International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

INTERNATIONAL CONFERENCE ON BIOMASS ENERGY TECHNOLOGIES
生物质能源技术国际会议

WBS 2014
World Bioenergy Symposium

Managing impacts of scale and sustainability in a BECCS context

Florian KRAXNER[1*], Sabine FUSS[2,1], Sylvain LEDUC[1], Georg KINDERMANN[1], Dmitry SCHEPASCHENKO[1], Anatoly SHVIDENKO[1,3], Yoshiki YAMAGATA[4,1], Ping YOWARGANA[5,1], Agung WICAKSONO[5], Kentaro AOKI[1,6], Dennis BEST[7], Wolf HEIDUG[7], et al.

[1]International Institute for Applied Systems Analysis (IIASA), Ecosystems Services and Management Program (ESM), Schlossplatz 1, A-2361, Laxenburg, Austria

[2]Research Group for Resources and International Trade, Mercator Research Institute on Global Commons and Climate Change (MCC), Berlin, Germany

[3]Sukachev Institute, Russian Academy of Sciences, Siberian Branch, Krasnoyarsk, Russia

[3]Rural and Renewable Energy Unit, Energy and Climate Change Branch, United Nations Industrial

[4]President's Delivery Unit for Development Monitoring and Oversight (UKP4), Jakarta, Indonesia

[5]Development Organisation (UNIDO), P.O. Box 300, A-1400, Vienna, Austria

[6]International Energy Agency, CCS Unit, Paris, France

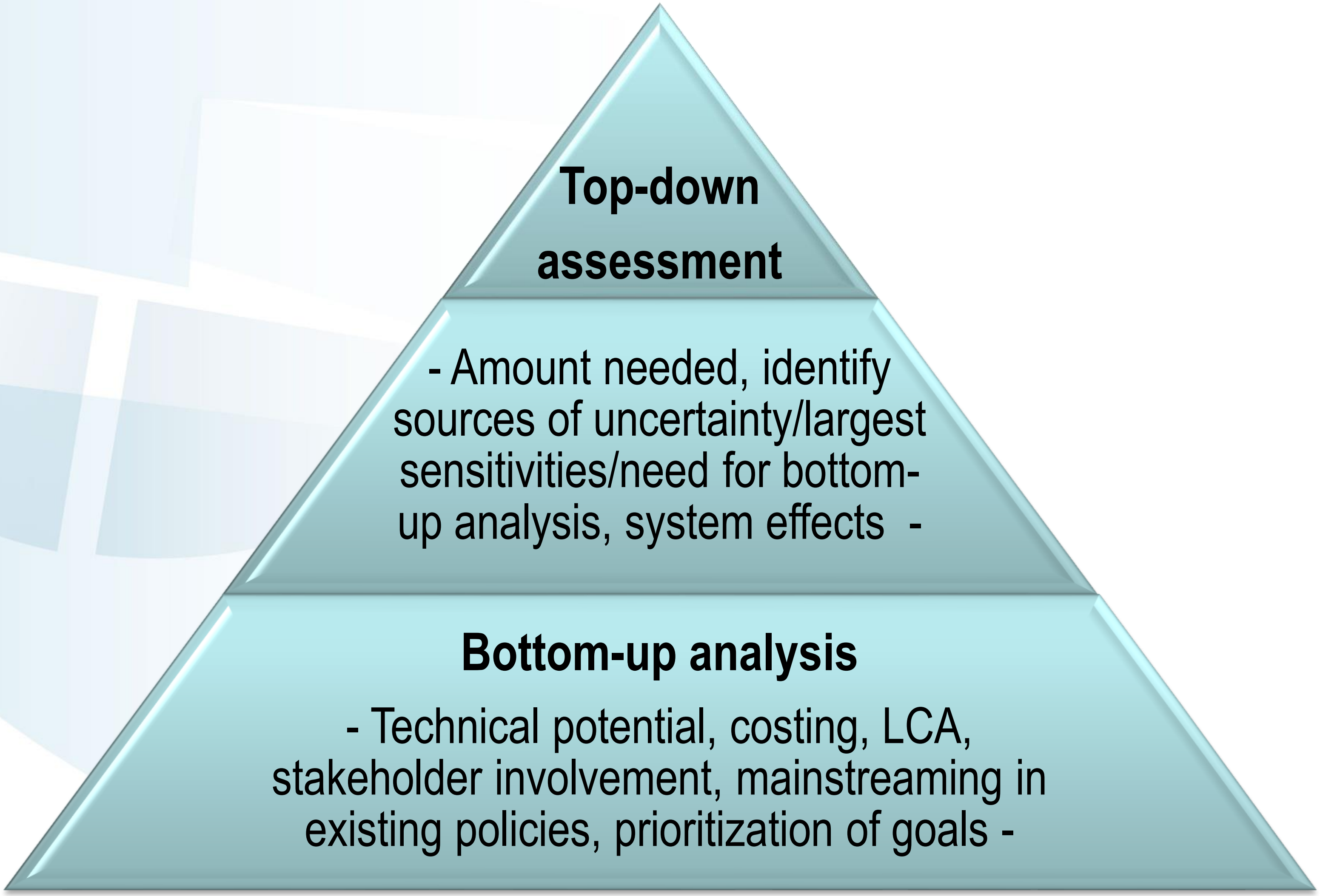
ICBT-WBS 2014 – Changsha, China
October, 17-19 2014
Session D: Bio-energy With Carbon Capture and Storage (BECCS)

science for global insight

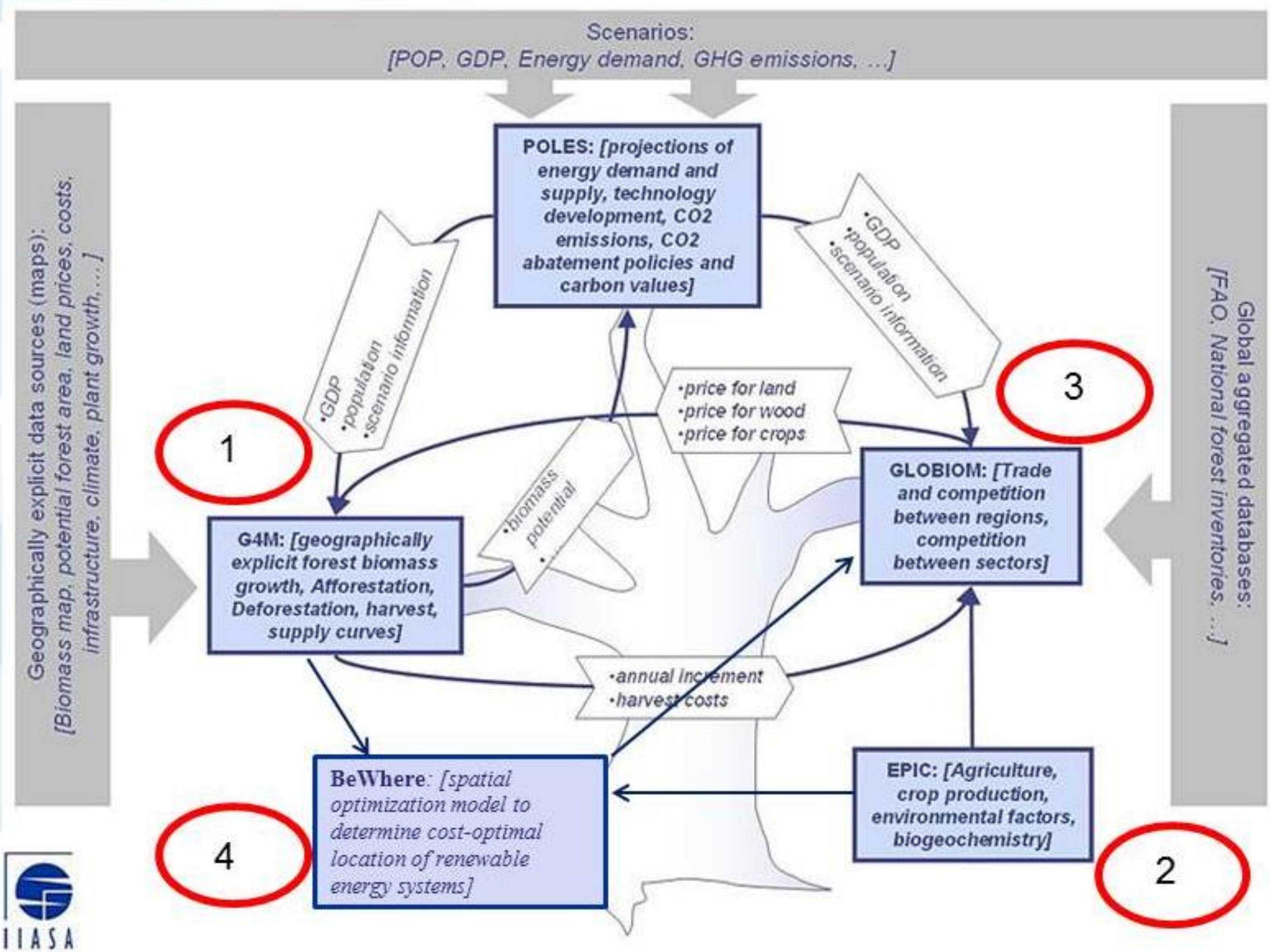
INTEGRATION OF SCALE




Joining top-down and bottom-up approaches



Modeling BECCS Potentials at Global Scale – An Integrated Modeling Approach



Source: IIASA (2014)

Bottom-up research at IIASA

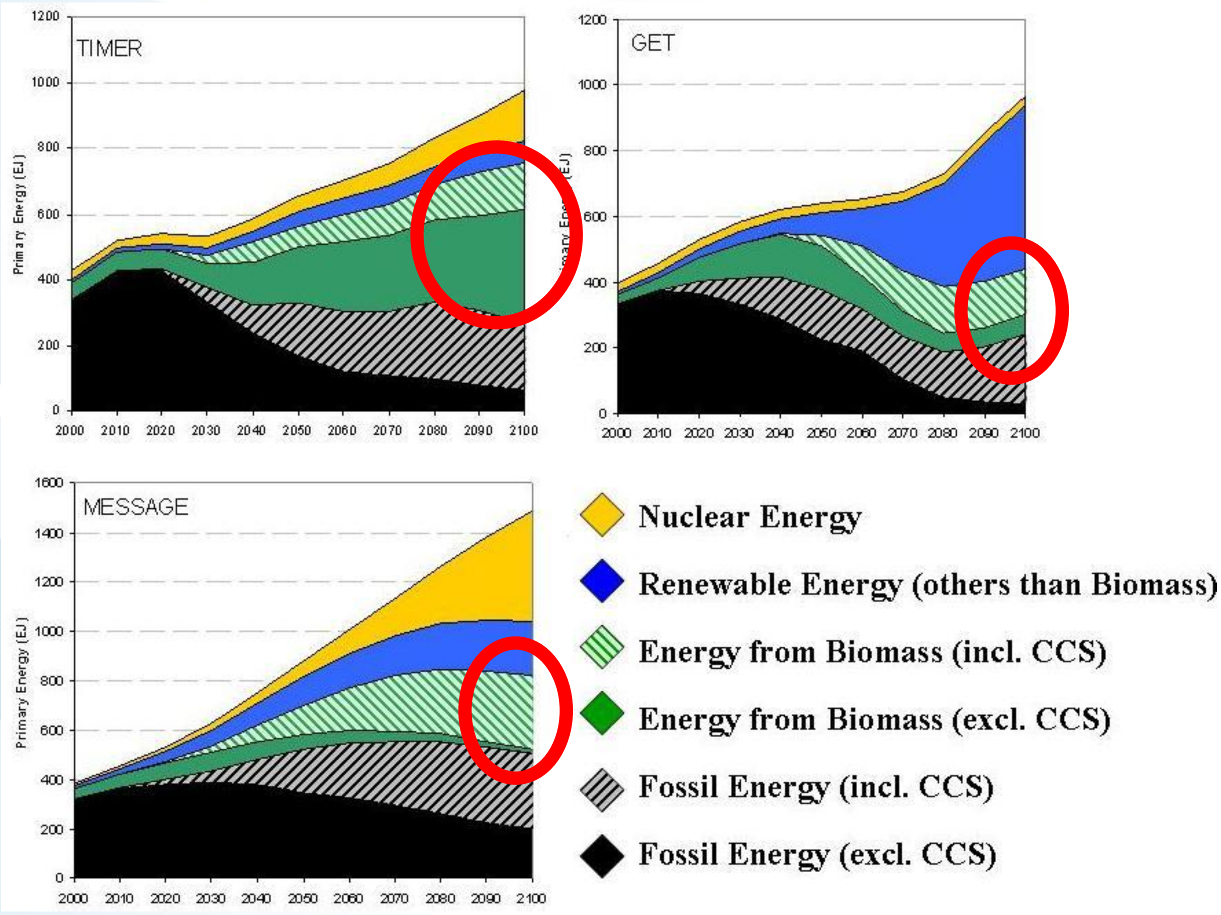
- Link with IEA and country stakeholders
  - Experts workshop, Laxenburg Nov 2011
  - Indonesia workshop, Jakarta Sep 2012
  - ⇒ http://www.iea.org/newsroomandevents/workshops/workshop/name,28877,en.html
  - Brazil workshop, Sao Paulo Jun 2013 (Prof. Moreira)
  - China, Sweden, Japan, US etc. to follow soon
- Bioenergy in socio-economic, political and environmental country-specific context with option for CCS.
  - Incentives and funding
  - Co-benefits
- Capacity building: e.g. IIASA at
  COP18, 2012 in Doha, Qatar

