BeWhere Tool
for Optimal Technology, Location and Capacity of Bio-energy Production Plants

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International Institute for Applied Systems Analysis (IIASA)

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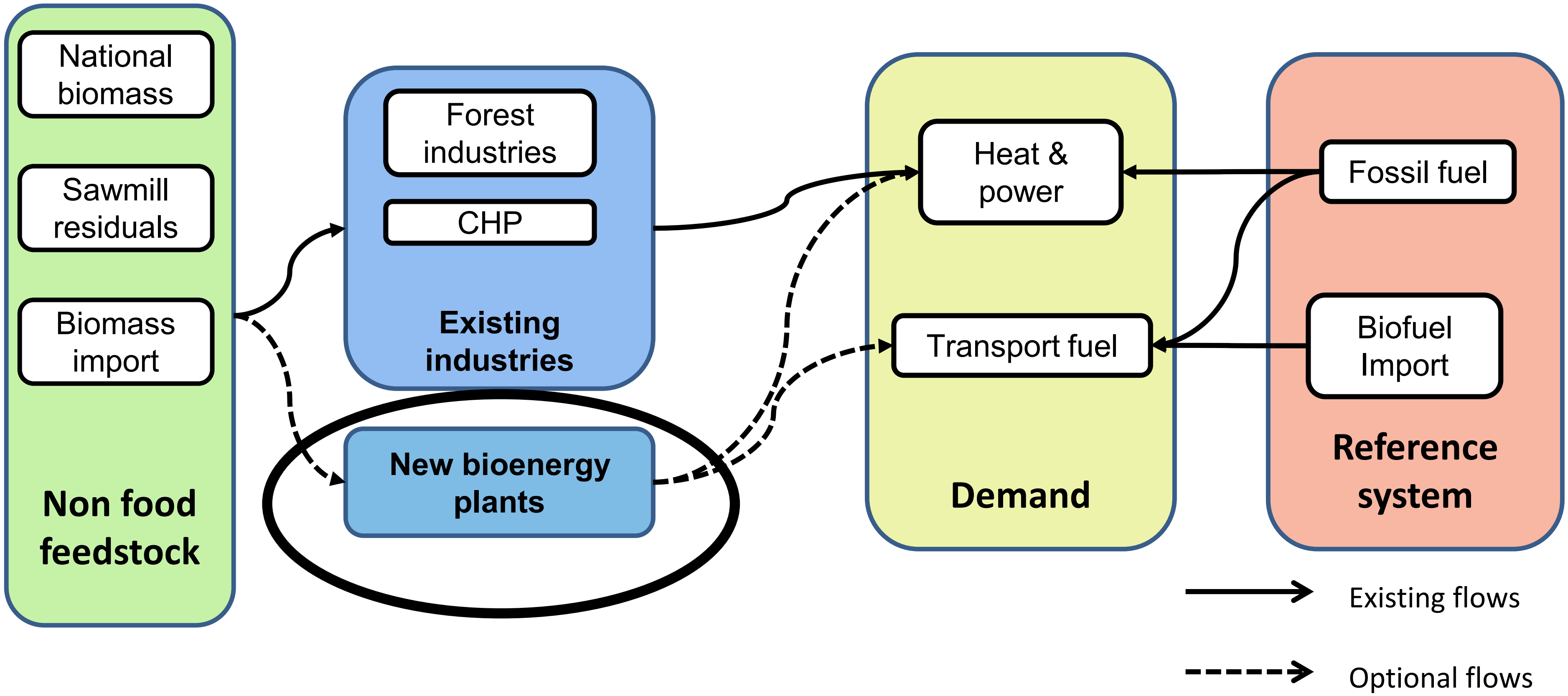
Outline

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

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

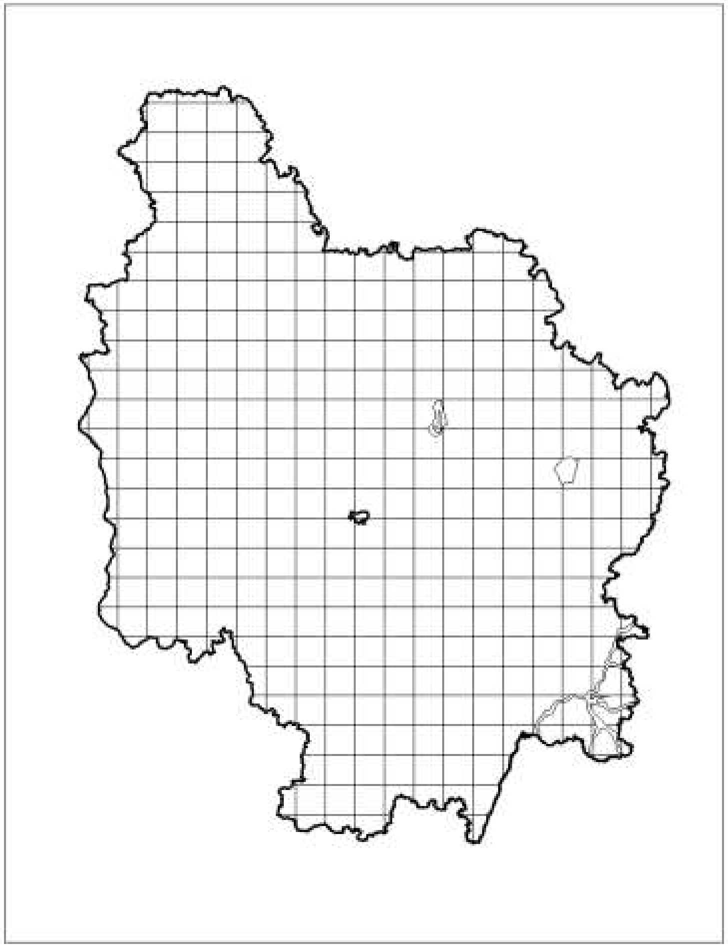
BeWhere / Locagistic

- **BeWhere**
- Supply chain optimization
- National level
- Rough grid
- Determine the optimal geographic location of production plants

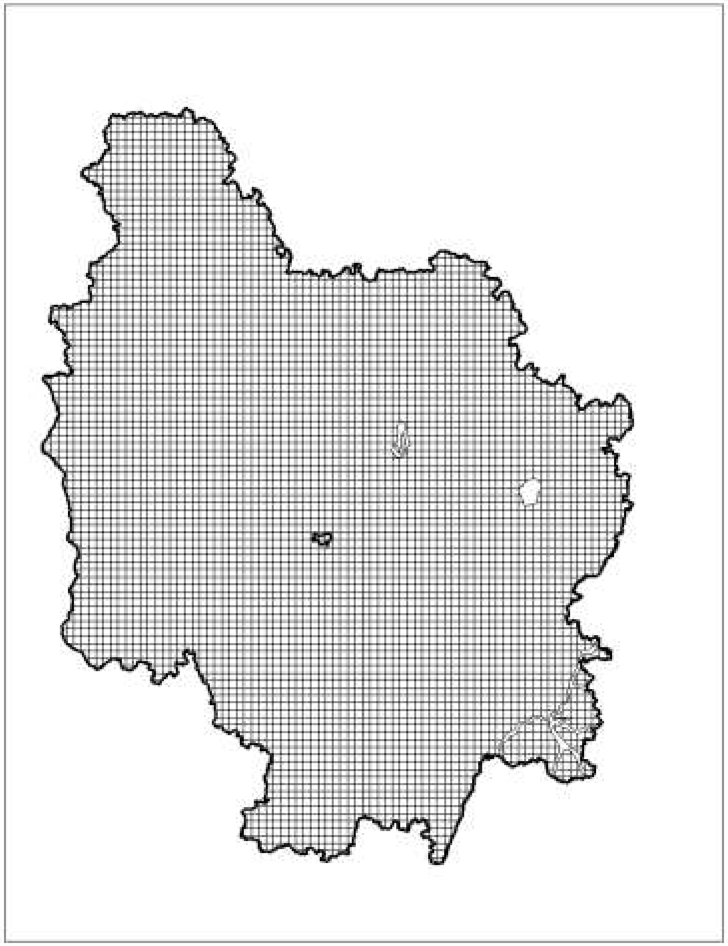
- **LOCAgistics**
- Supply chain simulation
- Regional level
- Finer grid
- Use the plant location optimized from BeWHere

