BeWhere tool:
optimal technology, location & capacity of bio-energy production plants

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International Institute for Applied Systems Analysis (IIASA)

S2Biom Summer School
17-20 May 2016

This project is co-funded by the European Union within the 7th Frame Programme. Grant Agreement n°608622.
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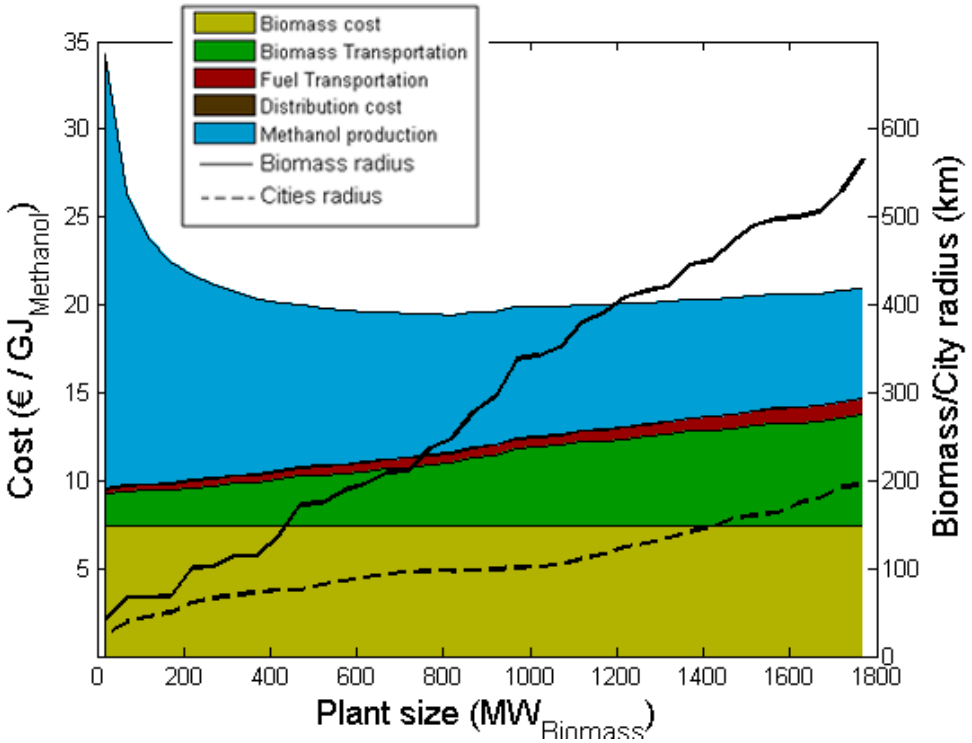
Outline

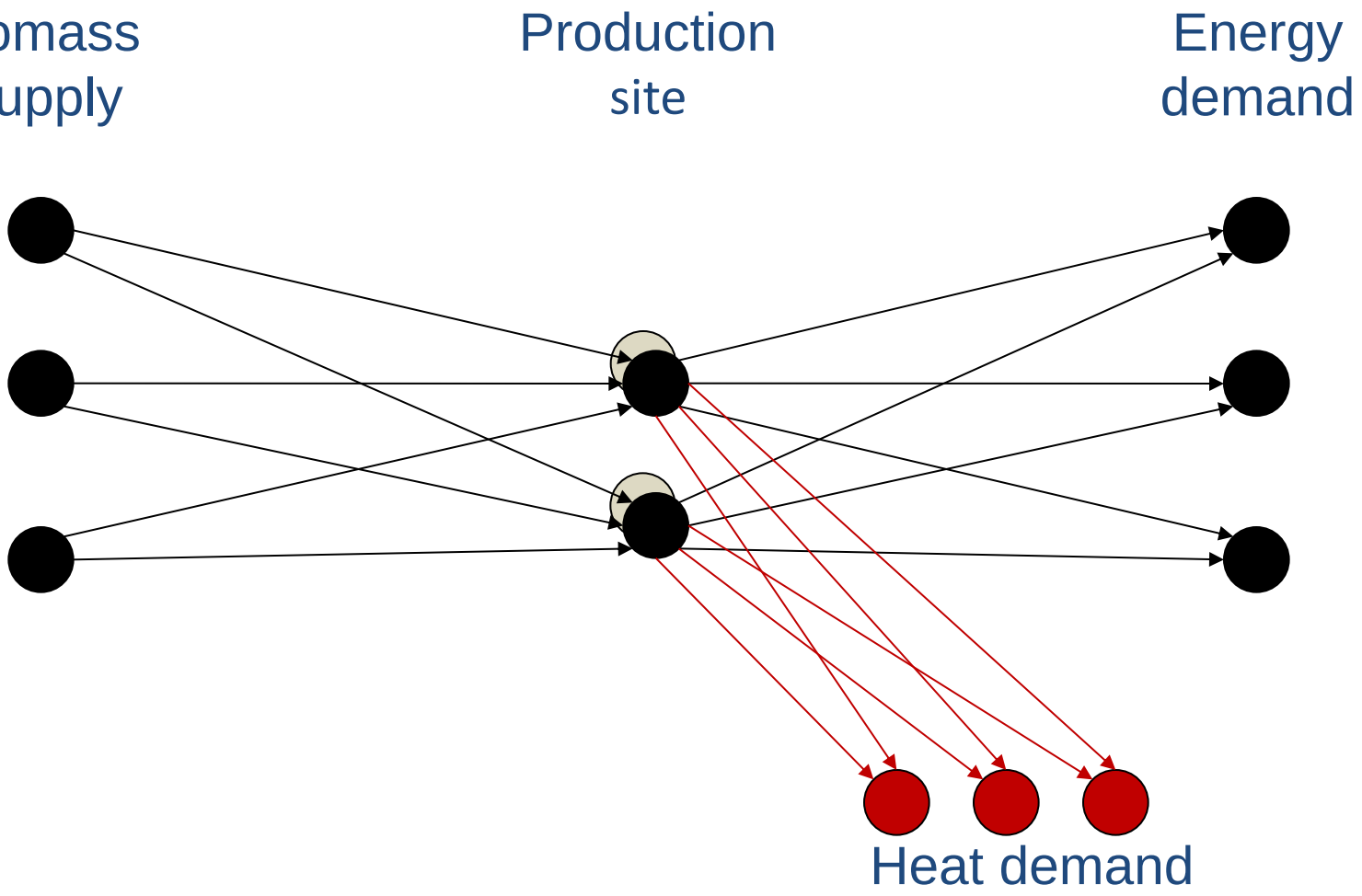
- Background
- Model description
- Case studies
- Visualization
- Wrap up
- Questions?