- GCP-IIASA workshops 2013/2014 tbc.
- REDD+BECCS Session at IUFRO World Congress 2014
- ICBT-WBS Session and presentations…

THE SYSTEMS VIEW

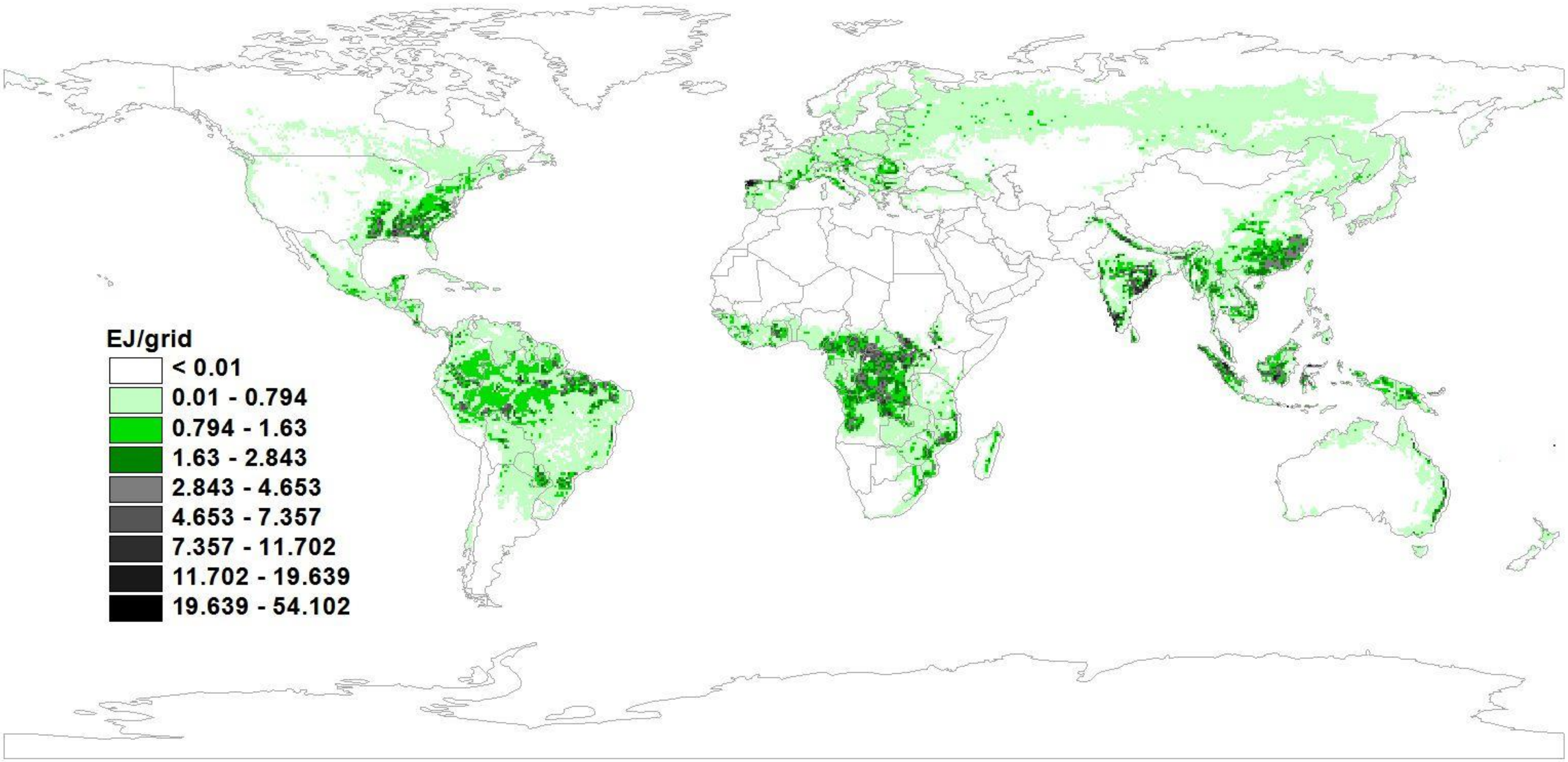



Global Future Energy Portfolios, 2000 – 2100

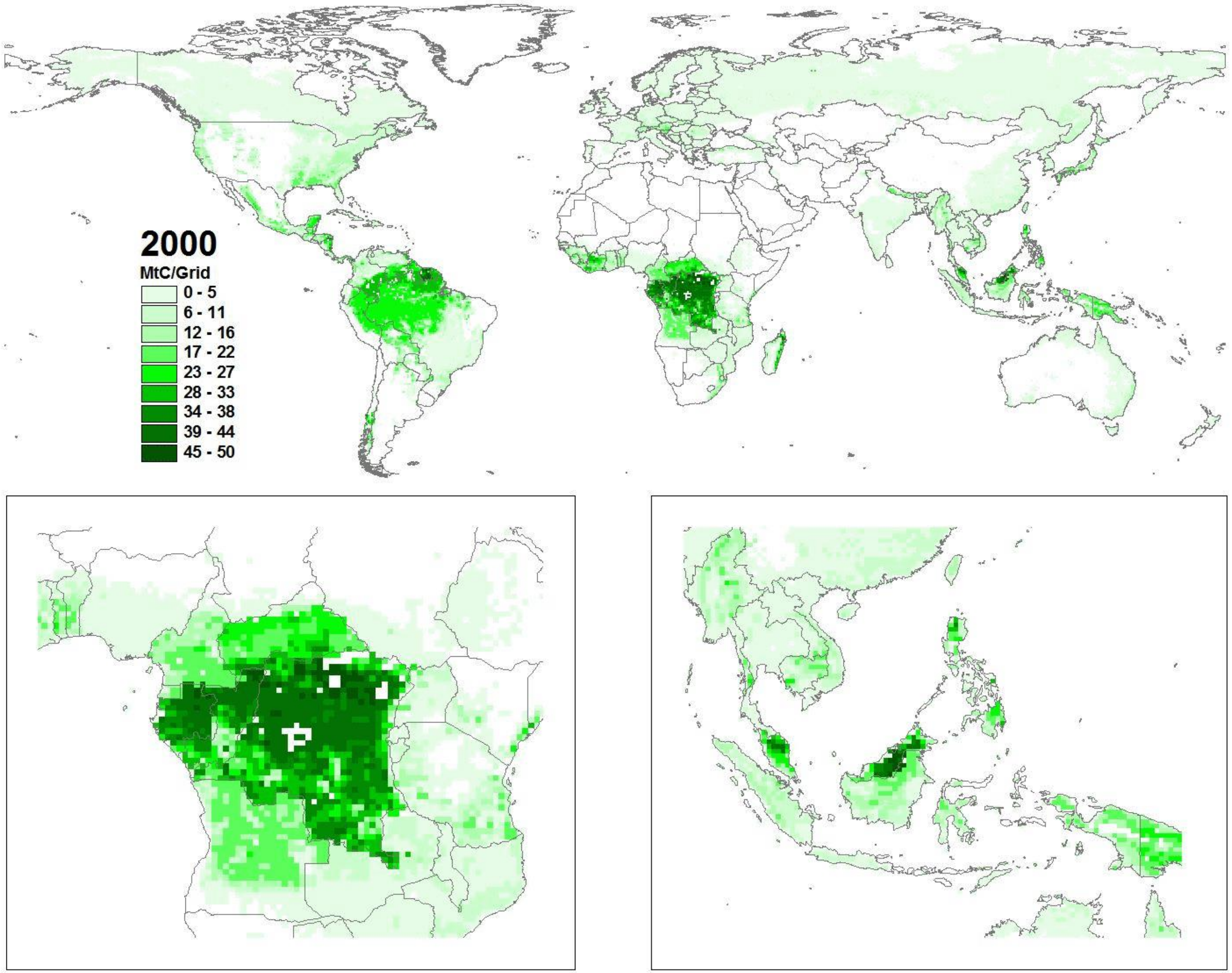


Source: modified after Azar et al., 2010

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



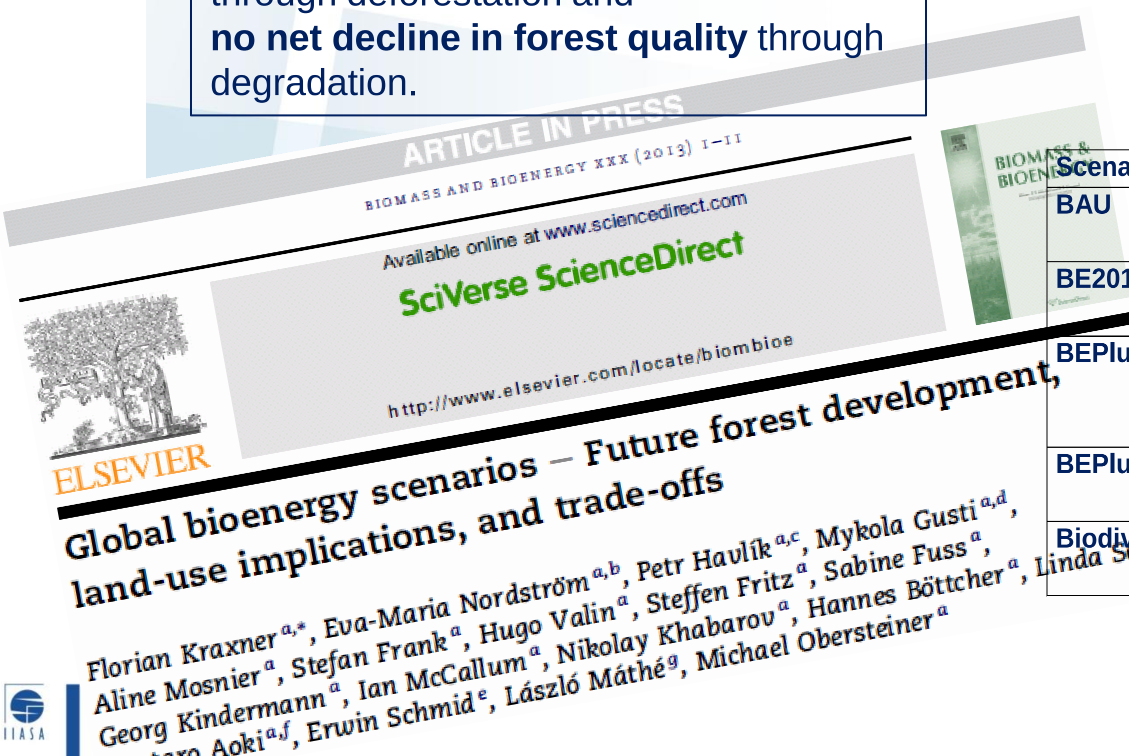
Source: IIASA, G4M (2008)

