SUSTAINABLE FOREST-BASED BIOENERGY IN EURASIA

Boreal Forest Resources and their Multiple Uses

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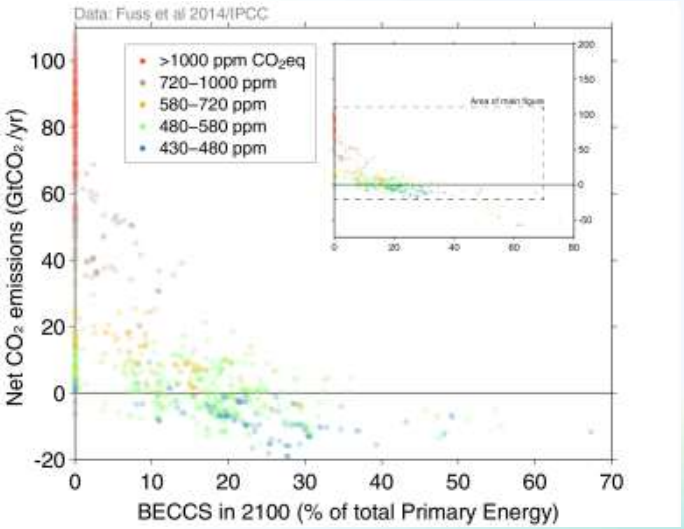
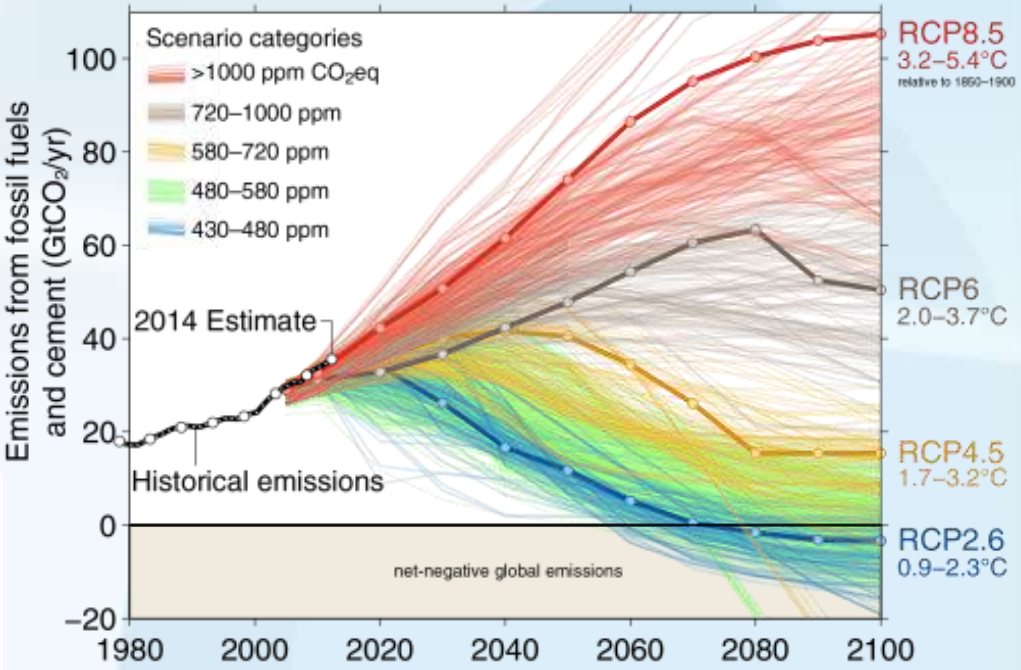
Motivation

Climate change mitigation & land

ESM

IPCC AR5: Achieving 2°C is still possible, but it entails huge contributions from bioenergy - in most scenarios combined with Carbon Capture & Storage to go “negative“.

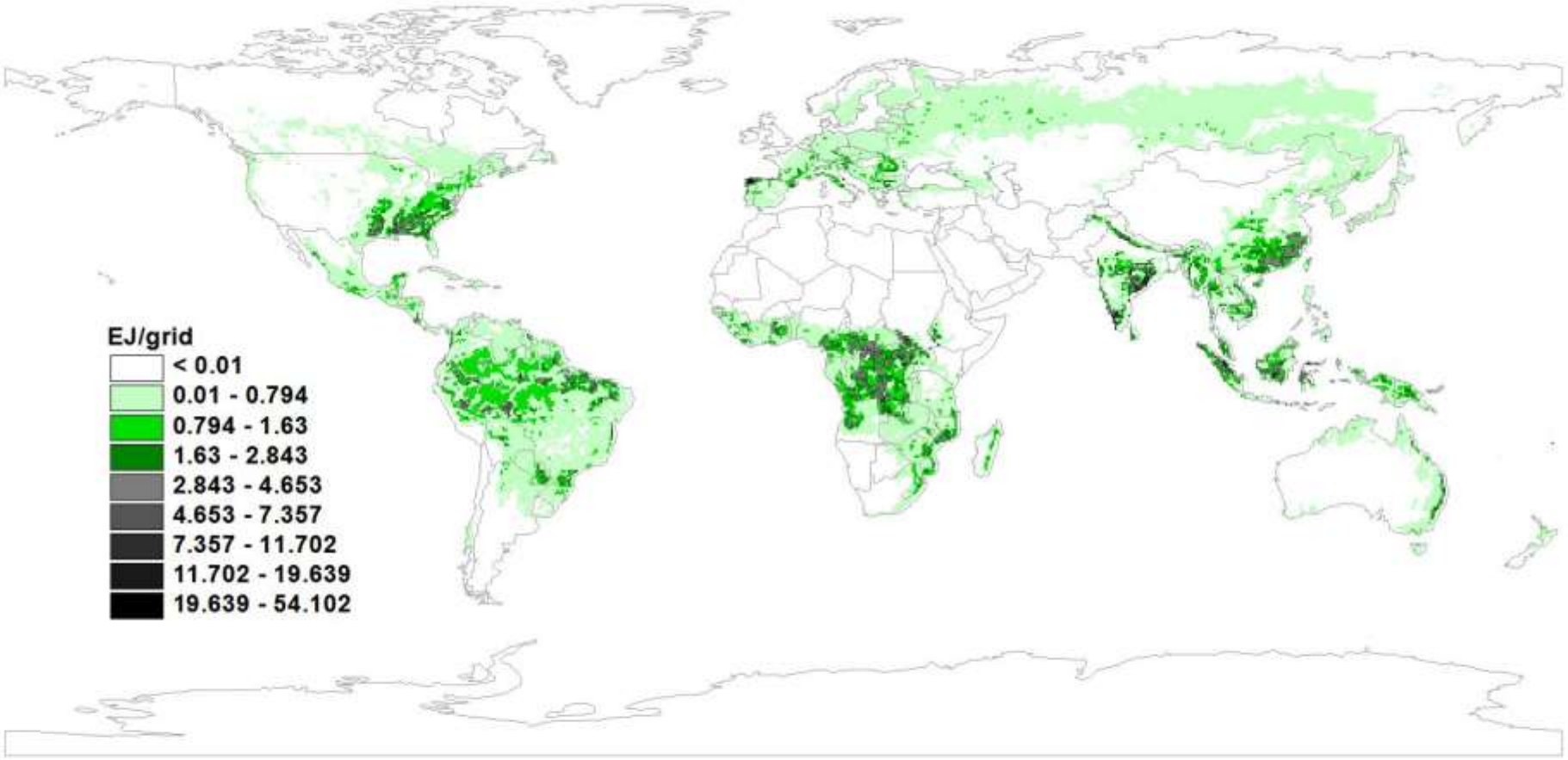




- BECCS need → 2-10 Gt CO2/yr in 2050 ≈ 5–25% of 2010 CO2 emissions
- Current global mean removal of CO2 by ocean and land sinks is 9.2 ± 1.8 Gt CO2 and 10.3 ± 2.9 Gt CO2, resp.

Source: Fuss et al. 2014

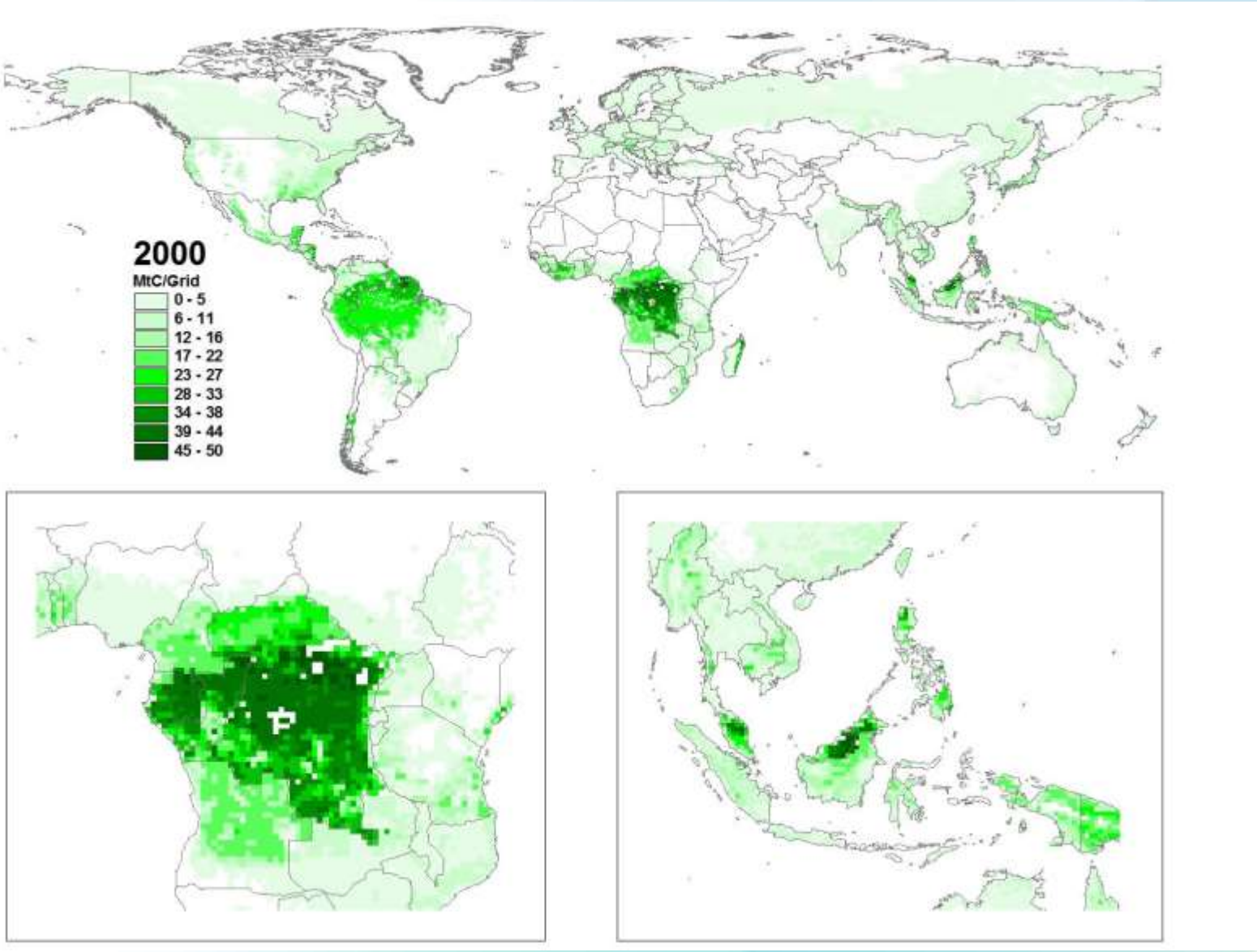
Cumulative biomass production (EJ/grid) for bioenergy



Source: Rokityanskiy et al. 2006 (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).

