Optimal use of woody biomass for bio-energy in Europe

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Wageningen University & Research, The Netherlands

S2Biom project and the BEST program seminar
17 November 2016




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Outline

- **Overview of S2BIOM**
- **Tools & online applications**
  - Bio2Match
  - BeWhere
  - LocaGIStics
- **Case studies**
  - Burgundy, Europe, Finland
- **Future development**

Project Structure

Coordination & Management

Theme 1: Data & Tools (WPs 1-4)

- Current and future sustainable lignocellulosic biomass costs and supply (domestic and from imports) in EU28; Western Balkans, Moldova, Ukraine and Turkey.
- Common operating data, models, and tools representing the entire biomass supply chain
- Incorporation of models and tools for technical, environmental, economic and social impact analysis

Theme 2: Strategies & Roadmaps (WPs 5-8)

- Policy and regulations for supplying the future bioeconomy
- Support for future industrial investments
- Clarity on cross sector sustainability
- Strategies & Roadmap
- Ex ante impact assessment

Theme 3: Validation & project outreach (WPs 9-10)

- Support for policymaking at local, national, regional and EU28 levels by visualizing the outcomes of proposed policies
- Case Studies
- Stakeholder engagement
- Information Campaign
- Improvement of public awareness, education, and outreach

Online tools

- **http://S2biom-test.Alterra.wur.nl**

- **Login:**
  - Username: demo
  - Password: helsinki

S2Biom Tools for biomass chains

2012 - Production from forests - Stemwood from final fellings & thinnings - Final fellings from nonconifer trees - base potential - energy value - area weighted

Administrative l...
- nuts0
- nuts1
- nuts2

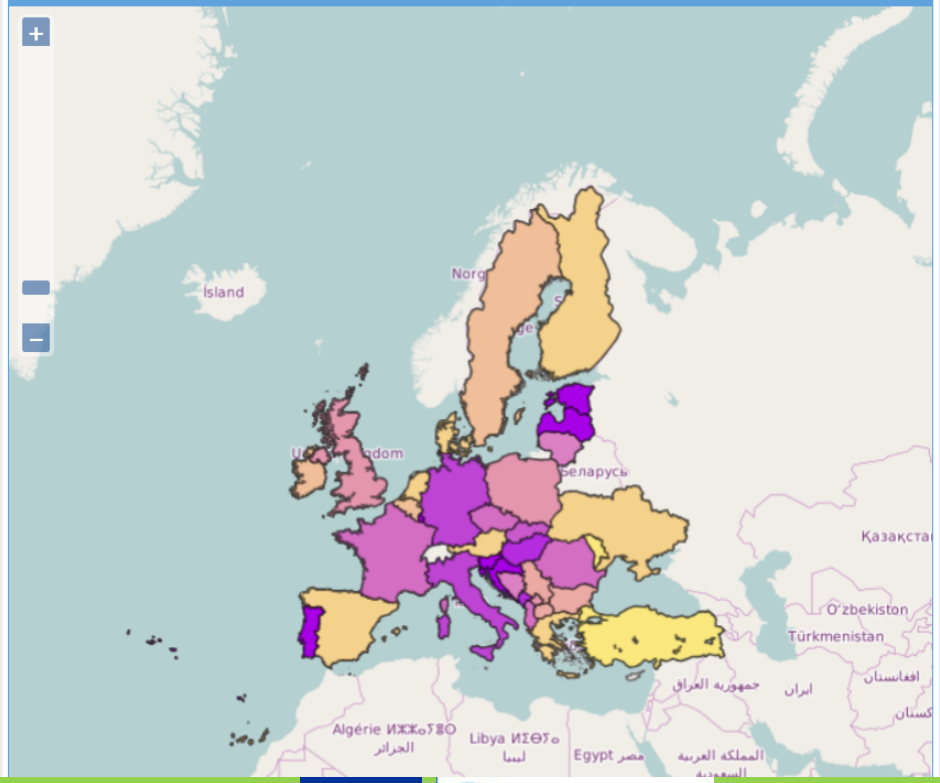
Scenario
- 2012
- 2020
- 2030

Category
- Production from forests
- Primary residues from forests
- Other land use

