Negative Emissions
BECCS Case Studies for Europe, South Korea, Japan and Russia

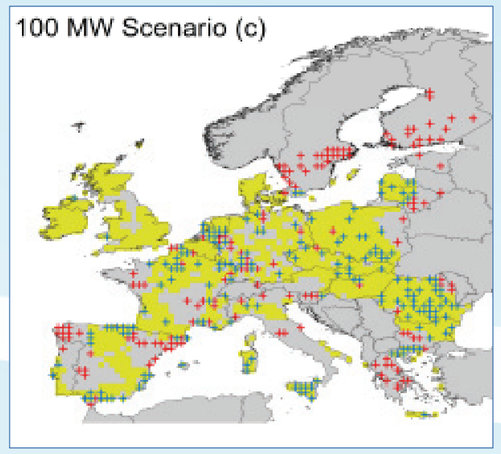
Kraxner F.[1]*, Leduc S.[1], Kindermann G.[1], Aoki K.[1,2], Fuss S.[1], Yang J.[3], Yamagata Y. [1,3], Il Tak K.[4], Schepaschenko D.[1], Shvidenko A.[1,5], Albrecht F.[1] and Obersteiner M.[1]

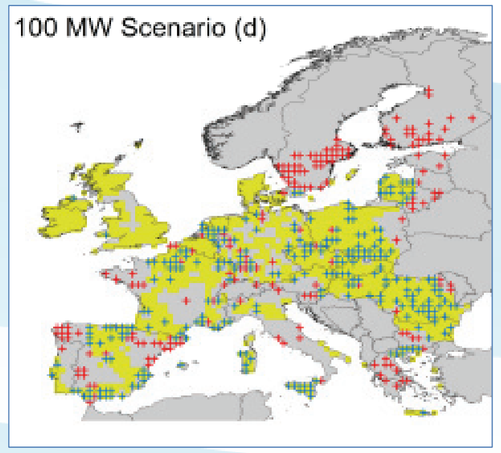
[1] Ecosystems Services and Management Program (ESM), International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
[2] Rural and Renewable Energy Unit, Energy and Climate Change Branch, United Nations Industrial Development Organisation (UNIDO), Vienna, Austria
[3] Center for Global Environmental Research (CGER), National Institute for Environmental Studies (NIES), Tsukuba, Japan
[4] Forest ResourcesDepartment, College of Forest Science, Kookmin University (KMU), Seoul, Republic of Korea
[5] Sukachev Institute, Russian Academy of Sciences, Siberian Branch, Krasnoyarsk, Russian Federation

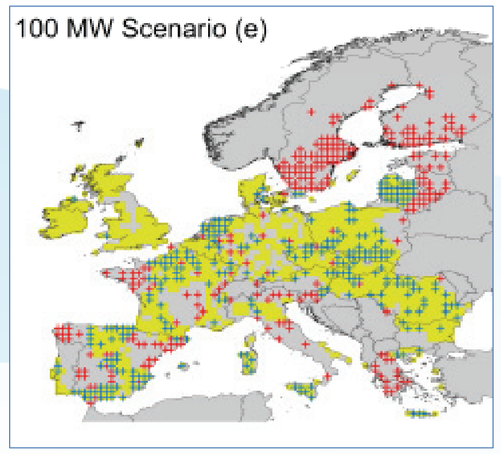
*** For questions please contact the corresponding author Florian Kraxner: Tel: +43 2236 807 233, Fax: +43 2236 807 299, E-mail: kraxner@iiasa.ac.at**

