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From Classic BECCS to Modern Negative Emissions

Florian Kraxner and the IIASA - ESM team

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International Institute for Applied Systems Analysis (IIASA)

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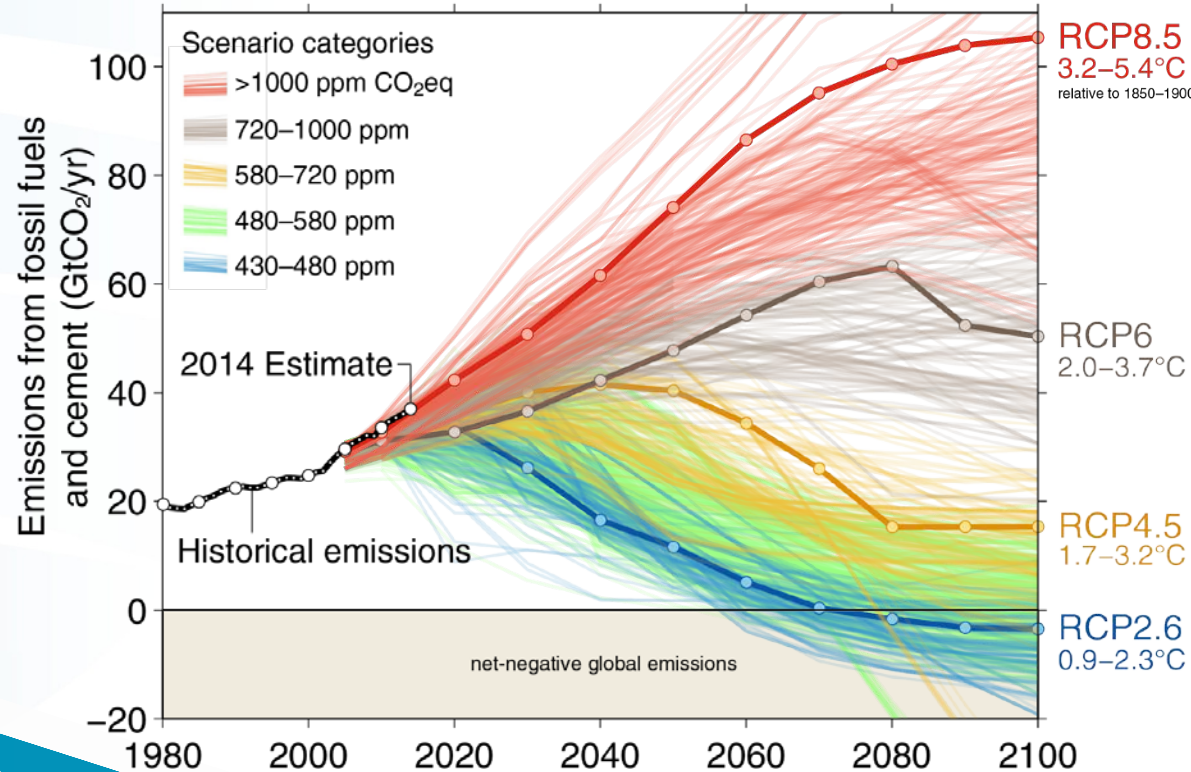
BACKGROUND

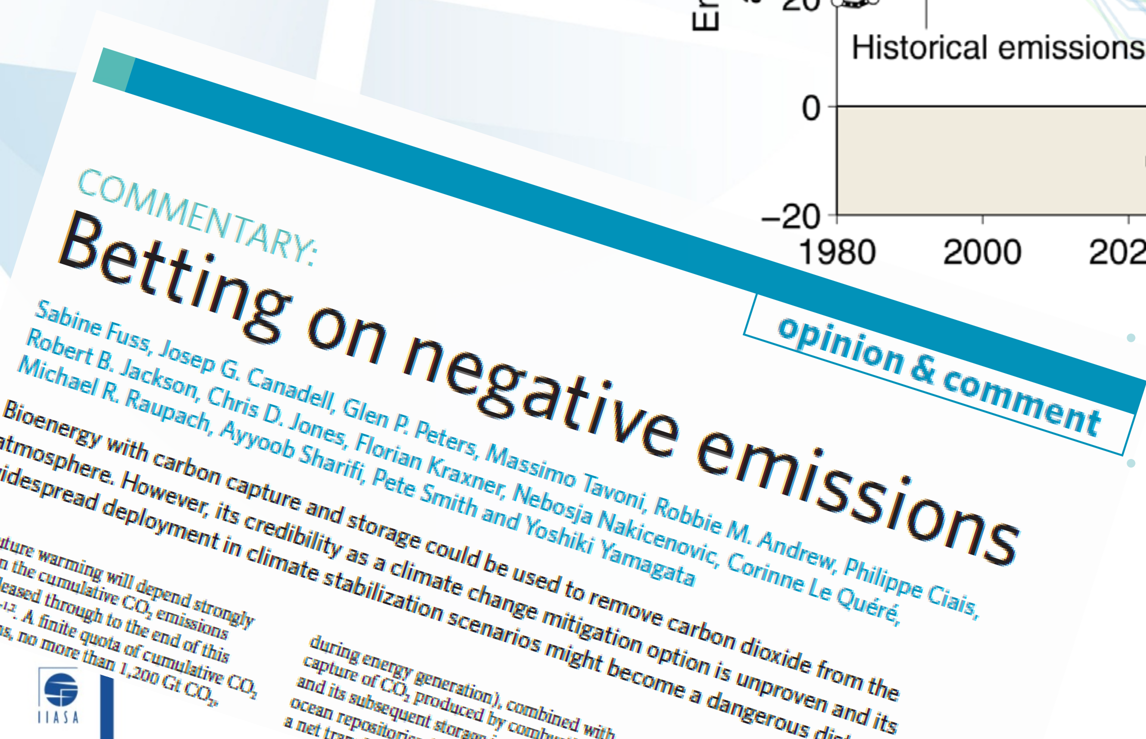
   

The Climate Change Mitigation Context

IPCC AR5:

Achieving 2°C is still possible, but it entails huge contributions from bioenergy - in most scenarios combined with Carbon Capture & Storage (BECCS) to go “negative“.




COMMENTARY:

Betting on negative emissions

opinion & comment

Sabine Fuss, Josep G. Canadell, Glen P. Peters, Massimo Tavoni, Robbie M. Andrew, Philippe Ciais,
Robert B. Jackson, Chris D. Jones, Florian Kraxner, Nebosja Nakicenovic, Corinne Le Quéré,
Michael R. Raupach, Ayyoob Sharifi, Pete Smith and Yoshiki Yamagata

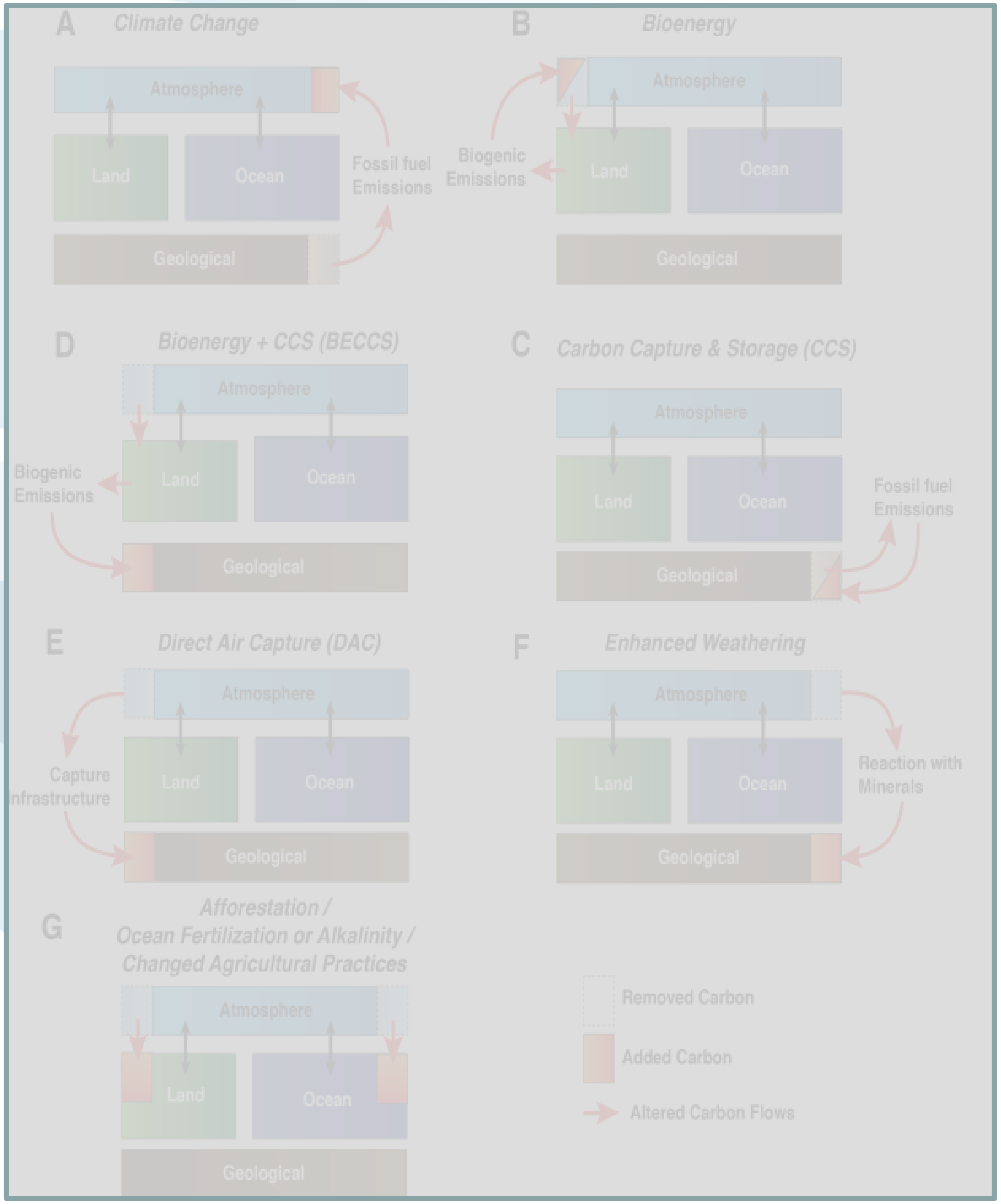
Bioenergy with carbon capture and storage could be used to remove carbon dioxide from the
atmosphere. However, its credibility as a climate change mitigation option is unproven and its
idespread deployment in climate stabilization scenarios might become a dangerous dis

- BECCS need → 2-10 Gt CO_2/yr in 2050 ≈ 5–25% of 2010 CO_2 emissions
- Current global mean removal of CO_2 by ocean and land sinks is 9.2 ± 1.8 Gt CO_2 and 10.3 ± 2.9 Gt CO_2, resp.