Burgundy case study

BeWhere 377 grid points

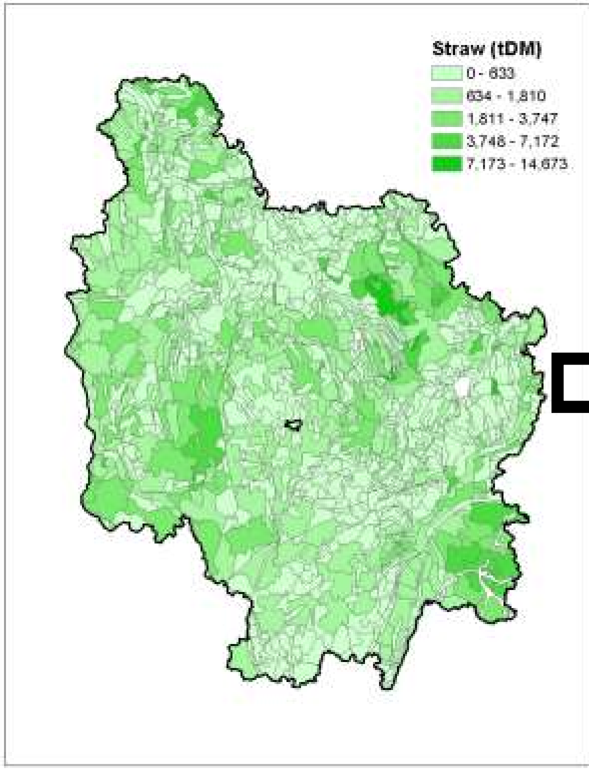


LOCAgistics - 5,357 grid points



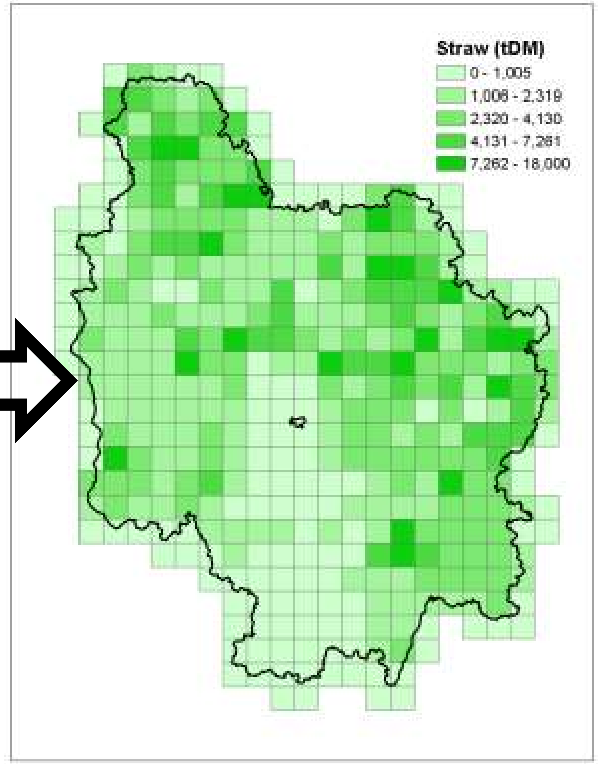
Input: biomass

Straw availability



Source: INRA

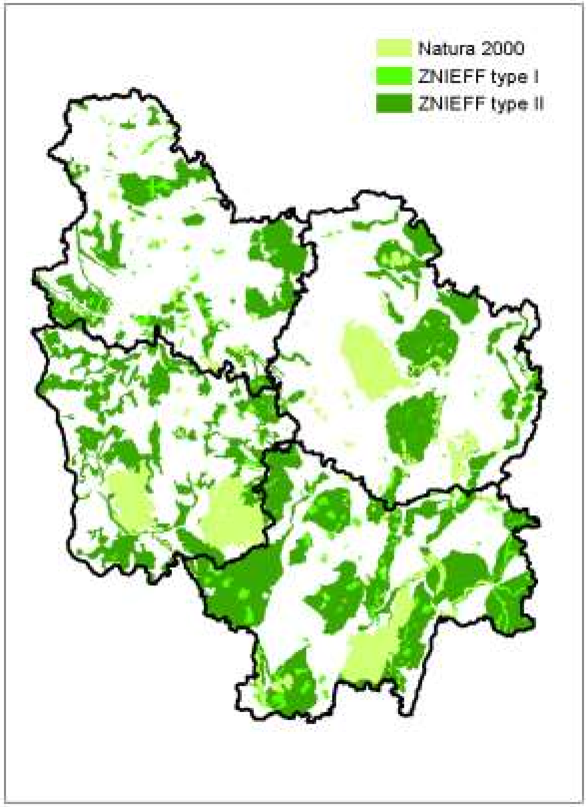
Aggregation



Input

- Biomass available
- Biomass cost
- Emissions

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*

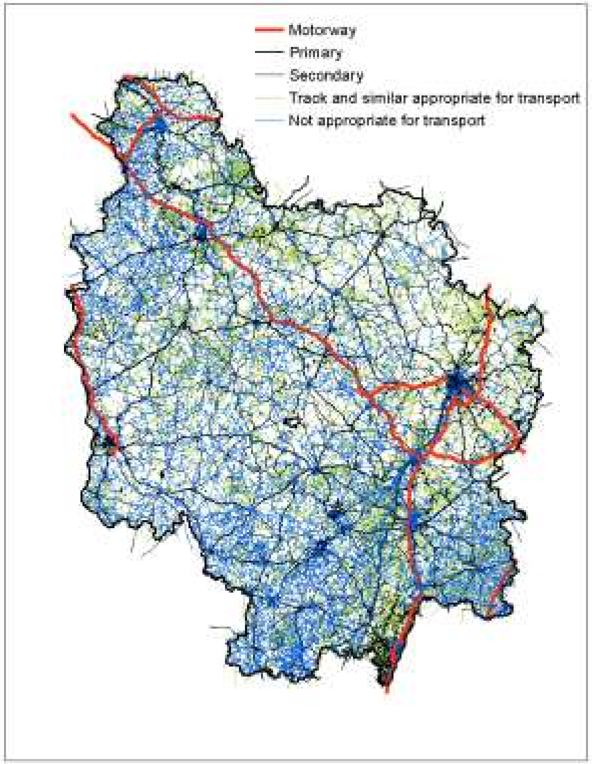
Input: technology

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

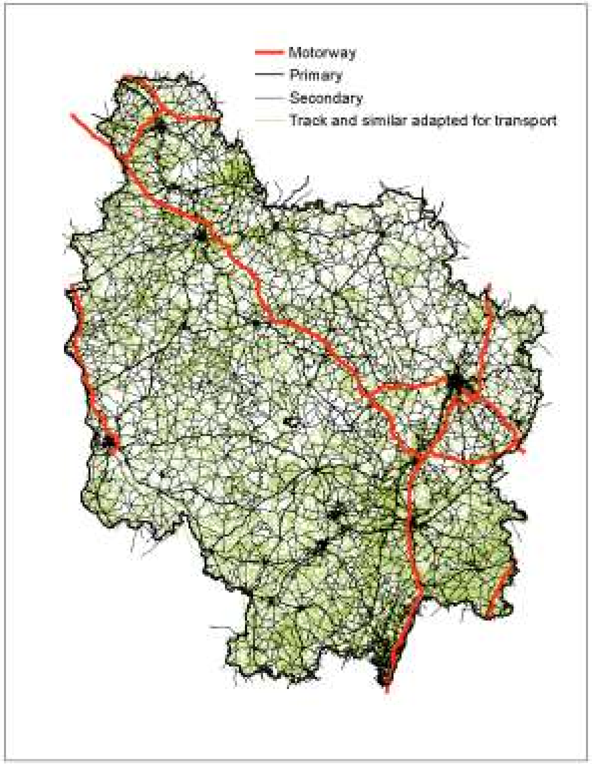
Source: S2Biom, WP2