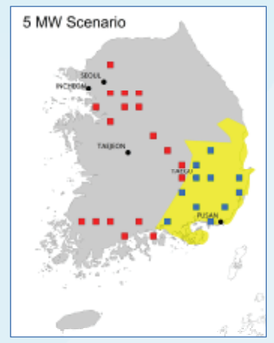
Background and Methodology

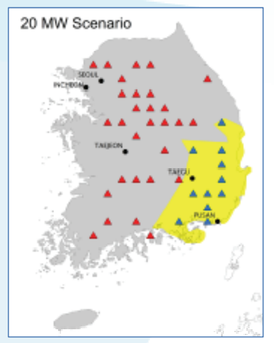
The use of bioenergy in combination with carbon capture and storage (BECCS) could make a substantial contribution to achieving low atmospheric CO2 concentration levels. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) considers BECCS as "a potential rapid-response prevention strategy for abrupt climate change" and thus as one of the options for achieving compliance with the targets agreed under the Kyoto Protocol. The objective of the presented case studies is to analyze the in situ BECCS capacity for green-field bioenergy plants in four different regions – Europe, Japan, Korea and Russia. The technical assessment is used to support a policy discussion on the suitability of BECCS as a mitigation tool. We examined the technical potential of bioenergy production from sustainably grown regional forest biomass. In a first step, IIASA's biophysical Global Forestry Model (G4M) was applied to estimate biomass availability. In a second step, the results from G4M were used as input data to IIASA's engineering model BeWhere, which optimizes scaling and location of coupled heat and power plants (CHP). The geographically explicit locations and capacities obtained for forest-based bioenergy plants were then overlaid with a geological suitability map for carbon storage (see maps in the center of the poster). From this, a theoretical potential for in situ BECCS was derived (displayed in the regional tables on the right).

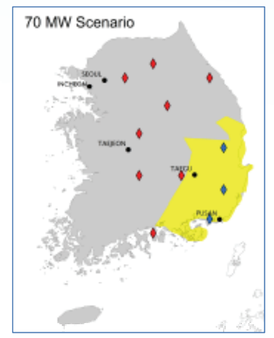










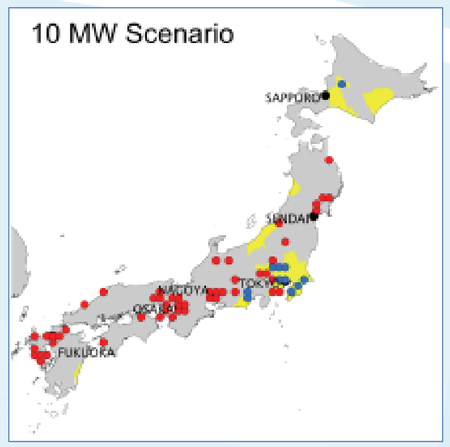


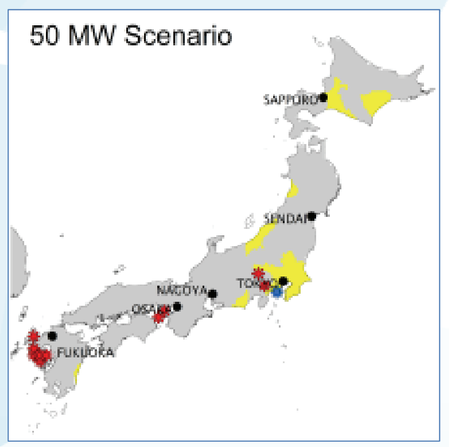
Europe

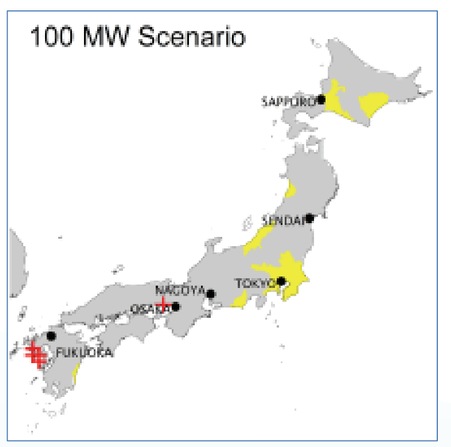
BECCS, using CHP technology, might contribute substantially to reaching the 20-20-20 targets of the European Union (i.e., generating 20 percent of the total energy demand from renewables and reduce total EU emissions by 20 percent until 2020, calculated from a 1990 baseline). Bioenergy production (from green field CHP plants) has the technical potential to contribute more than 60 percent toward achieving the goal of 20 percent renewable energy share in the EU by 2020. When assuming in situ storage at the location of the bioenergy plants, about half of the "carbon-neutral emissions" from these bioenergy plants could be captured, stored, and accounted for as negative emissions (see map).