Subcategory
- Stemwood from final fellings & thinnings

Type
- Final fellings from nonconifer trees
- Final fellings from conifer trees
- Thinnings from nonconifer trees

Map



energy value | weight | volume

area weighted | absolute

Unit: GJ/km2
- 0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500

Current selection | Identify result

NUTS level	nuts0
Scenario	2012

2012 - Primary residues from forests - Logging residues from final fellings & thinnings - Logging residues from final fellings from nonconifer trees - base potential - energy value - ar...

Administrative l...
- nuts1
- nuts2
- nuts3

Scenario
- 2012
- 2020
- 2030

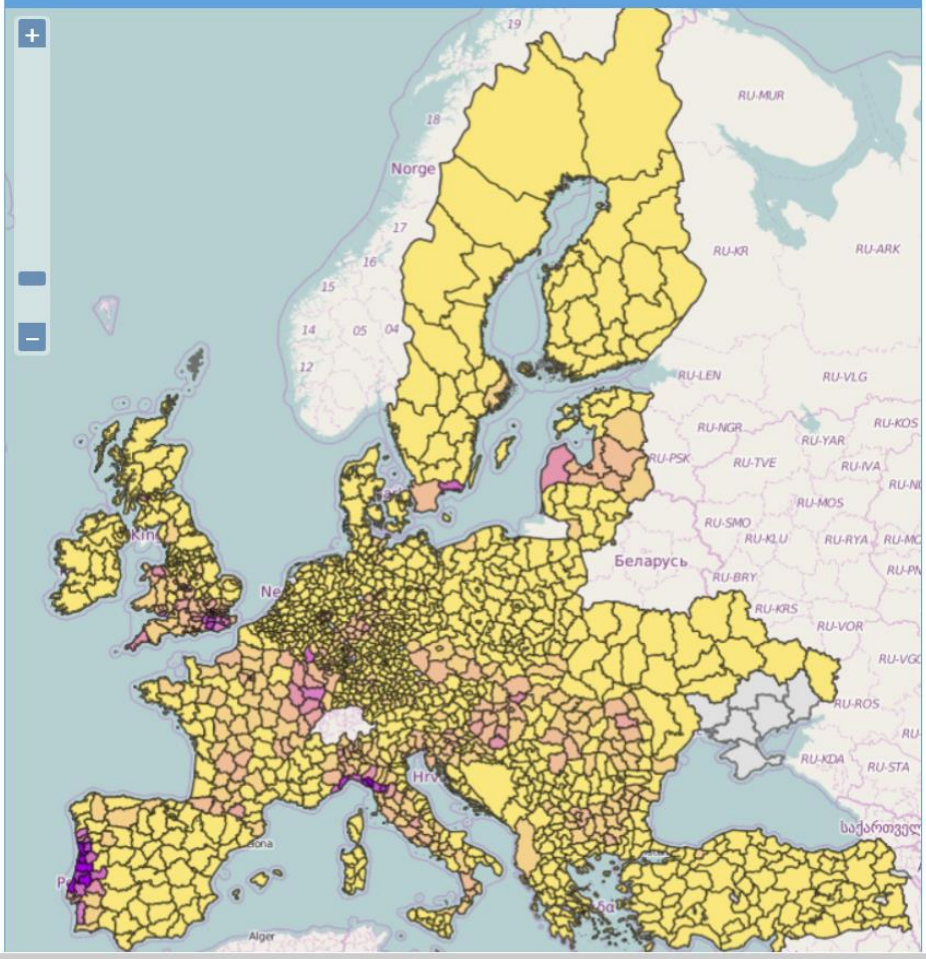
Category
- Production from forests
- Primary residues from forests
- Other land use

Subcategory
- Logging residues from final fellings & thinnings
- Stumps from final fellings & and thinnings

Type
- Logging residues from final fellings from nonconi...
- Logging residues from final fellings from conifer t...
- Logging residues from thinnings from nonconife...