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


ARTICLE IN PRESS

BIOMASS AND BIOENERGY XXX (2013) 1–11

Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

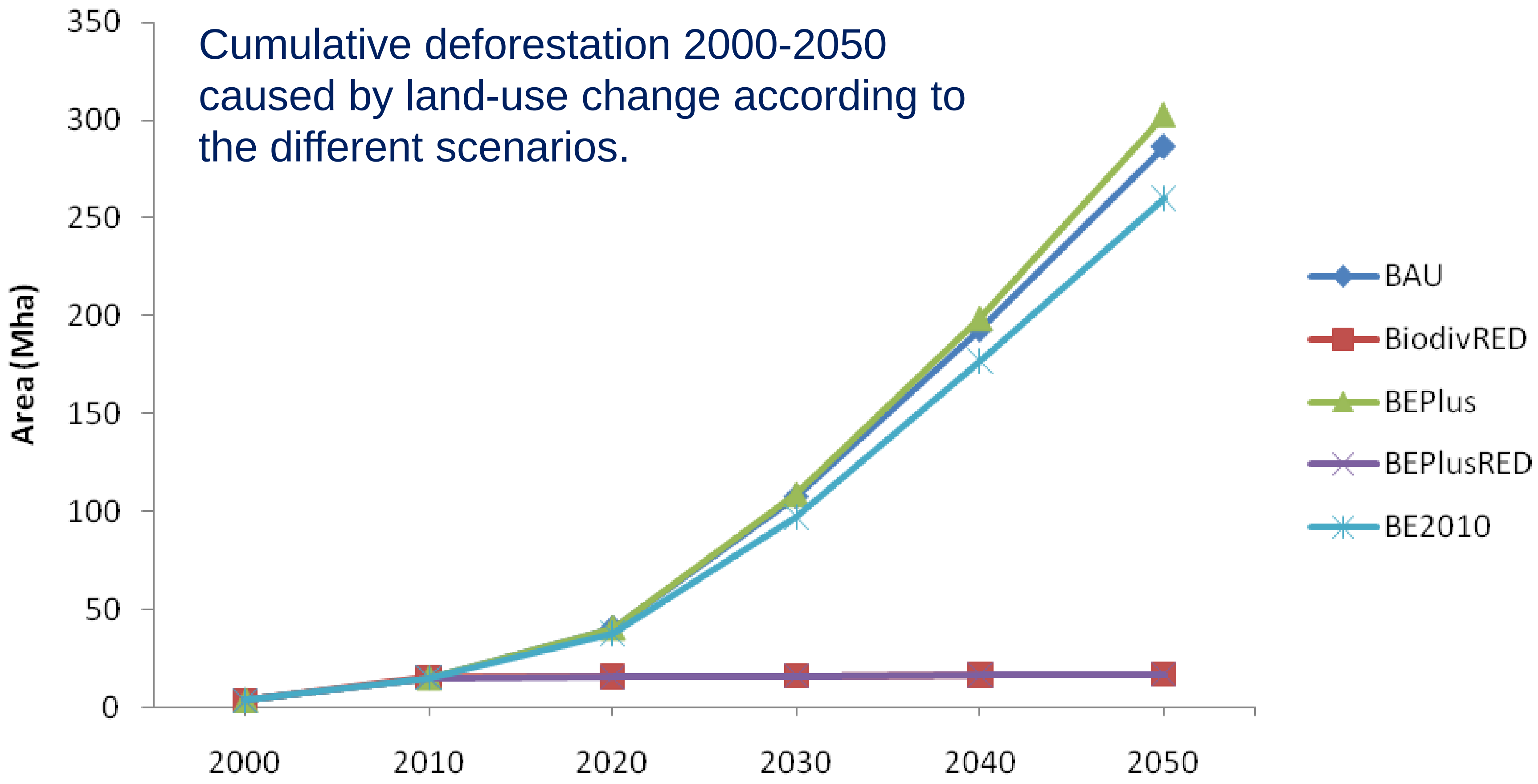
ELSEVIER

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'

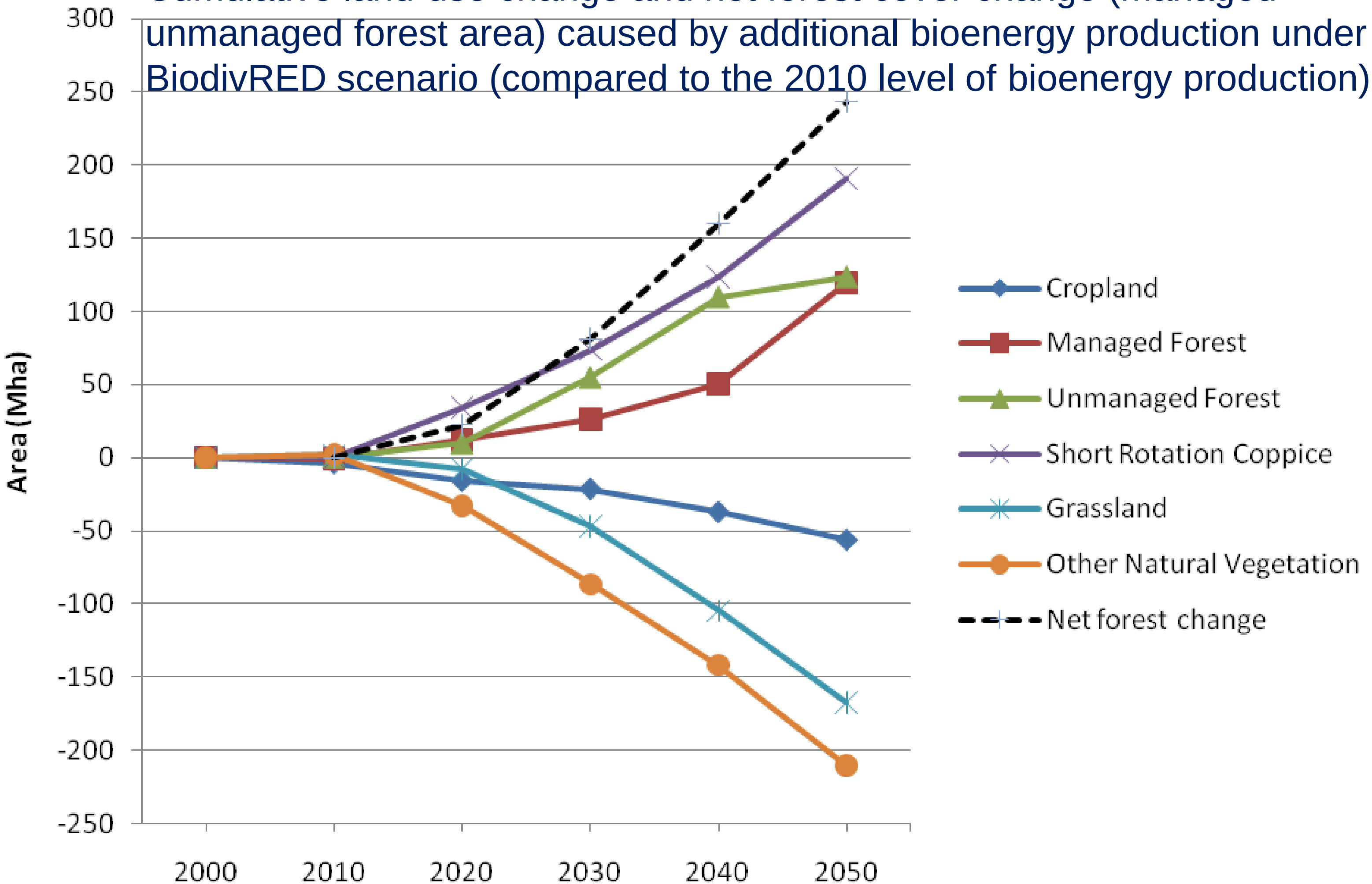
Global Deforestation Trends



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

Land Use Change – Effect of Adding BE, Biodiv & RED – rel to BAU

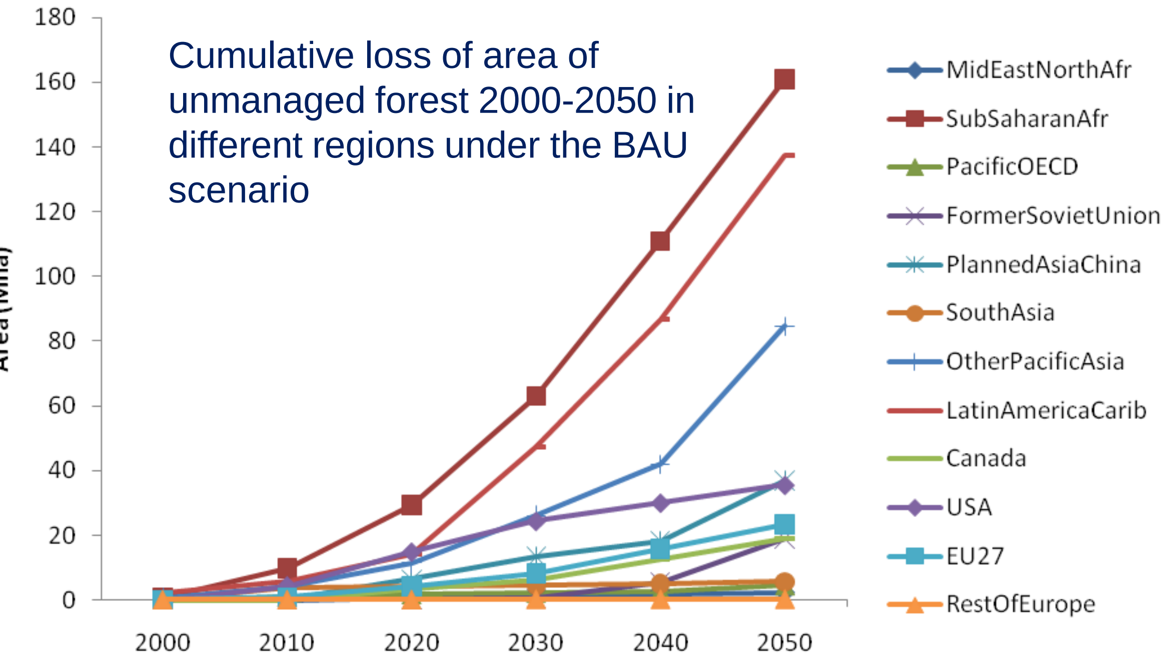
Cumulative land-use change and net forest cover change (managed + unmanaged forest area) caused by additional bioenergy production under the BiodivRED scenario (compared to the 2010 level of bioenergy production)

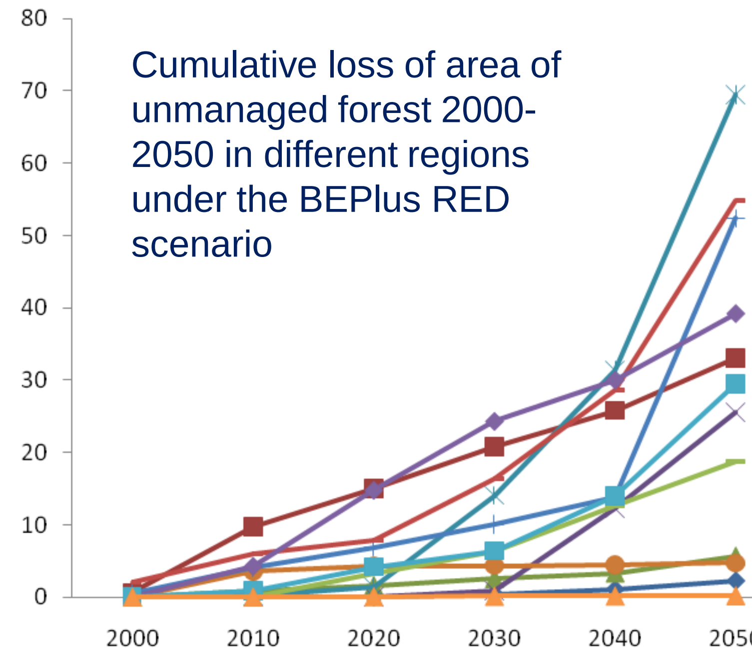


- Net gain of total forest area due to restriction of deforestation
- Protection of biodiversity within pristine and other types at the costs of grassland and savannah (which is mostly located in the southern hemisphere)