Input: logistics

Road Network



Used road network



Input

- Transport cost
- Emissions
- Terminals / pretreatment

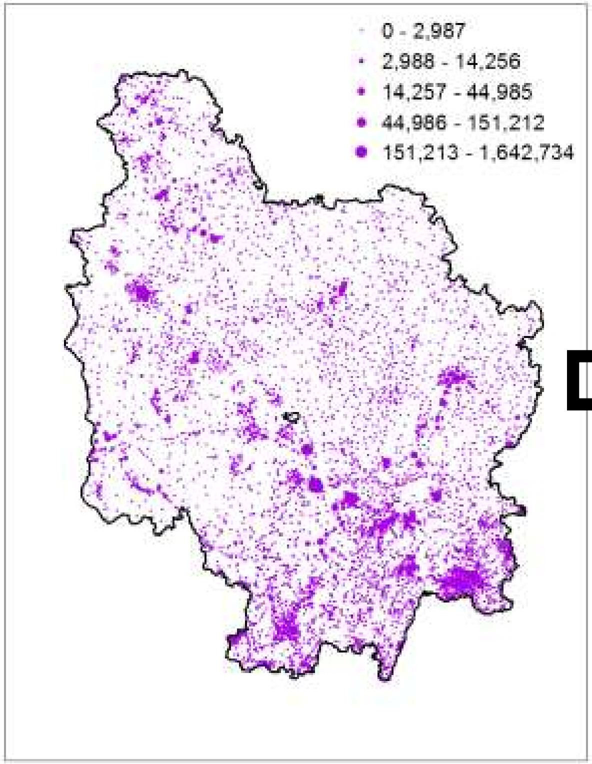
- Distances from all points to all points based on Min(*t*) or Min(*d*)

Source: OpenStreetMap.org

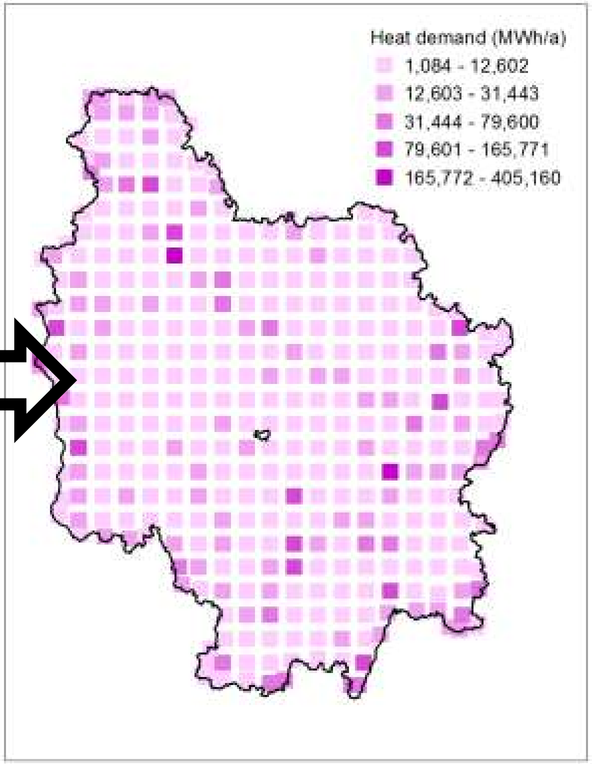
Input: demand

S2Biom

Population



Aggregation



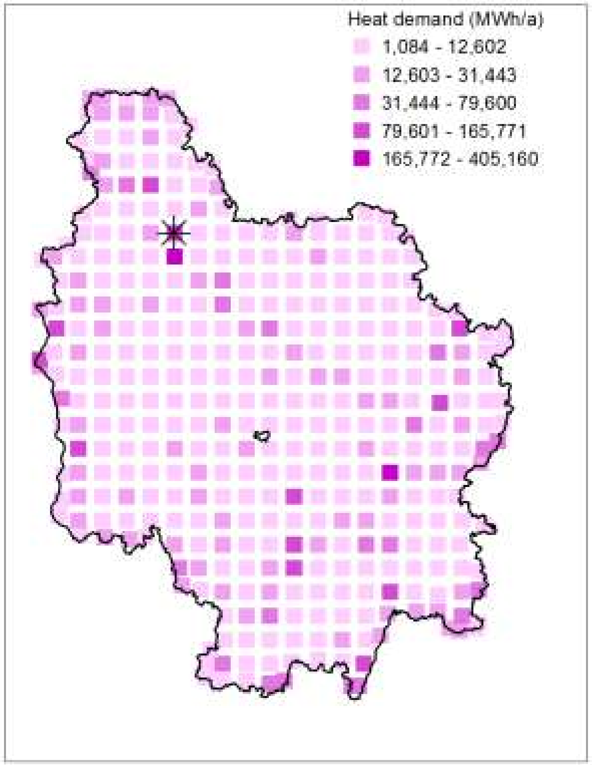
Input needed

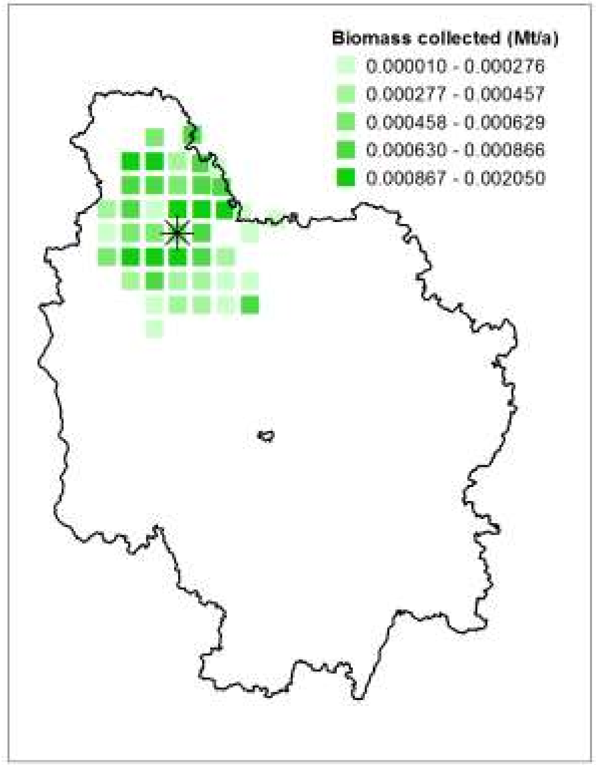
- Heat consumption
- Power consumption
- Transport fuel consumption
- Price of competing
  - heat
  - power
  - transport fuel