Potential
- base potential
- technical potential
- user defined 1

Map



energy value | weight | volume

area weighted | absolute

Unit: GJ/km2

0
0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
350 - 400
400 - 450
450 - 500

Current selection | Identify result

NUTS level	nuts3
Scenario	2012
Category	Primary residues from forests
Subcategory	Logging residues from final f...
Type	Logging residues from final f...
Potential	base potential

Bio2Match

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Tools for biomass chains

Home | General data | Biomass chain data | Tools | Strategies, roadmaps & implementation plans | Maintain

Tools:
- Bio2Match
- BeWhere
- LocaGIStics

Home

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terra.wur.nl/web/guest/bewhere

Bio2Match

S2Biom

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Tools / Bio2Match

User instructions

Select rows and columns

Switch rows and columns

Columns - Conv...	Rows - Biomass ...
Syngas platf...	Production f...
Gasification ...	Primary resi...
Direct comb...	Primary pro...
Anaerobic di...	Agricultural ...
Biochemical ...	Grassland
Torrefaction	Other land ...
Treatment i...	Secondary r...
Fast pyrolysis	Secondary r...
	Municipal w...
	Waste from ...

Match

Name	Syngas to methanol (41)	Producer gas to biomet...	Syngas to FT-diesel (52)
Final fellings from nonconifer trees	✓	✓	✓
Final fellings from conifer trees	✓	✓	✓
Thinnings from nonconifer trees	✓	✓	✓
Thinnings from conifer trees	✓	✓	✓
Early thinnings from nonconifer trees	✗	✗	✗
Early thinnings from conifer trees	✓	✓	✓

Matching chara...

- Anaerobic di...
- Biochemical ...
- Physical trea...
- Thermal con...

Product groups

- electricity
- biofuels and biobased...
- heat

Regions

Bio2Match

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Tools / Bio2Match

User instructions

Select rows and columns

Switch rows and columns

Columns - Conversion technologies

- Syngas platform
  - Syngas to FT-diesel (52)
  - Syngas to methanol (41)
  - Producer gas to biomethane (44)
- Gasification technologies
- Direct combustion of solid biomass
- Anaerobic digestion
- Biochemical treatment
  - Kraft process with Lignoboost (16)
  - Prehydrolysis kraft (17)
  - Ethanol from lignocellulose (dilute acid...
- Torrefaction
- Treatment in subcritical water
- Fast pyrolysis

Rows - Biomass types

- Production from forests
  - Stemwood from final fellings originatin...
  - Stemwood from final fellings originatin...
  - Stemwood from thinnings originating f...
  - Stemwood from thinnings originating f...
  - Stemwood from final fellings and thinni...
  - Stem and crown biomass from early th...
  - Stem and crown biomass from early th...
- Primary residues from forests
- Primary production of lignocellulosic biom...
- Agricultural residues
  - Rice straw
  - Cereals straw
  - Oil seed rape straw
  - Maize stover
  - Sugarbeet leaves
  - Sunflower straw
  - Residues from vineyards