Background

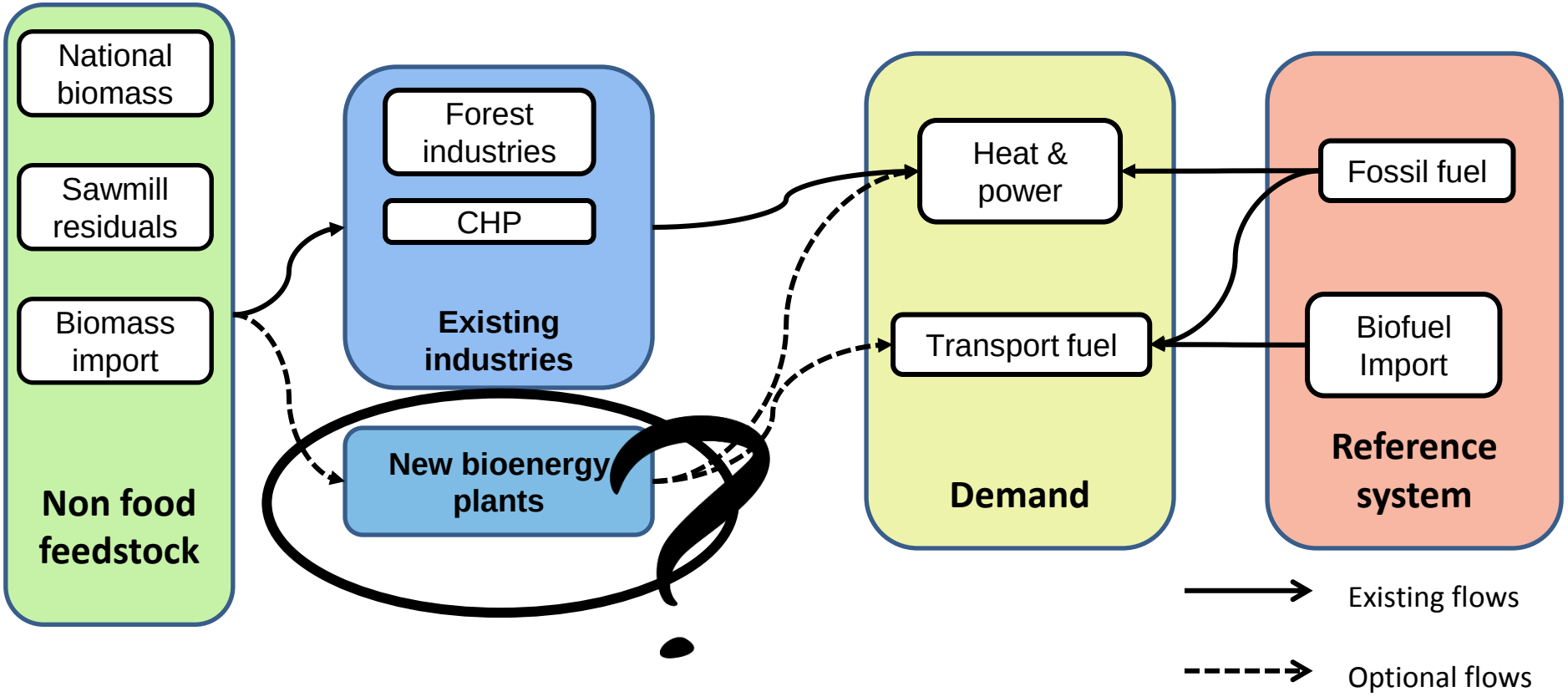


Source: Leduc et al. Methanol from gasification using a geographically explicit model. *Biomass and Bioenergy* 2009, 33 (5): 745-751.

- **Competitive costs to compete against fossil fuel**
- **Large production plants**
- **Logistic problems**
- **Location and size of the production plant is an issue**


Biomass supply
Production site
Energy demand
Heat demand

Supply chain



BeWhere Model

- Techno-economical model
- Mixed integer linear program
- 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

Input data / Summary

- **Biomass**
  - Location
  - Availability
  - Collecting cost
- **Existing industries**
  - Location
  - Feedstock demand
  - Power/heat output
- **Production plants**
  - Type of biomass
  - Biomass need
  - Economic parameters
  - Conversion efficiency
- **Transport**
  - Type of transport per feedstock
  - Costs
  - Emissions
- **Demand**
  - Location
  - Heat / power / transport fuel
  - Price of competing fossil fuel heat / power / transport fuel
- **Policy in place**
  - Carbon cost
  - Biofuel support
  - Subsidies