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

Result Example

First plant



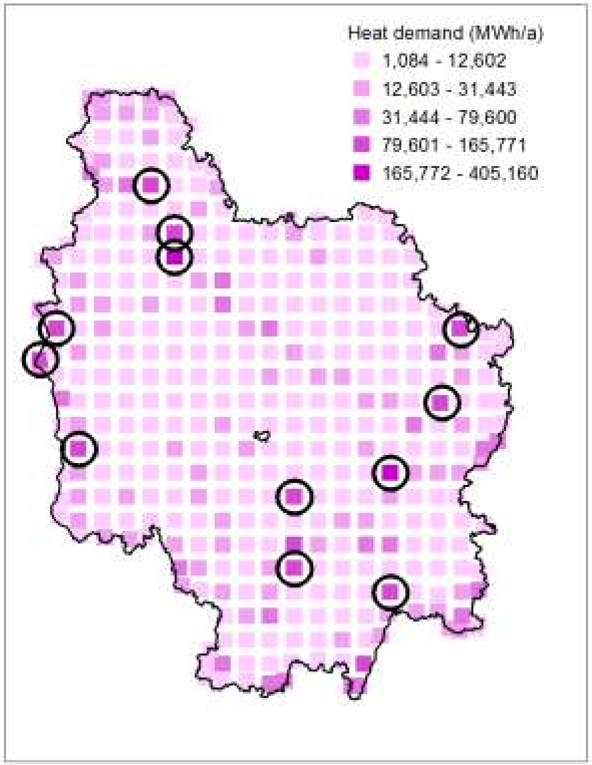


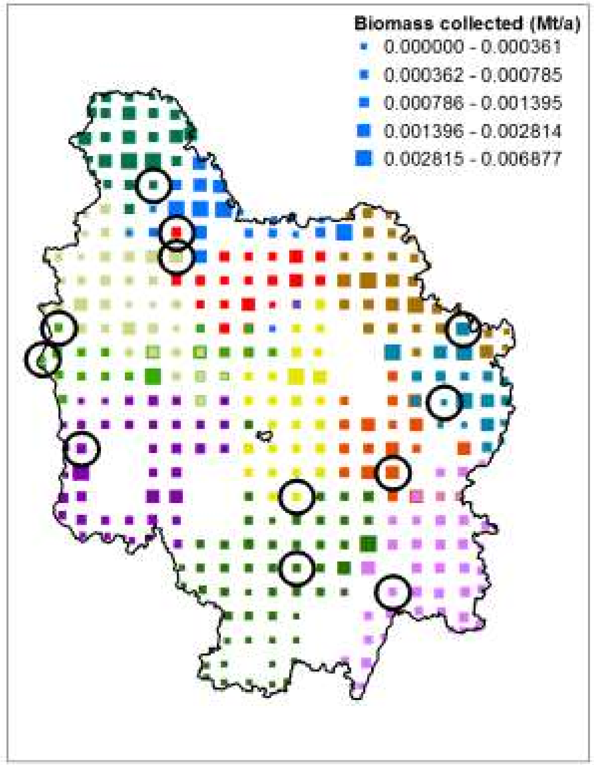
Radius (km)	65
Straw (t/a)	0
Miscanthus (t/a)	30,000
Power (MWh)	35,417
Heat (MWh)	85,000

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

Result Example

Maximize the fossil fuel substitution





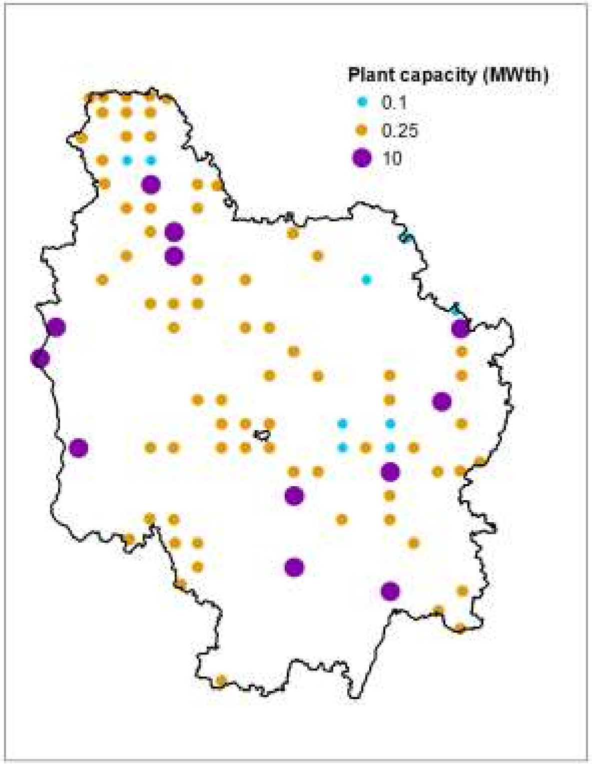
	Min	Max
Radius (km)	70	158
Straw (kt/a)	6,5	20,5
Miscanthus (kt/a)	9,5	18,5
Power (MWh)	24,792	35,417
Heat (MWh)	59,500	85,000

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

S2Biom

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

BeWhere

Determine the optimal location of plants

LOCAgistics

Calculations at the plant level

Final results

Quality check!