Source: CDIAC/GCP/IPCC/
Fuss et al. 2014, *NATURE CC*

OPTIONS

Summary of the carbon cycle impacts of different NETs



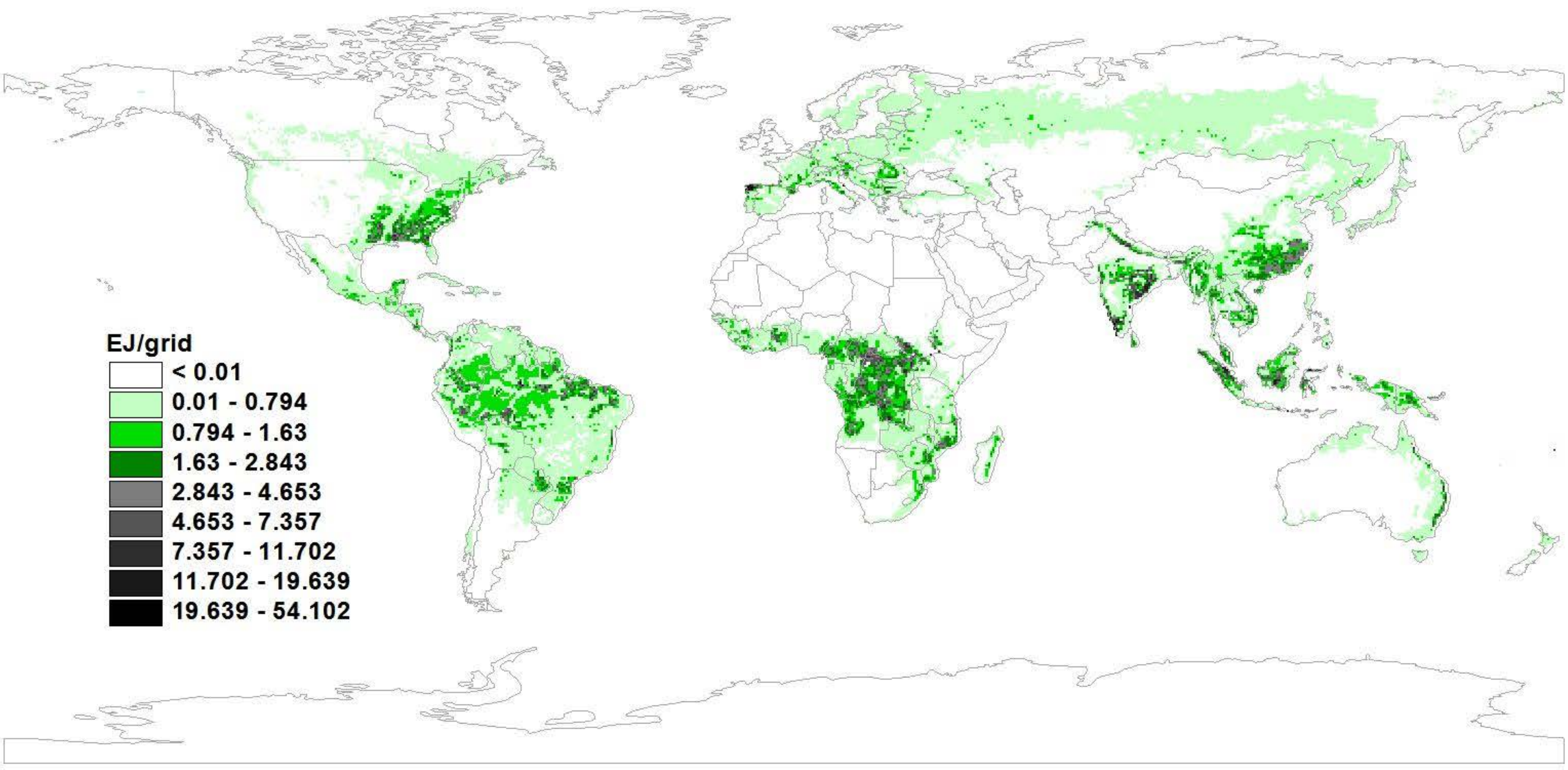
All NETs run into their limits and none is a silver bullet. A portfolio of NETs will probably be needed to ensure sustainable negative emissions.

Adapted from: Smith et al. 2015, *NATURE CC* (forthcoming)

LIMITS

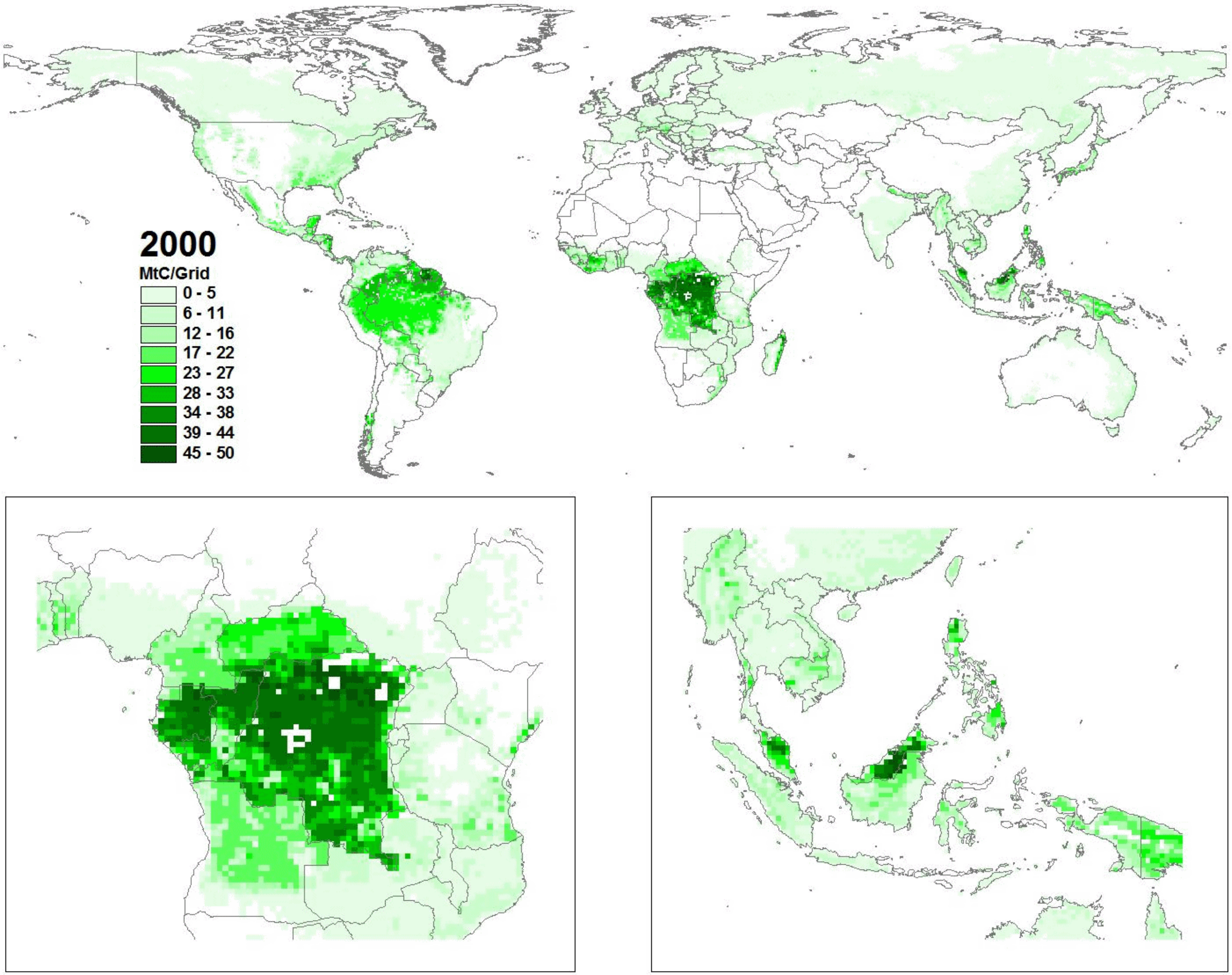



Cumulative biomass production (EJ/grid) for bioenergy between 2000 and 2100 at the energy price supplied by MESSAGE based on the revised IPCC SRES A2r scenario (country investment risk excluded).



Source: Rokityanskiy et al. 2006

Forest Area Development A2r (2000 – 2035)



Source: IIASA, G4M

Global BE Feedstock Scenarios – Definitions & Objectives

Objectives:

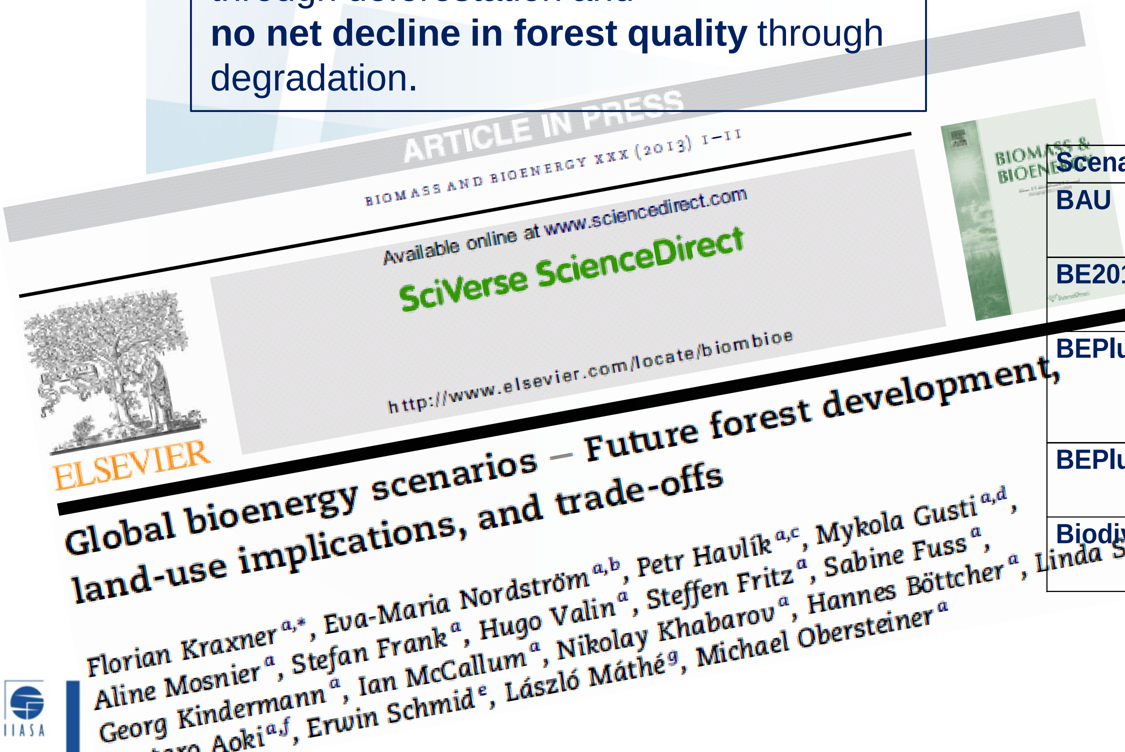
a) to achieve a global perspective using an integrated modeling approach;

b) to frame the boundaries for lower scale assessments; and

c) to identify potential trade-offs to be considered in future research.