Match

Name	Syngas to methanol (41)
Final fellings from nonconifer trees	✓
Final fellings from conifer trees	✓
Thinnings from nonconifer trees	✓
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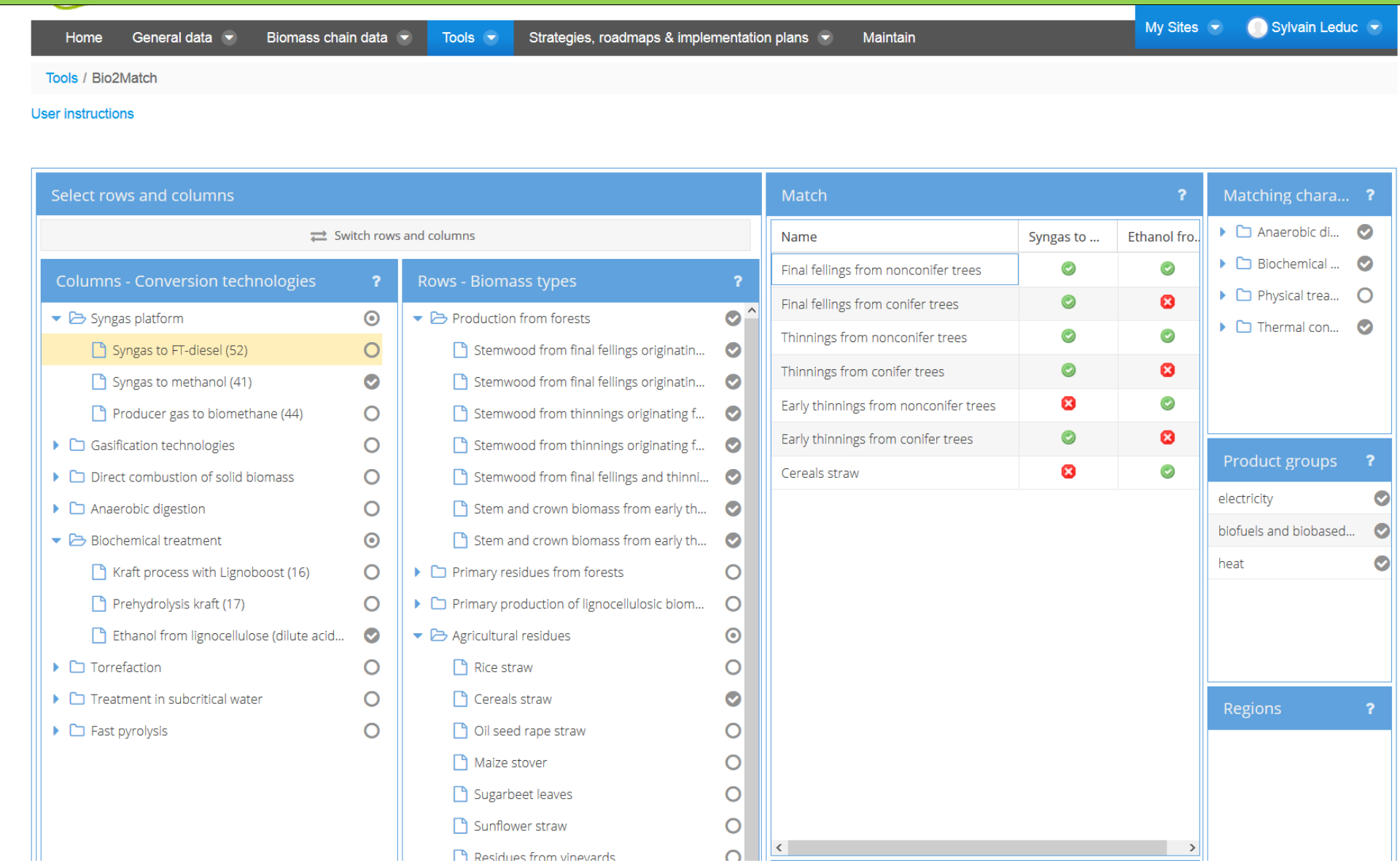
Regions

Bio2Match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Tools
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Sylvain Leduc
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Name
Syngas to ...
Ethanol fro..
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Early thinnings from conifer trees	✓	✓
Cereals straw	✗	✓