Korea

Although the geological formations suitable for in situ Carbon Storage (CS) in South Korea are limited, the theoretical potential for between 3 (70 MW plants) and 11 (5 or 20 MW plants) green-field BECCS plants with in situ CS. Based on our assumptions, the BECCS effect could remove 130,000–240,000 tons of CO_2 per year from the atmosphere, and a similar amount could be substituted for fossil fuel emissions. This means that about 3–4% of the total demand for heat energy in South Korea could be produced in BECCS plants with in situ CS. As a result, 3–4% of fossil fuel emissions could be substituted and additionally accounted for as negative. This BECCS effect is in addition to the multiple biomass co-benefits (green economy, rural development etc.) and could be used as one key issue for future policy design and decision making.





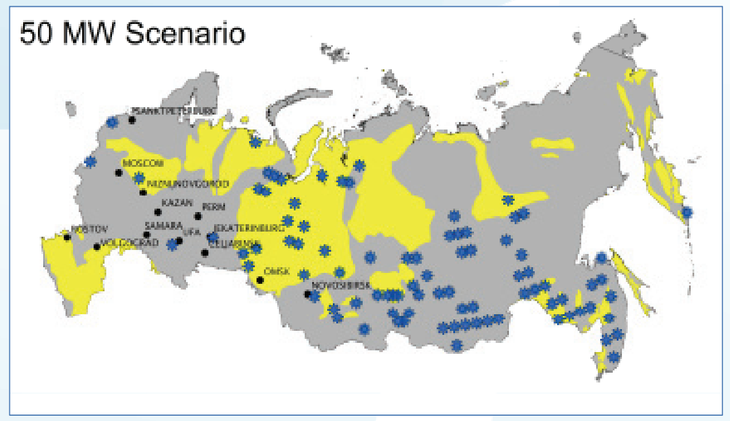


Japan

The 10 MW scenario turned out to offer the best country-wide coverage with its 61 green-field bioenergy facilities, which consequently could provide direct and indirect co-benefits such as driving the green economy, i.e. providing job opportunities both at the facility and in the biomass production. There is a theoretical potential for 1 (50 MW plants) to 10 (10 MW plants) green-field BECCS plants with in-situ CS. The BECCS-effect might amount to 1,3 – 1,5 million tons CO_2 per year in addition to an amount of 12-13 million tons CO_2 per year substituted fossil fuel emissions.

Russia

The 50MW scenario would be a compromise between reaching de-central areas and the economies of scale effect. The 100MW scenario features still a good distribution over the country. However, given its big size, the plants are more suitable close to big cities and industrial zones (Siberia). Total emission reductions (direct substitution of fossil fuels plus the negative emissions effect of the BECCS plant) was lowest with the low-capacity scenario and are increasing with the plant capacity reaching a maximum of some 13.5 Mt CO2/year. The mixed capacity scenario showed the 3rd highest emission reduction while it featured the relative highest emission savings effect through its BECCS plants.



Europe	plants	biomass used		heat	electricity	Total energy	CO_2 saved
Scenario (% of 20-20-20 target)	Total #	GJ/year	tdm/year	GJ/year	GJ/year	GJ/year	t_CO2/yr
c (45%)	332	4,703,707,678	254,254,469	2,824,580,000	1,552,223,534	4,376,803,534	507,705,427
d (55%)	434	5,440,188,728	294,064,256	3,410,660,000	1,795,262,280	5,205,922,280	593,357,853
e (62%)	552	8,125,200,000	439,200,000	4,468,860,000	2,681,316,000	7,150,176,000	751,449,670