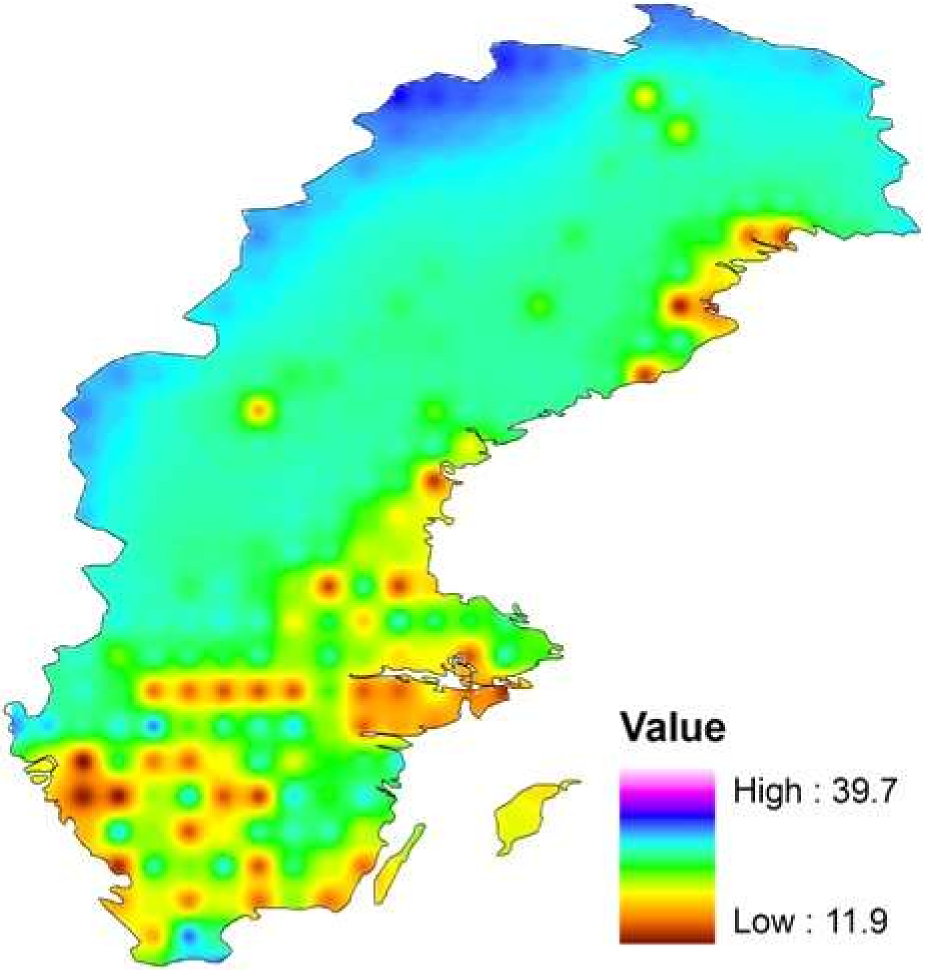
BeWhere / Locagistic

- **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

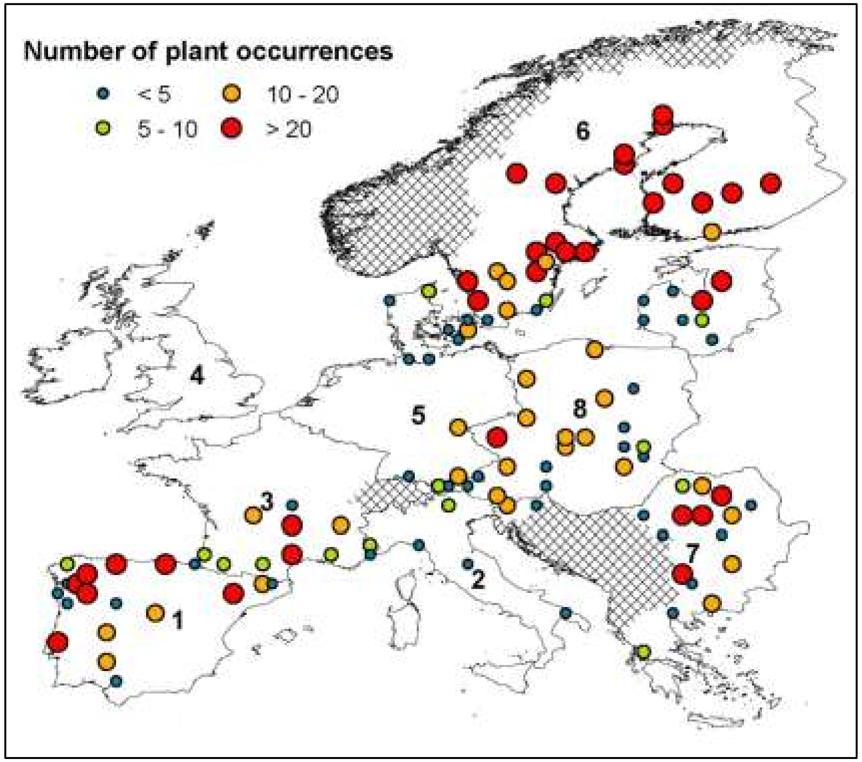
BeWhere and Europe

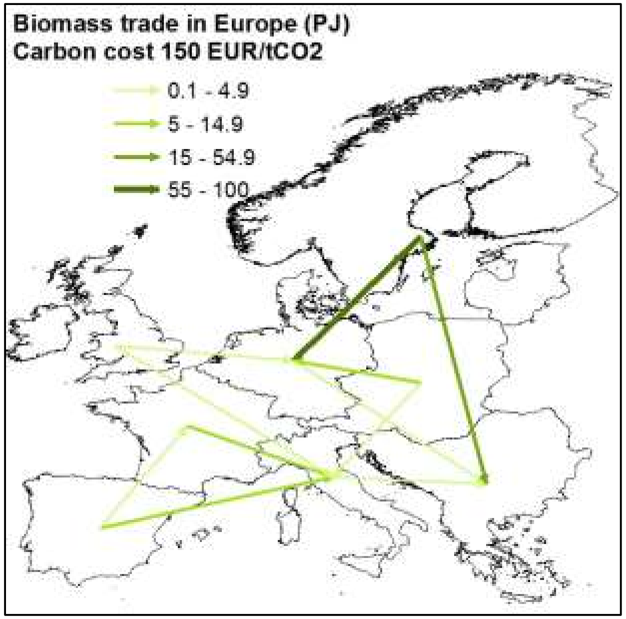
- BeWhere will be run for Europe
- Results will be extracted at the country level
- With a special focus on case studies

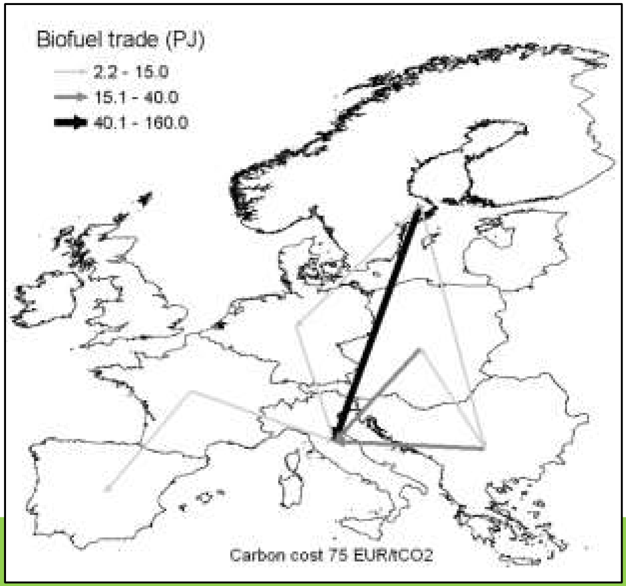
Sweden
Ethanol Production Cost (€/GJ)



European Model





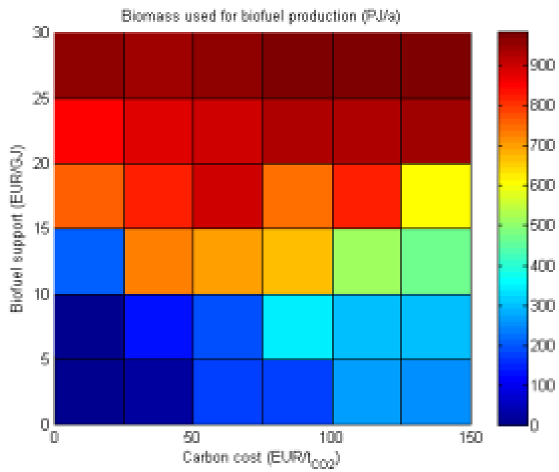


Biofuel Support vs Carbon Cost

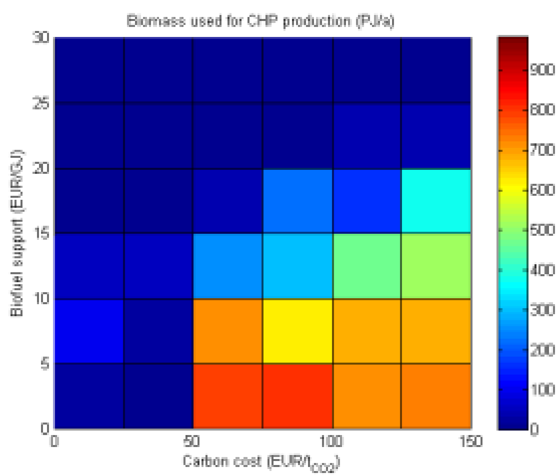
Biomass used (PJ/a)

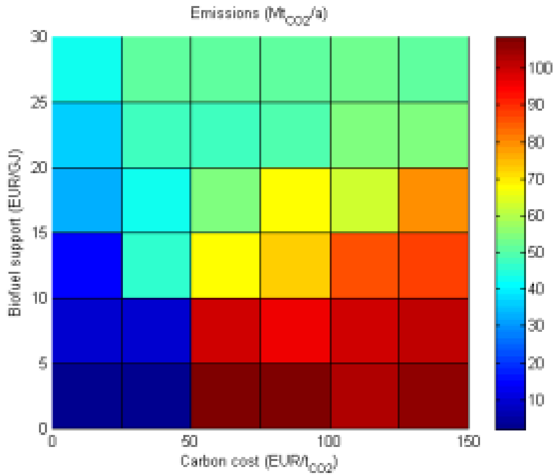
Emissions (Mt_{CO2}/a)