Zero Net Deforestation and Degradation (ZNDD) means **no net forest loss** through deforestation and **no net decline in forest quality** through degradation.

WWF, 2011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BIOMASS AND BIOENERGY XXX (2013) 1–11

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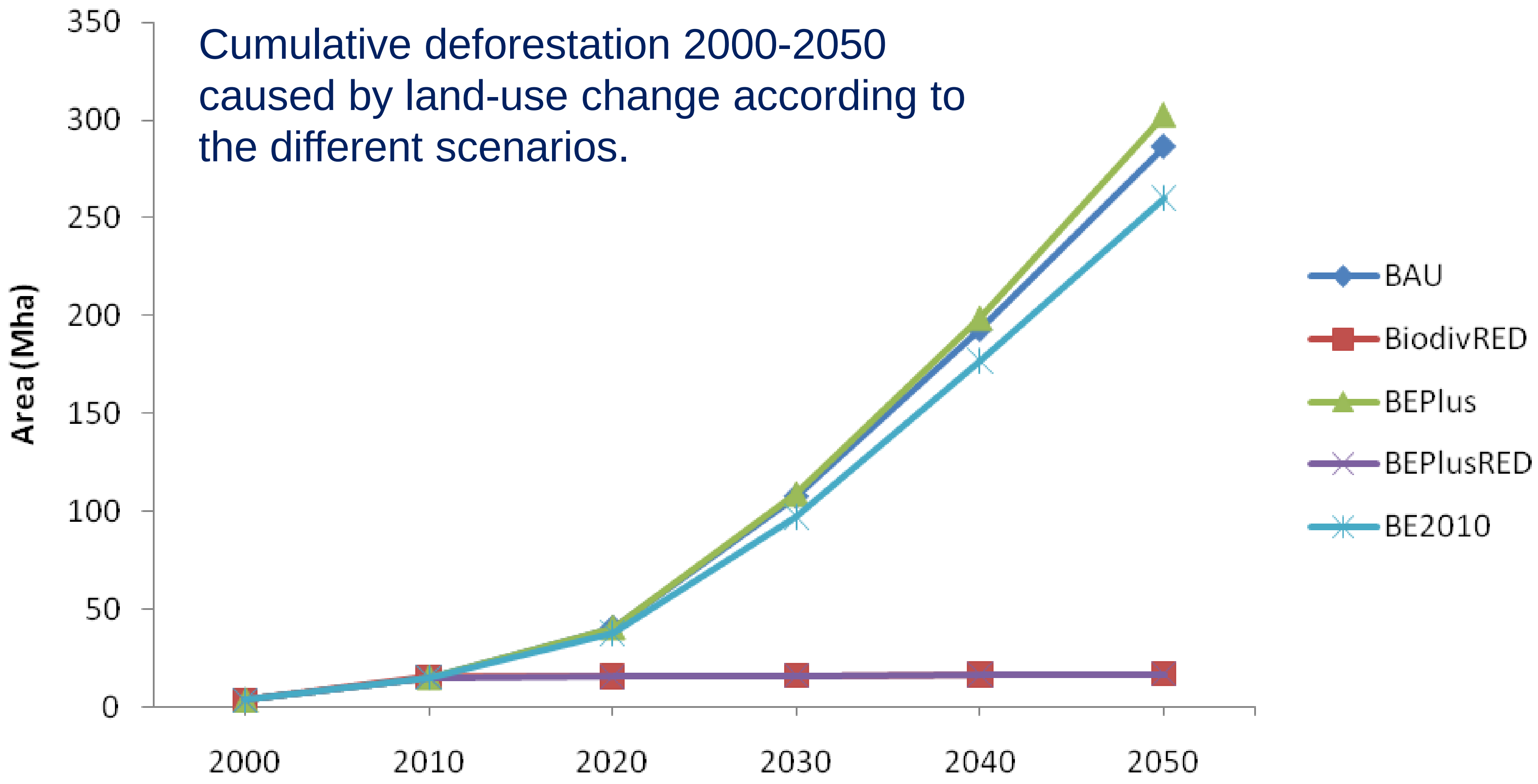
Global bioenergy scenarios – Future forest development, land-use implications, and trade-offs

Florian Kraxner[a,*], Eva-Maria Nordström[a,b], Petr Havlík[a,c], Mykola Gusti[a,d], Aline Mosnier[a], Stefan Frank[a], Hugo Valin[a], Steffen Fritz[a], Sabine Fuss[a], Georg Kindermann[a], Ian McCallum[a], Nikolay Khabarov[a], Hannes Böttcher[a], Linda See[a], ... Aoki[a,f], Erwin Schmid[e], László Máthé[g], Michael Obersteiner[a]

Scenario name	Description
BAU	"Business as usual": Projection of future development in line with historical trends
BE2010	As BAU but the production of bioenergy fixed at the level in 2010
BEPlus	Projection of bioenergy demand by 2050 as in the 100 per cent renewable energy vision by the Ecofys Energy Model
BEPlusRED	As BEPlus but with target "no net deforestation" (RED=Reducing Emissons from Deforestation)
BiodivRED	Stricter biodiversity protection combined with target 'no net deforestation'

Kraxner et al. 2014, *Biomass & Bioenergy*

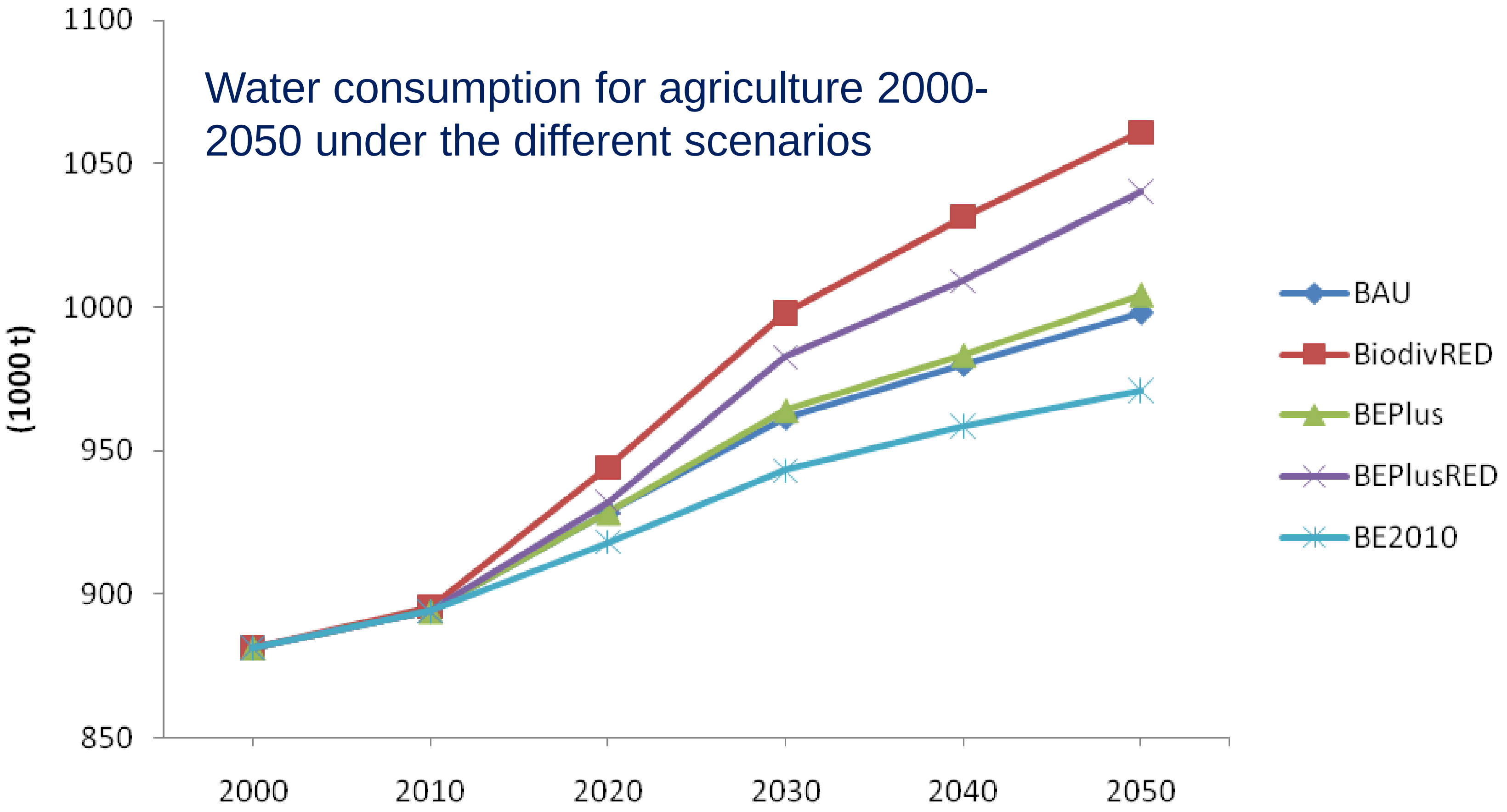
Global De



- •BEPlus similar to BAU
- •BE2010 on same high level because of unrestricted deforestation
- •RED keeps deforestation at present level

Kraxner et al. 2014, *Biomass & Bioenergy*

Agricultural Water Demand by Scenarios



- All scenarios show increased demand
- Lowest restriction on forest and biodiversity conservation show less water need
- Higher restriction implies less land available for eg food production = intensification

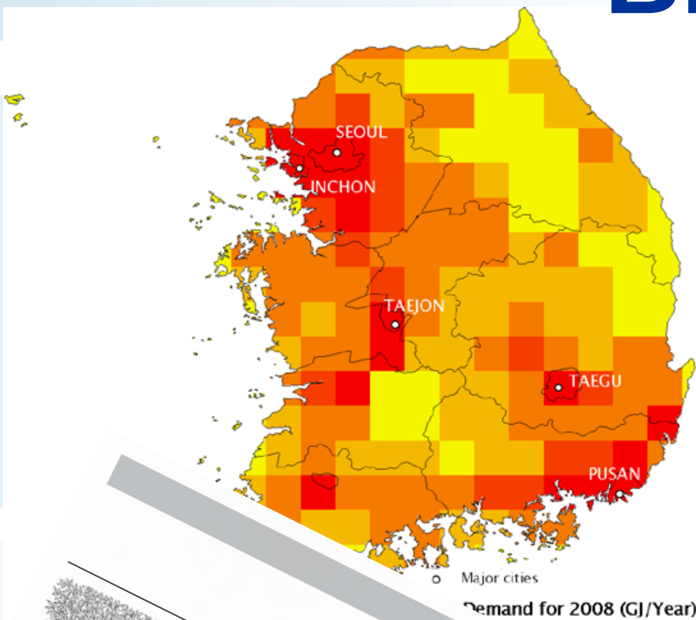
Kraxner et al. 2014, *Biomass & Bioenergy*