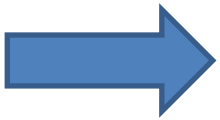
BeWhere answers…

(1)Number

(2)Technologies

(3)Size

(4)Locations



Policy tool

Costs

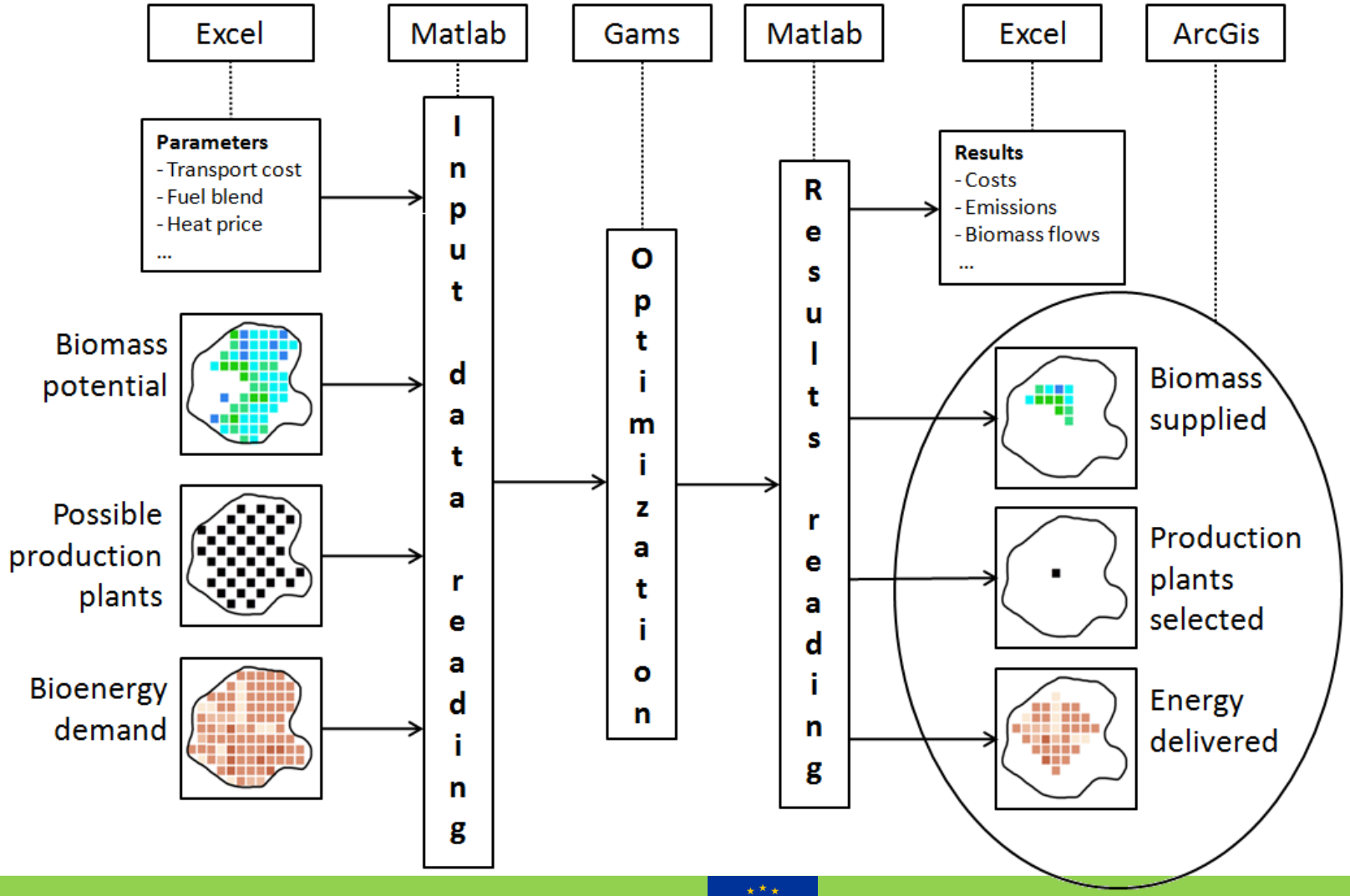
Emission avoided

Direct emissions

Economic potential

Trades

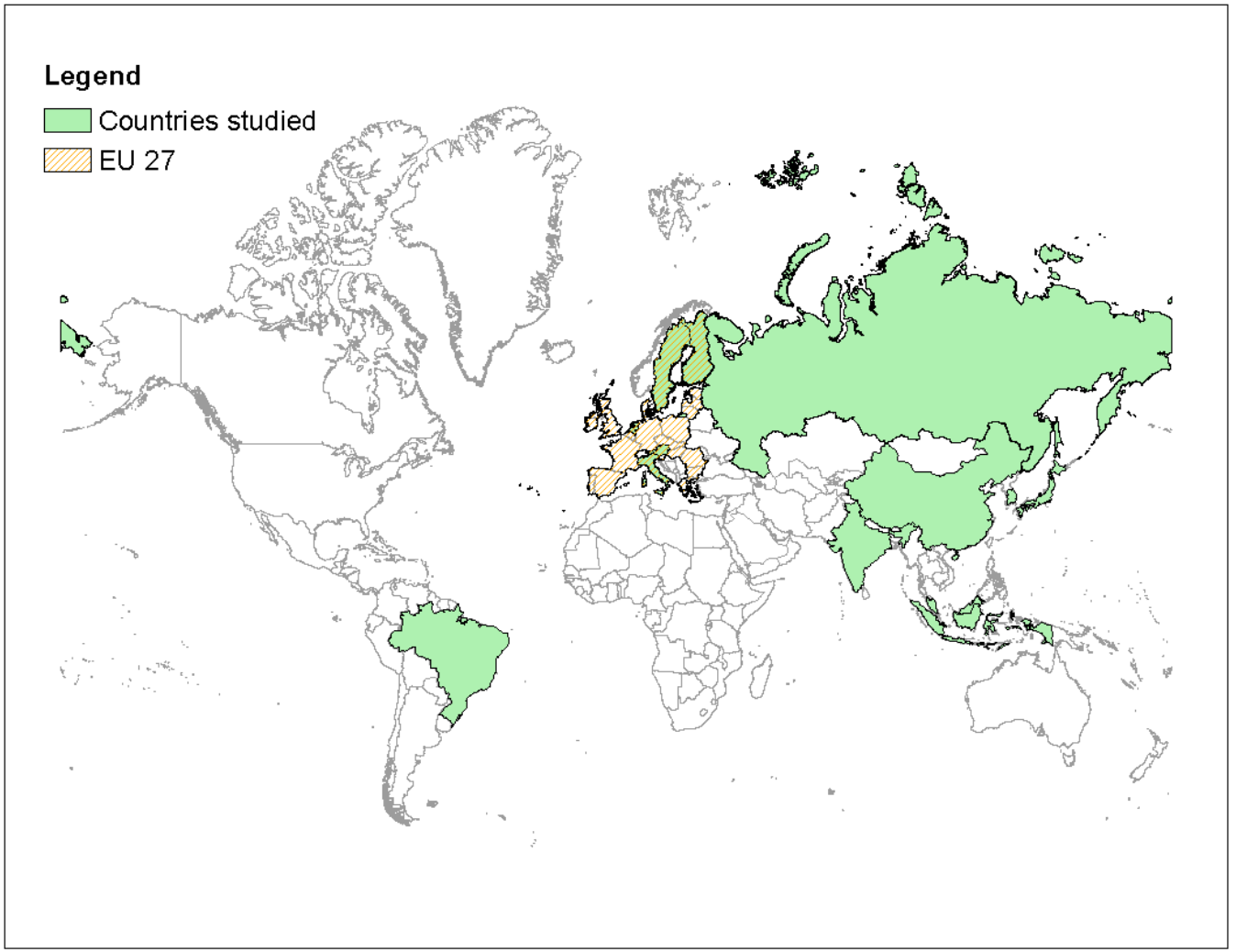
Methodology



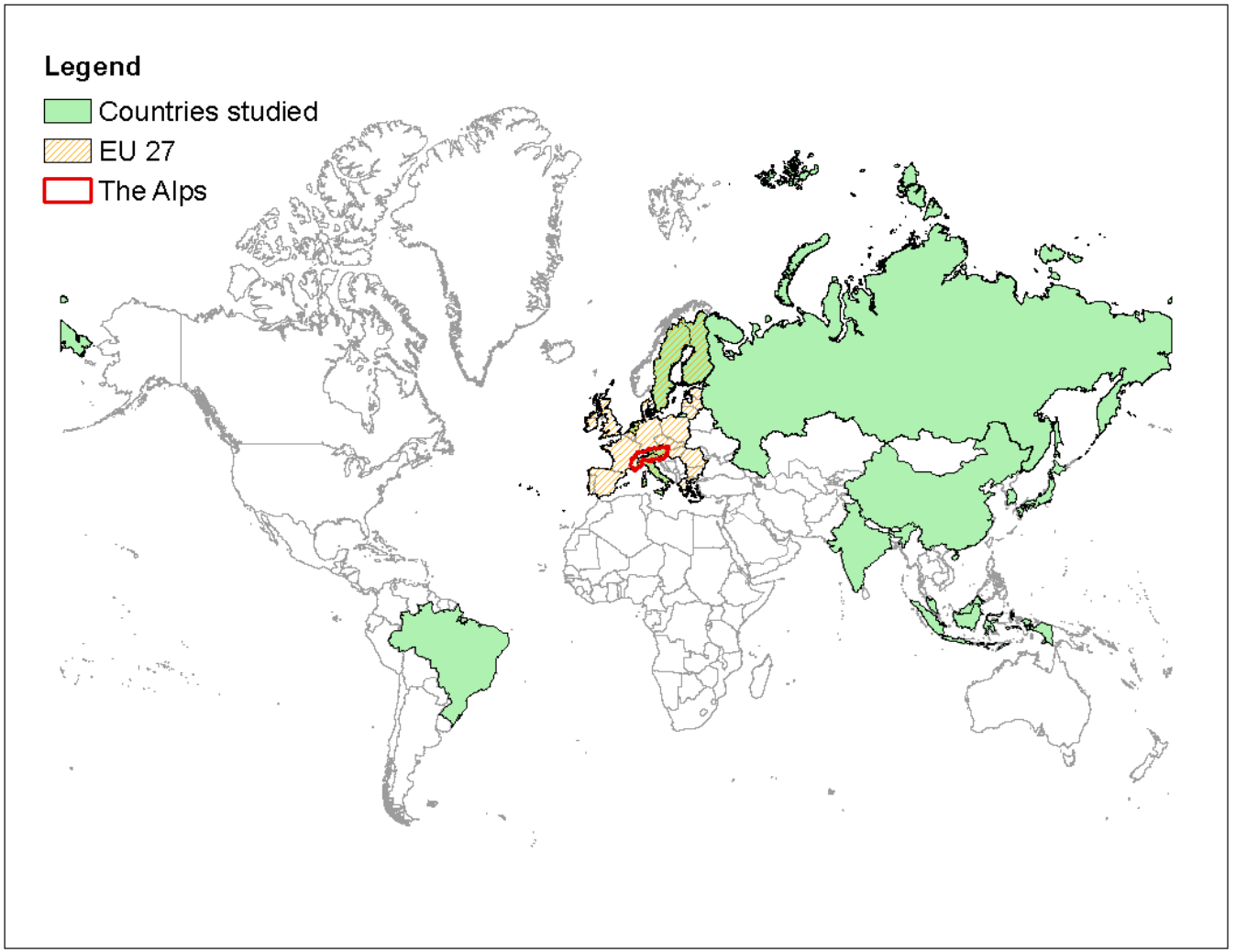
The BeWhere Umbrella

BeWhere Applications

BeWhere Applications



BeWhere Applications

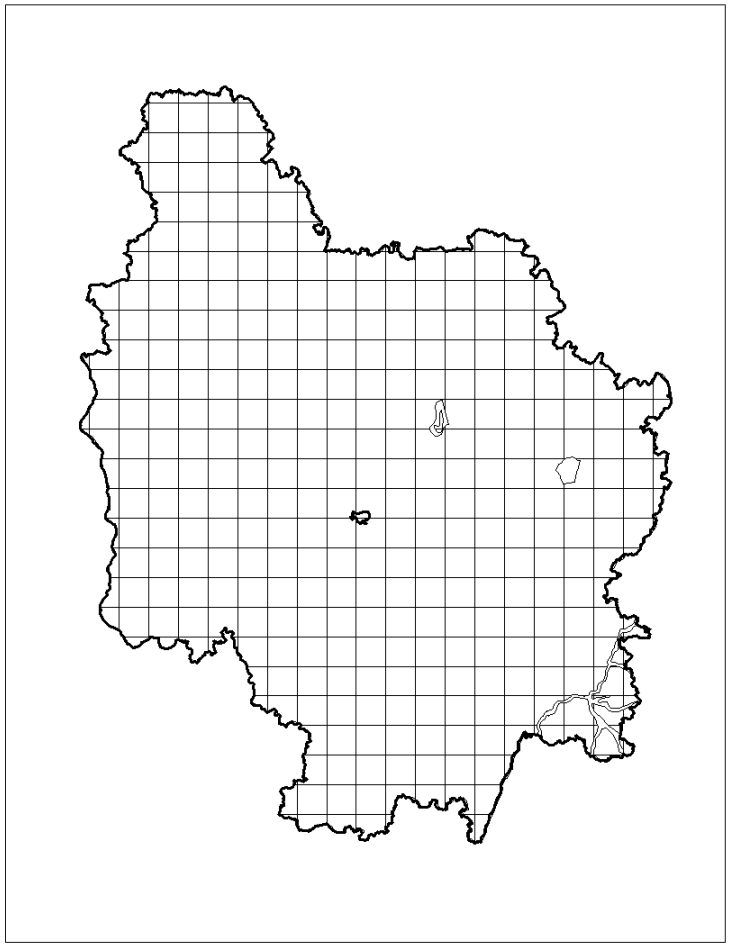


BeWhere / Locagistic

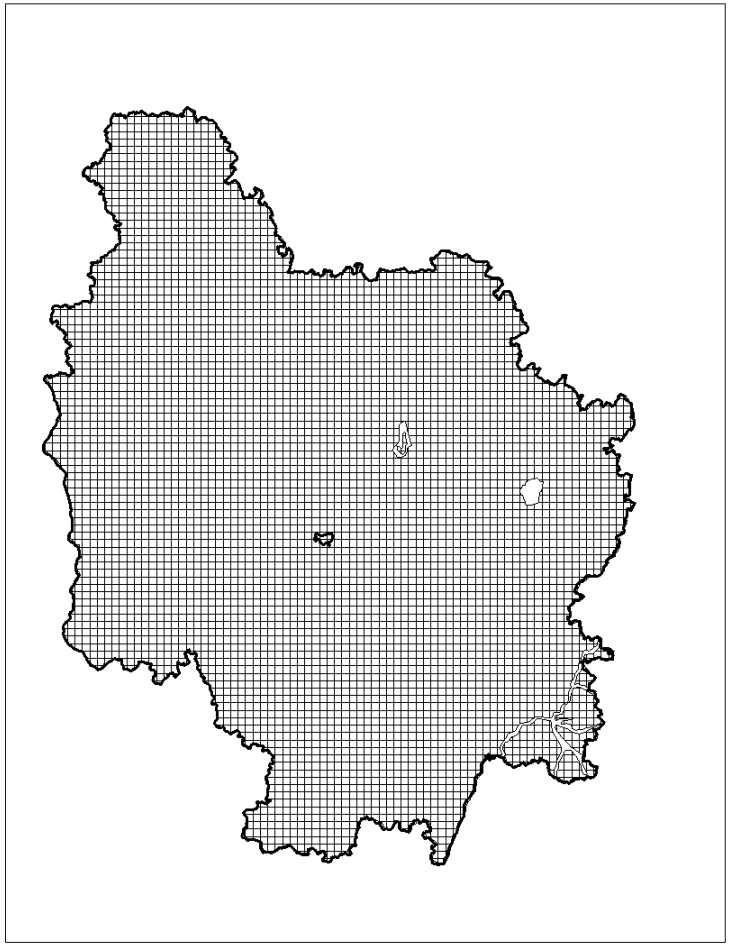
- **BeWhere**
  - Supply chain optimization
  - National level
  - Rough grid
  - Determine the optimal geographic location of production plants
- **LOCAgistics**
  - Supply chain simulation
  - Regional level
  - Finer grid
  - Use the plant location optimized from BeWHere

Burgundy case study

BeWhere 377 grid points

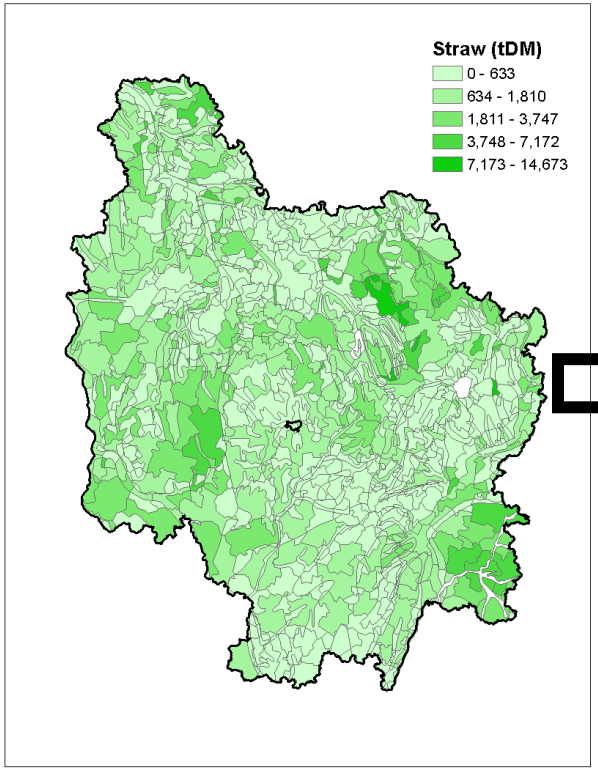


LOCAgistics - 5,357 grid points

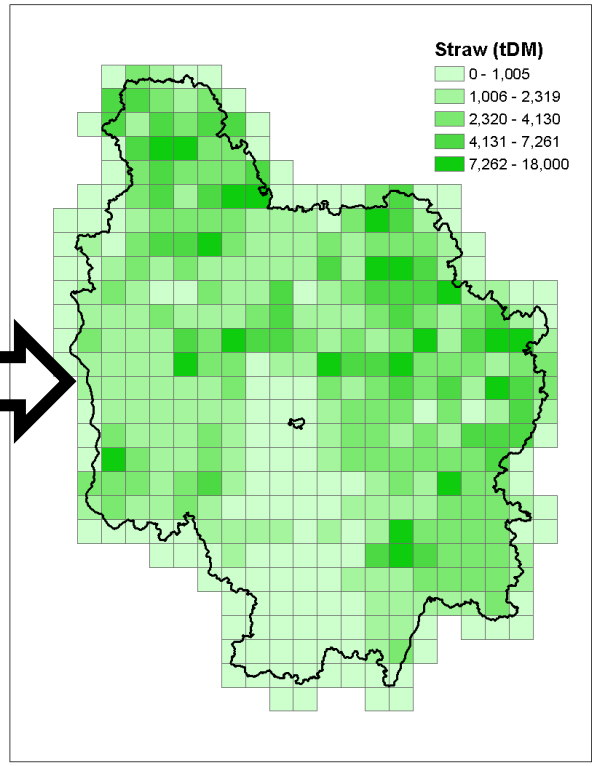


Input: biomass

Straw availability



Aggregation

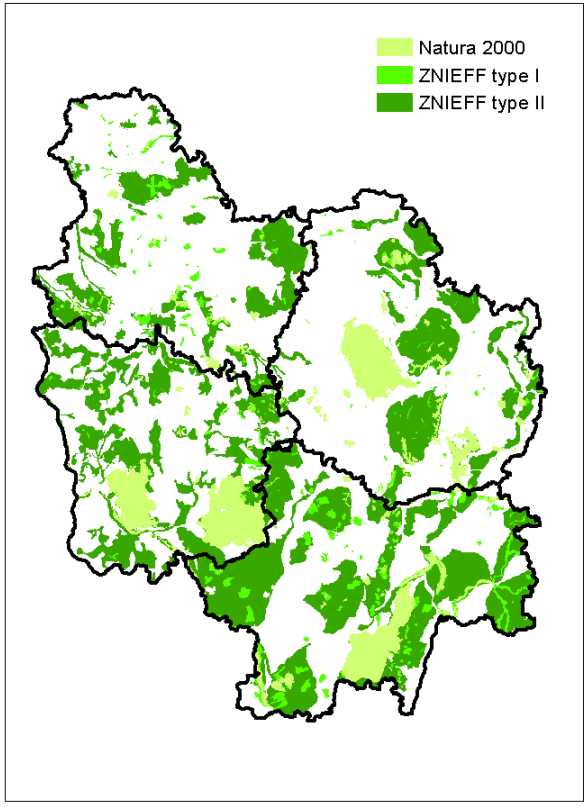


Input

- Biomass available
- Biomass cost
- Emissions

Source: INRA

Protected areas



Source:
Inventaire National du Patrimoine Naturel