Forest Area Development (2000 – 2035)

ESM



Source: IIASA, G4M (A2r)

ESM

IIASA

Forest

- **Total land area** of Russia1,638 million ha Total forest area estimated between 809 million and 817 million ha
- 87% of Russia's **forest area** (710 million ha) form part of the global boreal forest biome.
- **growing stock** of the Russian forest e.g. amounts to some 81,523 million m^3
- **Removals**: 186 million m^3 in 2005
- **living biomass** estimated between 75 Pg to a maximum estimation of 148 Pg biomass
- **Losses** of wood due to different reasons (inter alia natural and pathological dieback; stand-replacing disturbances; wastes due to logging and wood processing; etc.) exceed 1 billion m^3 per year, of which 50% occur on in territories of forest available for exploitation.

Energy

- **Energy equivalent for the Russian forest biomass** exceeds 1,400 EJ (33,440,000 ktoe), not including 8 Pg carbon (300 EJ = 7,170,000 ktoe) stored in above- and on-ground dead wood.
- The **gross energy content of the annual NPP** of the country's forest ecosystems is estimated to be about 85 EJ per year (2,030,000 ktoe).
- Estimated **bioenergy potential** for Russia of annually 50 - 205 EJ (1,200,000 – 4,900,00 ktoe) by 2050

Electricity and heat production and primary energy sources in Russia [ktoe]

Source / Product	Coal and Peat	Crude Oil and Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustable Renewables		Total Output
							Biomass	Waste	
Electricity	16,917	1,385	42,538	14,023	14,335	40.41	*2*	217	89,456
% of total Electricity	19	2	48	16	16	0	*0*	0	
Heat	29,556	7,984	93,138	328		7,803	*837*	1,907	141,553
% of total Heat	21	6	66	0	-	6	*1*	1	
Total	**46,514**	**9,376**	**135,790**	**14,367**	**14,351**	**7,849**	***839***	**2,125**	**231,009**

- **Canada** (74% -boreal forest share of its total forest area): 4.5% of total primary energy supply derived from bioenergy!
- **Russian total primary energy production** 1,254,000 ktoe, of which 45% are exported. 53% (230,831 ktoe) of the country's remaining total final energy consumption of 435,516 ktoe is used in the form of electricity and heat.
- Primary energy for **electricity generation** in Russia is dominated by fossil sources such as gas (48%) and coal/peat (19%). Additionally, some 16% of nuclear power and the same share from hydro power.
- **Heat production** also dominated by the fossil sources: gas (66%) and coal/peat (21%). Smaller contributions come from oil (6%) and other renewable sources than biomass (6%, i.e. geothermal and solar).
- The largest share (61%) from **combined heat and power CHP** plants

Objectives

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1. to better assess the present situation of forest-based bioenergy in Eurasia, i.e. Russia.

2. to provide technical options for an optimal bioenergy development with the help of a combination of 3 IIASA modeling tools.

3. to contribute to identify possible policy tools and solutions for an increased bioenergy use in Eurasia, i.e. Russia.

The Modeling

IIASA Integrated Assessment Framework

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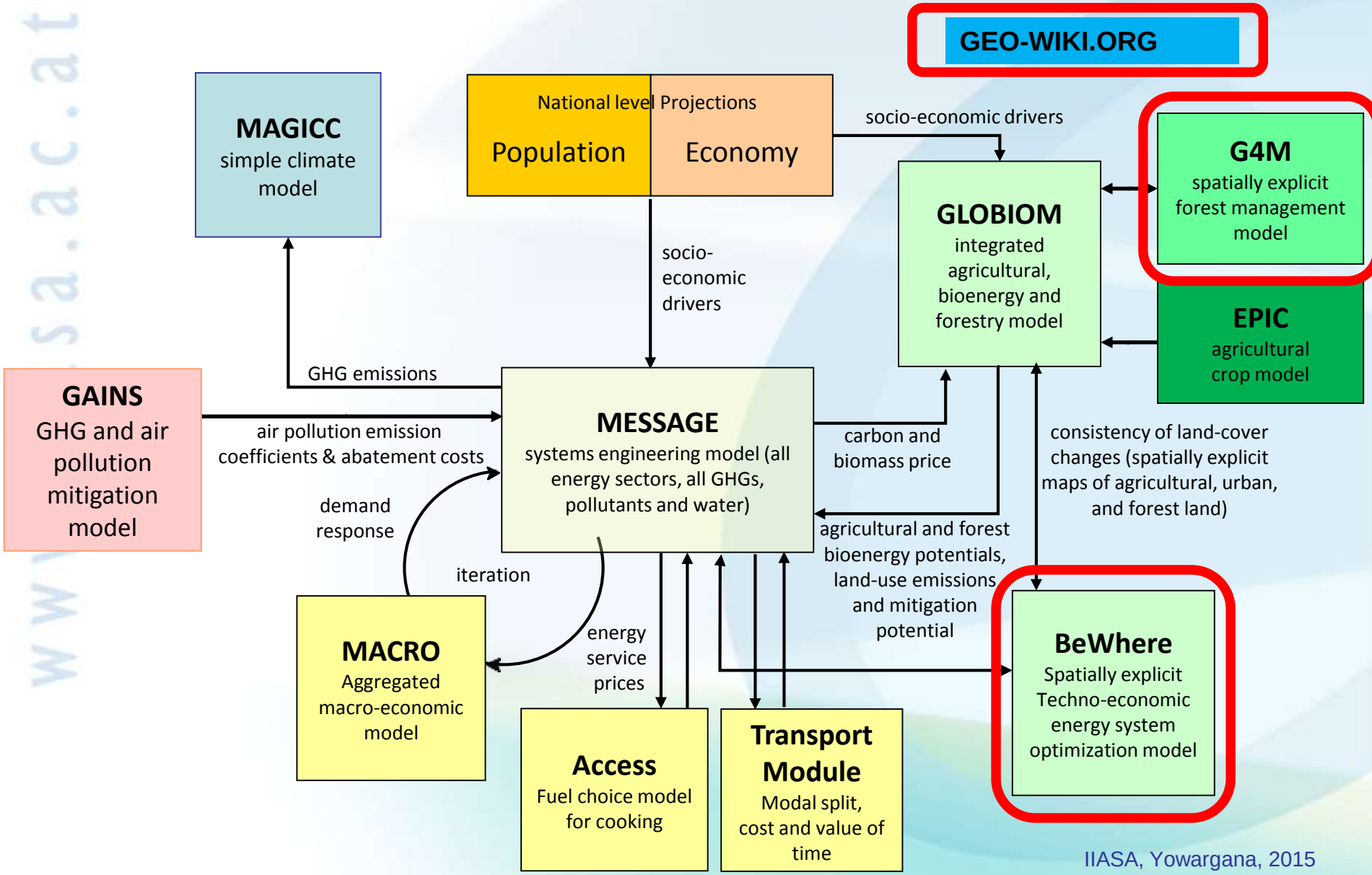