Biofuel



CHP



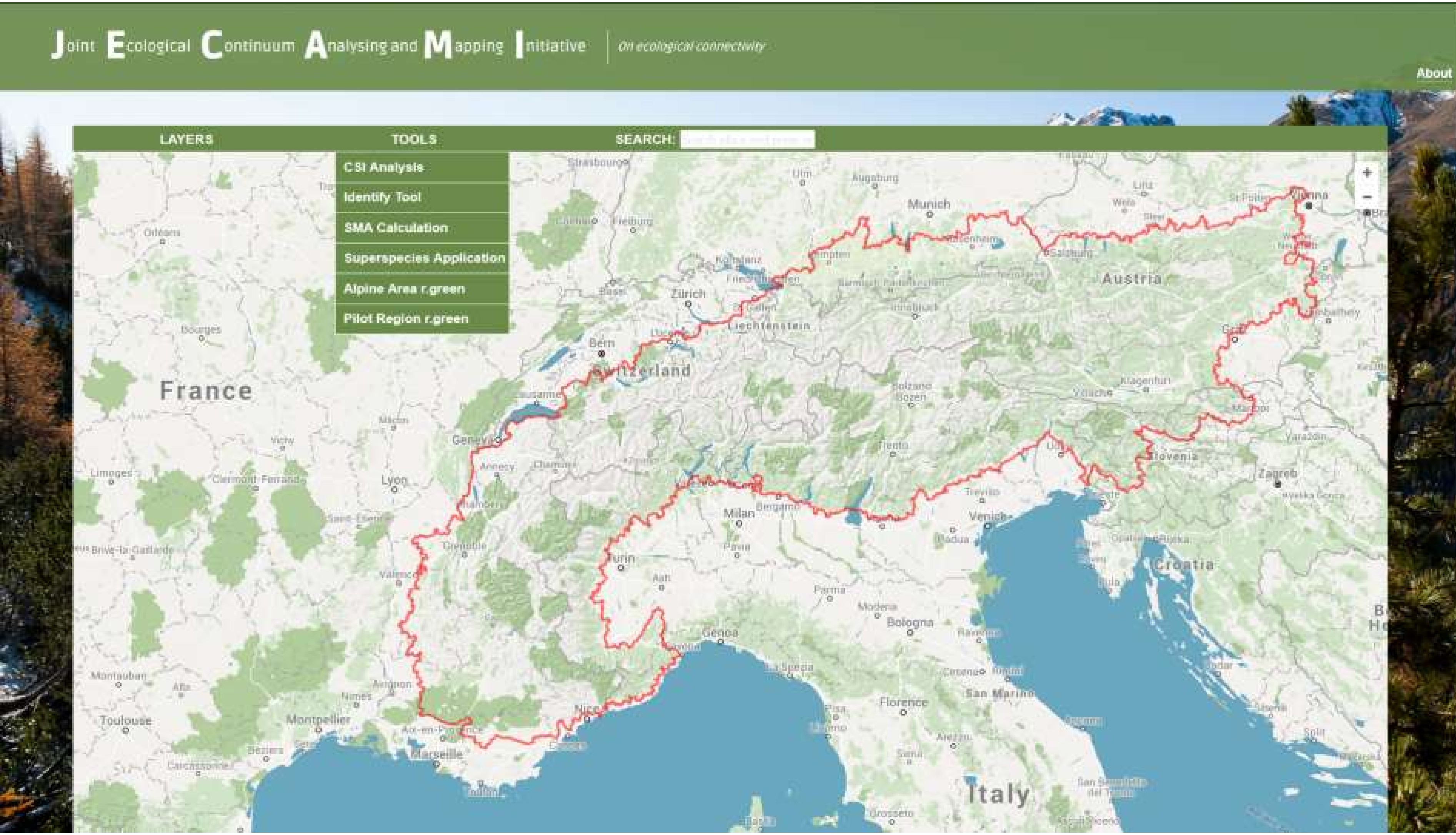


Visualization

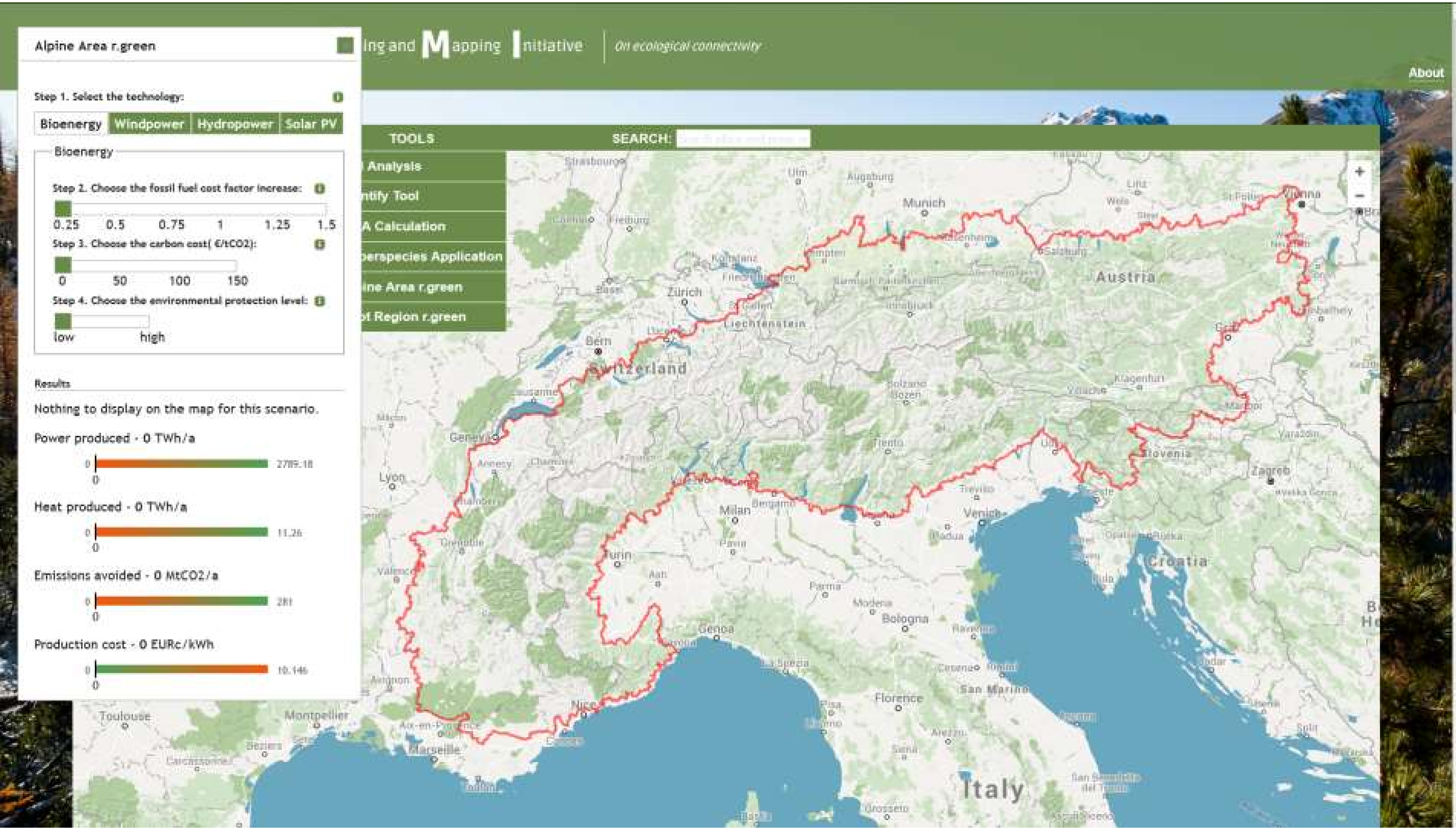
www.jecami.eu

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

BeWhere - DSS

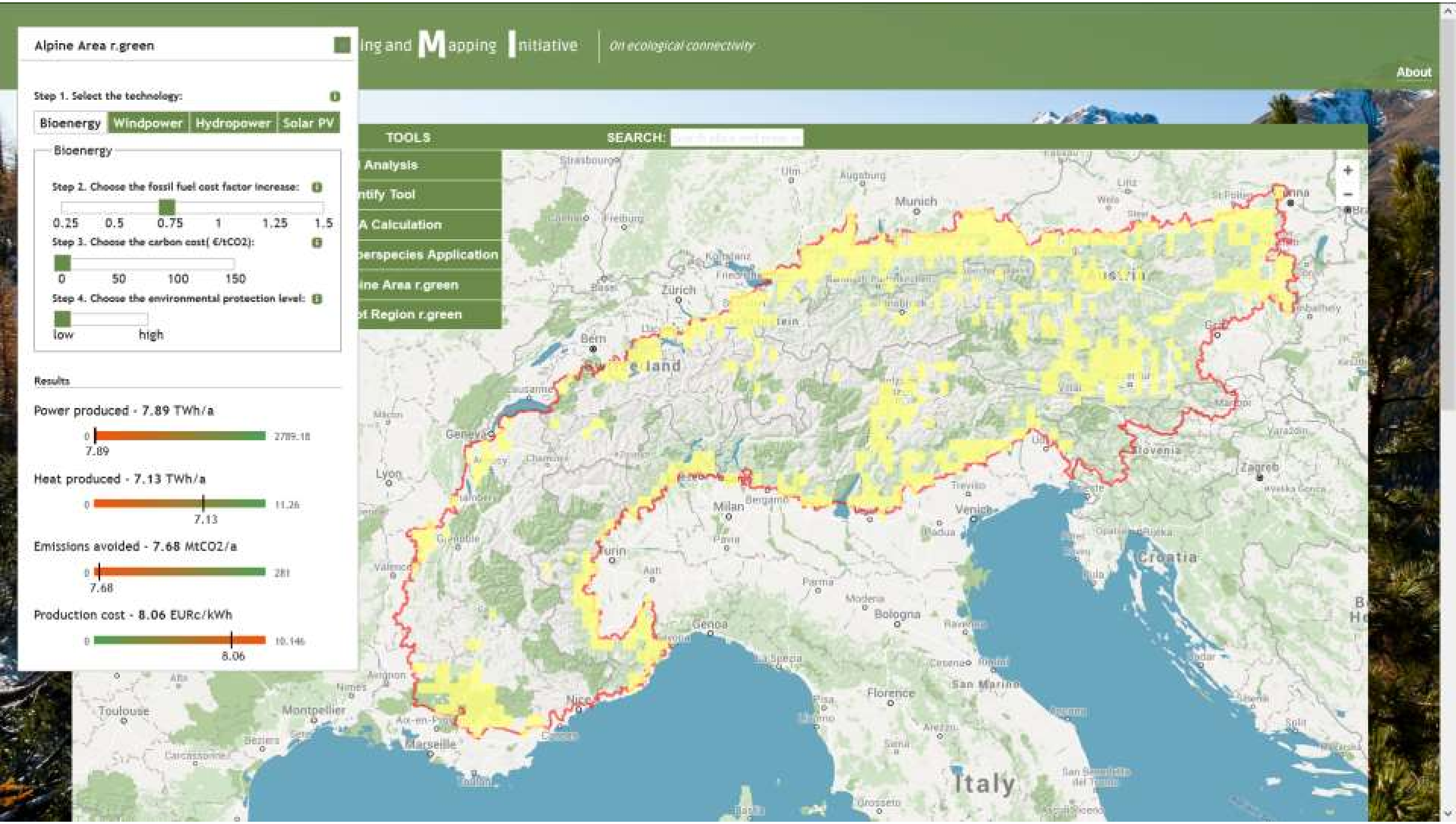

Joint Ecological Continuum Analysing and Mapping Initiative
On ecological connectivity
About
LAYERS
TOOLS
SEARCH:
CSI Analysis
Identify Tool
SMA Calculation
Superspecies Application
Alpine Area r.green
Pilot Region r.green
France
Switzerland
Austria
Italy
Croatia
Slovenia
Liechtenstein
Munich
Zurich
Bern
Geneva
Lyon
Milan
Turin
Venice
Genoa
Bologna
Florence
Nice
Marseille
Toulouse
Montpellier
Zagreb

BeWhere - DSS



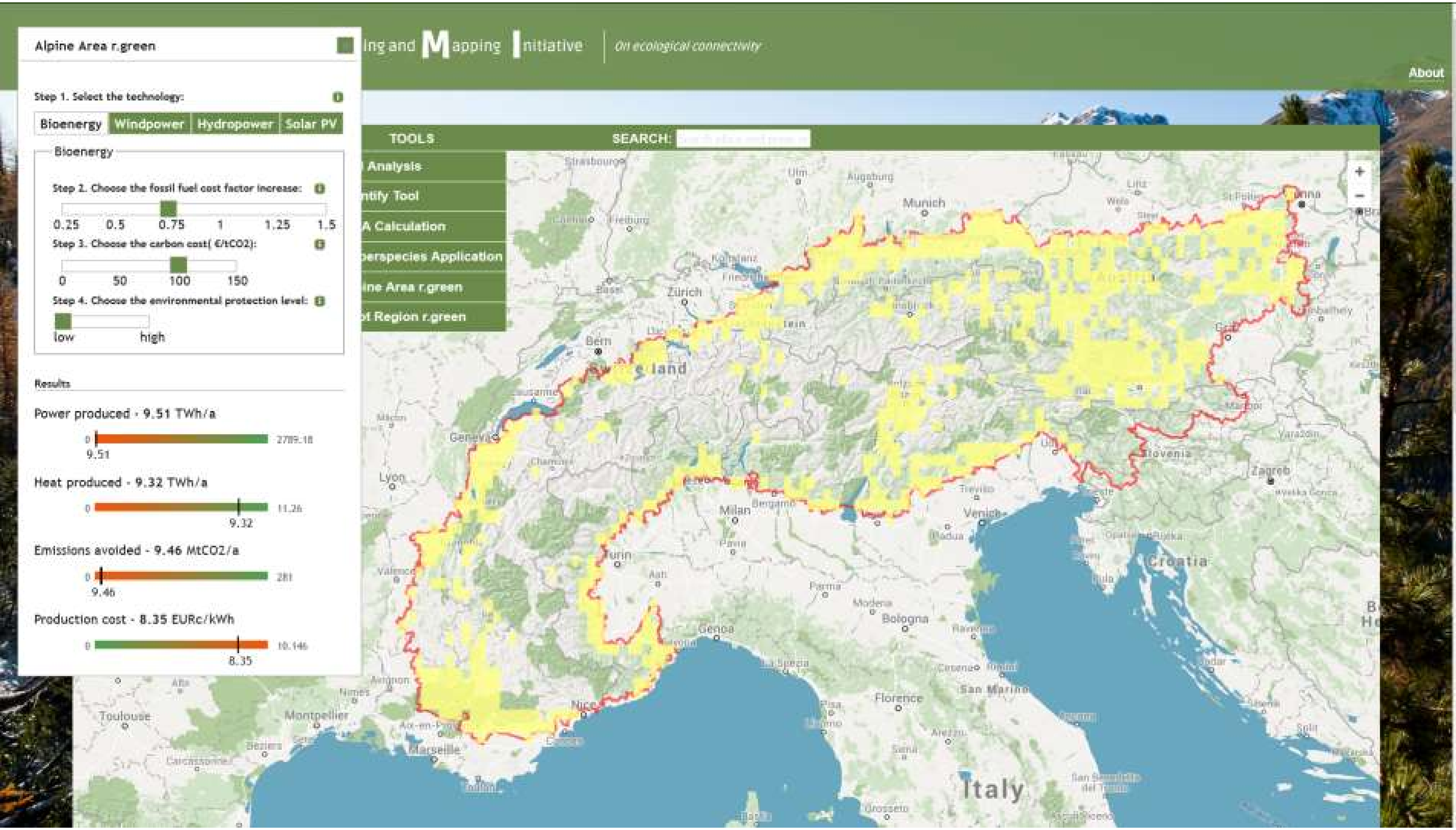
Alpine Area r.green
Step 1. Select the technology:
Bioenergy
Windpower
Hydropower
Solar PV
Step 2. Choose the fossil fuel cost factor increase:
0.25 0.5 0.75 1 1.25 1.5
Step 3. Choose the carbon cost(€/tCO2):
0 50 100 150
Step 4. Choose the environmental protection level:
low high