European Environment Agency (EEA)

ZNIEFF: Natural Areas of Ecological Fauna and Flora Interest

- type I: areas of great biological or ecological interest
- type II: large, rich and slightly modified natural landscapes, providing significant biological potential

Assumptions for Natura 2000 areas

- No extraction of biomass
- No power plants can be installed

Input: technology

Key parameters	*Unit*	*Methanol [a, b]*
Feedstock		Wood chips
Base plant capacity	$t_{biomass}$/hour	357
Cost		
Base investment	M€/a	505
O&M	M€/$PJ_{biofuel}$	1.2
Efficiencies		
Total	GJ_{in}/GJ_{out}	**0.66**
Biofuel	$GJ_{biofuel}/GJ_{biomass}$	**0.55**
Electrical	$GJ_{electricity}/GJ_{biomass}$	0
District heating	$GJ_{heat}/Gj_{biomass}$	0.11

[a] *Hamelinck , et al., 2002.*
[b] *Wahlund, et al., 2004.*

Input: technology

Key parameters	*Unit*	*Methanol [a, b]*	*Ethanol [c]*
Feedstock		Wood chips	Wood chips
Base plant capacity	$t_{biomass}$/hour	357	105
Cost			
Base investment	M€/a	505	143
O&M	M€/$PJ_{biofuel}$	1.2	2.5
Efficiencies			
Total	GJ_{in}/GJ_{out}	**0.66**	**0.81**
Biofuel	$GJ_{biofuel}/GJ_{biomass}$	**0.55**	0.30
Electrical	$GJ_{electricity}/GJ_{biomass}$	0	0.11
District heating	$GJ_{heat}/Gj_{biomass}$	0.11	**0.40**