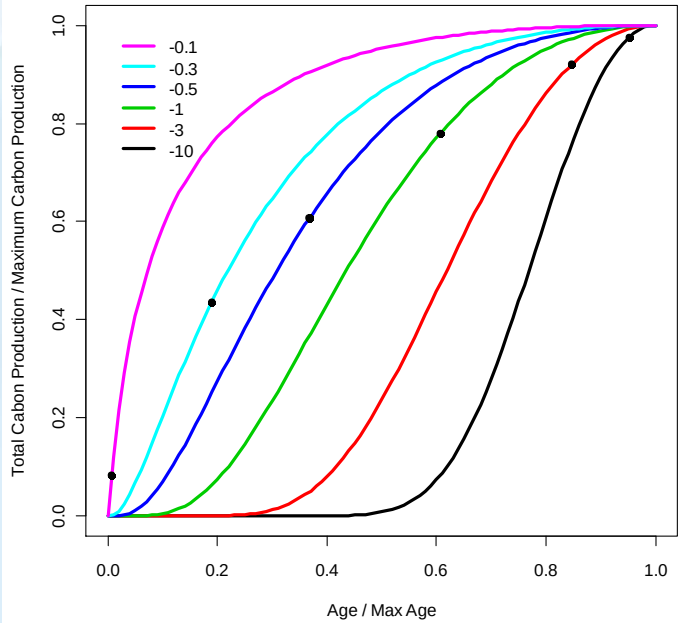
The Global Forest Model G4M

G4M

ESM

Forest parameters from G4M

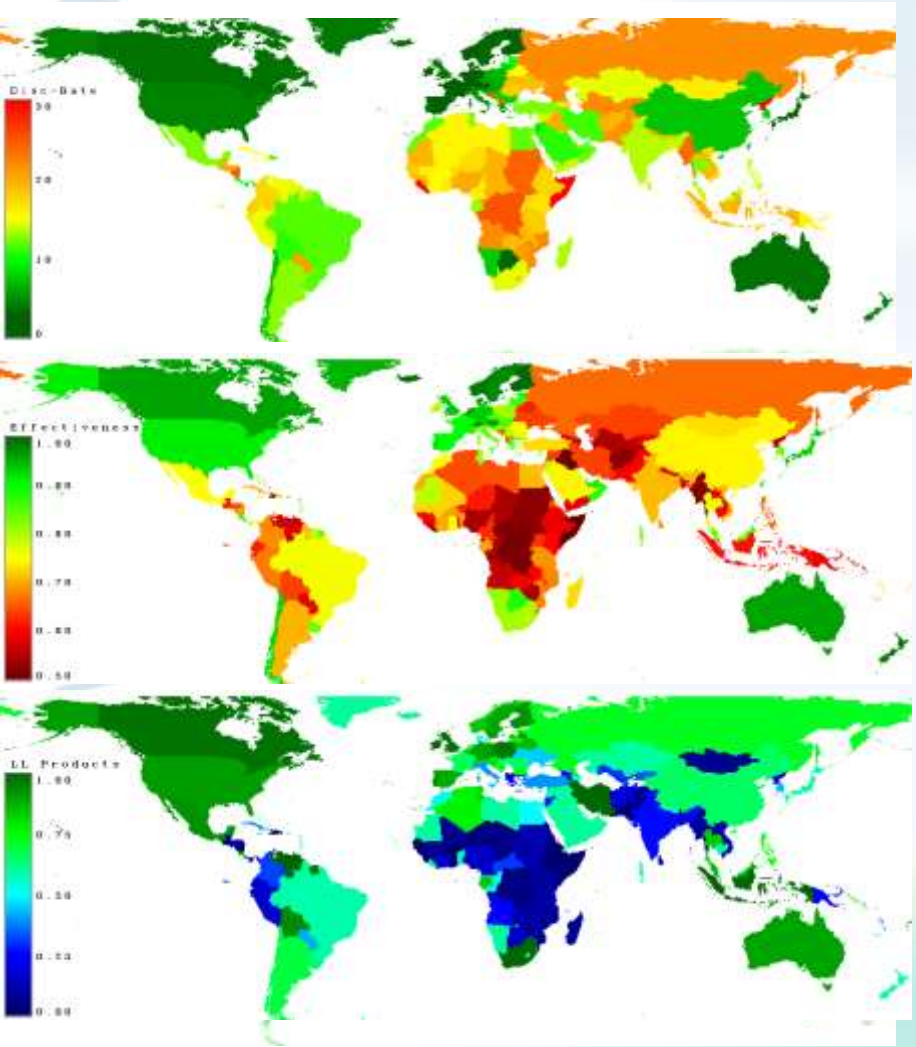
- Provides annual harvestable wood (for sawn wood and other wood)
- Afforestation/Deforestation (NPV)
- Forest management (rot/spec)
- Forest Carbon stock
  - Downscaling FAO country level information on above ground carbon in forests (FRA 2005) to 30 min grid (Kinderman et al., 2008)
- Harvesting costs
- Forest area change
- Spatially explicit



Source: IIASA, G4M, Kindermann

Model input

ESM



- NPP
- Population Density
- Land cover
- Agricultural suitability
- Forest Biomass
- Price level
- Discount rate
- Corruption
- Product use

Source: IIASA, G4M

Global Wood Supply Map

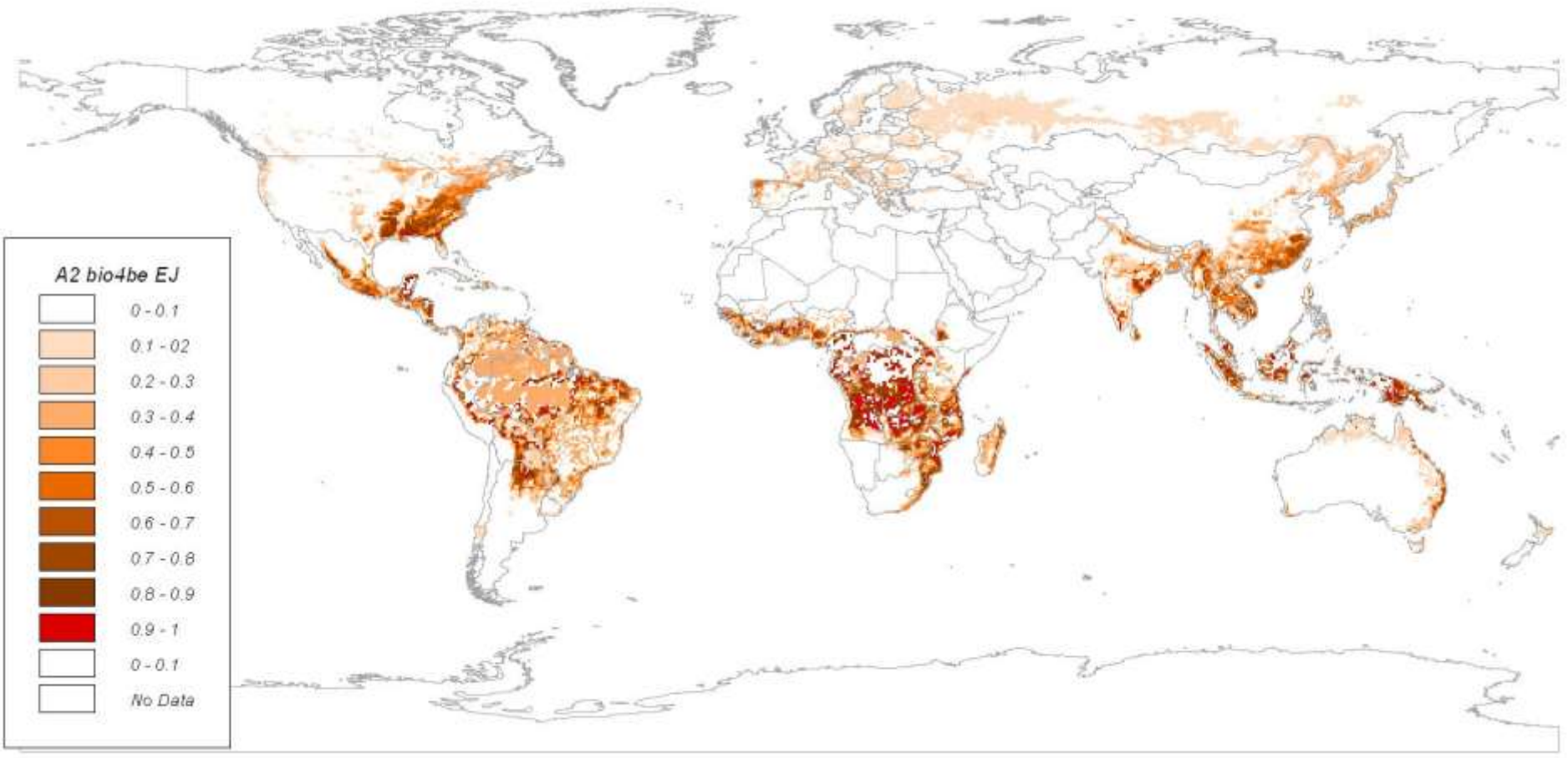
ESM

Currently manageable Forests

Source: IIASA, G4M, Kindermann

Bioenergy Supply for 2000-2100 (Price < 6$/GJ)

ESM

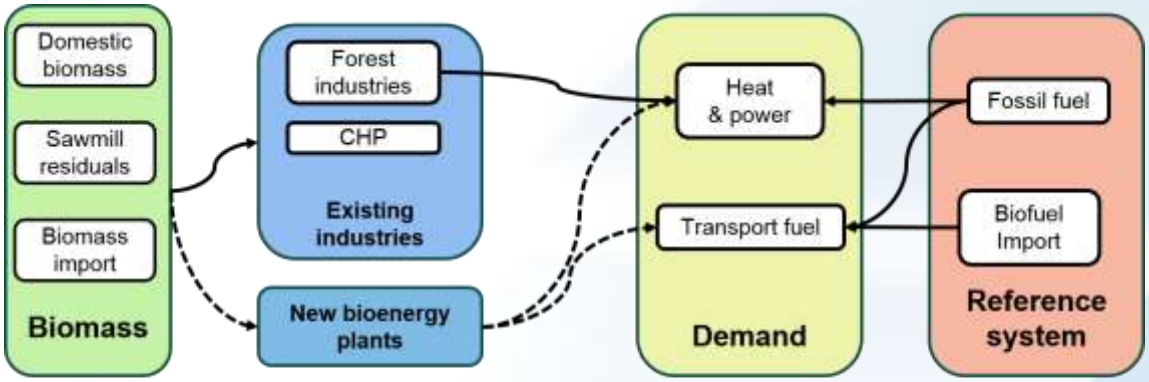


Source: Rokityanskiy et al. 2006 (A2)

The BeWhere Model

Methodology - BeWhere

ESM



- Techno-economic engineering model
- Mixed integer linear program (GAMS)
- Spatially explicit - 0.2 ˚ to 0.5˚grid cell
- Static - yearly basis, with fluctuation of heat demand over the year
- Minimize the total cost of the whole supply chain for the region's welfare