BECCS CASE STUDIES - EXAMPLES

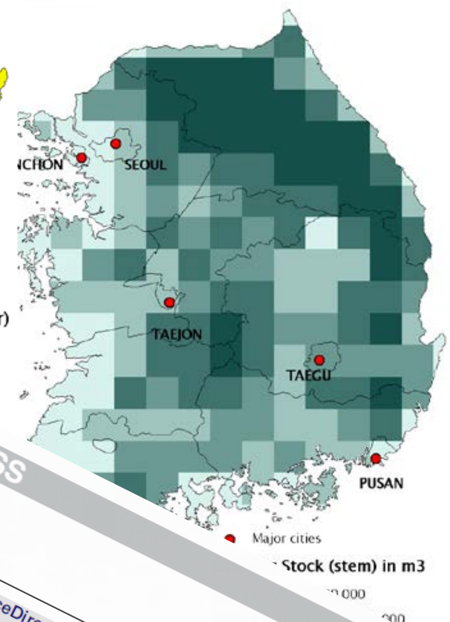



BECCS in South Korea

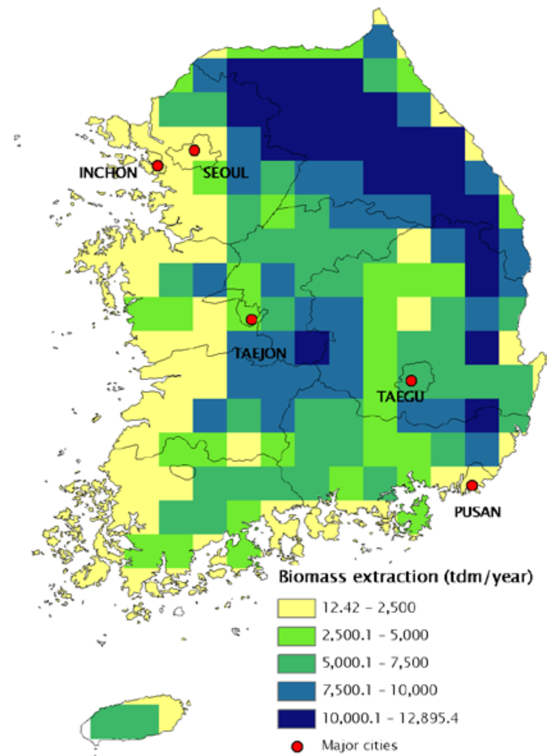
Demand vs Supply

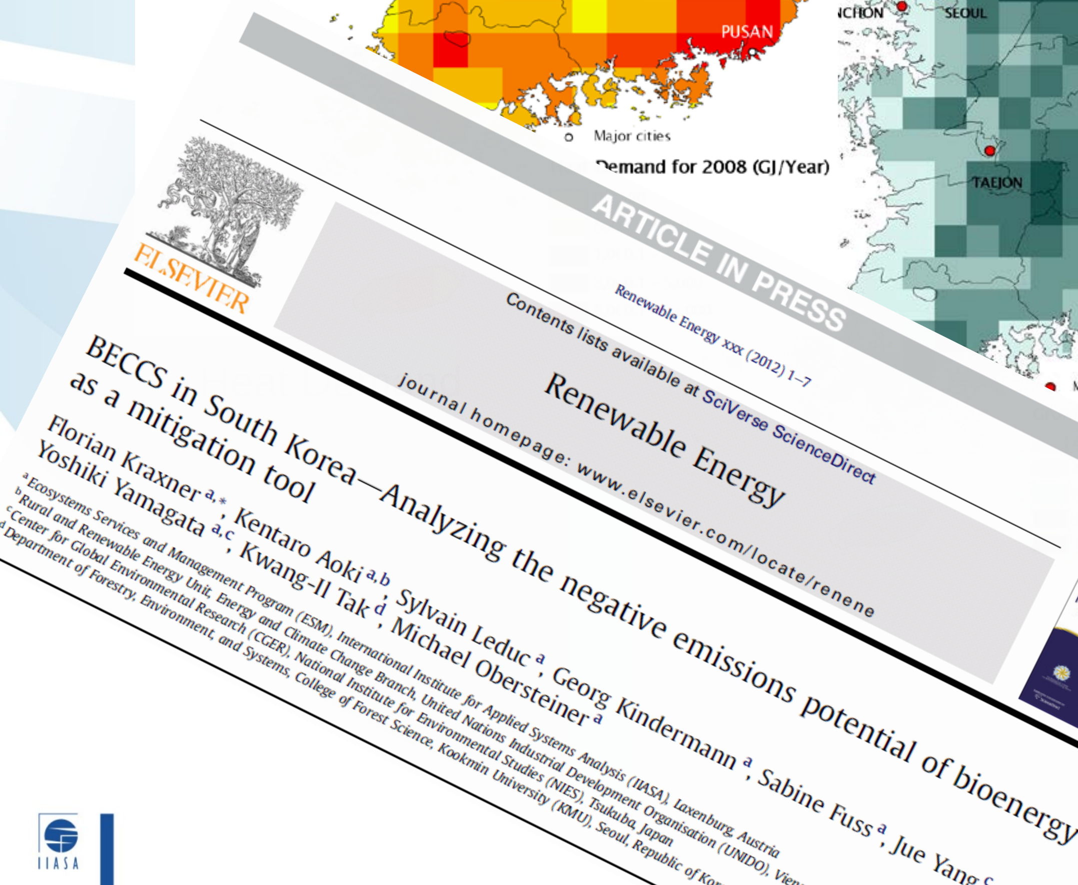


Growing Stock Modeled



Potential Biomass Extraction





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Renewable Energy xxx (2012) 1–7

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BECCS in South Korea—Analyzing the negative emissions potential of bioenergy as a mitigation tool

Florian Kraxner [a,*], Kentaro Aoki [a,b], Sylvain Leduc [a], Georg Kindermann [a], Sabine Fuss [a], Jue Yang [c], Yoshiki Yamagata [a,c], Kwang-Il Tak [d], Michael Obersteiner [a]

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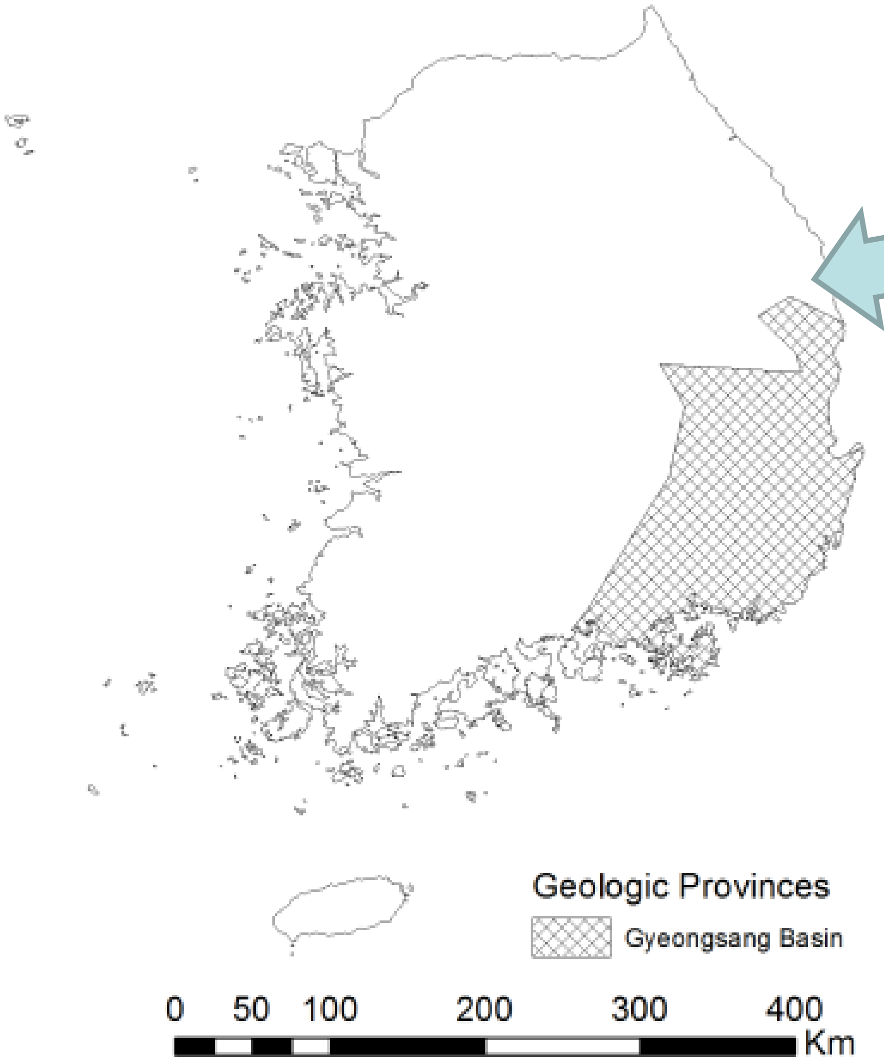
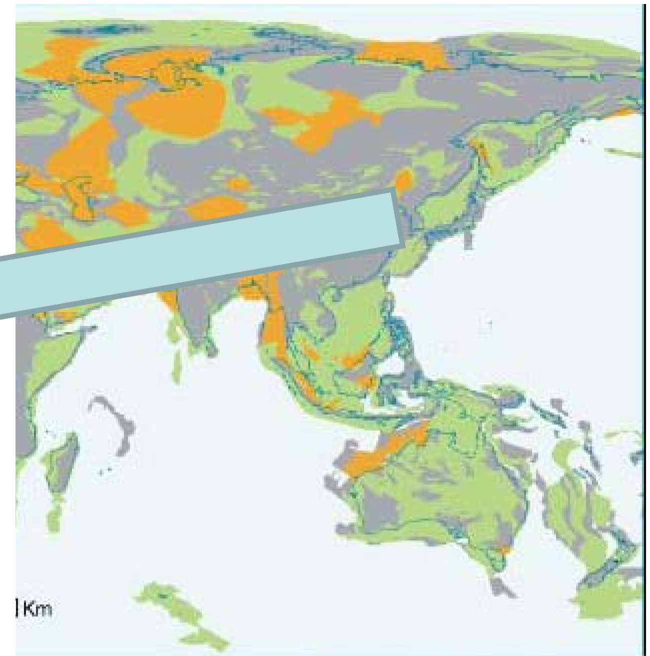
[c] Center for Global Environmental Research (CGER), National Institute for Environmental Studies (NIES), Tsukuba, Japan
[d] Department of Forestry, Environment, and Systems, College of Forest Science, Kookmin University (KMU), Seoul, Republic of Kor

Source: Kraxner et al. 2012, *Renewable Energy*

Where to store the carbon? Prospectivity?