Regional Effects by Adding BE, Biodiv, RED - Unmanaged Forest rel to BAU

Loss of pristine (unmanaged) forest as a proxy for BE production on Biodiversity



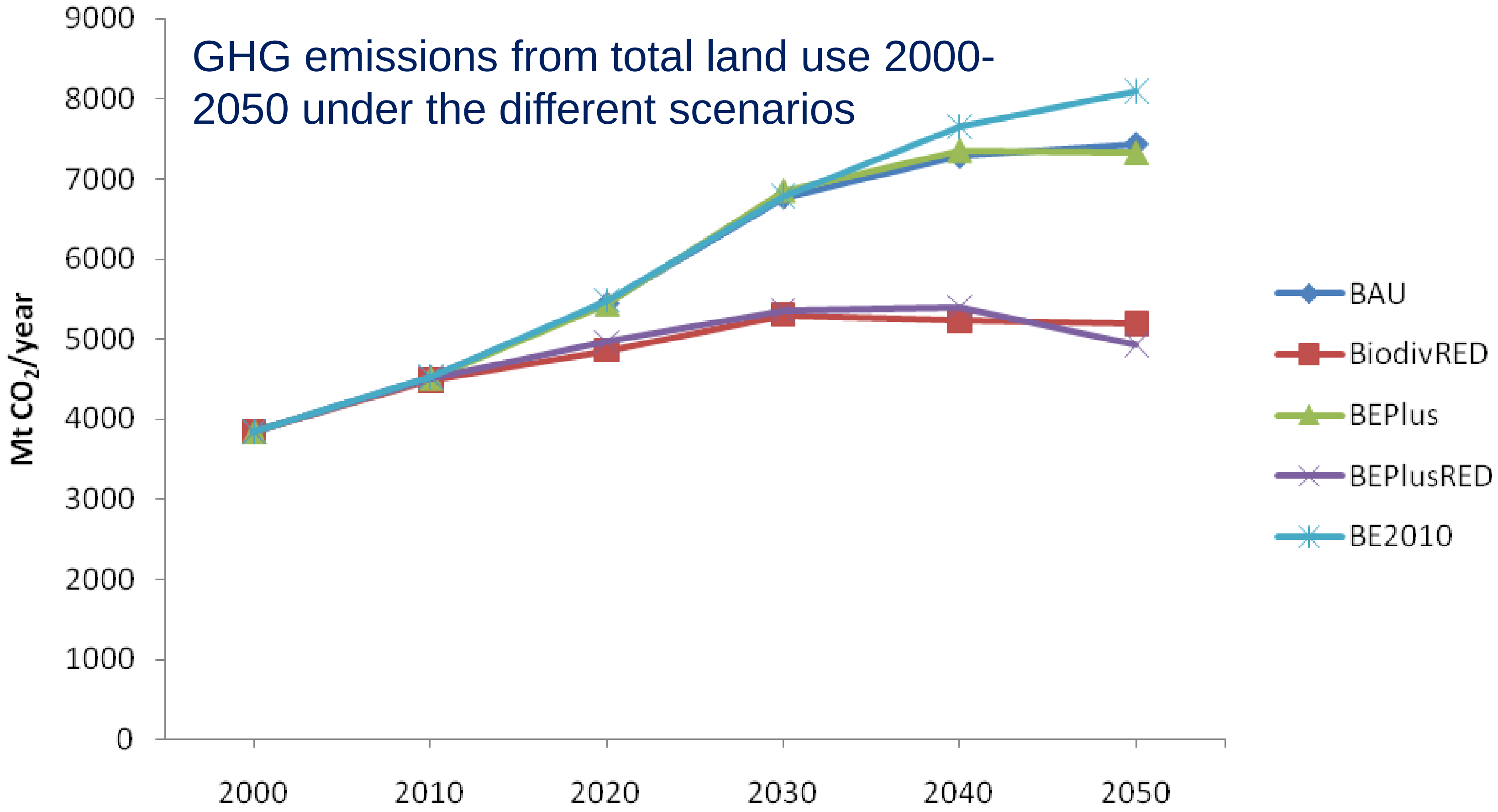


•most of the loss of unmanaged forest takes place in the tropical areas of South America, Africa and Asia

•the loss of unmanaged forest is not only considerably smaller but also more evenly distributed from a global perspective

IIASA

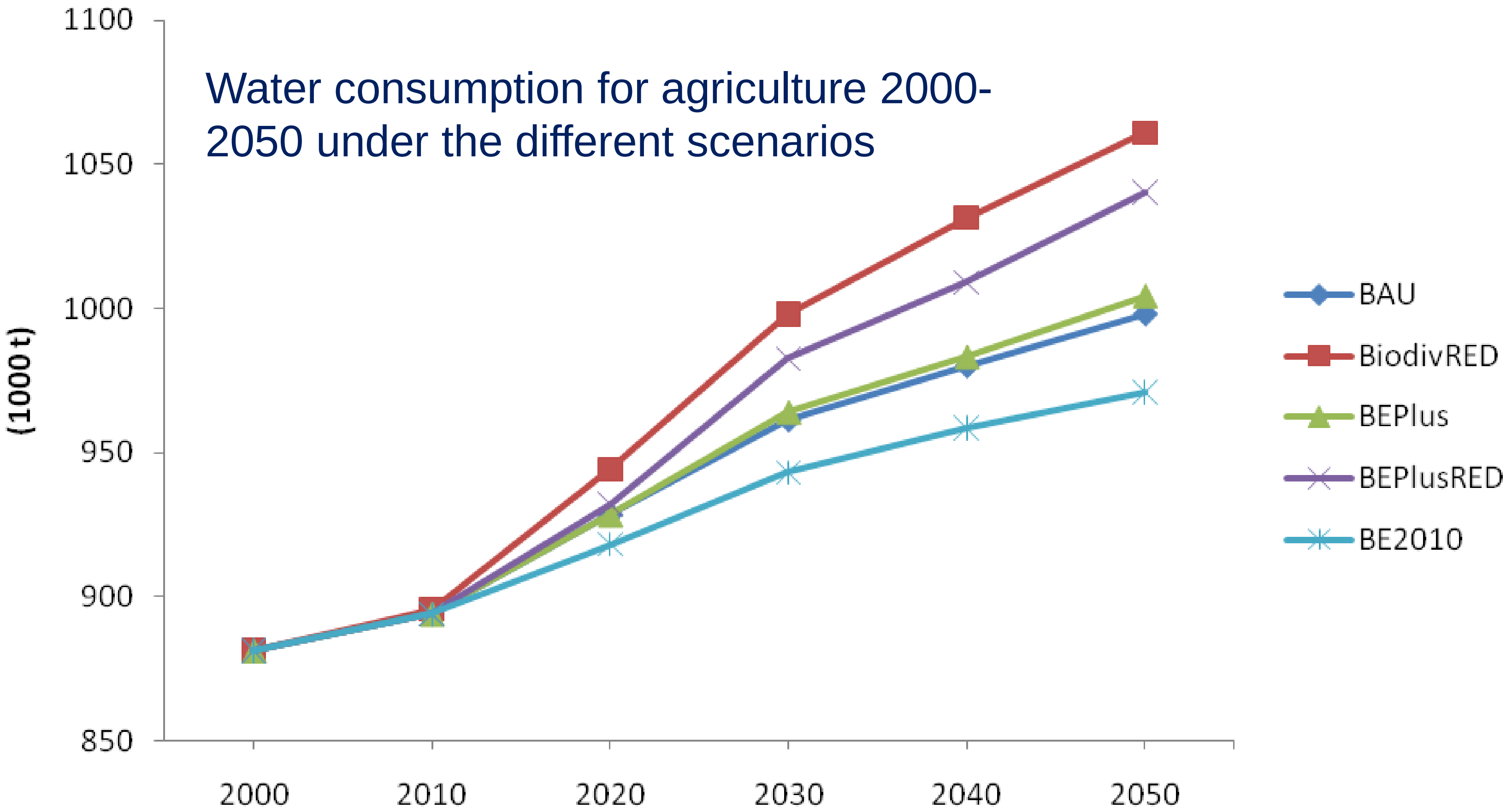
GHG Emissions by Scenarios



•Under the BE2010 scenario, the bioenergy use is small compared to the other scenarios, and the GHG emissions are the highest, 8,091 Mt CO2/year. The GHG emissions are lower under the BAU and BEPlus scenarios, where the bioenergy use is more extensive.

•Lowest GHG emissions can be achieved under the RED scenarios

Agricultural Water Demand by Scenarios



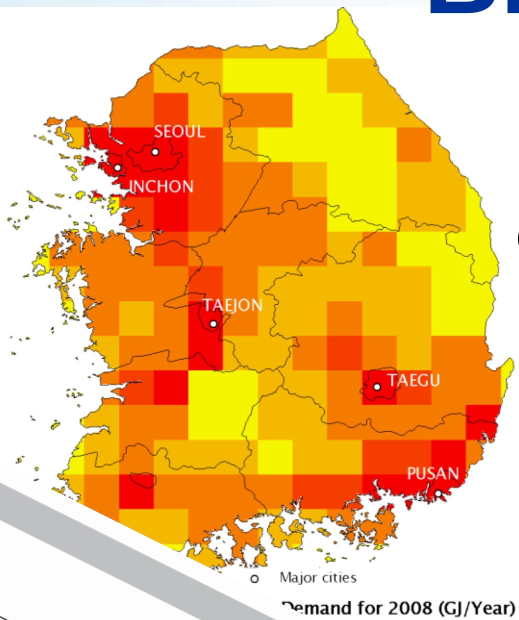
- All scenarios show increased demand
- Lowest restriction on forest and biodiversity conservation show less water need
- Higher restriction implies less land available for eg food production = intensification

BECCS CASE STUDIES - EXAMPLES

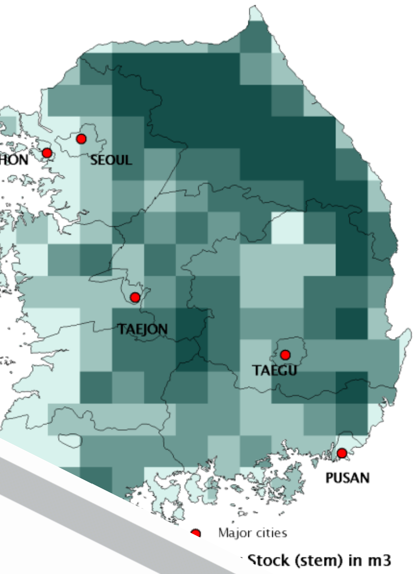



BECCS in South Korea

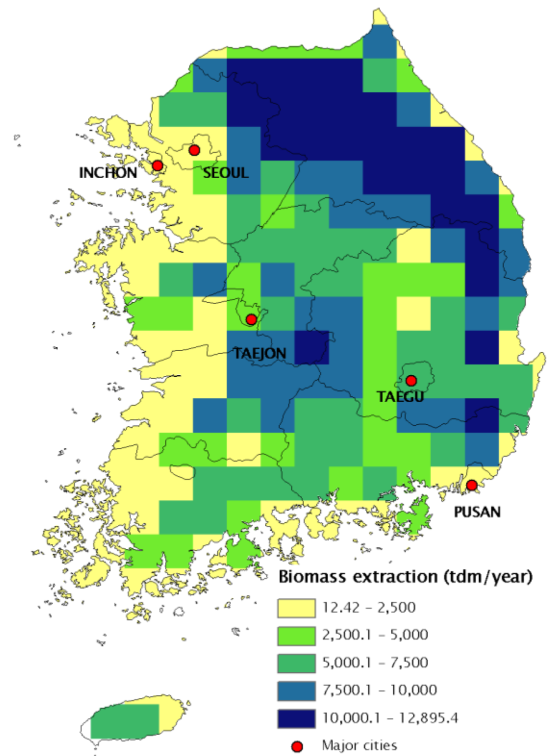
Demand vs Supply

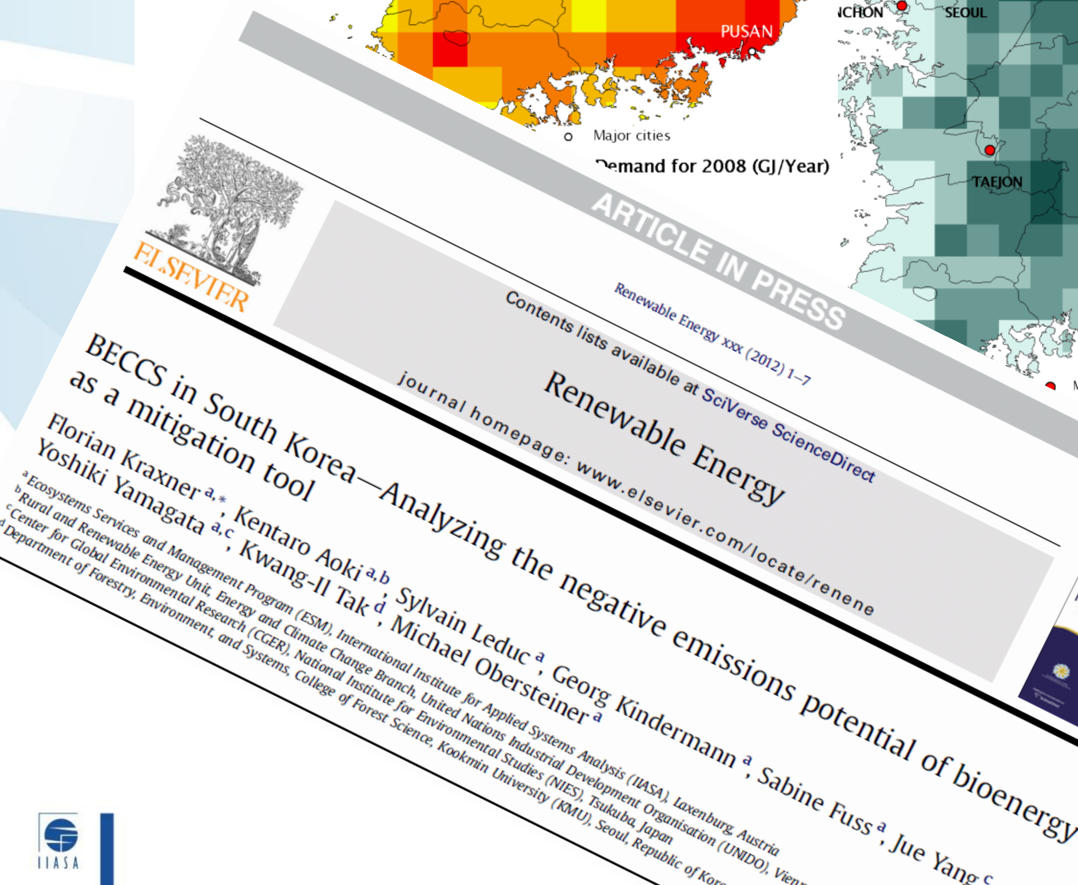


Growing Stock Modeled



Potential Biomass Extraction





ARTICLE IN PRESS

Renewable Energy xxx (2012) 1–7

Contents lists available at SciVerse ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