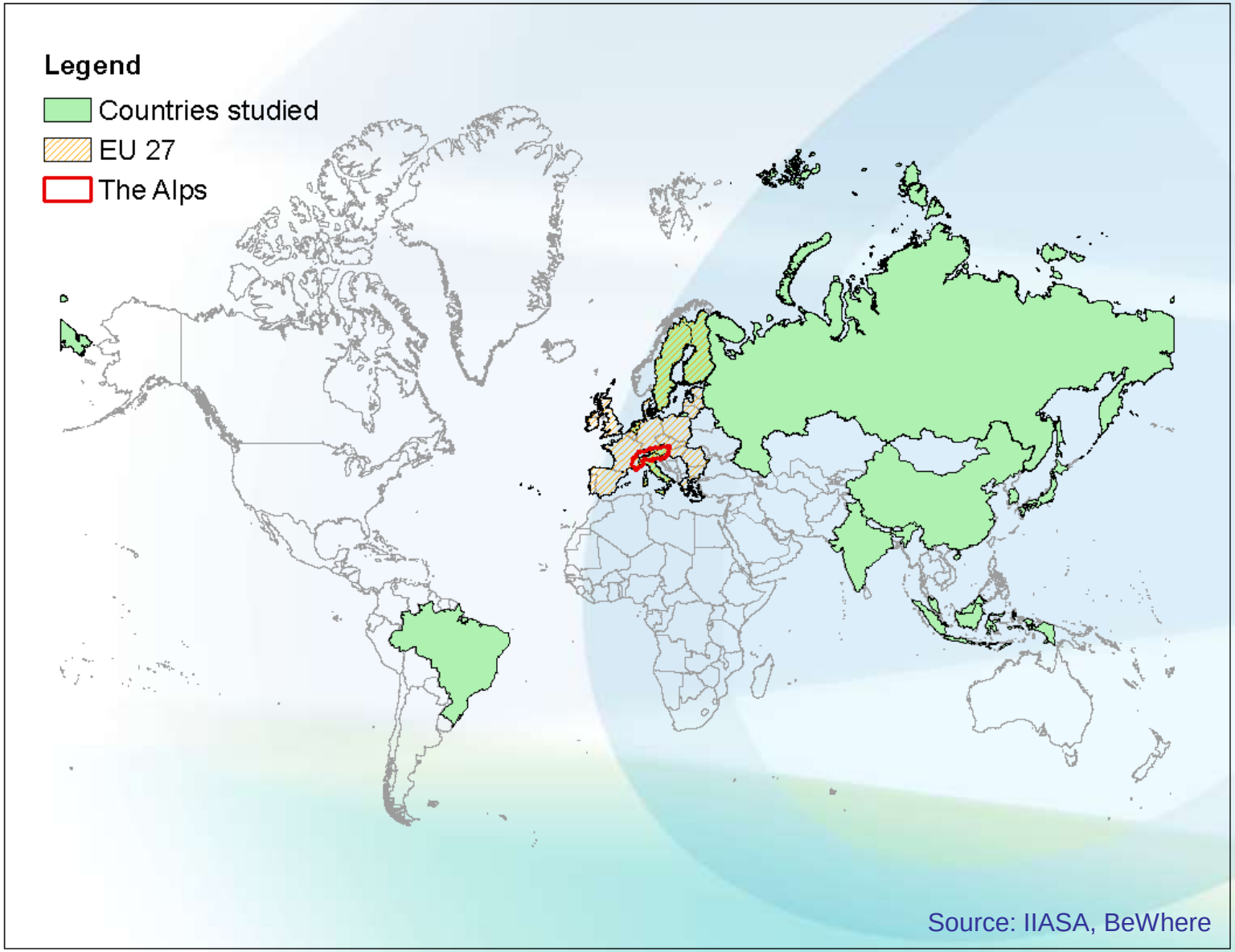
  min [Cost + Emissions * (Carbon Tax)]
- Does not maximize the profit of a plant