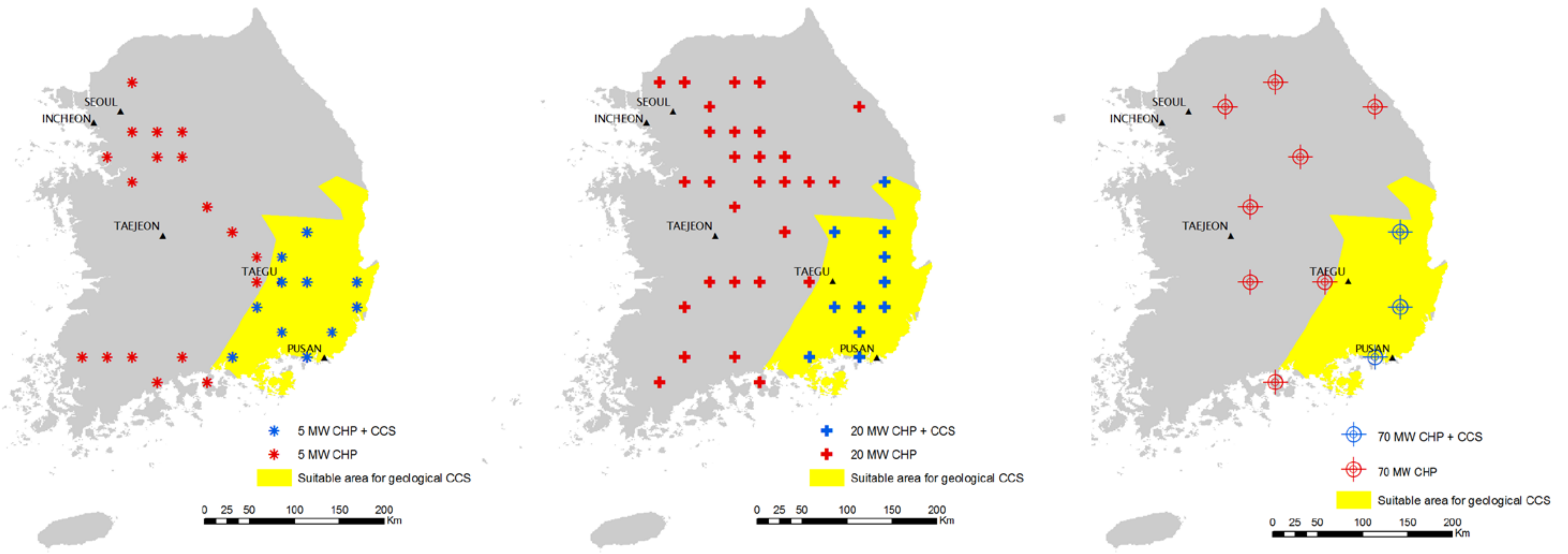




Scenario settings
CHP plants

Definition	Biomass input
Min Size	5 MW
Medium size	20 MW
Max Size	70 MW

Source: Kraxner et al. 2012, *Renewable Energy,* Bradshaw & Dance 2004



Plant size Technology	5 MW **NO** CCS	20 MW **NO** CCS	70 MW **NO** CCS	5 MW CCS	20 MW CCS	70 MW CCS
Plant #	18	29	8	11	11	3
Biomass used (tdm/year)	117,000	716,300	712,400	71,500	271,700	267,150
Heat produced (GJ/year)	1,190,475	7,288,353	7,248,670	727,513	2,764,548	2,718,251
El. produced (GJ/year)	757,575	4,638,043	4,612,790	462,963	1,759,258	1,729,796
Subst. emissions (tCO_2/year)	215,516	627,050	625,036	131,704	237,847	234,389
CCS Capacity (tCO2/year)	***0***	***0***	***0***	***131,704***	***237,847***	***234,389***

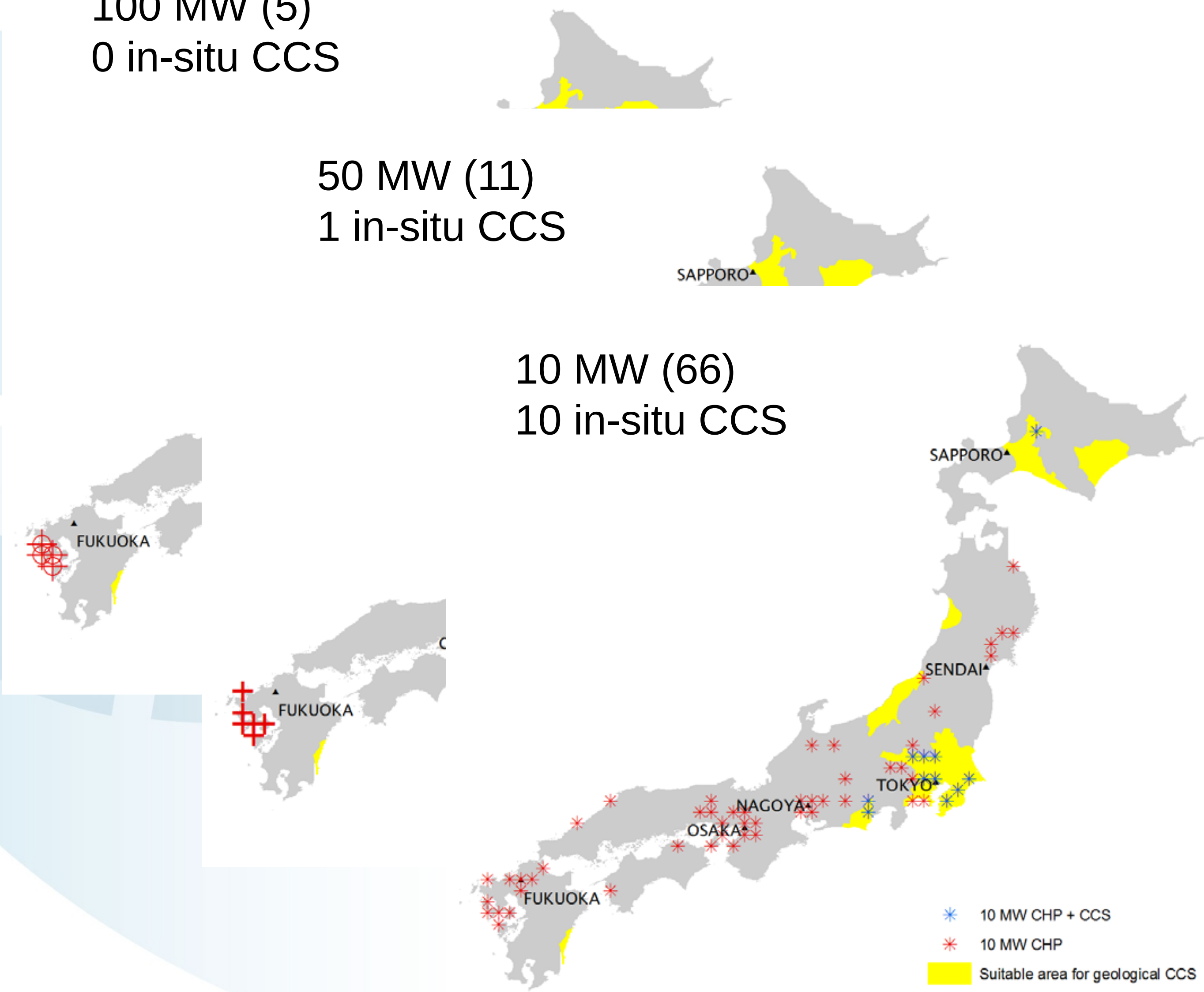
Kraxner, F., Aoki K, Leduc S, Kindermann G, Fuss S, Yang J, et al. BECCS in South Korea – Analyzing the negative emissions potential of bioenergy as a mitigation tool. Renewable Energy 2012; http://dx.doi.org/10.1016/j.renene.2012.09.064

In-situ BECCS Potential in Japan

100 MW (5)
0 in-situ CCS

50 MW (11)
1 in-situ CCS

10 MW (66)
10 in-situ CCS

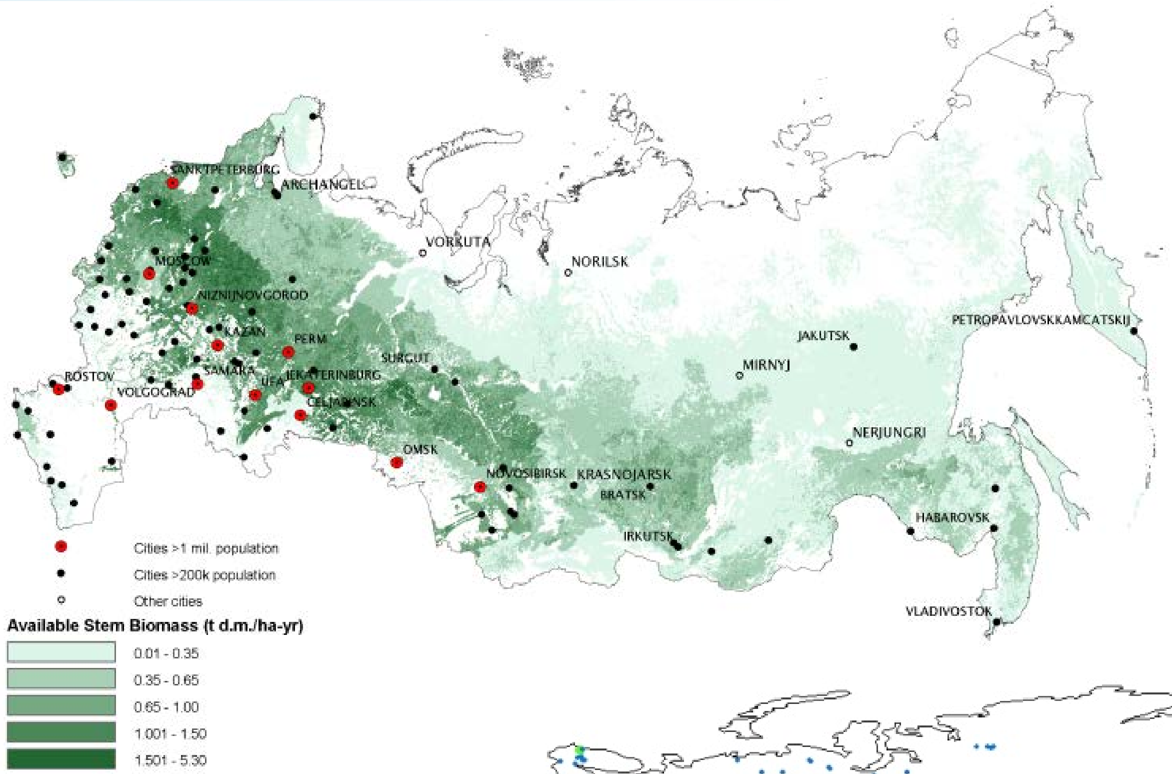


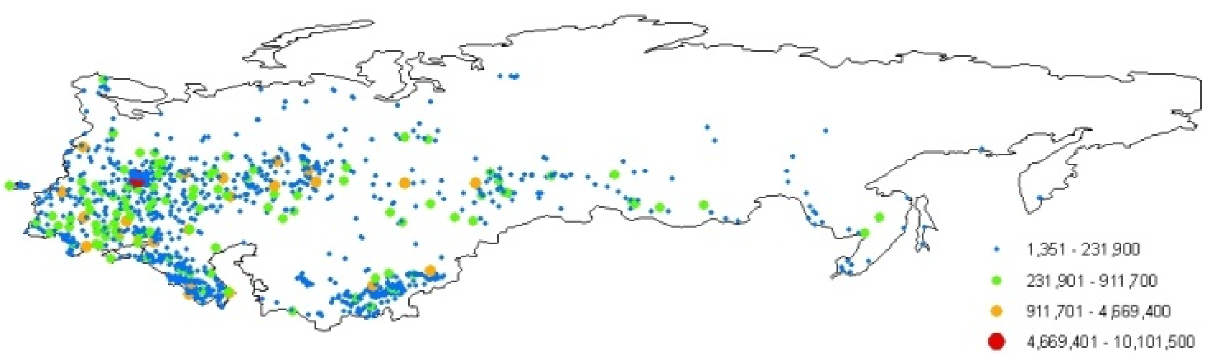
Total potential "in-situ" BECCS Effect: 1.5 million tons CO_2 per year