ELSEVIER

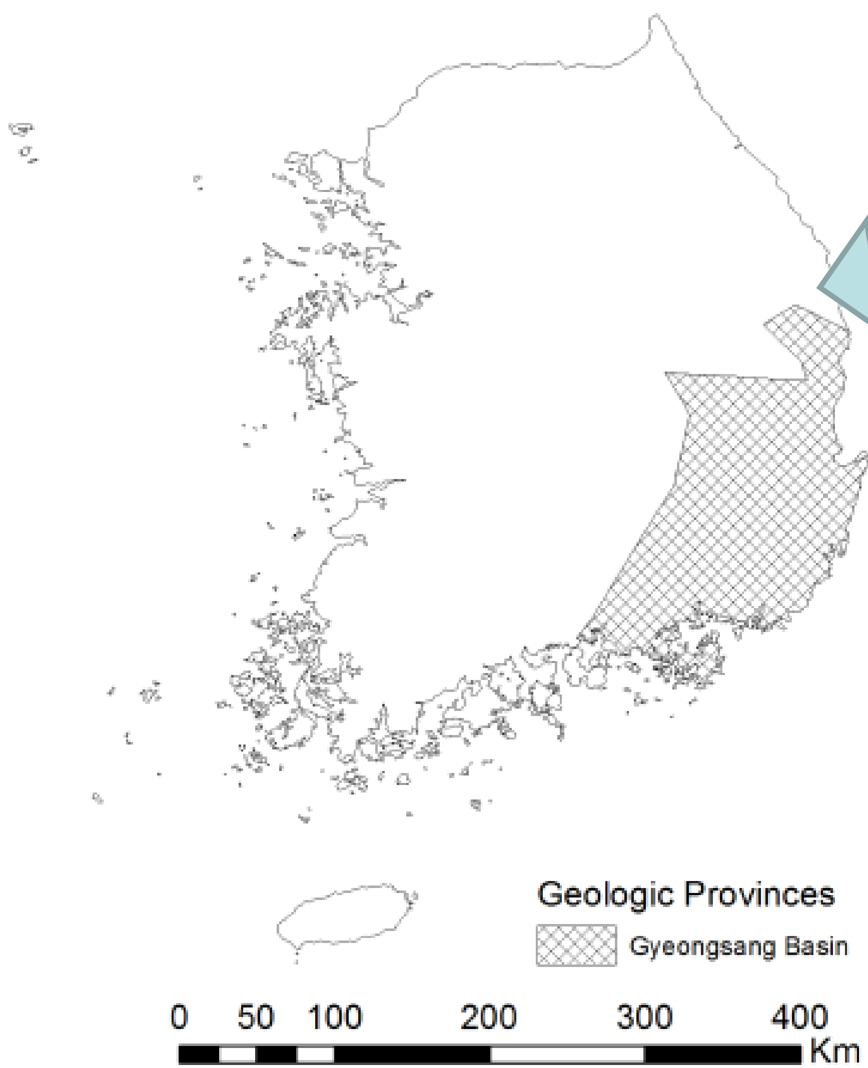
BECCS in South Korea—Analyzing the negative emissions potential of bioenergy as a mitigation tool

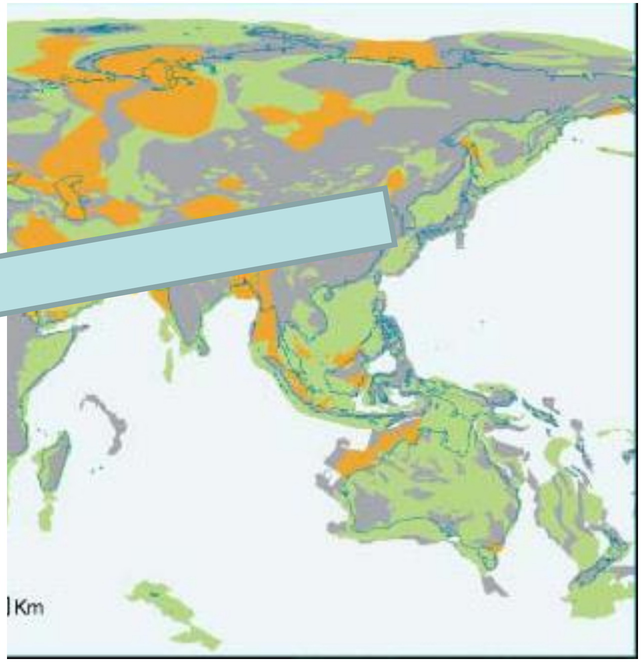
Florian Kraxner [a,*], Kentaro Aoki [a,b], Sylvain Leduc [a], Georg Kindermann [a], Sabine Fuss [a], Jue Yang [c], Yoshiki Yamagata [a,c], Kwang-Il Tak [d], Michael Obersteiner [a]

[a] Ecosystems Services and Management Program (ESM), International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
[b] Rural and Renewable Energy Unit, Energy and Climate Change Branch, United Nations Industrial Development Organisation (UNIDO), Vien
[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

Where to store the carbon? Prospectivity?

