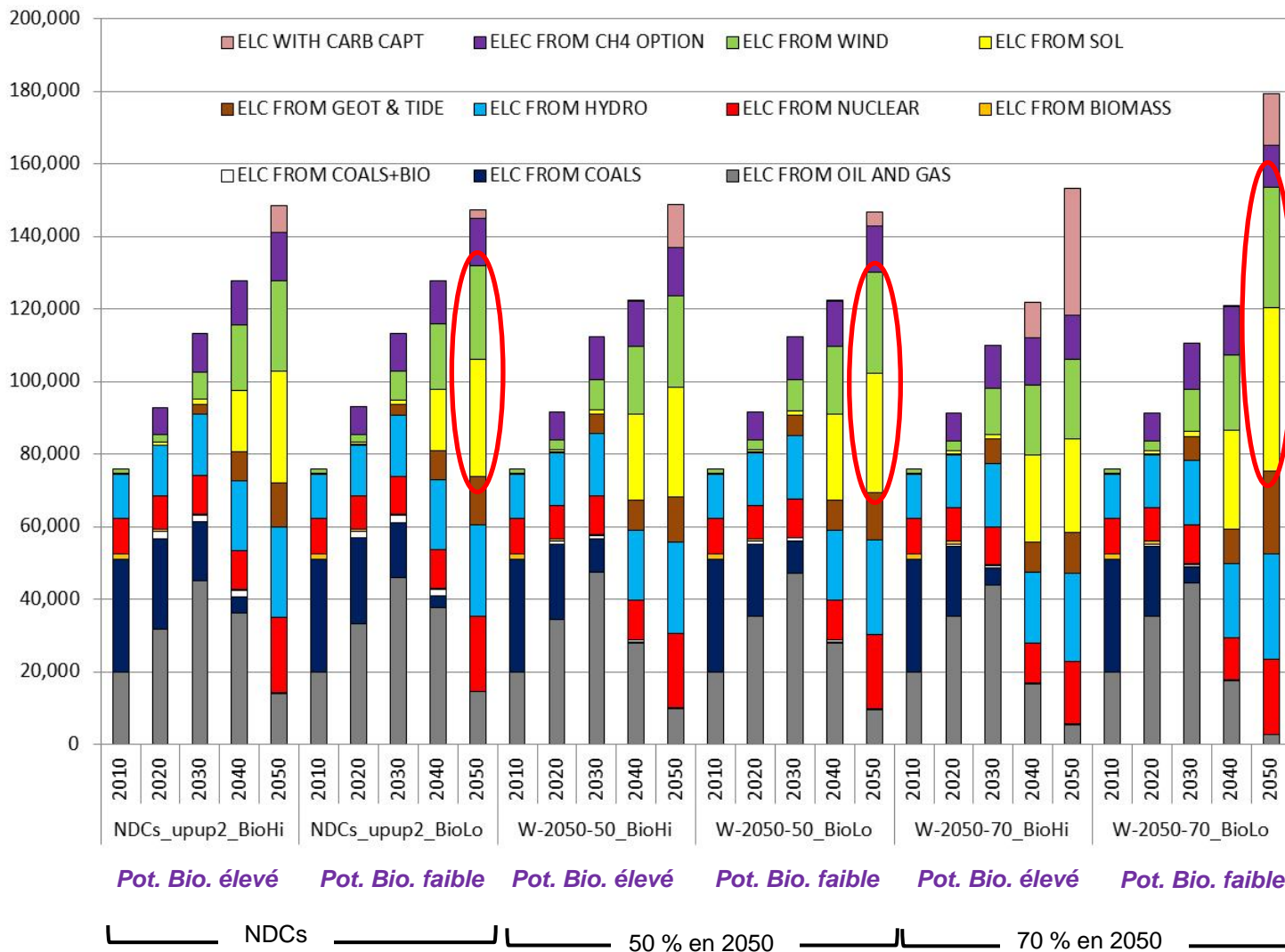
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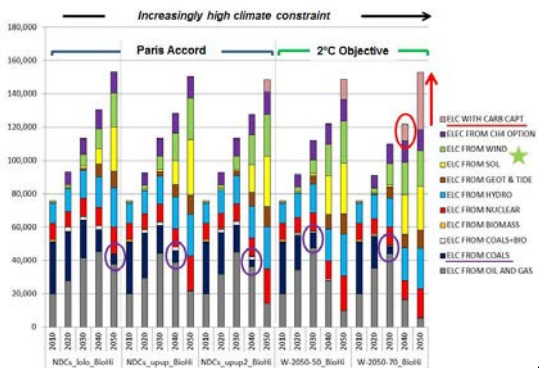
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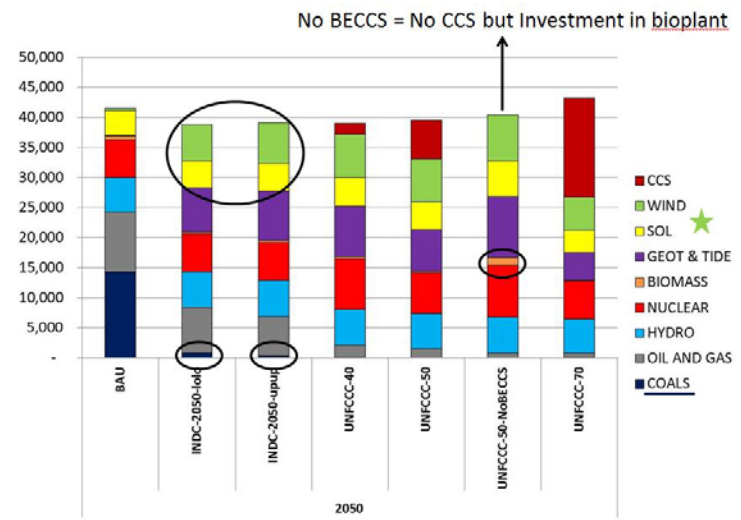
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# Impact of a contrasted biomass potential on the world electric production (PJ)