www.iiasa.ac.at/bewhere

Source: IIASA, BeWhere

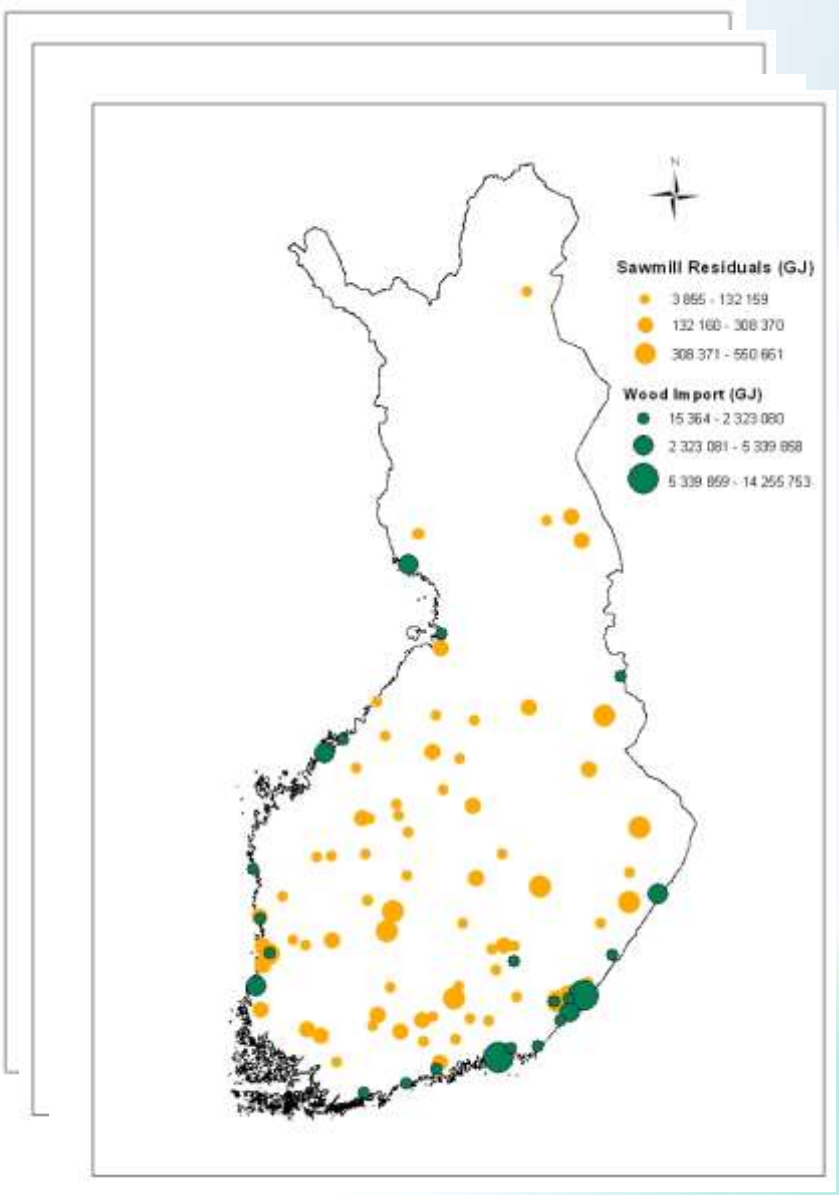
BeWhere Applications

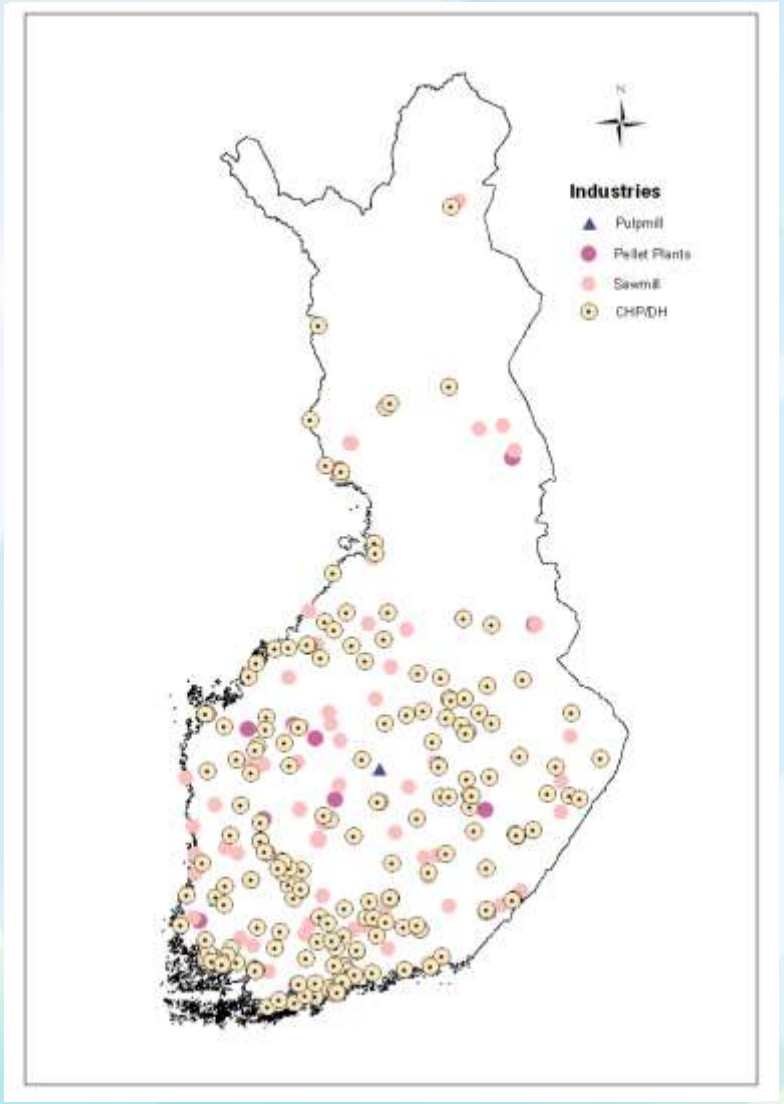
ESM



Spatial distribution of feedstock resources

ESM

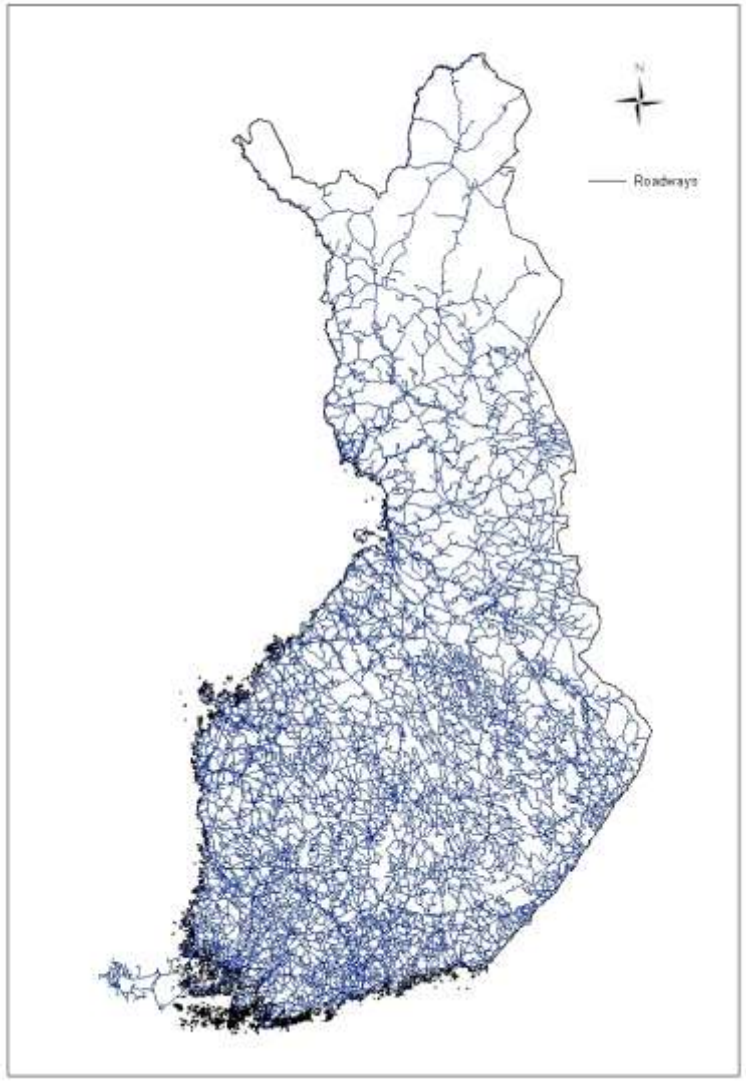


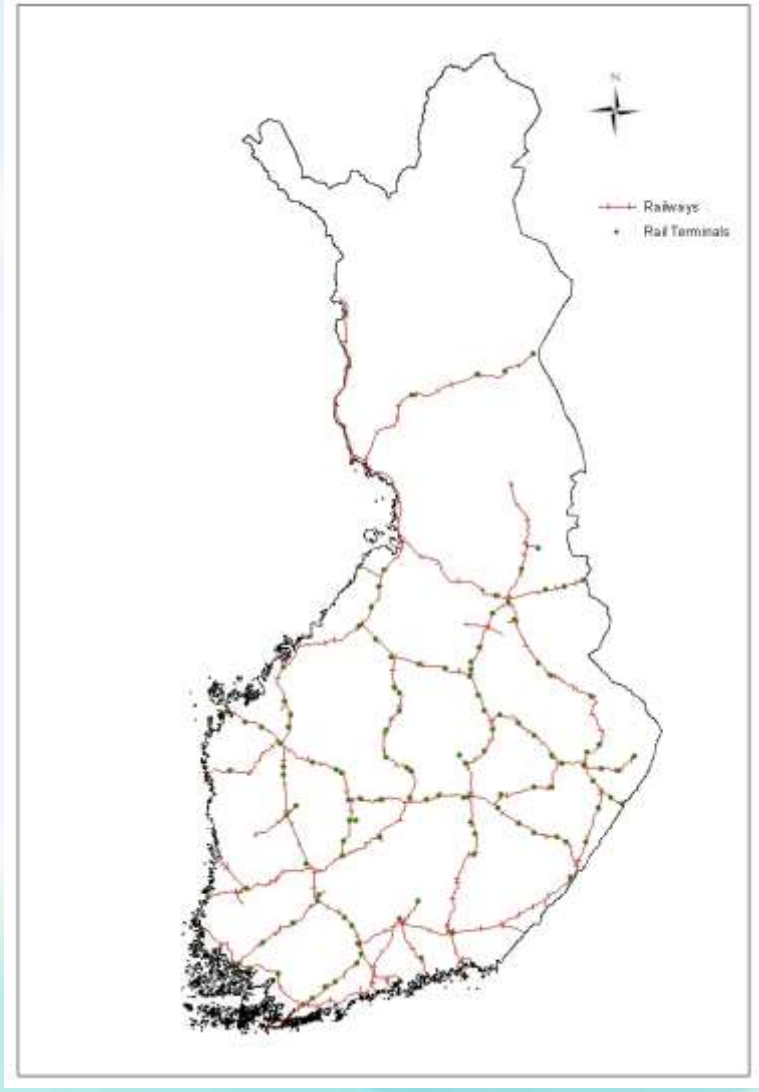


Source: IIASA, BeWhere