Results
Nothing to display on the map for this scenario.
Power produced - 0 TWh/a
Heat produced - 0 TWh/a
Emissions avoided - 0 MtCO2/a
Production cost - 0 EURc/kWh
TOOLS
SEARCH:
About
On ecological connectivity
Switzerland
Austria
Italy
Croatia
Slovenia
Liechtenstein
Munich
Milan
Turin
Genoa
Venice
Zürich
Bern
Geneva
Lyon
Nice
Marseille
Bologna
Florence
Zagreb
Toulouse
Montpellier

BeWhere - DSS



Alpine Area r.green
Step 1. Select the technology:
Bioenergy
Windpower
Hydropower
Solar PV
Bioenergy
Step 2. Choose the fossil fuel cost factor increase:
0.25 0.5 0.75 1 1.25 1.5
Step 3. Choose the carbon cost(€/tCO2):
0 50 100 150
Step 4. Choose the environmental protection level:
low high
Results
Power produced - 7.89 TWh/a
Heat produced - 7.13 TWh/a
Emissions avoided - 7.68 MtCO2/a
Production cost - 8.06 EURc/kWh
TOOLS
SEARCH:
On ecological connectivity
About
Munich
Zürich
Bern
Milan
Turin
Venice
Genoa
Bologna
Florence
Marseille
Nice
Lyon
Geneva
Zagreb
Italy
Croatia