Industrialized countries

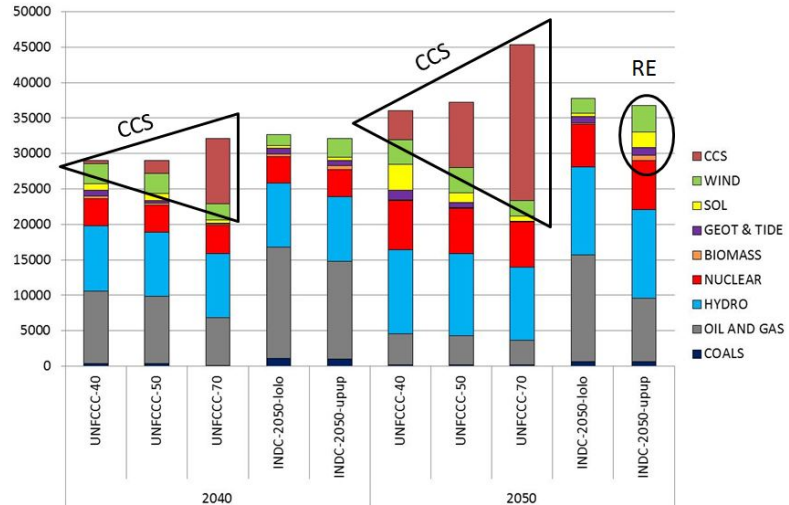
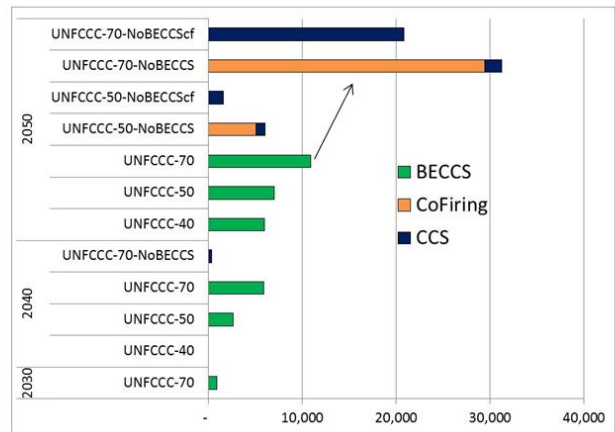