[a] *Hamelinck , et al., 2002.*
[b] *Wahlund, et al., 2004.*
[c] *Barta, et al., 2010.*

Input: technology

Key parameters	*Unit*	*Methanol [a, b]*	*Ethanol [c]*	*FT diesel [b]*
Feedstock		Wood chips	Wood chips	Wood chips
Base plant capacity	$t_{biomass}$/hour	357	105	100
Cost				
Base investment	M€/a	505	143	67
O&M	M€/$PJ_{biofuel}$	1.2	2.5	2.9
Efficiencies				
Total	GJ_{in}/GJ_{out}	**0.66**	**0.81**	**0.57**
Biofuel	$GJ_{biofuel}/GJ_{biomass}$	**0.55**	0.30	0.45
Electrical	$GJ_{electricity}/GJ_{biomass}$	0	0.11	0.06
District heating	$GJ_{heat}/Gj_{biomass}$	0.11	**0.40**	0.06

[a] *Hamelinck , et al., 2002.*
[b] *Wahlund, et al., 2004.*
[c] *Barta, et al., 2010.*
[d] *S2Biom*

Input: technology

Key parameters	*Unit*	*Methanol [a, b]*	*Ethanol [c]*	*FT diesel [b]*	*CHP[d]*
Feedstock		Wood chips	Wood chips	Wood chips	Straw
Base plant capacity	$t_{biomass}$/hour	357	105	100	3.75
Cost					
Base investment	M€/a	505	143	67	0.63
O&M	M€/$PJ_{biofuel}$	1.2	2.5	2.9	1.75
Efficiencies					
Total	GJ_{in}/GJ_{out}	**0.66**	**0.81**	**0.57**	**0.85**
Biofuel	$GJ_{biofuel}/GJ_{biomass}$	**0.55**	0.30	0.45	-
Electrical	$GJ_{electricity}/GJ_{biomass}$	0	0.11	0.06	**0.25**
District heating	$GJ_{heat}/Gj_{biomass}$	0.11	**0.40**	0.06	**0.60**

[a] *Hamelinck , et al., 2002.*
[b] *Wahlund, et al., 2004.*
[c] *Barta, et al., 2010.*
[d] *S2Biom*

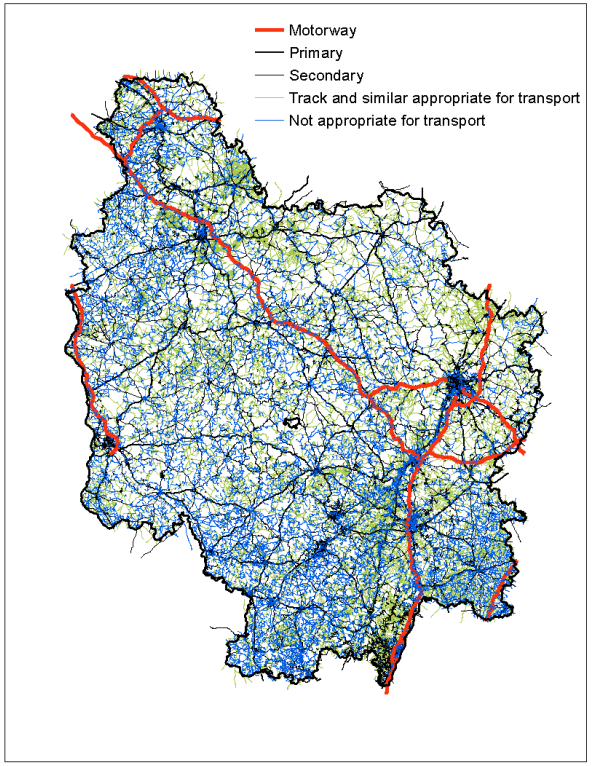
Input: technology

Technology	Operating hours hours/year	Investment cost MEUR	Heat MW_{th}	Power MW_e	Heat efficiency	Power efficiency
Fixed bed for CHP	7,200	0.2	0.1	0.05	0.5	0.23
Pyrolysis combustion engine (compression-ignition)	7,500	0.7	0.25	0.25	0.4	0.4
Fixed bed, direct combustion	8,500	2.5	5		0.88	
BFB for CHP	8,500	18	8	5	0.52	0.3
Grate boiler for CHP	8,500	25	10	5	0.6	0.25

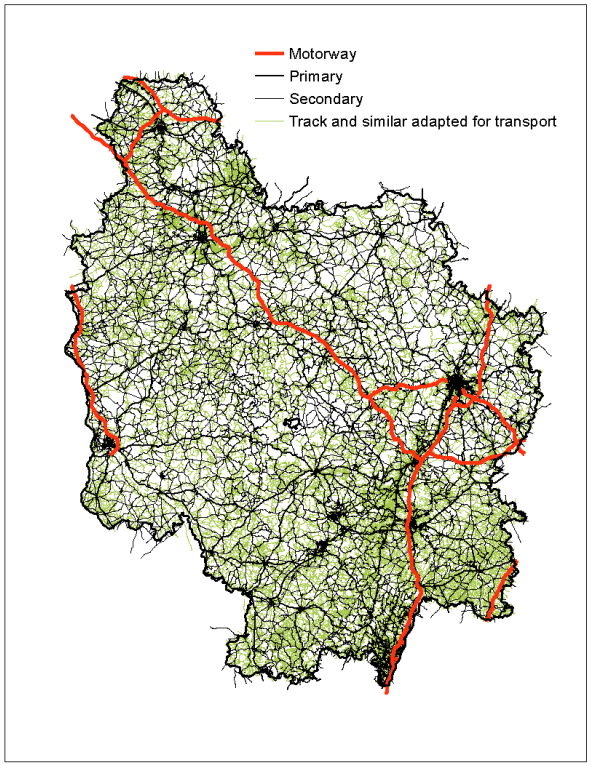
Source: S2Biom, WP2

Input: logistics

Road Network



Used road network



Input

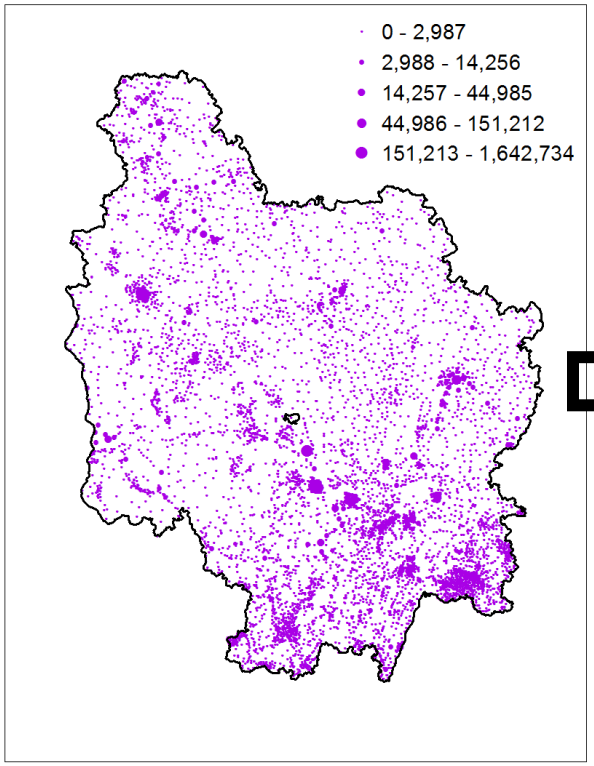
- Transport cost
- Emissions
- Terminals / pretreatment

- Distances from all points to all points based on Min(*t*) or Min(*d*)