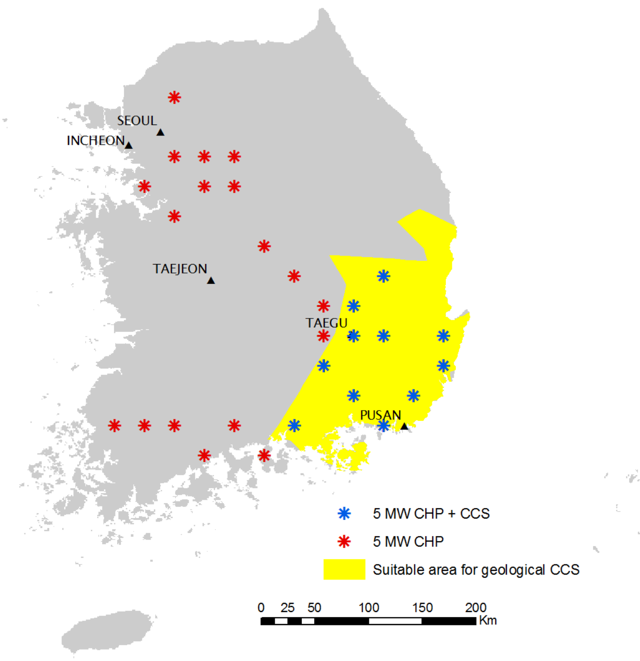


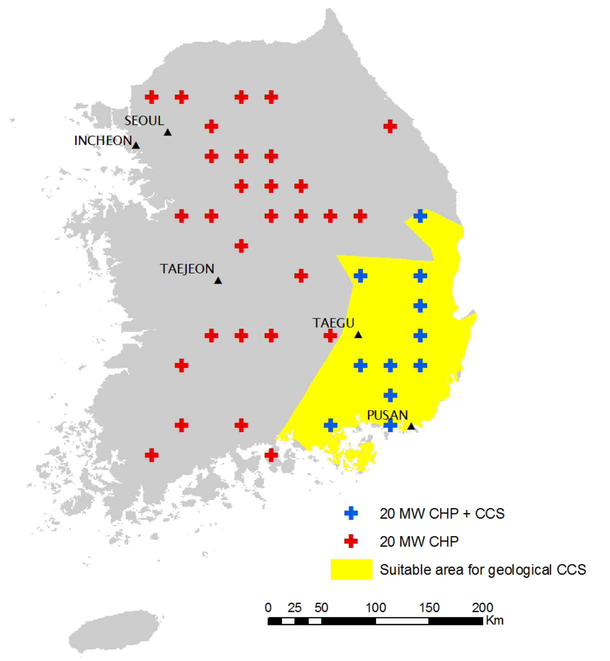


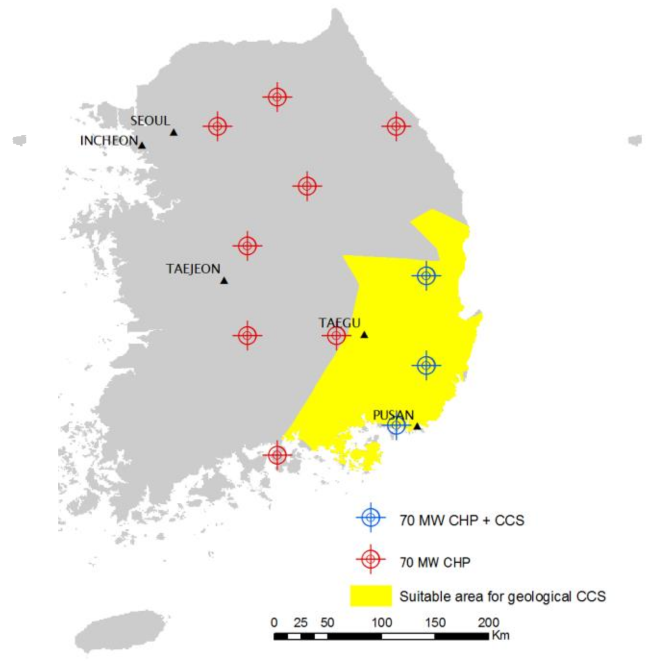
Scenario settings
CHP plants

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

Source: Bradshaw & Dance 2004



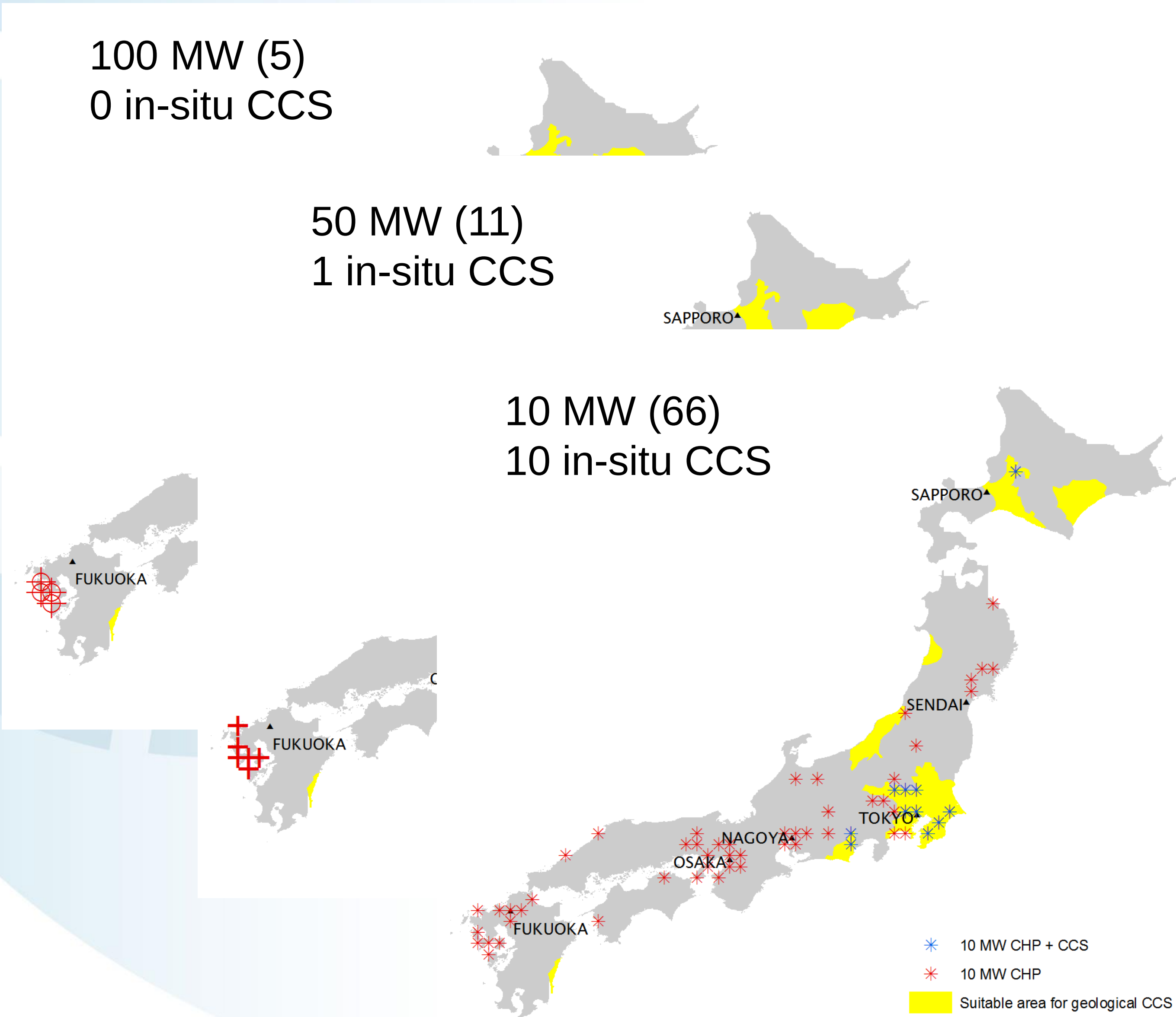




Plant size Technology	5 MW **NO** CCS	20 MW **NO** CCS	70 MW **NO** CCS	5 MW CCS	20 MW CCS	70 MW CCS
Plant #	18	29	8	11	11	3
Biomass used (tdm/year)	117,000	716,300	712,400	71,500	271,700	267,150
Heat produced (GJ/year)	1,190,475	7,288,353	7,248,670	727,513	2,764,548	2,718,251
El. produced (GJ/year)	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

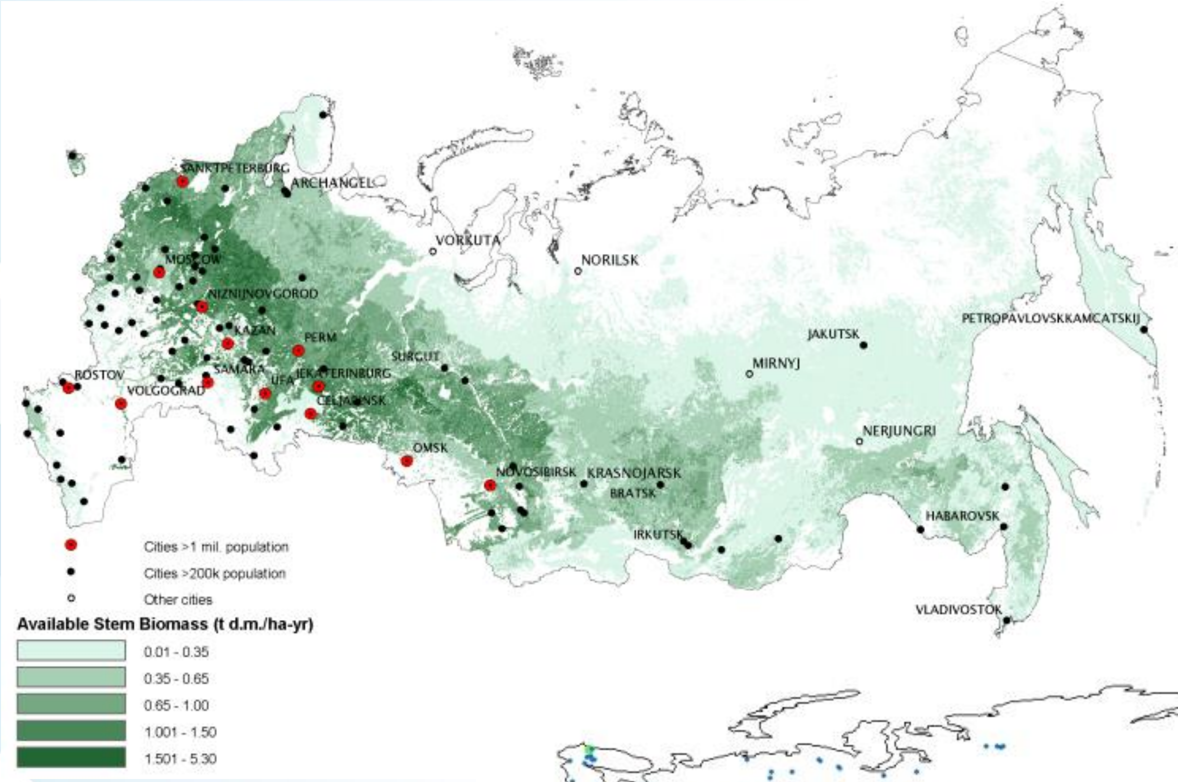
In-situ BECCS Potential in Japan

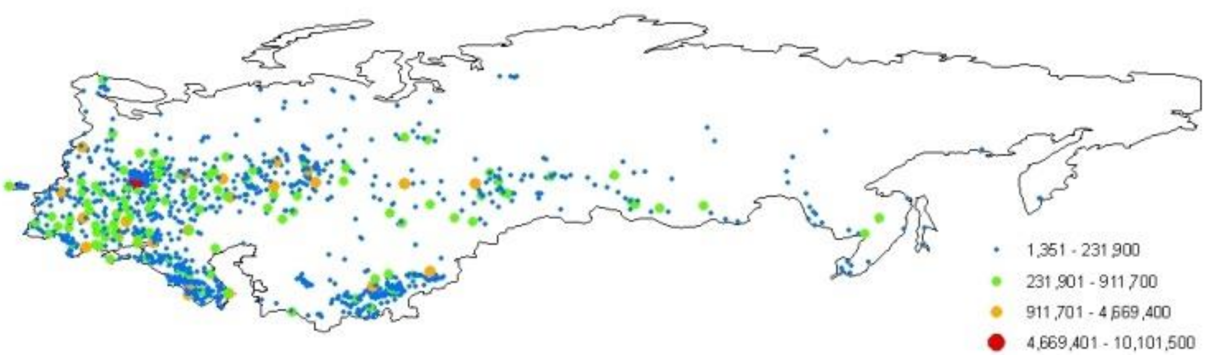


Total potential "in-situ" BECCS Effect: 1.5 million tons CO_2 per year

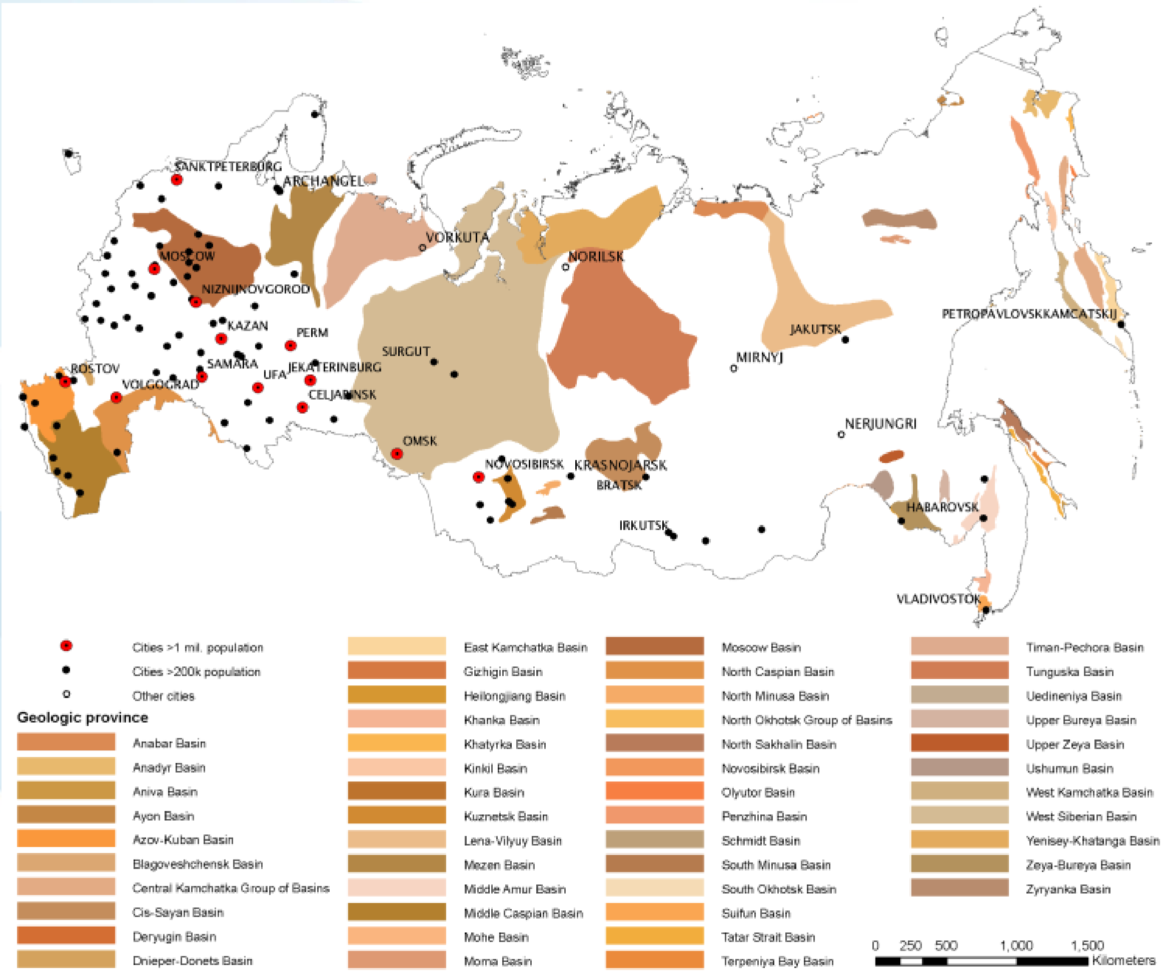
Total potential CO_2 substitution effect: 12-13 million tons CO_2 per year

Biomass Availability and Energy Demand for Russia





Geological suitability for carbon storage

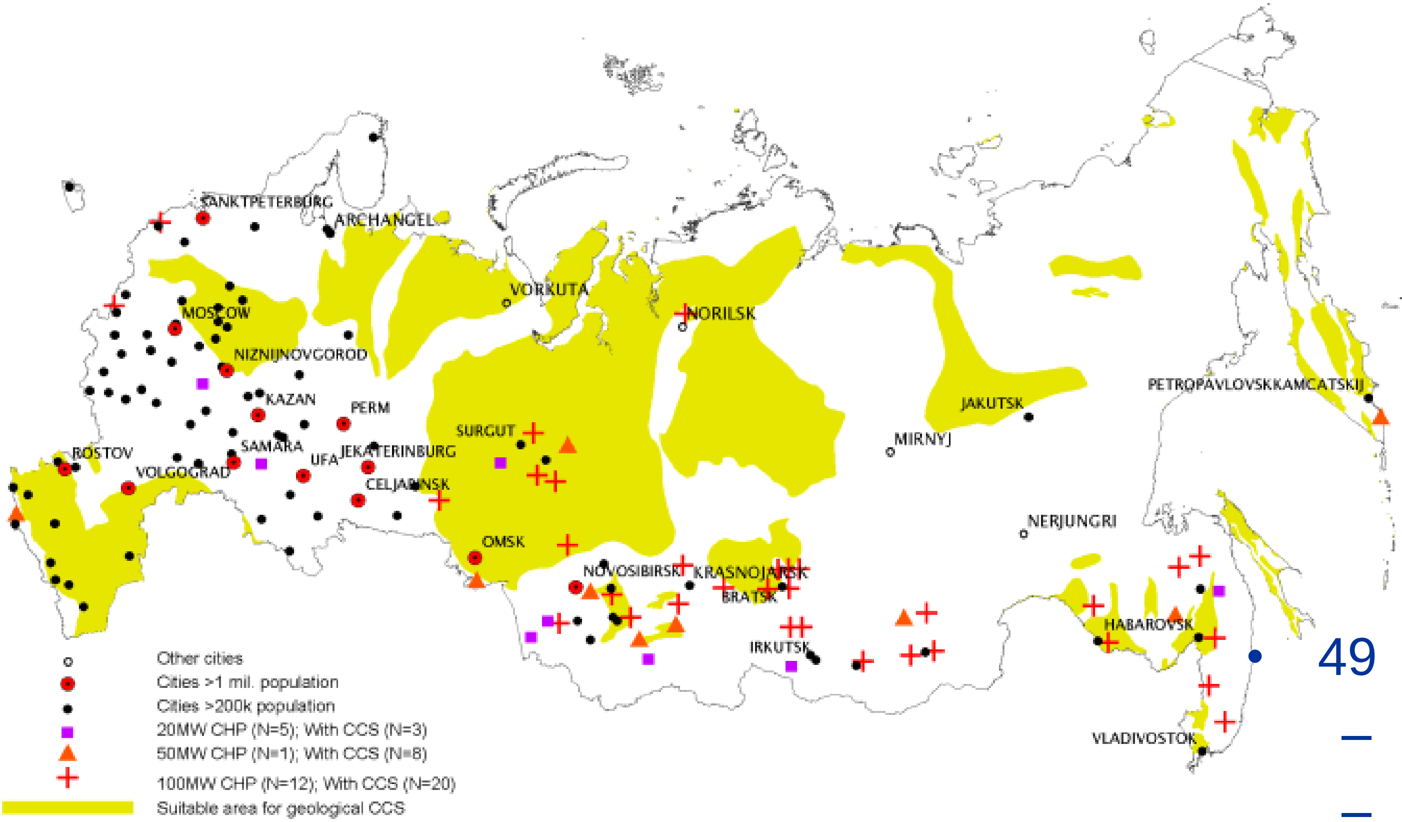


Suitable: basins formed in mid-continental locations; 2) basins formed near the edge of stable continental plates; 3) basins behind mountains formed by plate collision