Transport Network

ESM

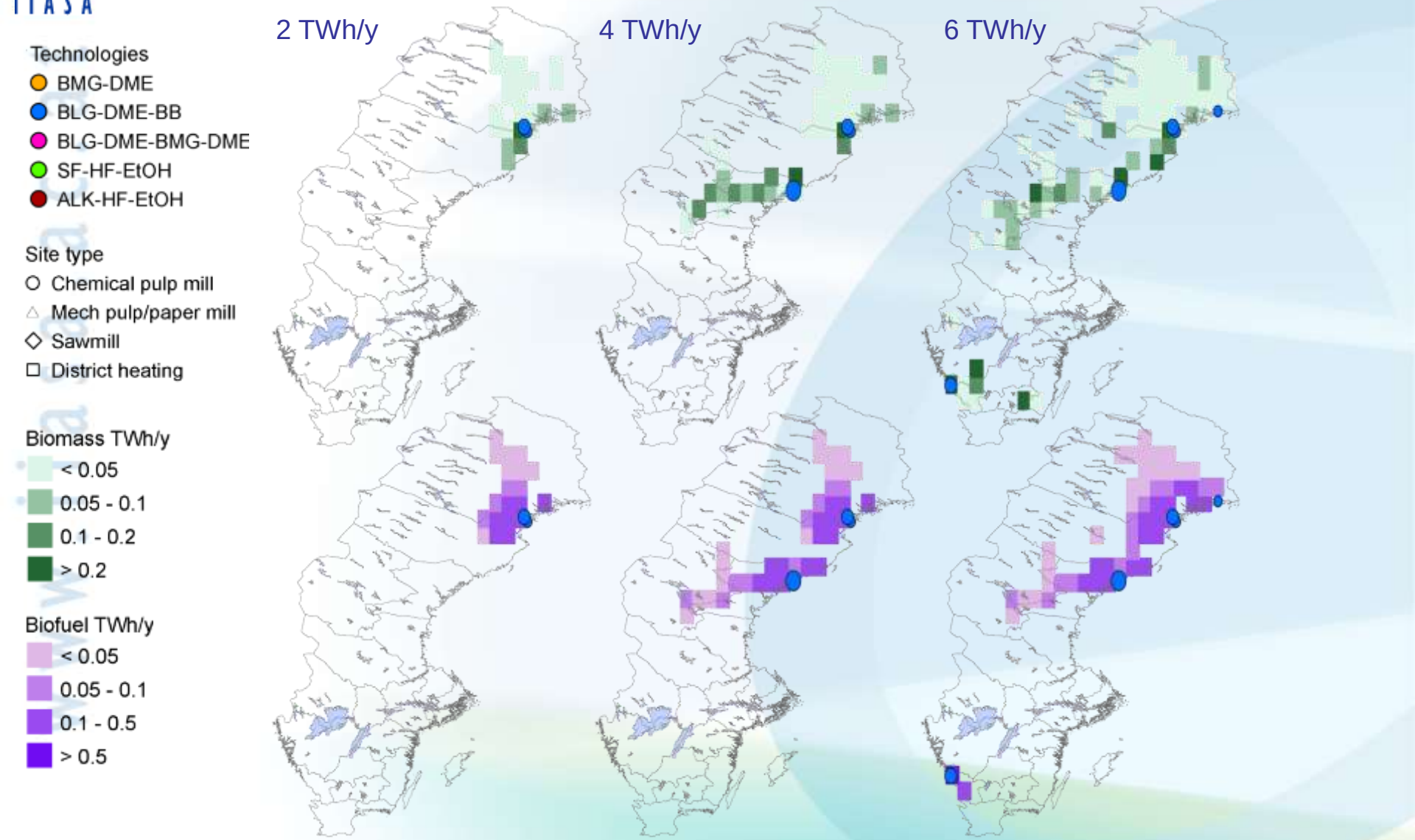




Source: IIASA, BeWhere

Sweden: Process Integration

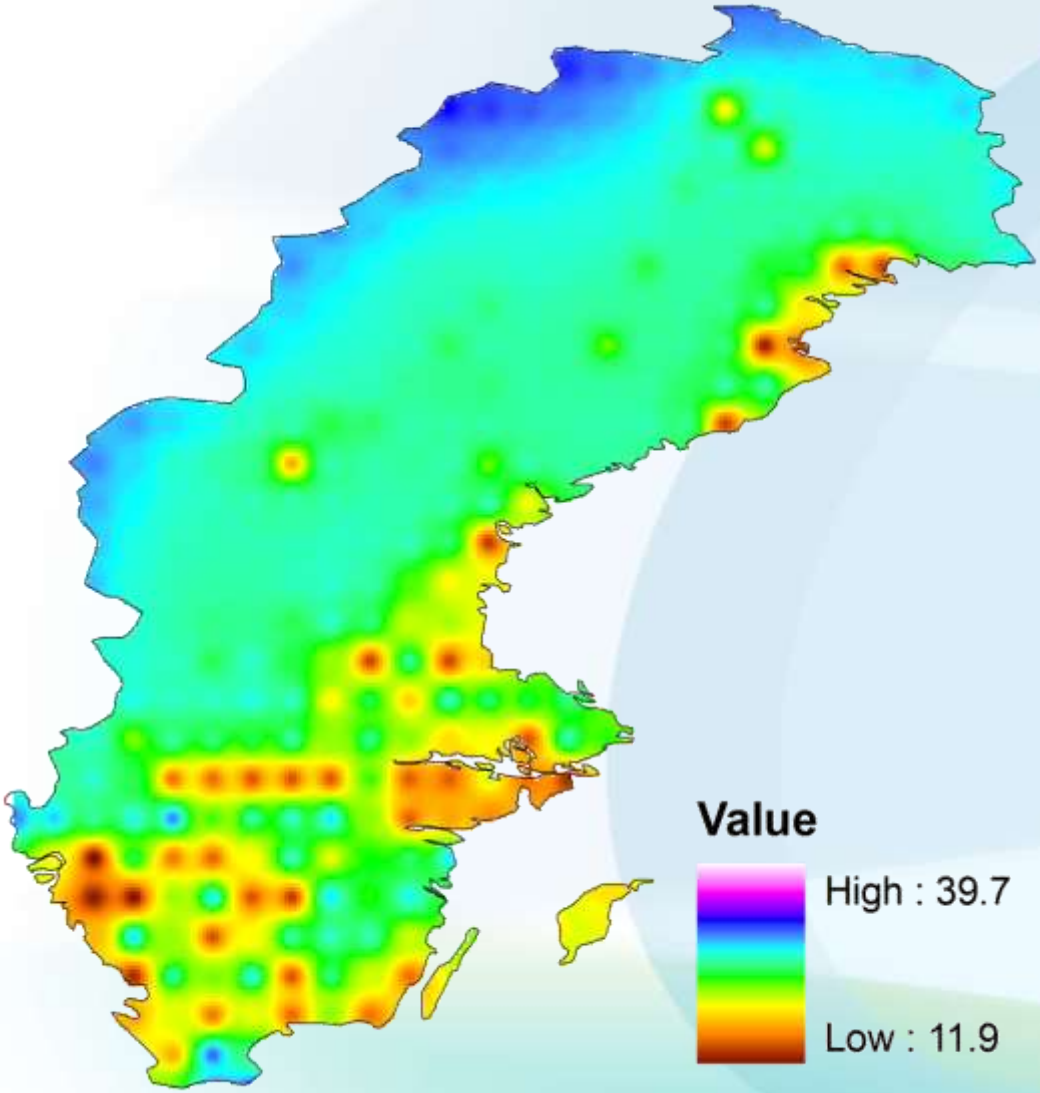
ESM



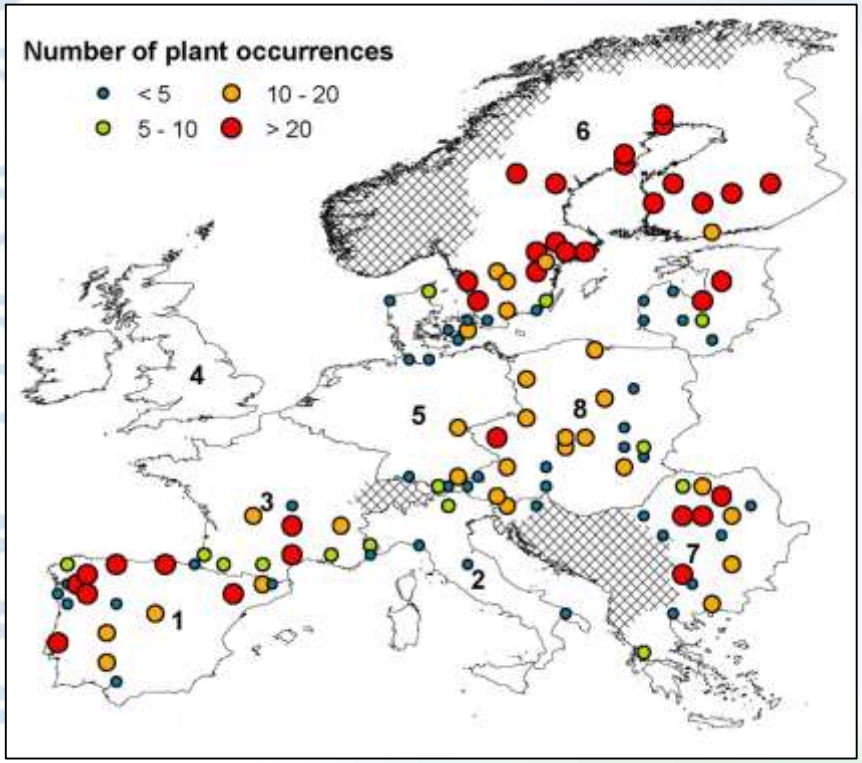
Source: IIASA, BeWhere

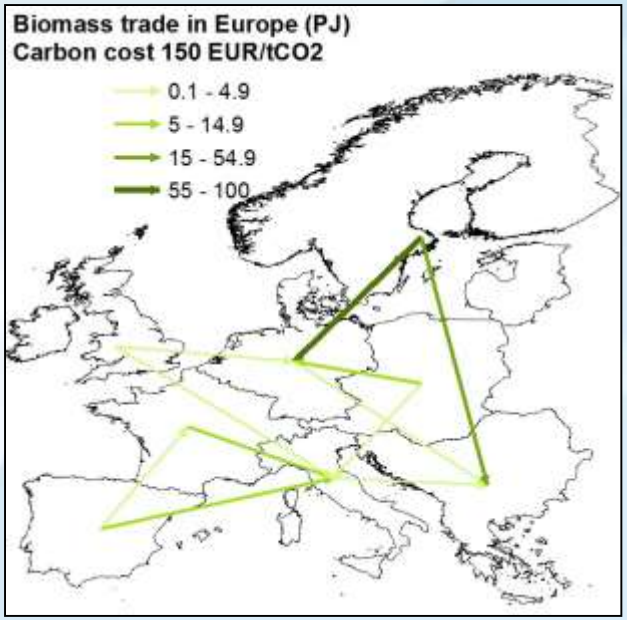
Sweden - Ethanol Production Cost (€/GJ)