Total potential CO_2 substitution effect: 12-13 million tons CO_2 per year

Source: Kraxner et al. 2015, *Energy Procedia*

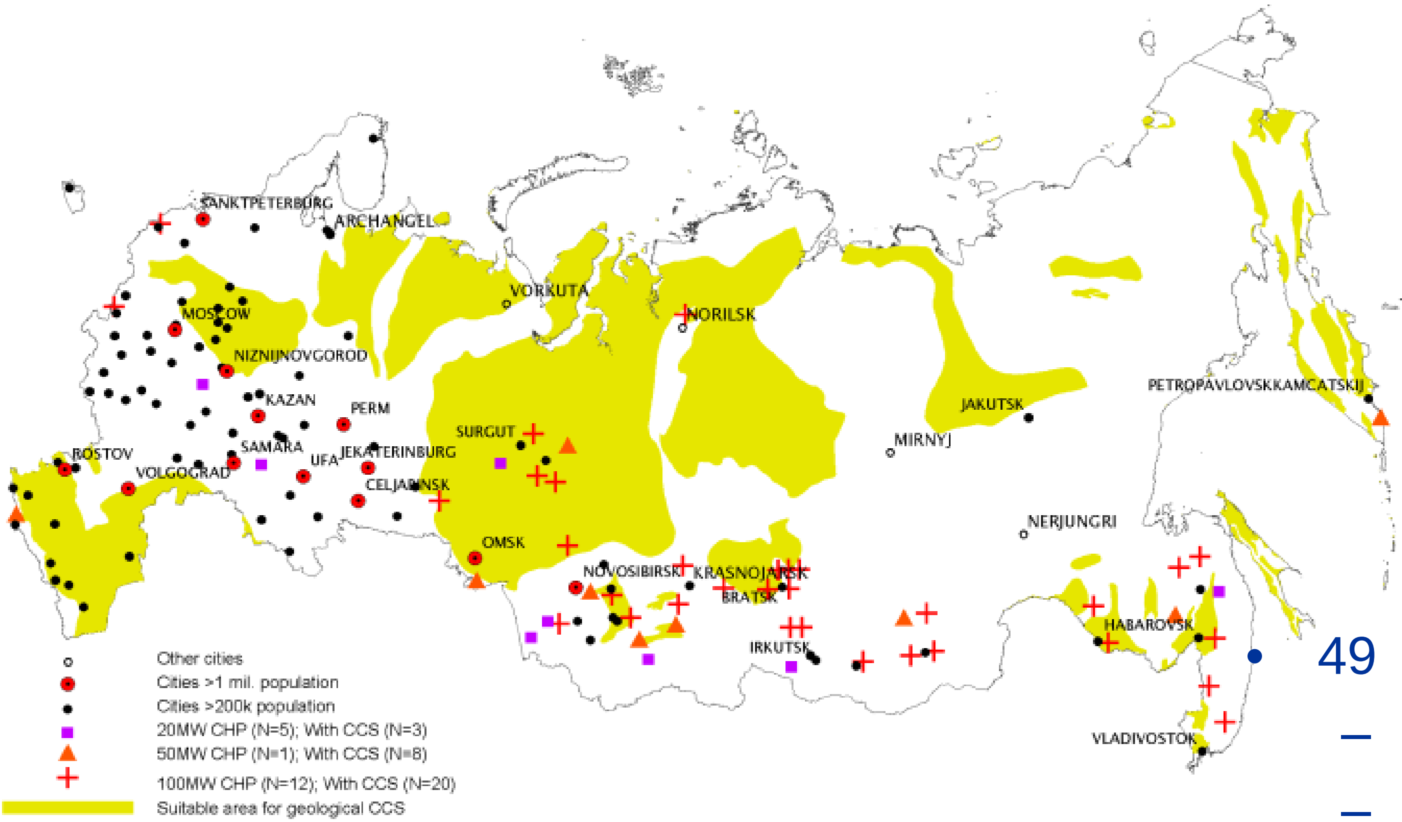
Biomass Availability and Energy Demand for Russia





Source: Kraxner et al. 2012

Potential in situ BECCS units: Combined 20/50/100 MW scenario



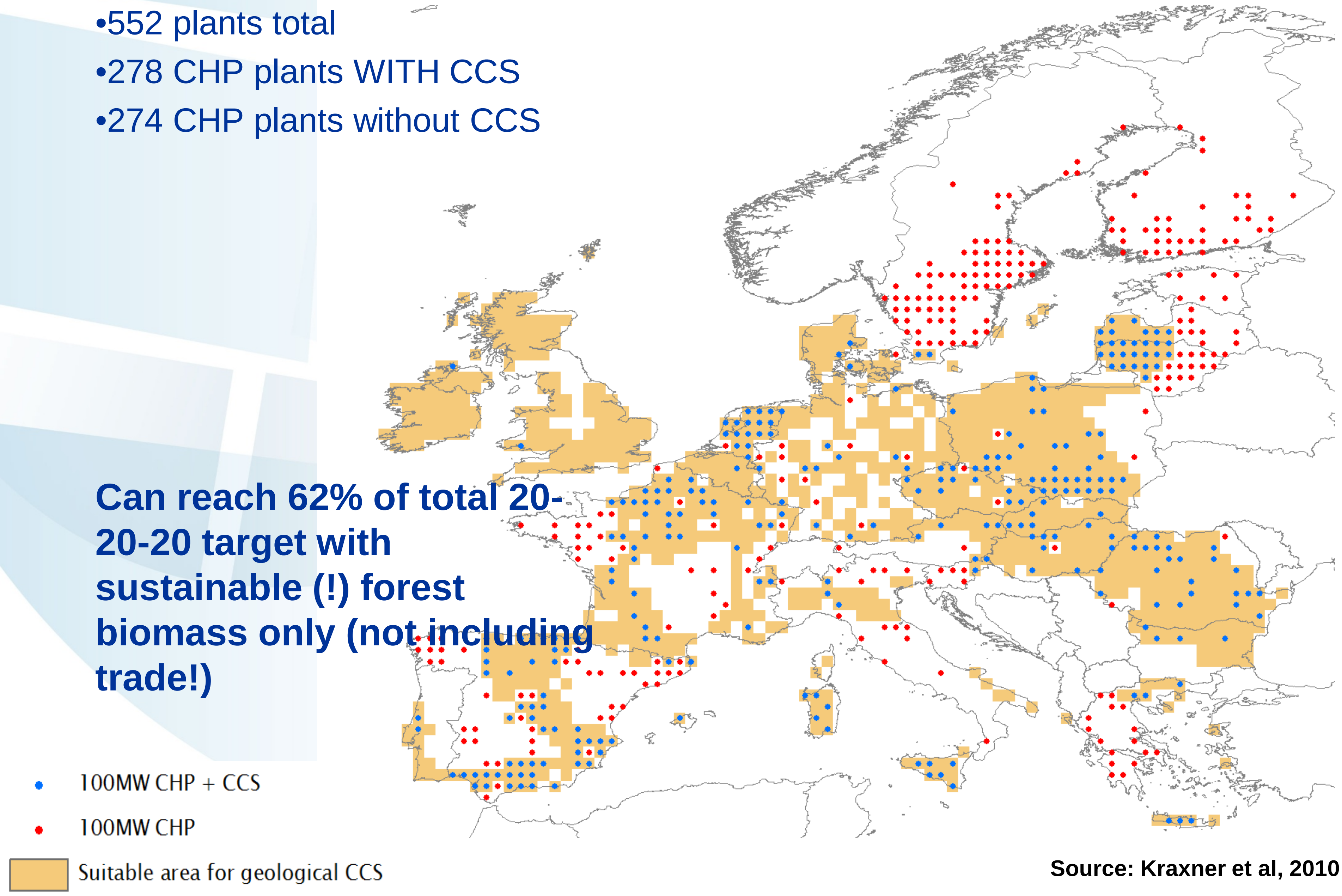
- 49 plants
  - 32 for 100MW plants
  - 8 for 20MW plants
  - 9 for 50MW plants
- 31 suitable for BECCS

Source: Kraxner et al. 2012

Forest biomass share: 206 Mtoe (~62% of the RE target by 2020)