Source: OpenStreetMap.org

Input: demand

Population



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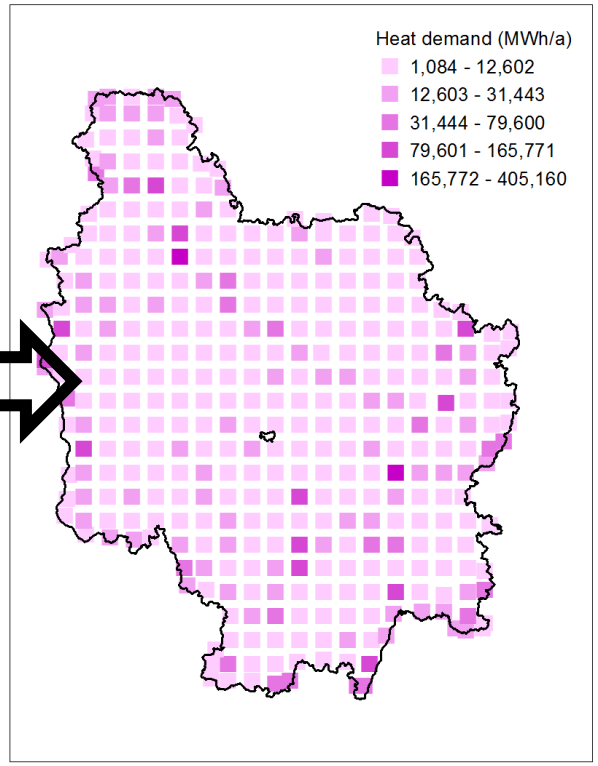


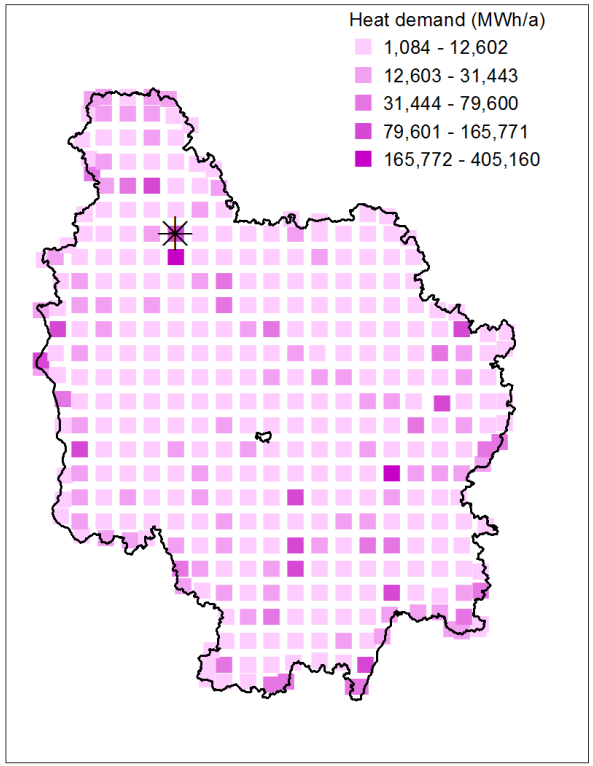
Input needed

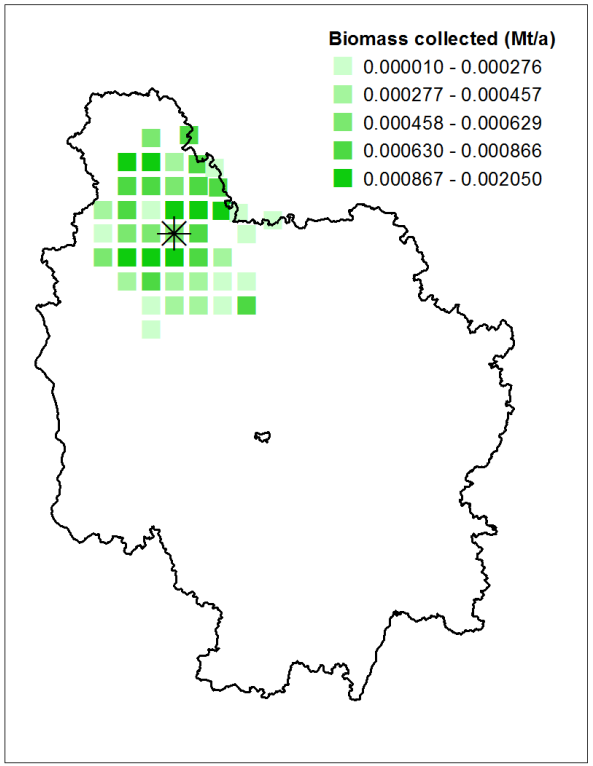
- Heat consumption
- Power consumption
- Transport fuel consumption
- Price of competing
  - heat
  - power
  - transport fuel

Source:
OpenStreetMap.org
Réseau de Transport d'Électricité, www.rte-france.com

Result Example

First plant



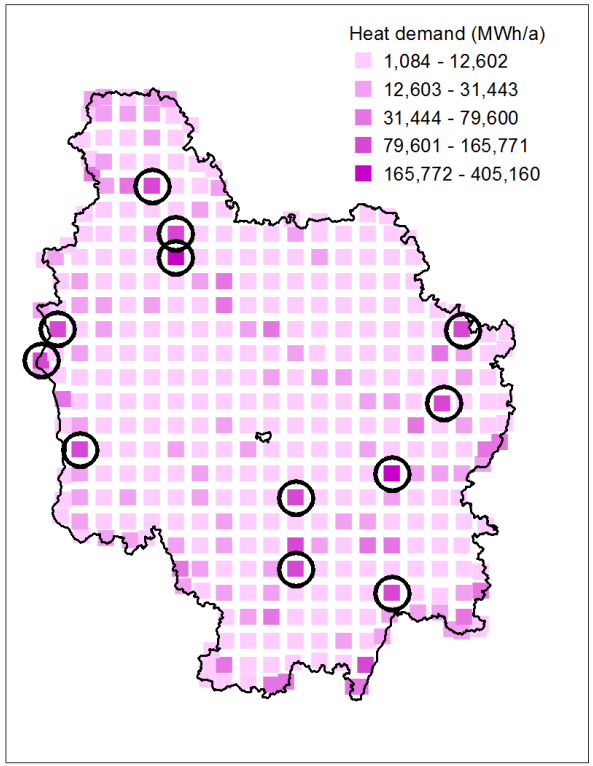


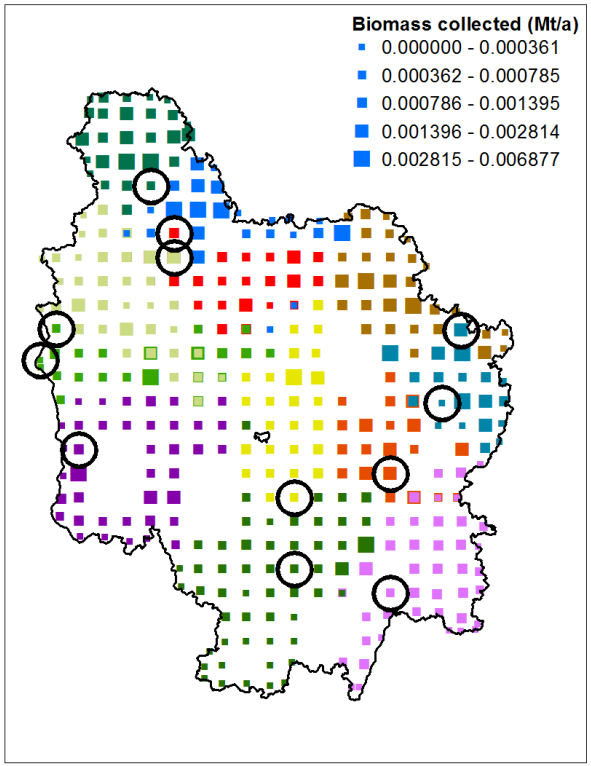
Radius (km)	65
Straw (t/a)	0
Miscanthus (t/a)	30,000
Power (MWh)	35,417
Heat (MWh)	85,000

Plant technology: Grate boiler for CHP
Largest capacity
Close to high heat demand

Result Example

Maximize the fossil fuel substitution





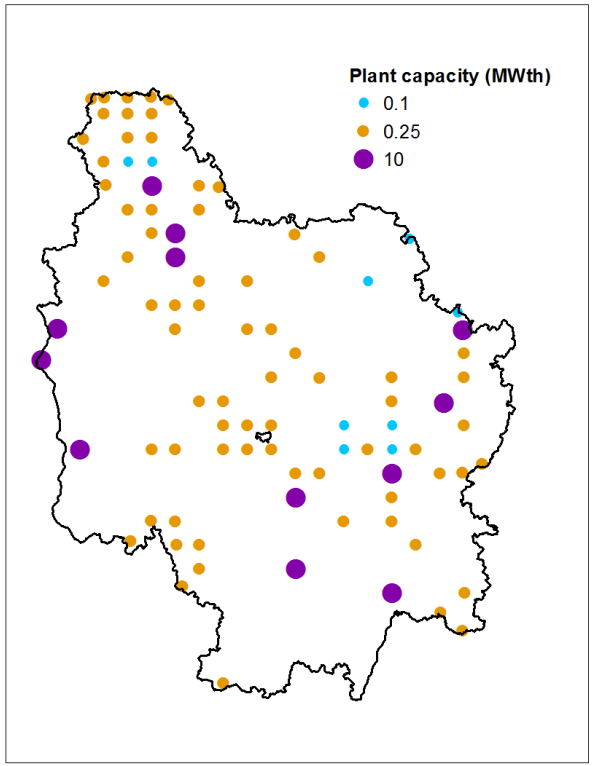
	Min	Max
Radius (km)	70	158
Straw (kt/a)	6,5	20,5
Miscanthus (kt/a)	9,5	18,5
Power (MWh)	24,792	35,417
Heat (MWh)	59,500	85,000