Not suitable: Other geological formations such as shield areas (e.g., Scandinavia) or tectonically active areas (e.g., Japan) are less suitable for geological CO2 storage.

Geological suitability for CS depends to a large extent on local conditions.

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

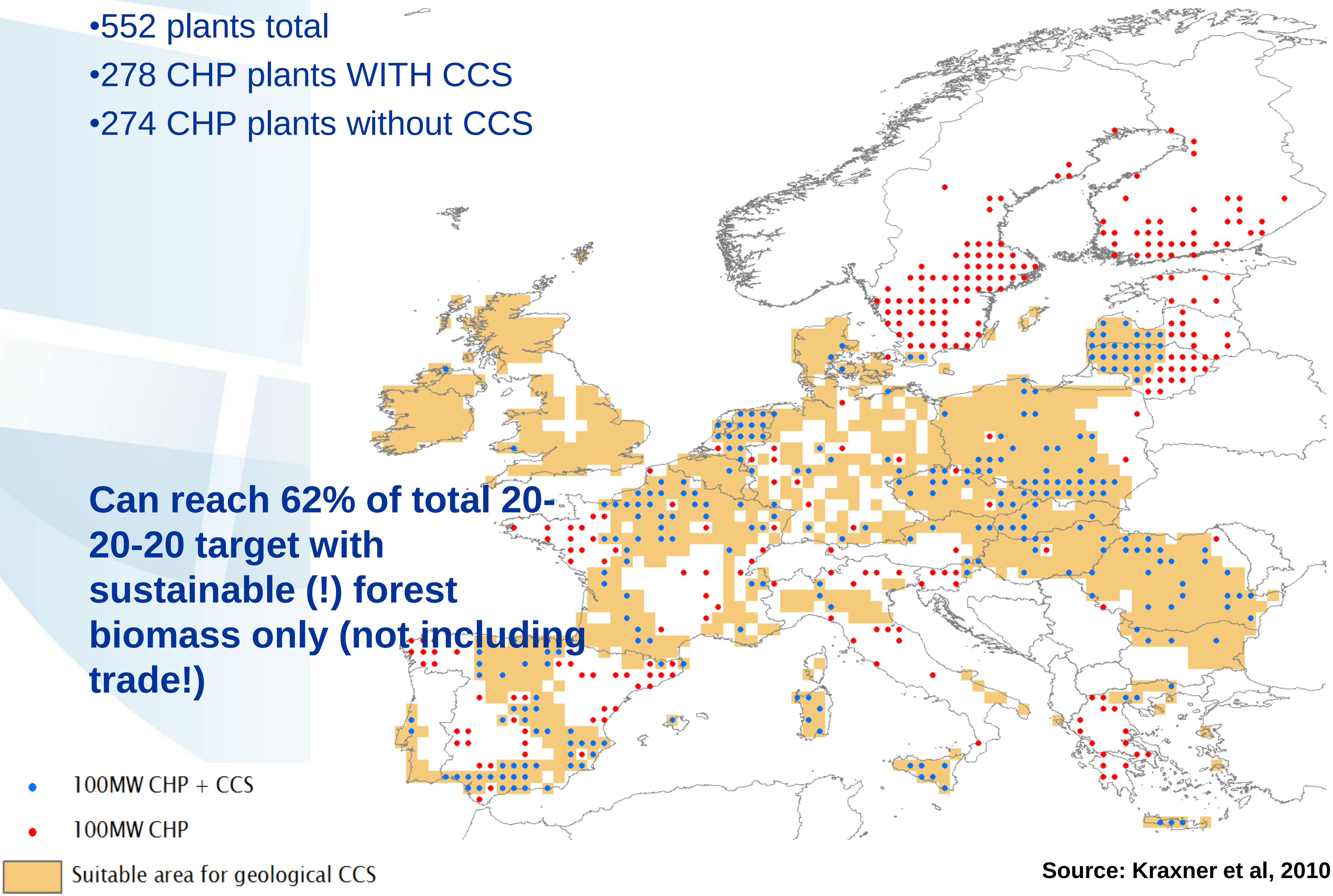


- 49 plants
  - 32 for 100MW plants
  - 8 for 20MW plants
  - 9 for 50MW plants
- 31 suitable for BECCS

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

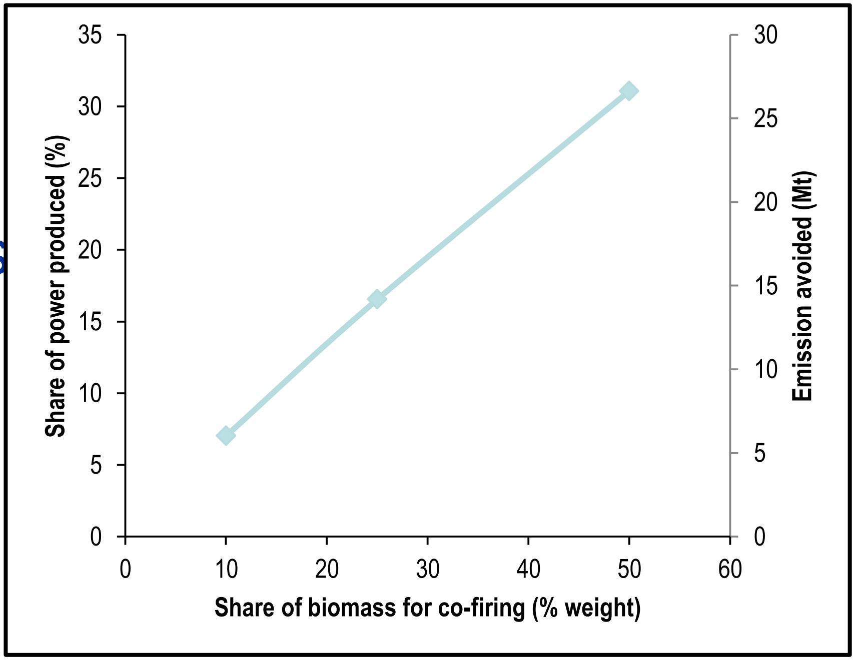
BIOMASS CO-FIRING AS A KICK-OFF OPPORTUNITY




Indonesia co-firing

- Coal plants installed capacity ~19 GW
- Indonesia electricity consumption ~ 140 TWh
- Target: to meet 10% / 30% of power consumption from renewable in co-firing

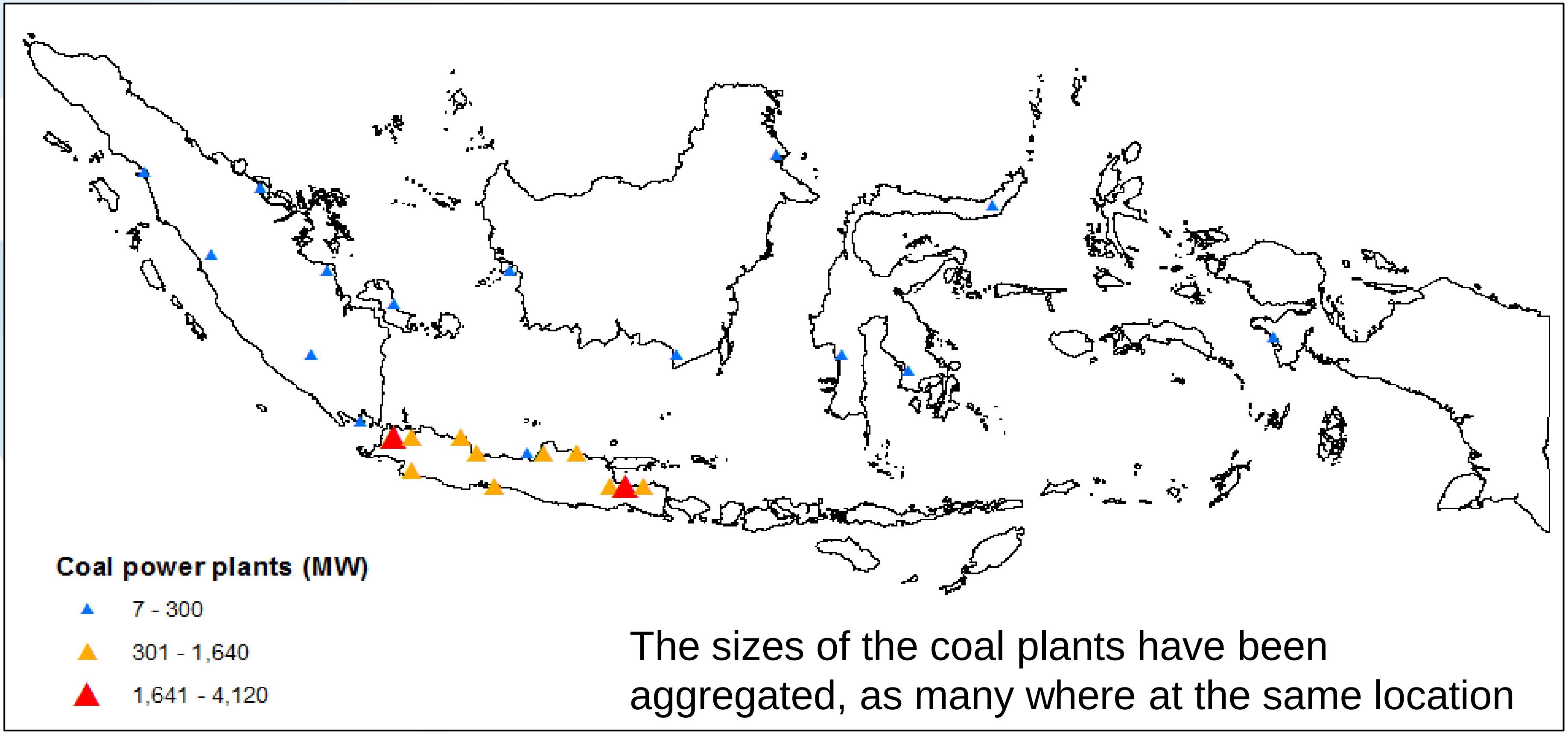
- 20% / 50% biomass co-fired
- ~ 20 / ~55 Mm^3 forest biomass



Scenarios	Co-firing	Forest
S1	20%	Managed
S2	20%	Managed and unmanaged
S3	50%	Managed
S4	50%	Managed and unmanaged