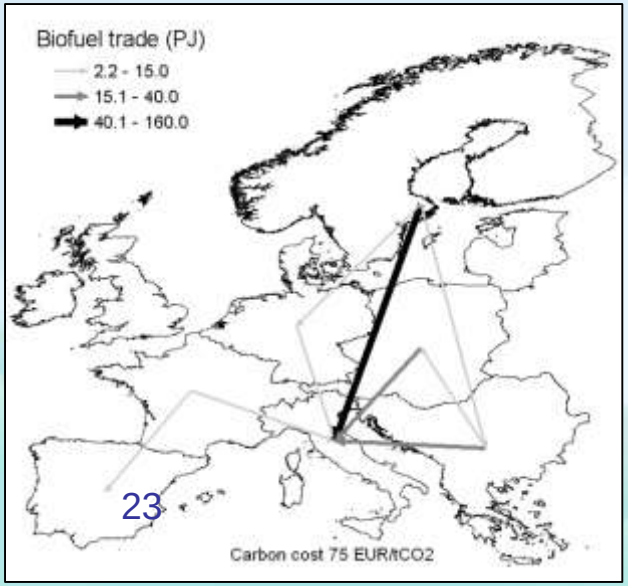
ESM



Example of Results - EU



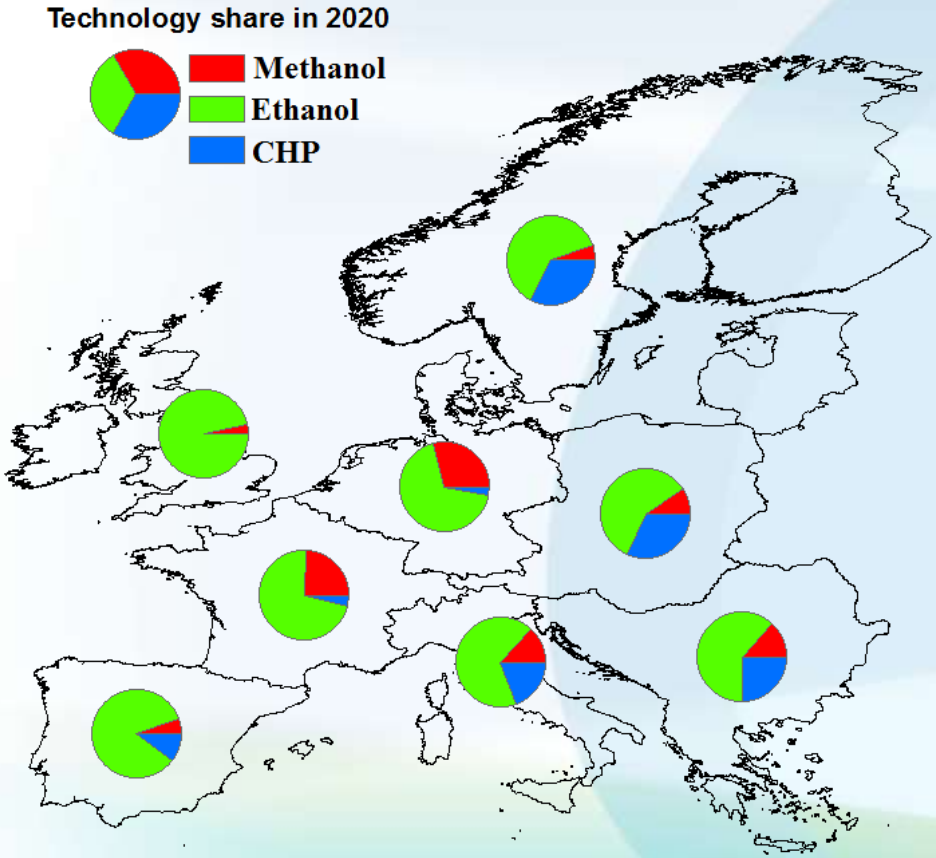




Source: IIASA, BeWhere

Share of biomass potentials per technology

ESM



Source: IIASA, BeWhere

First Results on Western Eurasia

Assumptions for the modeling work

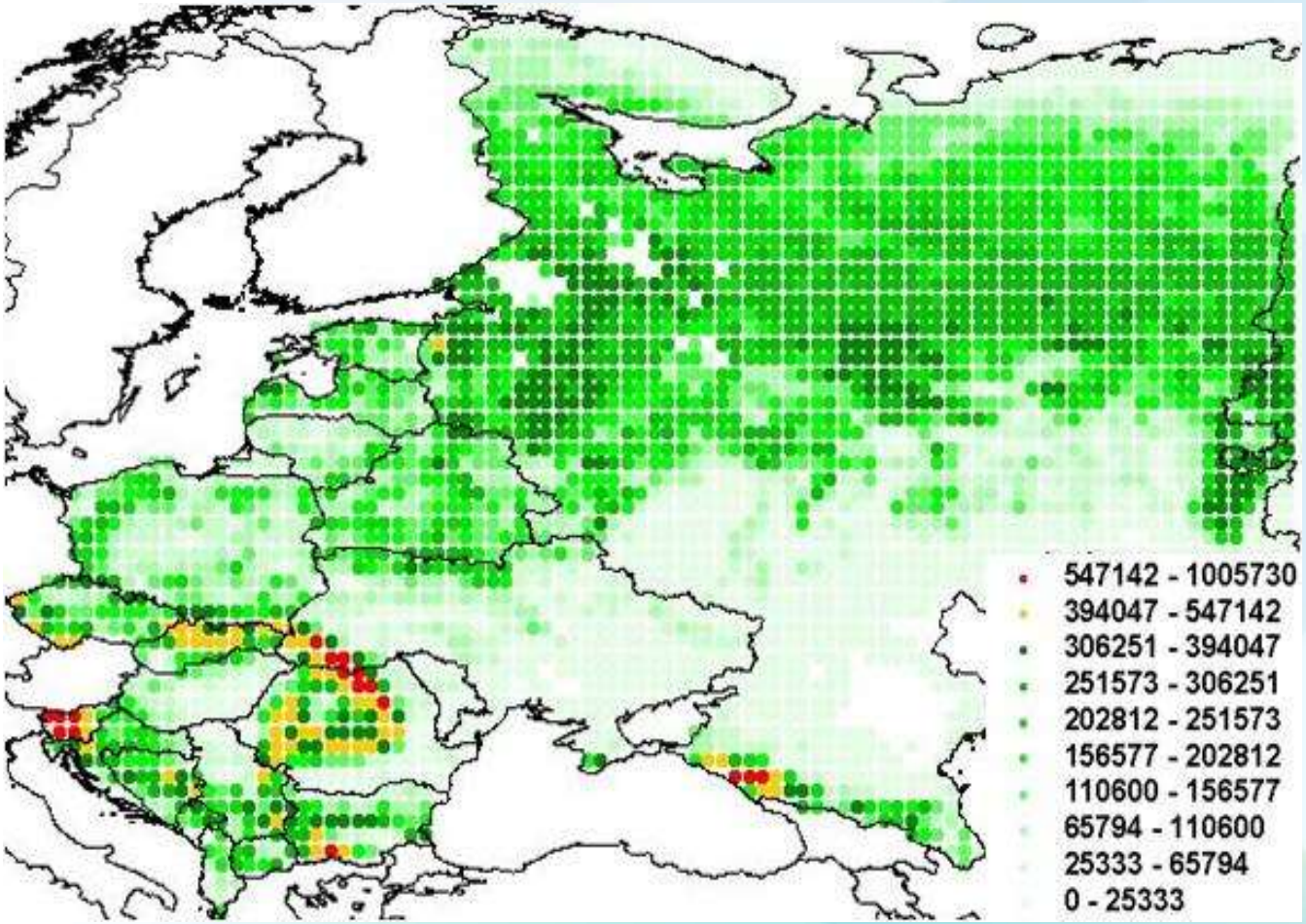
ESM

1. **G4M provides the data on sustainable forest biomass to the BeWhere** model. The BeWhere model chooses – under the sustainable forest management assumption that in no case more biomass than the annual forest growth can be harvested and that protected areas are excluded – from all available biomass resources.

2. **Extensive DH grids are fully operational** and a majority of the urban population is linked. The population density as an important driver for the entire optimization process of BeWhere (i.e. as a demand proxy when facing sub-optimal information) is used for the identification of the optimal location of a green-field (new) plant with respect to demand (heat/electricity demand by the population) and supply (distance to forest biomass).

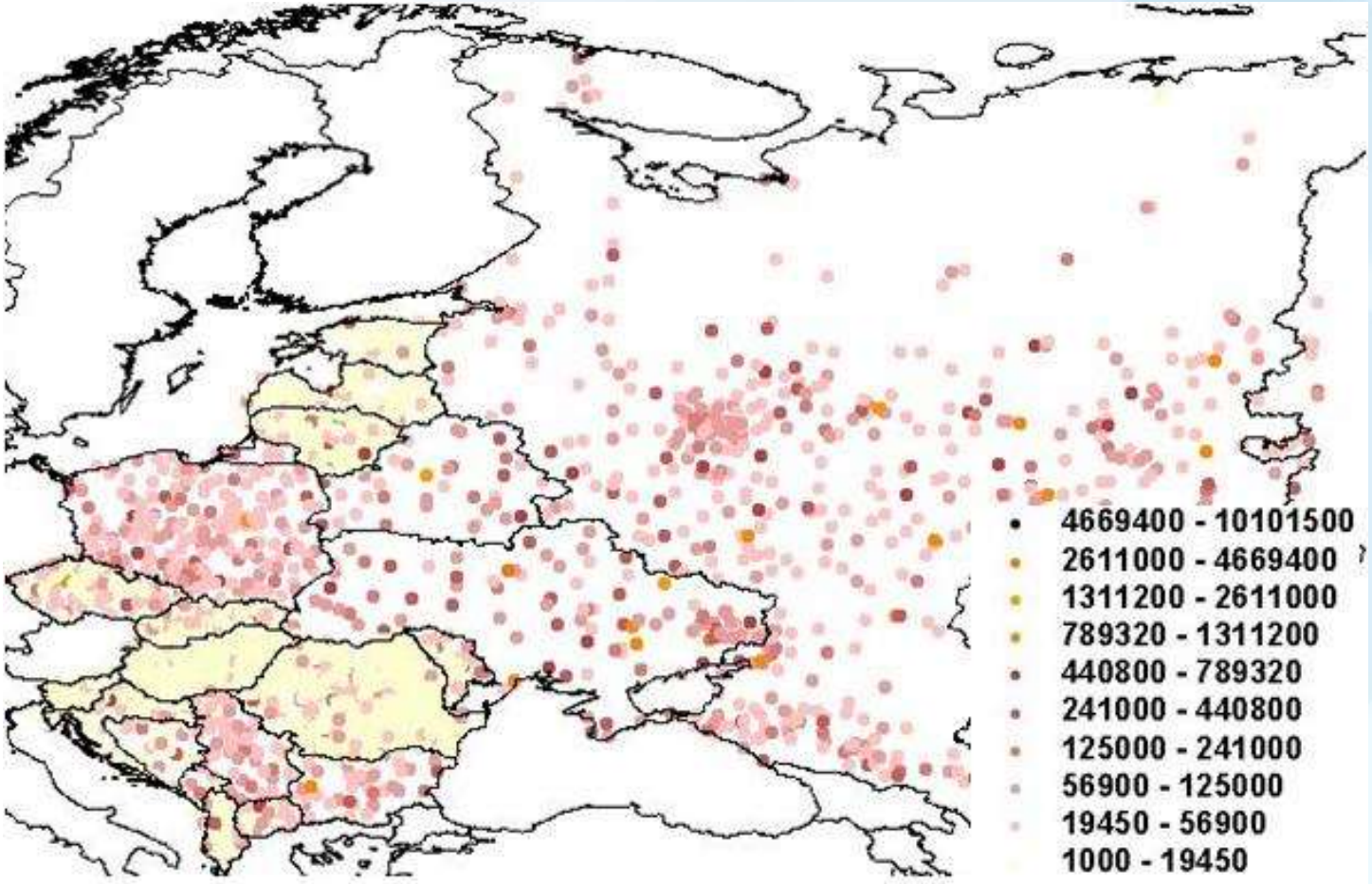
3. **Brown-field (existing) plants are not only modernized but in most cases (depending on the specific demand and supply situation) transformed into forest-based bioenergy plants** of the latest technology (CHP). Green-field forest-based bioenergy plants are mostly to be introduced in more remote areas or as new clusters in order to use the existing infrastructure of energy production units or industry.

Forest biomass intensity for Central-East Europe and European Russia in tons per grid and year (t/grid/y). Grid size: 0.5 degree (approx. 50 km grid length at the Equator).



Source: IIASA, G4M

Population distribution for Central-East Europe and European Russia.

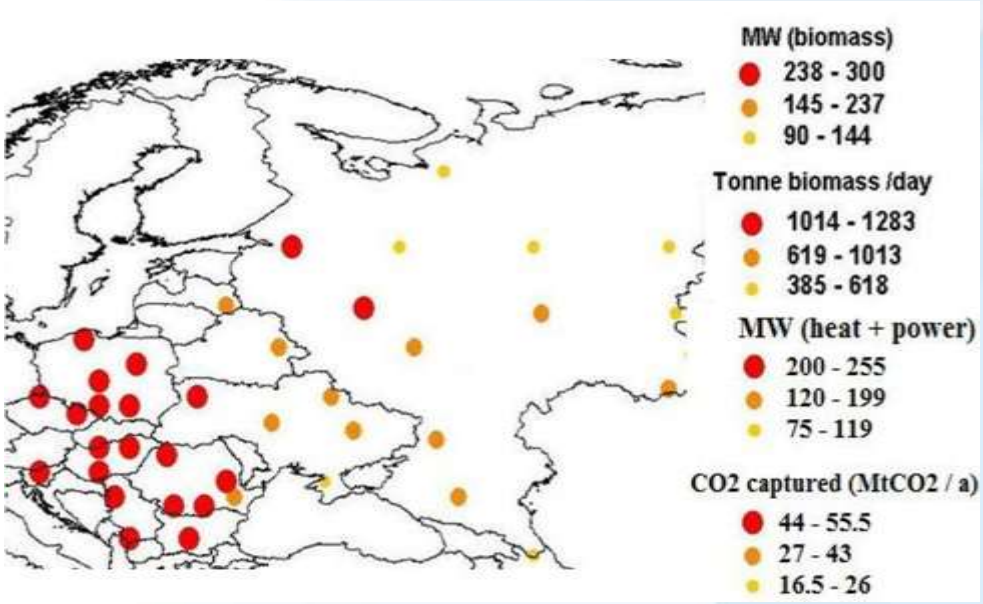


Source: IIASA, BeWhere

Doubling Russia's Bioenergy Production

ESM

Major clusters of forest-based green field biomass plants projected for Central-East Europe and European Russia. Different scales indicated by primary energy demand (MW), biomass demand (tons/day), combined heat and electricity supply (MW), and GHG emission savings ($MtCO_2/y$).



Plant type	Large		Medium		Small		Total	
Number	2		5		6		13	
Capacity	Min	Max	Min	Max	Min	Max	Min	Max
Input [MW]	476	600	725	1,185	540	864	1,741	2,649
Biomass input [tons/day]	2,028	2,566	3,095	5,065	2,310	3,708	7,433	11,339
Output [MW]	400	510	600	995	450	714	1,450	2,219
CO_2 saved [$MtCO_2$/year]	88	111	135	215	99	156	322	716

Source: IIASA, BeWhere

Relevance

ESM

Relevance to **official logging**:

In order to produce energy equivalent to 1,500 ktoe (doubling the present bioenergy production), some 3.78 million tons (6.16 million m^3) of dry matter biomass need to be supplied annually.