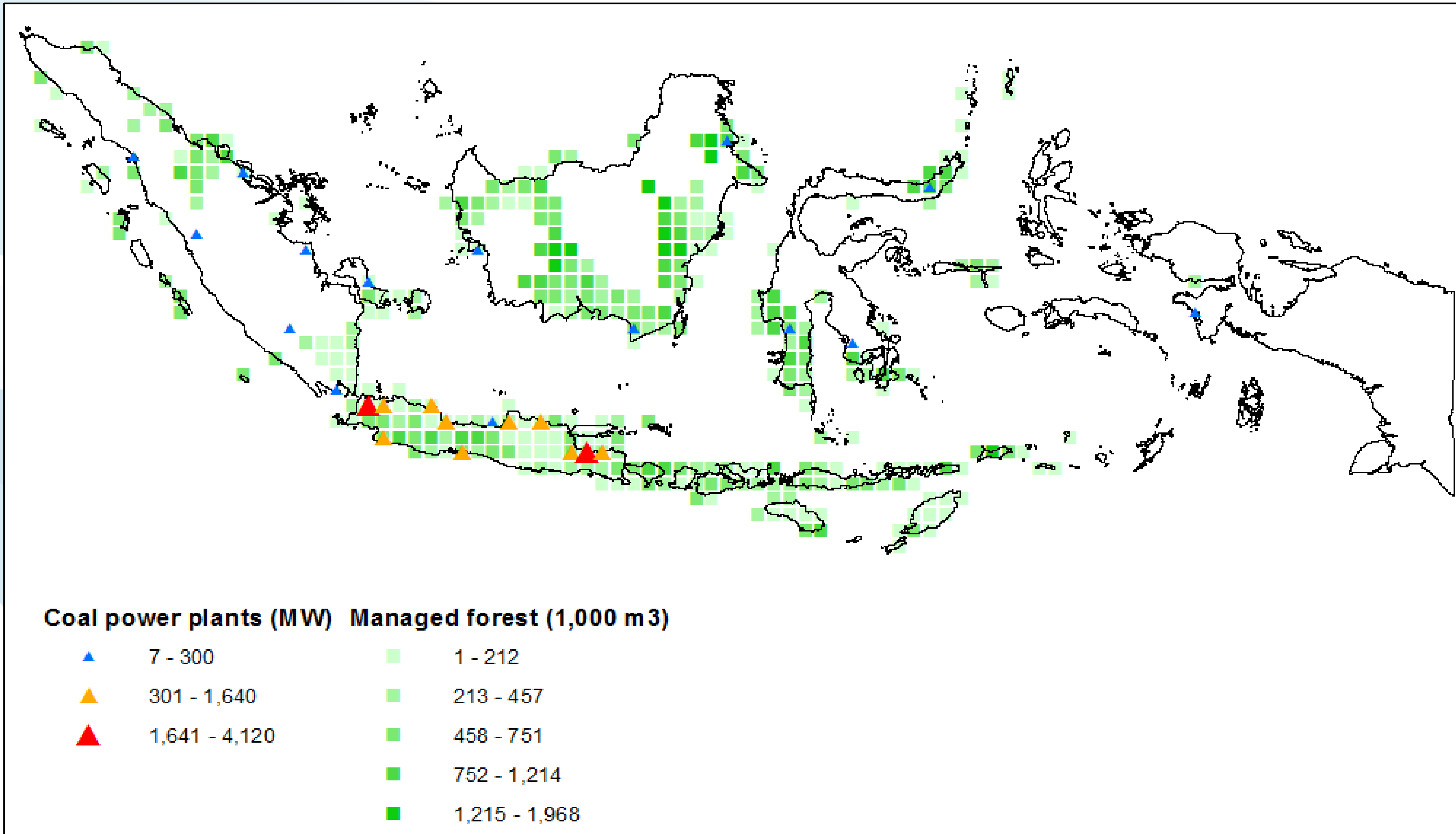
- 552 plants total
- 278 CHP plants WITH CCS
- 274 CHP plants without CCS

Can reach 62% of total 20-20-20 target with sustainable (!) forest biomass only (not including trade!)



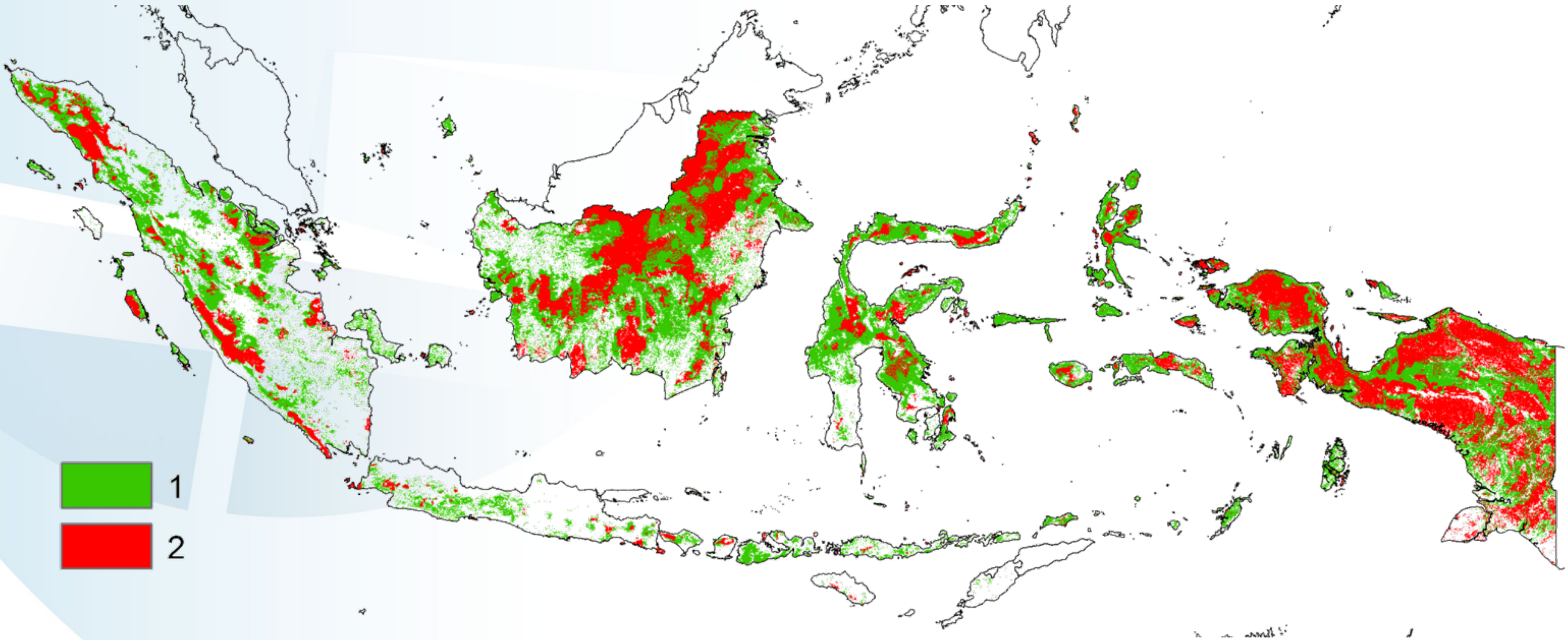
Source: Kraxner et al, 2010

50% co-firing / managed forest



Source: Kraxner et al. 2013

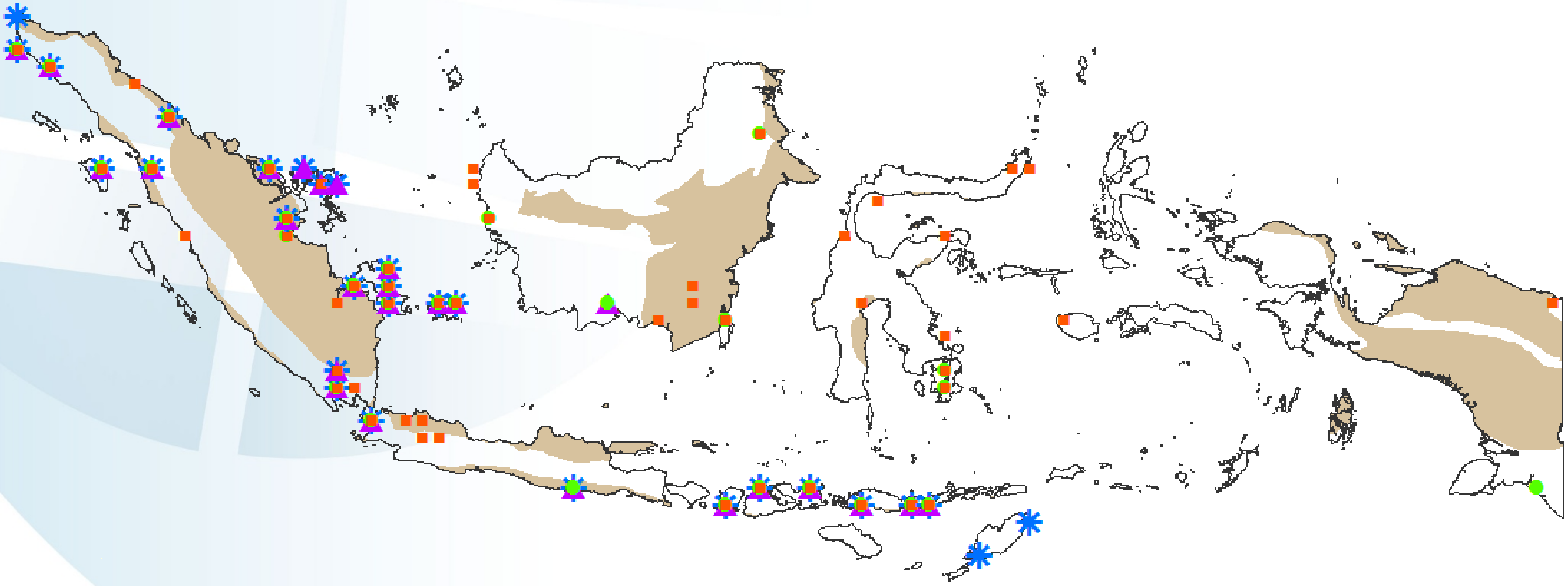
REDD map for Indonesia.



Source: Kraxner et al., CFCC 2015

1, Biomass potential outside conservation and protected forest areas.
2, Biomass potential within conservation and protected forest areas which may be inaccessible under REDD+ policies

BeWhere – optimized green-field bioenergy - plant locations and capacities combined with geological suitability for in-situ CCS (BECCS)