Plant technology: Grate boiler for CHP
Largest capacity
Close to high heat demand

Heat demand has stronger impact on the location than the distribution of biomass

Result Example

Biomass available +25%



Capacity	Radius	Straw	Miscanthus	Power	Heat
MWth	km	Mt/a	Mt/a	MWh	MWh
10	109	12,521	17,479	35,417	85,000
0.25	30	893	97	1,869	1,869
0.1	23	271	34	331	720

- Bigger plants are chosen first due to the economy of scale.
- Increasing the feedstock availability, leave some room for smaller plant.

BeWhere / Locagistic

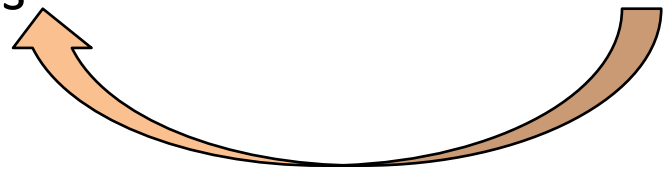
- Plants location, size and technology
- Biomass used
- Costs
- Emissions avoided

BeWhere

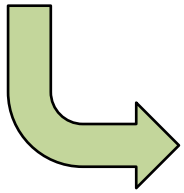
Determine the optimal location of plants

LOCAgistics

Calculations at the plant level



Quality check!



Final results

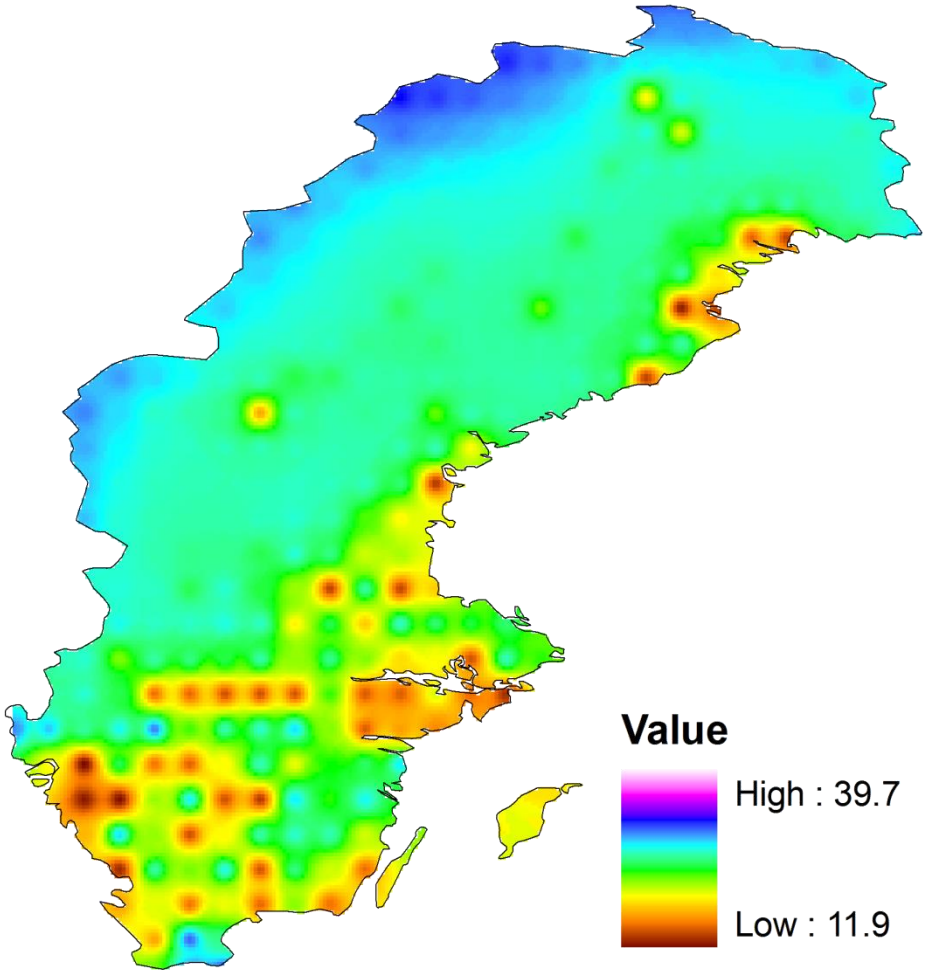
BeWhere / Locagistic

- **BeWhere**
  - National level
  - Geographic location of plant
  - Based on techno-economic approach
- **LOCAgistics**
  - Regional level
  - Input from BeWHere
  - Detailed allocation of biomass to selected plants

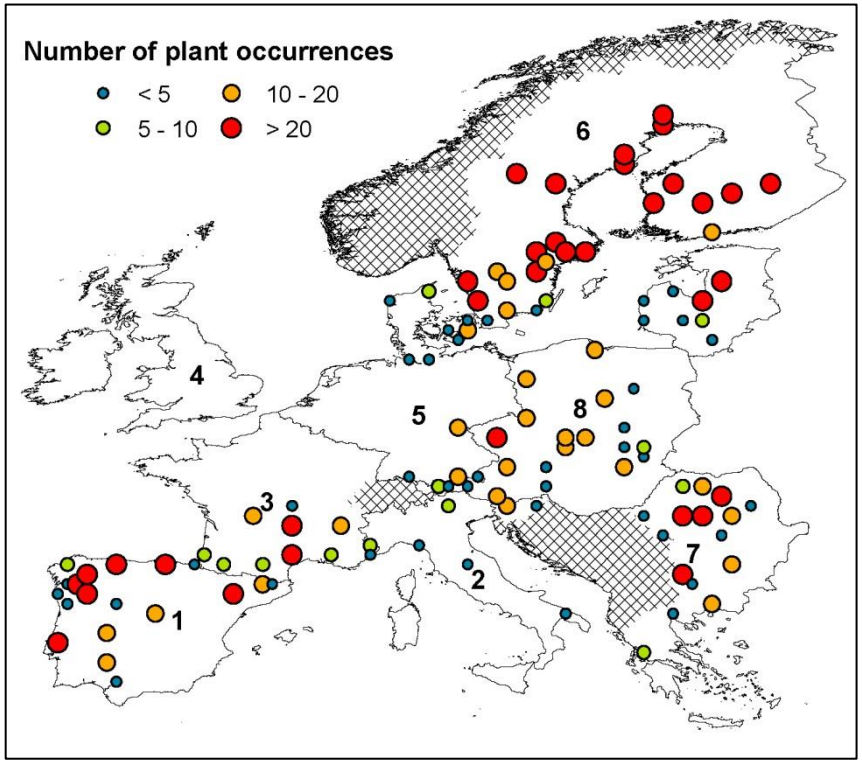
BeWhere and Europe

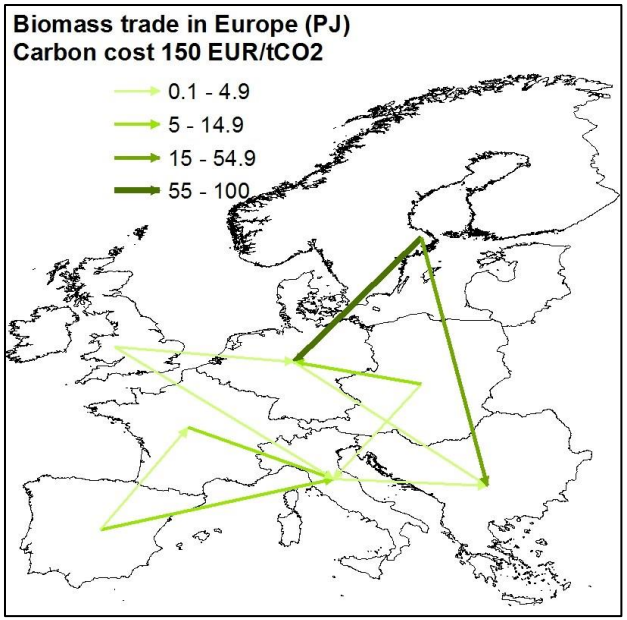
- BeWhere will be run for Europe
- Results will be extracted at the country level
- With a special focus on case studies