The necessary amount for producing twice as much forest biomass-based energy in Russia, equals for example some 3.3% of the total removals, 4.6% of the removals of industrial roundwood, or 12% of the total harvest of woodfuel.

Relevance to **illegal logging**:

According to official Russian statistics by the Forest State Agency, there has been illegal logging of some 1.34 million m^3 in 2010. However, other literature states illegal logging of additional 30% to the existing legal harvest in 2005. Consequently, some 11% of the total illegal harvest in 2005 or 40.3% of only the illegal harvest of woodfuel would suffice to double the energy generation from forest-based biomass in Russia.

Relevance to **household heating**:

By additionally producing the double amount of the present bioenergy, another 444,000 households could be provided with heat and even 1.8 million Russian households could be provided with green electricity.

Relevance

ESM

Socio-economic issues:

Investment in enhancing bioenergy production creates green jobs. In order to install additional 2,219 MW, during e.g. 20 months of construction some 4,500 workers would find a job. Additionally, there would be permanent jobs created for some 2,000 people in the biomass supply and processing sector, as well as some 500 long-term jobs in the new power plants.

Substitution of fossil fuel:

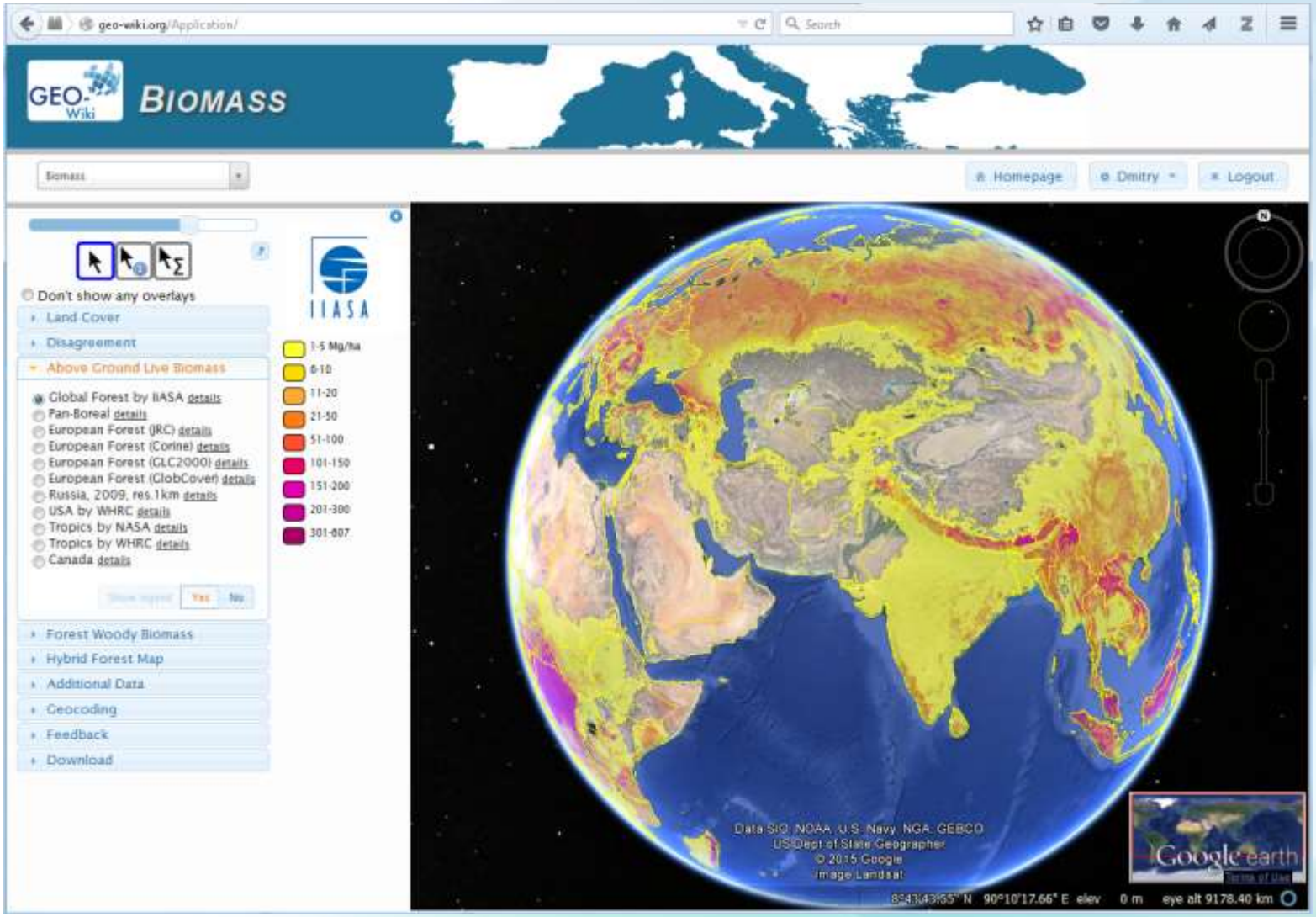
A further benefit would be the substitution of some 2.7 million tons coal, 1.7 million tons oil or 1.8 billion m^3 of gas, resulting in avoiding fossil GHG emissions of 716 million tons CO_2 annually.

Cost aspects:

Assuming the use of presently existing DH grid infrastructure as well as retrofitting existing fossil fuel based CHP plants for bioenergy use, on average some 1.5 million Euro (2 million US Dollars) might need to be invested per 1MW plant capacity.

Sustainability

Visualization and validation platform for biomass datasets



Source: Kraxner et al., CFCC 2015, IIASA, geo-wiki.org

Geo-Wiki mobile

Source: IIASA, geo-wiki.org

Forest Management Certification on geo-wiki

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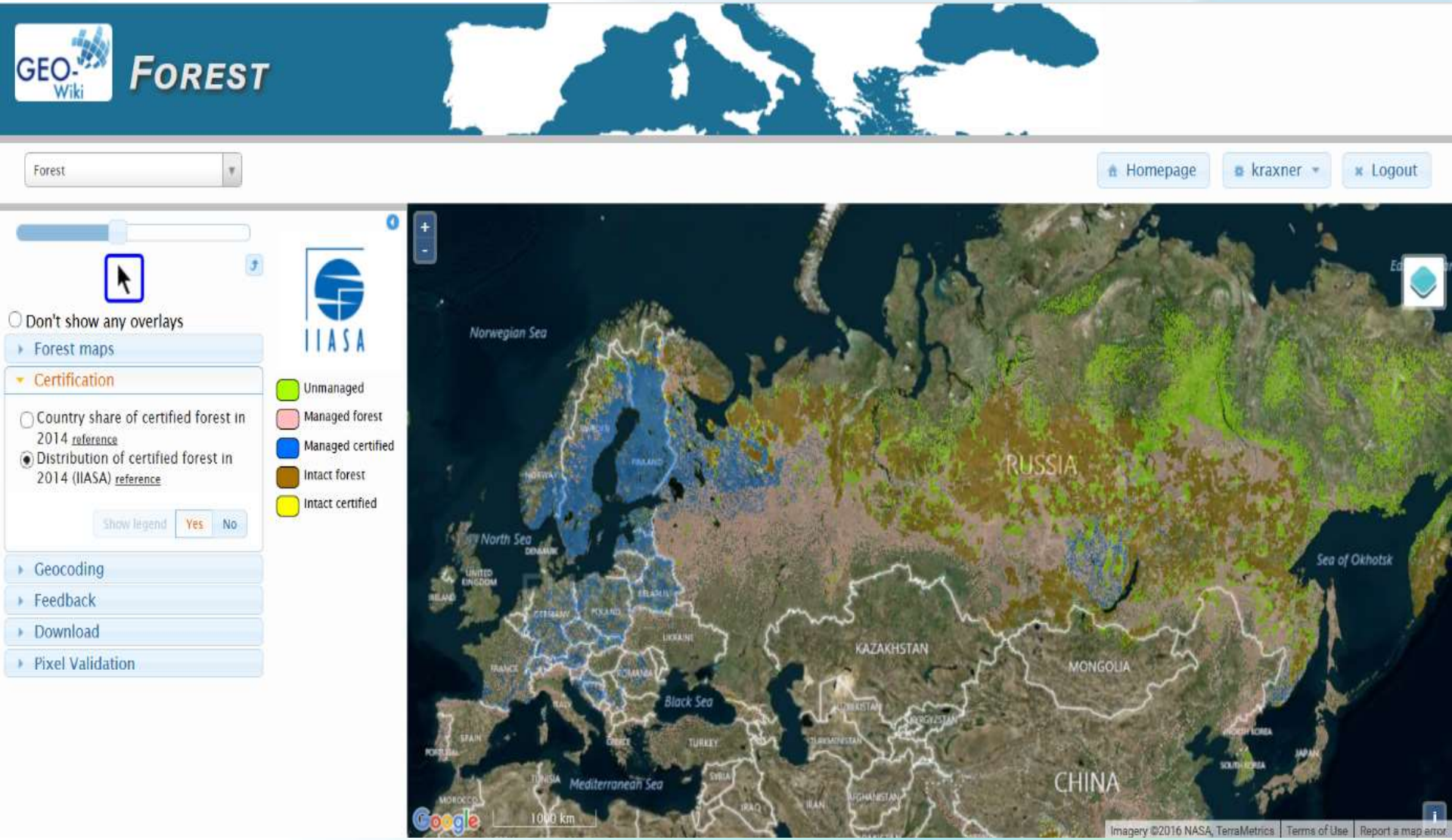
GEO-Wiki FOREST



Source: Kraxner et al. 2016, IIASA, geo-wiki.org

Conclusions

- Multiple (co-) benefits for increased biomass generation in the region
- Other improved biomass information need to be applied
- Extension of study to entire Eurasia
- Detailed economic analysis with respect to incentive building (e.g. feed-in tariffs, carbon tax, targeted subsidies or future international carbon trading schemes) necessary
- Further research needs are also identified with respect to the inclusion of detailed data of brown-field (to be modernized and substituted) energy systems, plants and the linked industry in Russia.
- Also moving towards higher value-added biorefinery products and negative emissions through BECCS (Bioenergy production with carbon capture and storage) seem to be interesting future options

Contact

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