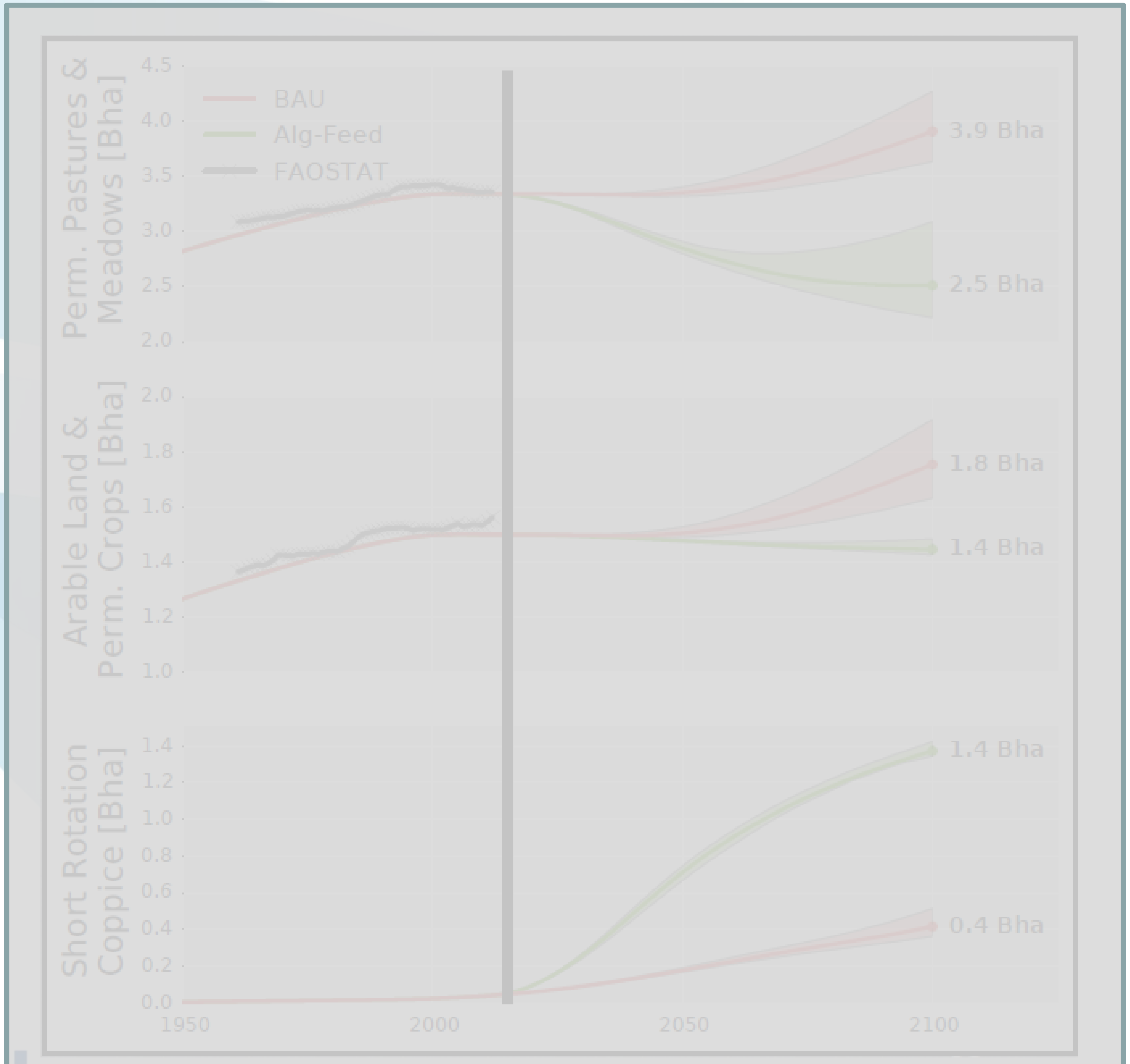
Source: Kraxner et al., CFCC 2015

CAN WE DO THE TRICK?

ALGAE for negative emissions !?

- Huge productivities: up to 150 tDM/ha/y in Benelux
- Not limited to the Sahara.
- Can be produced on degraded or unproductive land
- …in salt & brackish water
- …fed with flue gas & waste water
- …closes critical carbon, water, and fertilizer (N and P) cycles
- Could avoid the tradeoffs and problem shifting we see with other biofuels…
- Compelling technology from a systems perspective
- Multiple usage

Land Demand from Feedstock Production



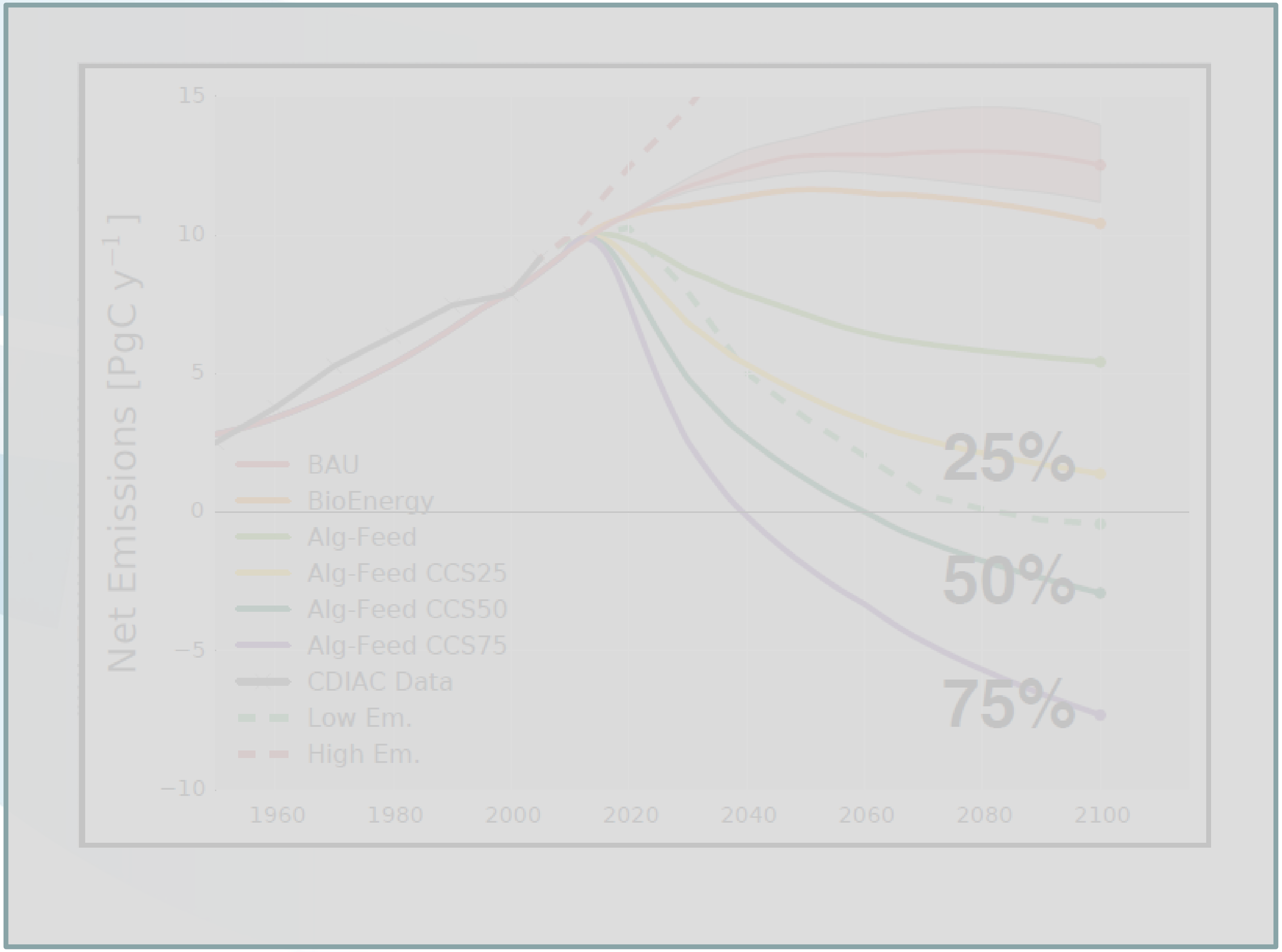
Currently using
~ 5Bha for agriculture
25% for food
75% for feed!!

~ 5.7 Bha by 2100

At 35% of feed demand, algae can free 1.7B ha of agricultural land

Source: www.FeliXmodel.org, 2015

ALGAE + Feedstock + BECCS…



Source: Walsh et al., 2015, www.FeliXmodel.org, 2015

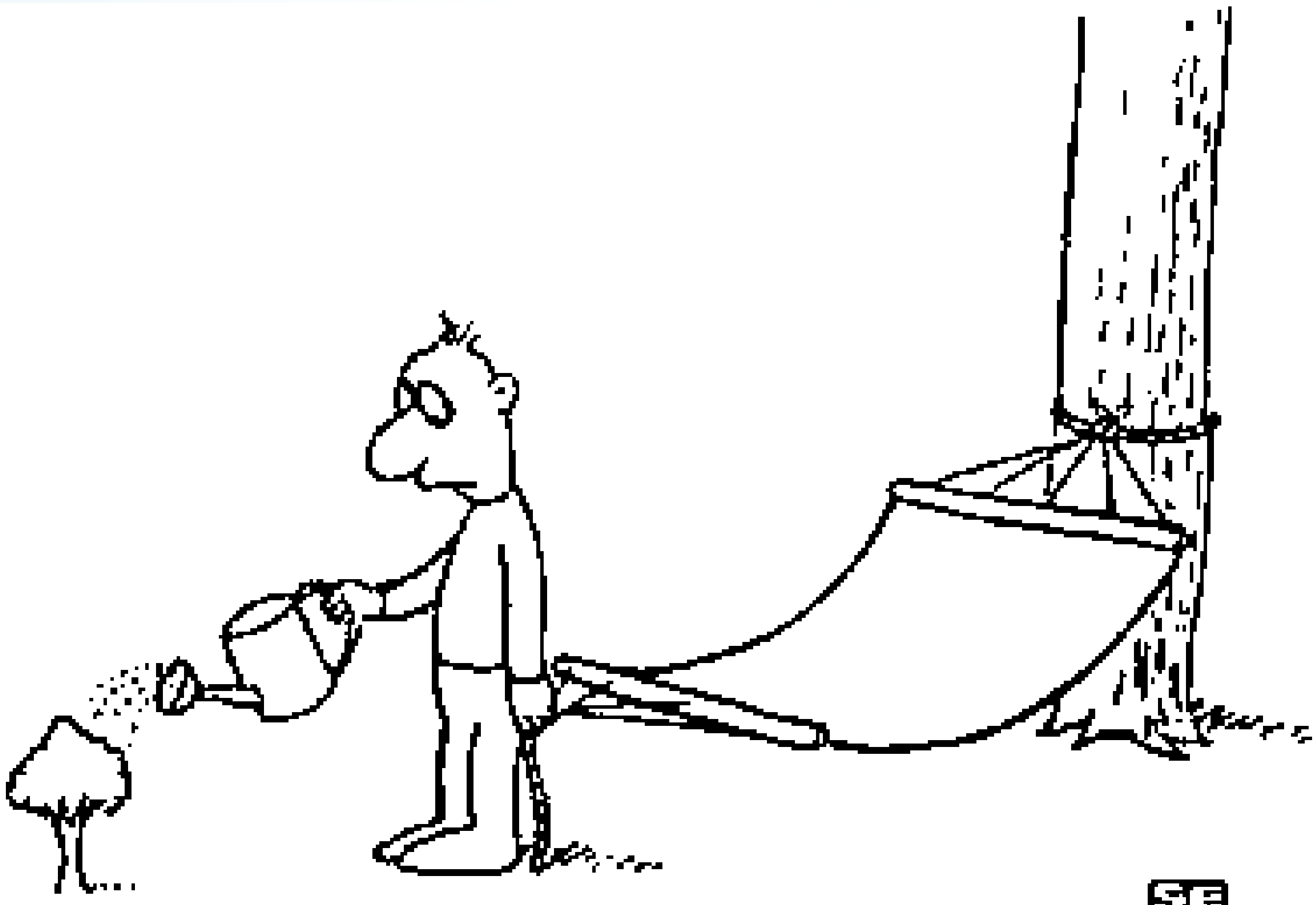
SUMMARIZING THOUGHTS

Summary

- Negative Emissions are needed
- Biomass conversion with CCS (BECCS) is the only available technology at large scale
- **Ramp-up time!**
- **Landuse implications!**
- **Environmental implications (e.g. biodiversity, water…)!**
- **BECCS or NETs does NOT allow for BAU!**
- Land demand for feed/-stock is one of the largest issues
- Algae can help taking pressure from land
- Detailed country studies are to be seen as a pre-requisite
    - R&D is needed
    - Funding is needed
    - Capacity building is needed

High hopes…



Contact

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