MW Scenarios South Korea		10	50	100
NoCCS	Number of Plants	50	10	5
	Biomass used (tdm/year)	554,125	487,957	487,957
	Heat produced (GJ/year)	6,613,750	6,613,750	6,613,750
	Power produced (GJ/year)	4,208,750	4,208,750	4,208,750
	Subst. emissions (tCO2/year)	1,214,525	1,214,525	1,214,525
	CCS Capacity (tCO2/year)	**0**	**0**	**0**
BECCS	Number of Plants	11	1	0
	Biomass used (tdm/year)	630,957	552,957	487,957
	Heat produced (GJ/year)	8,068,775	7,275,125	6,613,750
	Power produced (GJ/year)	5,134,675	4,629,625	4,208,750
	Subst. emissions (tCO2/year)	13,203,405	11,904,750	10,822,500
	CCS Capacity (tCO2/year)	**1,481,721**	**1,335,978**	**1,214,525**

MW Scenarios Japan		5	20	70
NoCCS	Number of Plants	18	29	8
	Biomass used (tdm/year)	117,000	716,300	712,400
	Heat produced (GJ/year)	1,190,475	7,288,353	7,248,670
	Power produced (GJ/year)	757,575	4,638,043	4,612,790
	Subst. emissions (tCO2/year)	215,516	627,050	625,036
	CCS Capacity (tCO2/year)	**0**	**0**	**0**
BECCS	Number of Plants	11	11	3
	Biomass used (tdm/year)	71,500	271,700	267,150
	Heat produced (GJ/year)	727,513	2,764,548	2,718,251
	Power produced (GJ/year)	462,963	1,759,258	1,729,796
	Subst. emissions (tCO2/year)	131,704	237,847	234,389
	CCS Capacity (tCO2/year)	**2.10**	**3.22**	**5.73**

MW Scenarios Russia		10	20	50	100	20/50/100
NoCCS	Number of Plants	78	65	41	20	5/1/12
	Biomass used (Mtdm/year)	1.13	1.75	3.18	3.83	1.76
	Heat produced (PJ/year)	11.46	17.79	32.35	38.99	17.86
	Power produced (PJ/year)	7.29	11.32	20.59	24.81	11.36
	Emission savings from CHP (MtCO2/year)	1.88	3.08	4.60	4.18	2.86
BECCS	Number of Plants	87	68	51	34	3/8/20
	Biomass used (Mtdm/year)	1.00	1.62	2.35	2.21	3.20
	Heat produced (PJ/year)	11.42	17.53	31.19	38.70	32.54
	Power produced (PJ/year)	7.27	11.15	19.85	24.63	20.71
	Emission savings from CCS (MtCO2/year)	0.98	1.59	2.30	2.16	3.13
	Emission savings from CHP (MtCO2/year)	2.10	3.22	5.73	7.11	5.22

Legend

- 100 MW CHP
- 100 MW CHP + CCS
- 70 MW CHP
- 70 MW CHP + CCS
- 50 MW CHP
- 50 MW CHP + CCS
- 20 MW CHP
- 20 MW CHP + CCS
- 10 MW CHP
- 10 MW CHP + CCS
- 5 MW CHP + CCS
- 5 MW CHP + CCS
- Suitable area for geological CCS

Key References:

Azar C, Lindgren K, Obersteiner M, Riahi K, van Vuuren DP, den Elzen MGJ, Möllersten K, Larson ED (2010). The feasibility of low CO2 concentration targets and the role of bio-energy carbon-capture and storage. Climatic Change 100(1):195–202.