Fast developing countries

Developing countries

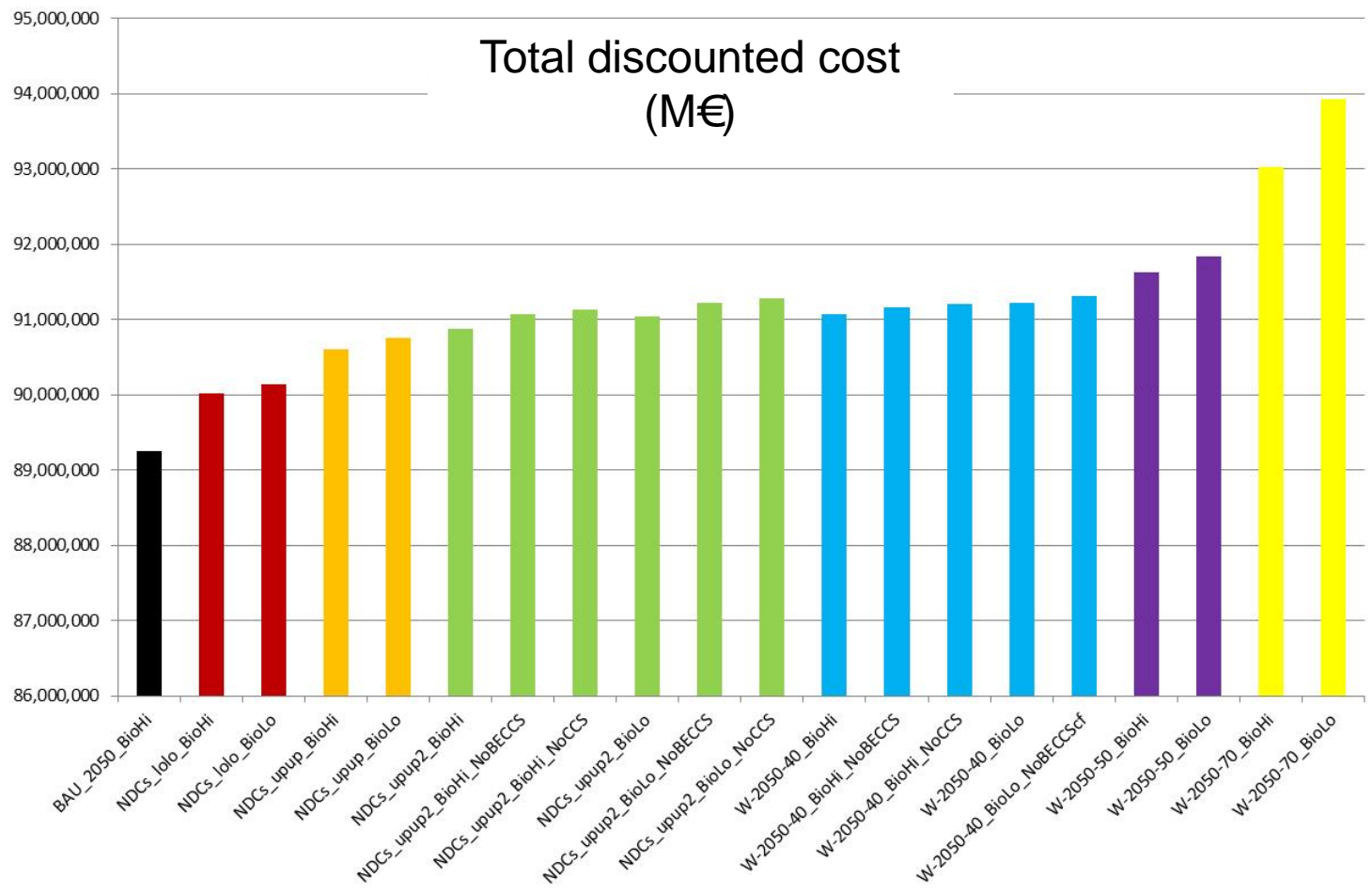
INDCs Scenarios: no CCS but electricity from bioplant is more important

UNFCCC-70-NoBECCS: decarbonized electricity system (solar)





# 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