BeWhere - DSS


Alpine Area r.green
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Solar PV
Bioenergy
Step 2. Choose the fossil fuel cost factor increase:
0.25 0.5 0.75 1 1.25 1.5
Step 3. Choose the carbon cost(€/tCO2):
0 50 100 150
Step 4. Choose the environmental protection level:
low high
Results
Power produced - 9.51 TWh/a
9.51
Heat produced - 9.32 TWh/a
9.32
Emissions avoided - 9.46 MtCO2/a
9.46
Production cost - 8.35 EURc/kWh
8.35
TOOLS
SEARCH:
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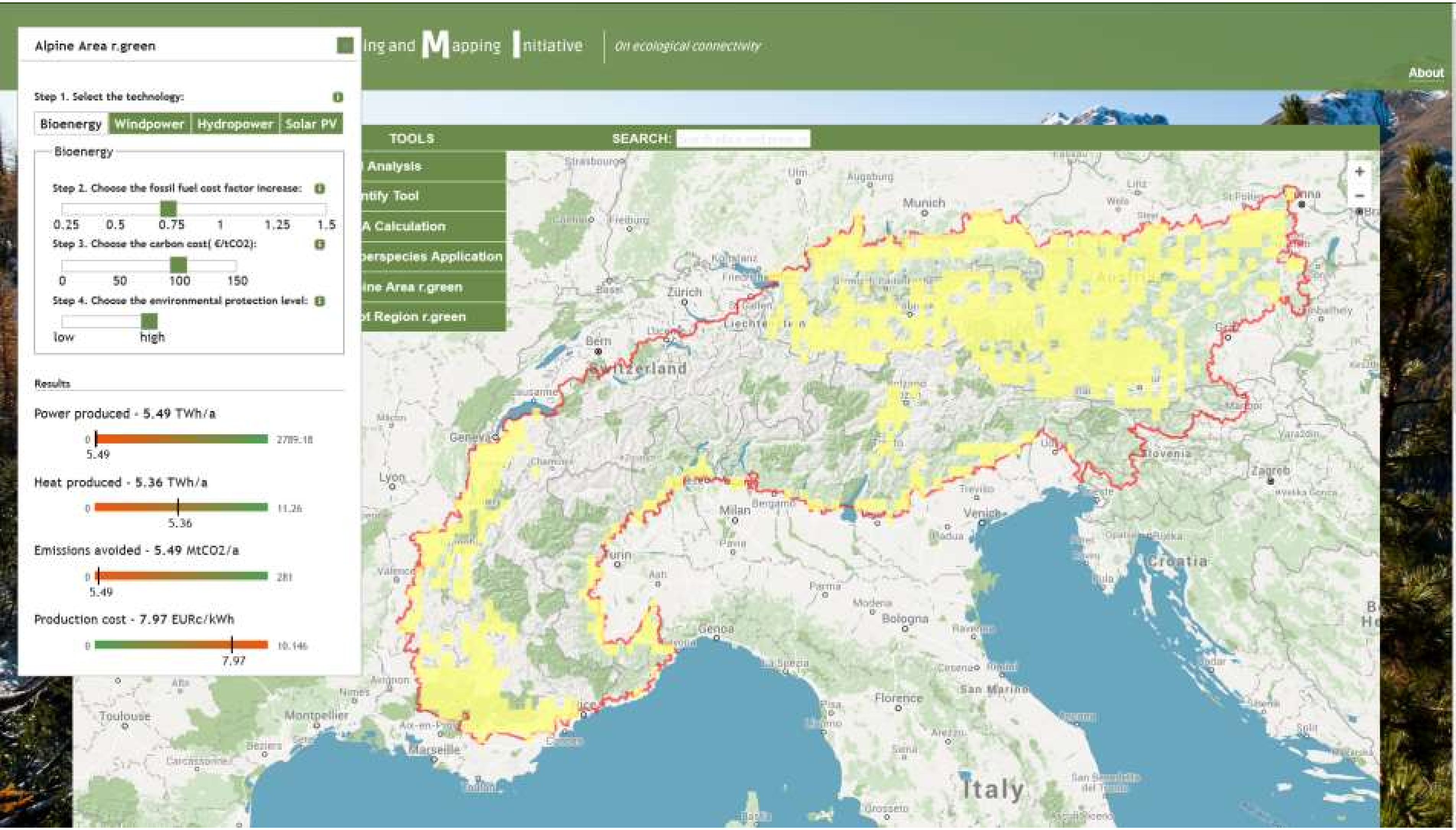
On ecological connectivity
Analysis
Region r.green

BeWhere - DSS


Alpine Area r.green
Step 1. Select the technology:
Bioenergy
Windpower
Hydropower
Solar PV
Bioenergy
Step 2. Choose the fossil fuel cost factor increase:
0.25 0.5 0.75 1 1.25 1.5
Step 3. Choose the carbon cost(€/tCO2):
0 50 100 150
Step 4. Choose the environmental protection level:
low high
Results
Power produced - 5.49 TWh/a
5.49
Heat produced - 5.36 TWh/a
5.36
Emissions avoided - 5.49 MtCO2/a
5.49
Production cost - 7.97 EURc/kWh
7.97
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perspecies Application
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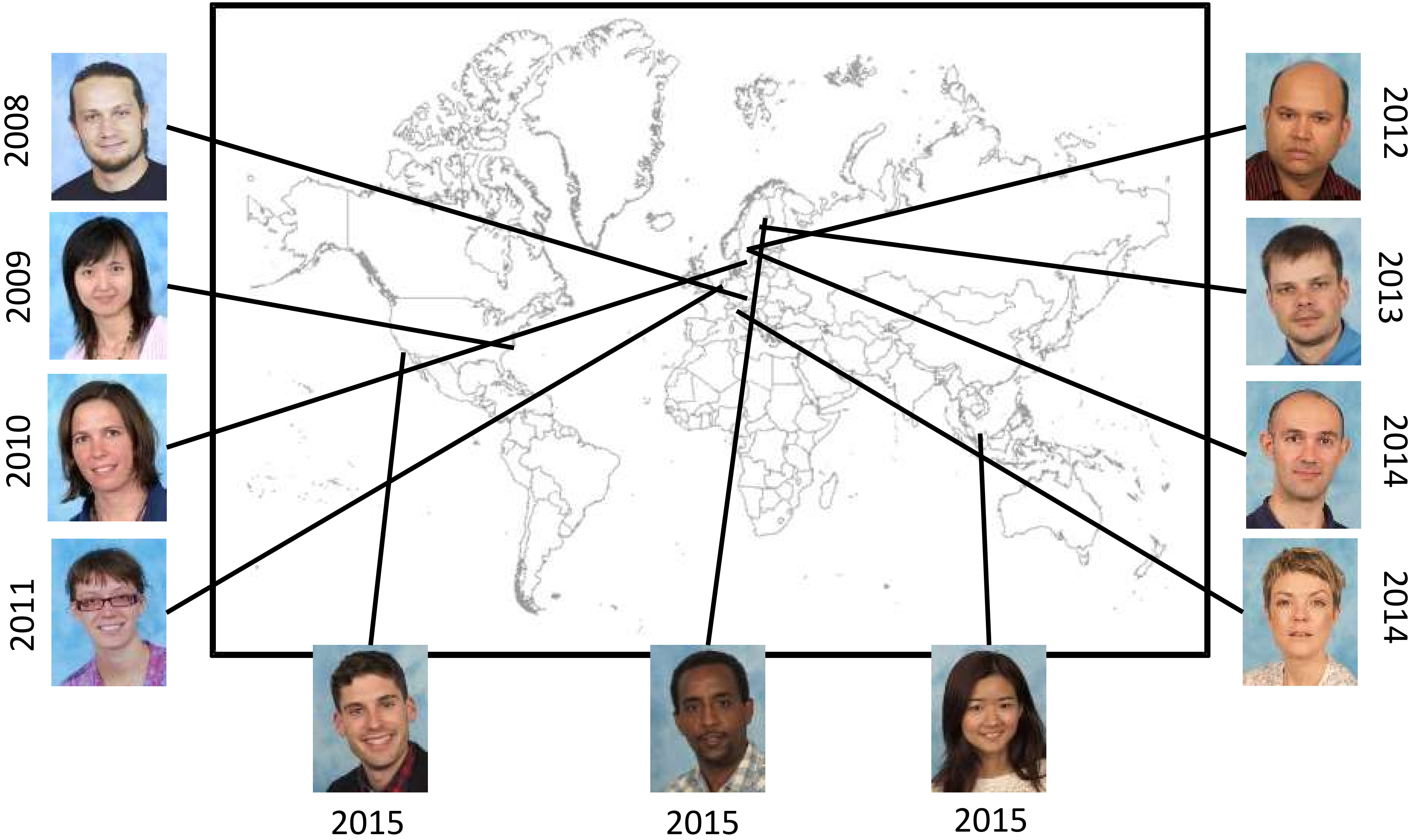
Marseille
Italy

BeWhere and YSSP



Thank you for your attention !!

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More about BeWhere

www.iiasa.ac.at/bewhere




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