Kraxner F, Nilsson S, Obersteiner M, Negative emissions from BioEnergy use, carbon capture and sequestration (BECS)—the case of biomass production by sustainable forest management from semi-natural temperate forests. Biomass Bioenerg 24 (2003) 285 – 296

Kraxner F, Kindermann G, Leduc S, Aoki K, Obersteiner M. Bioenergy Use for Negative Emissions—Potentials for Carbon Capture and Storage (BECCS) from a Global Forest Model Combined with Optimized Siting and Scaling of Bioenergy Plants in Europe. Paper presented at the First International Workshop on Biomass & Carbon Capture and Storage, October 2010, University of Orléans, France; http://www.univ-orleans.fr/leo/bccs/index.php

Kraxner F, Aoki K, Leduc S, Kindermann G, Fuss S, Kinoshita T, Yang J, Yamagata Y, Obersteiner M. BECCS in Japan – The Potential of Negative Emissions from Bioenergy Paper presented at the 2nd Biomass & Carbon Capture and Storage (Bio-CCS) Workshop, 25-26 October 2011, Cardiff University, Wales, UK; http://www.cugtrc.co.uk/categories.html?cid=55

Kraxner F, Aoki K, Leduc S, Kindermann G, Yang J, Yamagata Y, Il Tak K, Obersteiner M. BECCS in South Korea – An Analysis of Negative Emissions Potential for Bioenergy as a Mitigation Tool. Proceedings of the World Renewable Energy Congress (WREC), 8–13 May, 2011, Linköping, Sweden; Linköping University Electronic Press, Linköpings Universitet; ISBN: 978-91-7393-070-3; pp: 676-683.

Kraxner, F., Aoki, K., Leduc, S., Kindermann, G., Fuss, S., Yang, J., Yamagata, Y., Il Tak, K. and Obersteiner, M. (in press), BECCS in South Korea - An analysis of negative emissions potential for bioenergy as a mitigation tool. Renewable Energy (issue forthcoming).

Kraxner F, Fuss S (eds.), Proceedings, IEA/IIASA BECCS Experts Workshop, 3-4 November 2011, Laxenburg, Austria; http://www.iea.org/newsroomandevents/workshops/workshop/name,28877,en.html

Kraxner F, Nordström E-M, Havlik P, et al. (in press). Global Bioenergy Scenarios - Future Forest Development, Land-Use Implications, and Trade-Offs. Biomass and Bioenergy (issue forthcoming)

Kraxner F, Leduc S, Aoki K, Fuss S, Obersteiner M, Schepaschenko D, Shvidenko A (2011). Forest-based bioenergy in the Eurasian context. Boreal Forests in a Changing World: Challenges and Needs for Action. Proceedings of the international conference IBFRA, Sukachev Institute of Forest SB RAS, 15-21 August 2011, Krasnoyarsk, Russia.

Kraxner F, Aoki K, Leduc S, Fuss S, Kindermann G, Schepaschenko D, Shvidenko A, Obersteiner M (2012). Negative Emission Through Bioenergy – A Geographically Explicit BECCS Study on Russia. Paper presented at the 4th International Conference on Applied Energy "Energy Solutions for a Sustainable World", 5-8 July 2012, Suzhou, China.

Lemoine D M, Fuss S, Szolgayova J, Obersteiner M, Kammen D M. The influence of negative emission technologies and technology policies on the optimal climate mitigation portfolio, Climatic Change, doi: 10.1007/s10584-011-0269-4, (2011) 1-22.

Obersteiner M, Azar Ch, Kauppi P, Möllersten K, Moreira J, Nilsson S, Read P, Riahi K, Schlamadinger B, Yamagata Y, Yan J, van Ypersele J-P, Managing climate risk, Science 294(5543) (2001) 786–787.

Acknowledgements:

The authors would like to thank: EC's FP7, GA n°212535, *CC-TAME* (Climate Change – Terrestrial Adaptation and Mitigation in Europe), www.cctame.eu; *BIOMASS FUTURES* project (www.biomassfutures.eu), funded by the EC's Intelligent Energy Programme, GA n°IEE 08 653 SI2. 529 241; Ecosystems Services and Management Program (*ESM*) at the International Research Institute for Applied System Analysis (*IIASA*), National Institute for Environmental Studies (*CGER / NIES*), International Research NGO Global Alpine Synergies (*GAS*, www.global-syn.org), Austria, for their dedicated support to carry out this research.