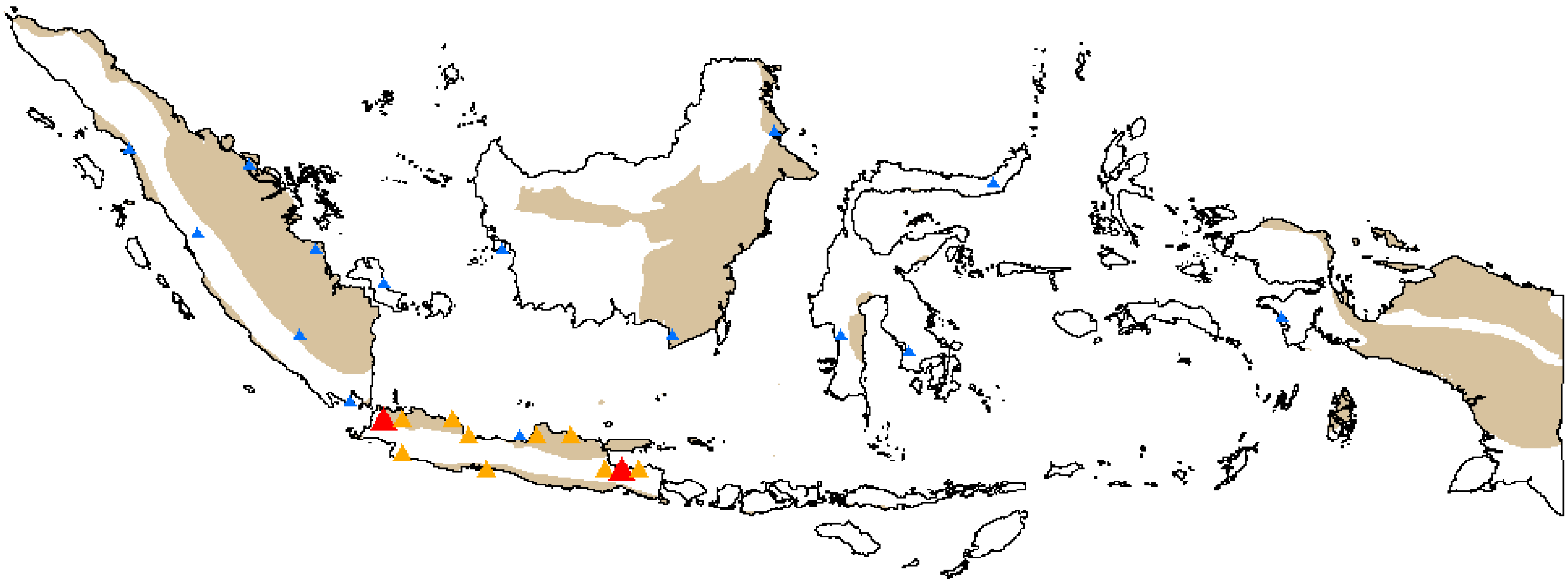
IIASA

Coal plants



The sizes of the coal plants have been aggregated, as many where at the same location

Coal plants and geographical basins

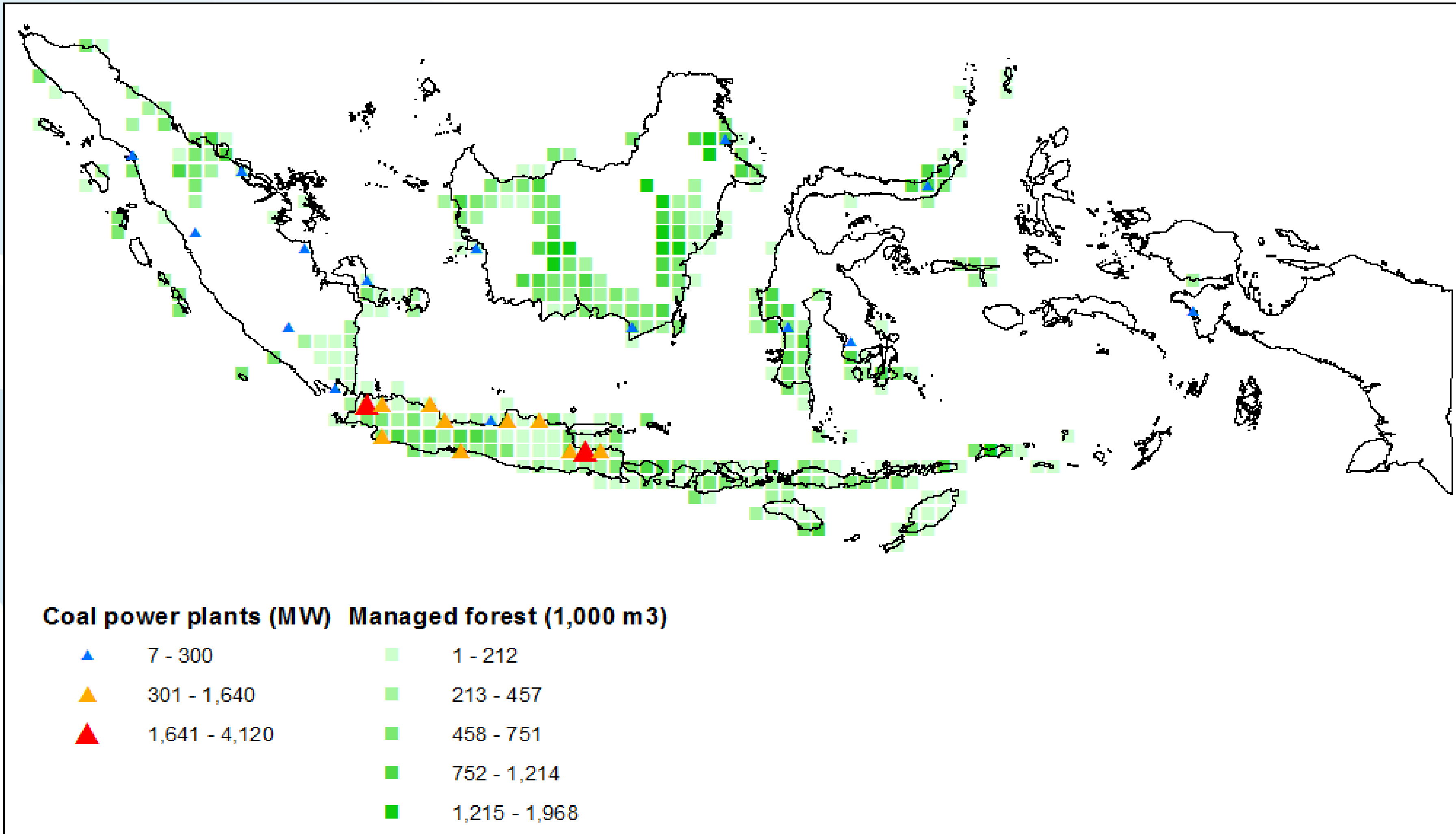


Coal power plants (MW)

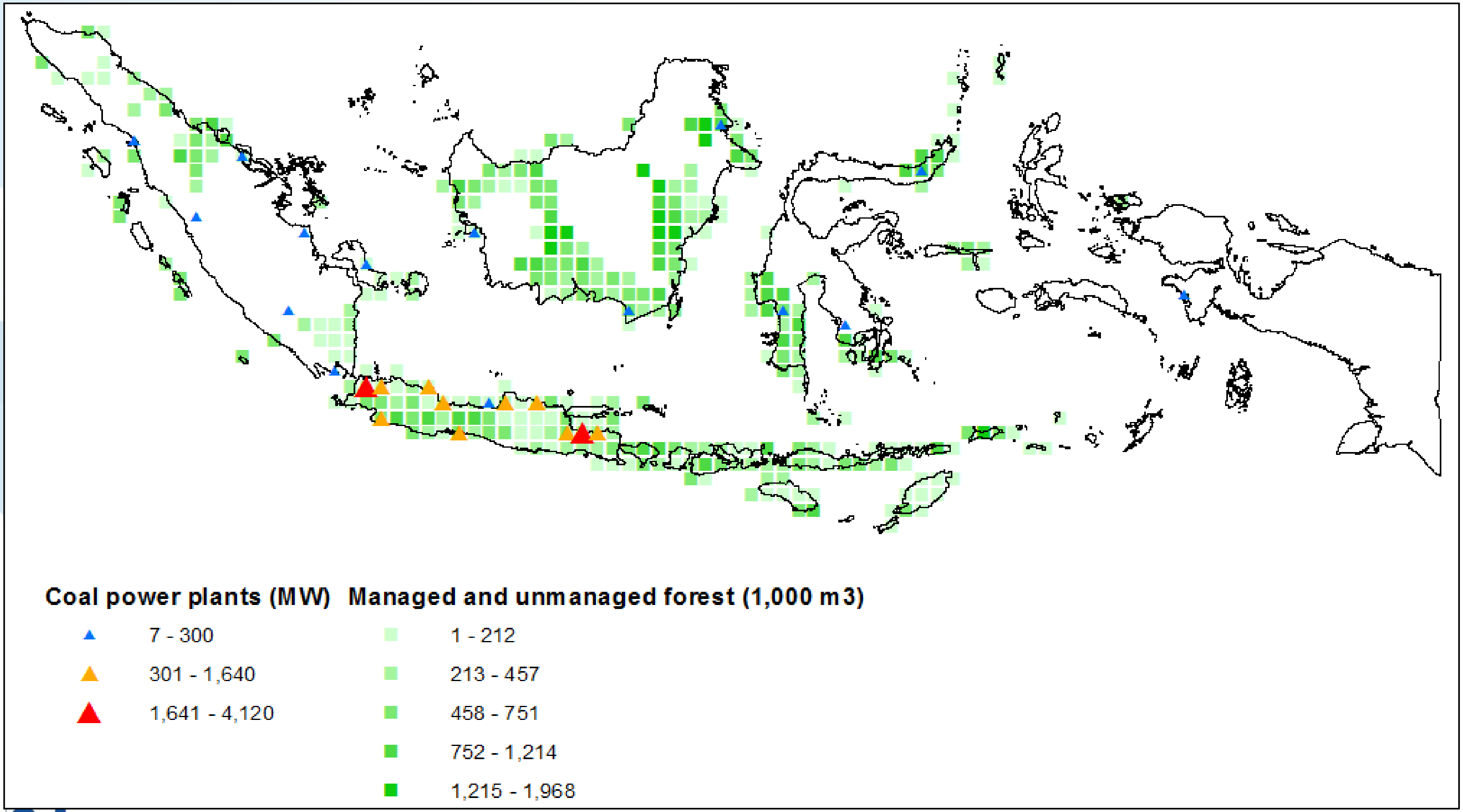
- 7 - 300
- 301 - 1,640
- 1,641 - 4,120
- Geological bassins

Most of the plants are located close to sequestration geographical basin, just 6 minor ones are not

50% co-firing / managed forest



50% co-firing / managed and unmanaged forest



First Results on Co-Firing with Biomass

Scenarios	Coal plants CO_2 emissions [Mt CO_2]	Biomass Co-Firing CO_2 emissions [Mt CO_2]	Saved emissions [Mt CO_2]	Substituted emissions [Mt CO_2]	Total system emissions [Mt CO_2]	Emissions captured through fossil CCS [Mt CO_2]	Negative emissions through BECCS [Mt CO_2]	Total System emission ballance [Mt CO_2]
No Co-Firing	294	0	0	0	294	294	0	**0**
20% Co-Firing	236	20	38	58	256	236	20	**- 20**
50% Co-Firing	148	51	103	154	199	148	51	**-51**

With BE/CCS

Example for Carbon benefit (50% co-firing + BE/CCS) @ 5 US$/ton:

2.3 Billion US $ / year

Co-benefits and other policy objectives

- Economic development & employment effects
  - Construction of infrastructure
  - Operation of bioenergy plants, transport, storage and management/harvesting of biomass feedstock
  - Electrification of rural households, decentralized energy solutions
  - Knock-on effects on local economies
- Conservation effects (sustainability/corridors)
- Health effects (clean energy access)
- Versus economy of scale

SUMMARY & CONCLUSIONS




- Need both – top-down & bottom-up
- Full scale/systems boundary (economic) assessment
- Competition for land, other products, water -> efficient management
- Sustainability criteria
- Geographic/climatic/social differences – low capacities under present conditions (harvested amount/products) for northern hemisphere…
- Which technology where?
- Bundling of capture (other CCS units), C-transport, C-storage (Geo)
- Efficiency varies strongly over technology
- Co-Benefits: BECCS, Avoiding Deforestation (Afforestation etc.) and Food security are necessary for long-term sustainability
- BECCS, REDD+ and Food can be synergistic if efficiently planned.
- Green Economy/Development/Energy access etc.
  - Trade, Investment, Technology
- Only a global and integrated land use approach will deliver
- Consider the ramp-up time… start now!

Contact

Florian Kraxner

Deputy Director
Ecosystem Services and Management Program
International Institute for Applied Systems Analysis, IIASA
Laxenburg, Austria
kraxner@iiasa.ac.at
http://www.iiasa.ac.at