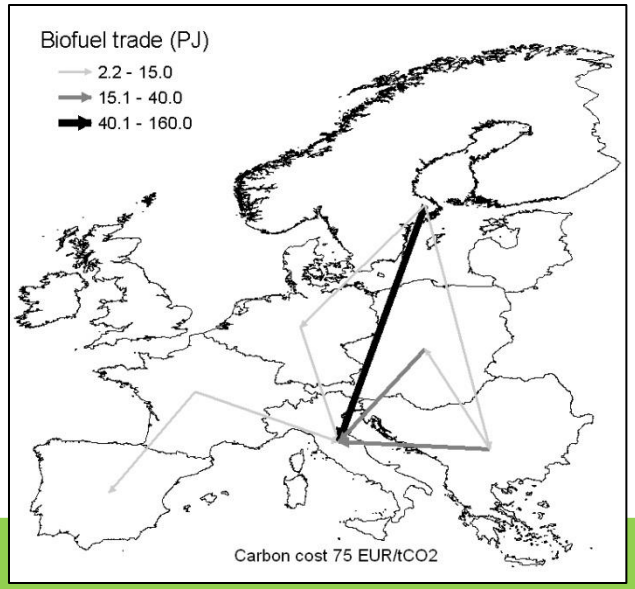
Sweden
Ethanol Production Cost (€/GJ)



European Model





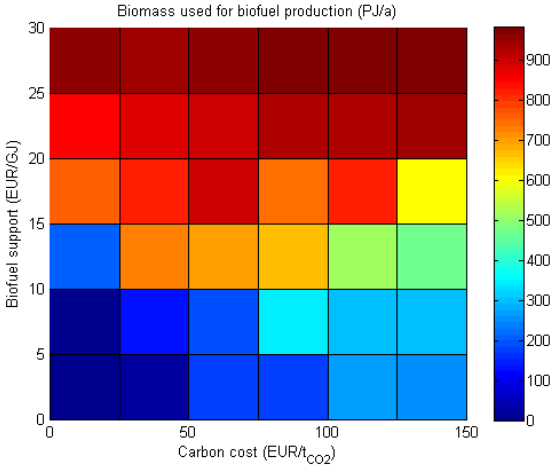


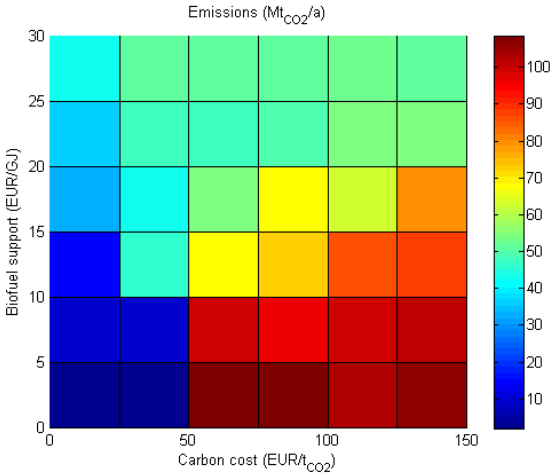
Biofuel Support vs Carbon Cost

Biomass used (PJ/a)

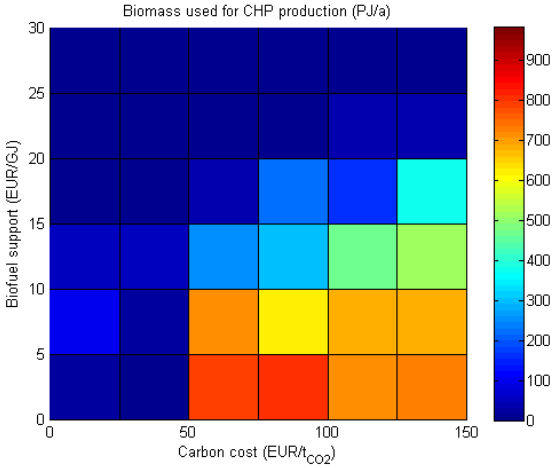
Emissions (Mt_{CO2}/a)

Biofuel





CHP

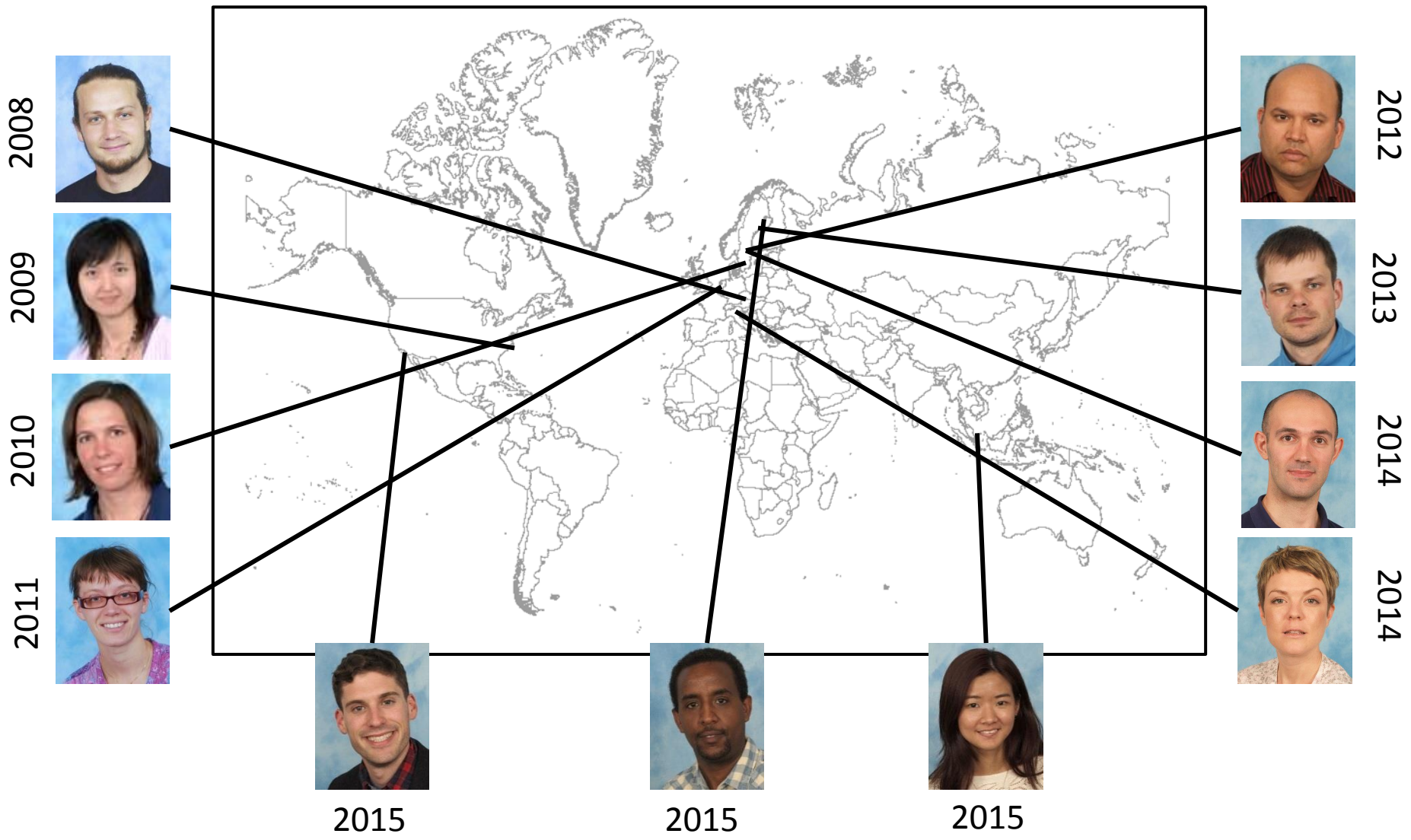


Visualization

www.jecami.eu

http://webarchive.iiasa.ac.at/Research/FOR/bewhere/Results/

BeWhere and YSSP



Thank you for your attention !!

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More about BeWhere

www.iiasa.ac.at/bewhere

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