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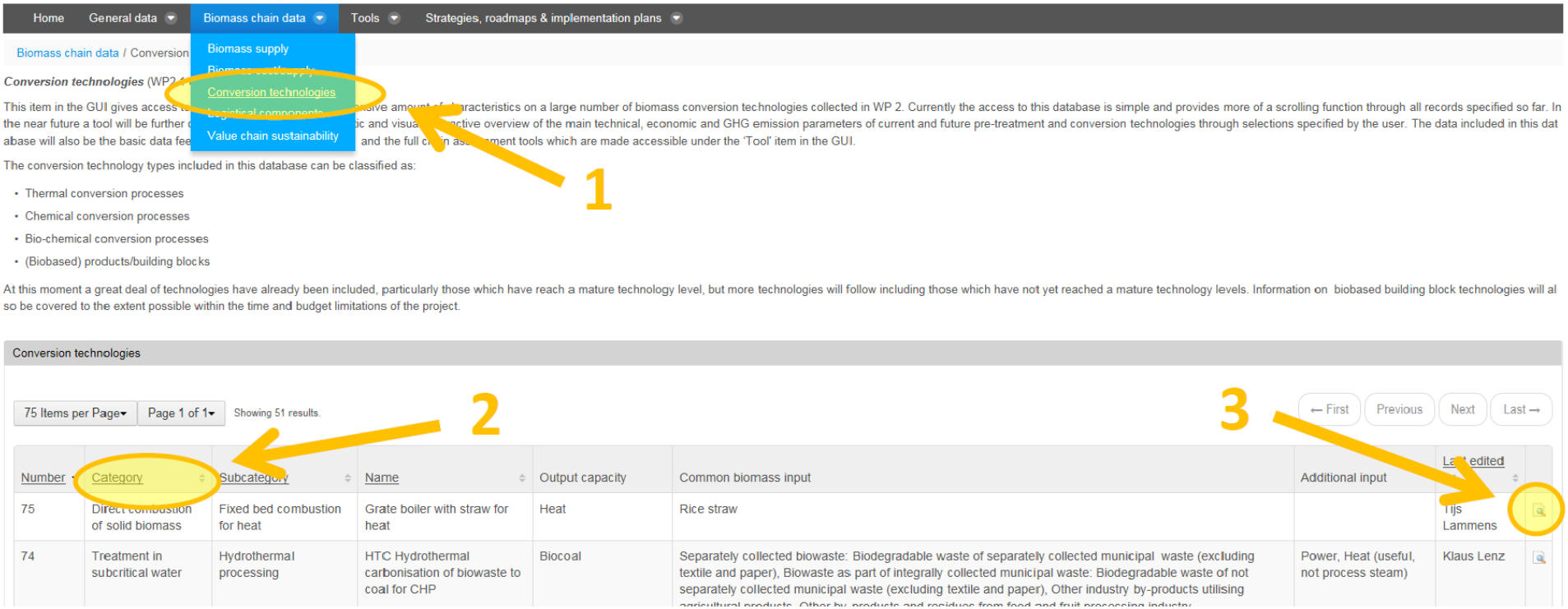
Bio2Match



Conversion technologies (WP2.1

This item in the GUI gives access t sive amount of characteristics on a large number of biomass conversion technologies collected in WP 2. Currently the access to this database is simple and provides more of a scrolling function through all records specified so far. In the near future a tool will be further d ic and visua ctive overview of the main technical, economic and GHG emission parameters of current and future pre-treatment and conversion technologies through selections specified by the user. The data included in this dat abase will also be the basic data fee and the full c n ass ment tools which are made accessible under the 'Tool' item in the GUI.

The conversion technology types included in this database can be classified as:

- Thermal conversion processes
- Chemical conversion processes
- Bio-chemical conversion processes
- (Biobased) products/building blocks

At this moment a great deal of technologies have already been included, particularly those which have reach a mature technology level, but more technologies will follow including those which have not yet reached a mature technology levels. Information on biobased building block technologies will al so be covered to the extent possible within the time and budget limitations of the project.

BeWhere

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Tools:
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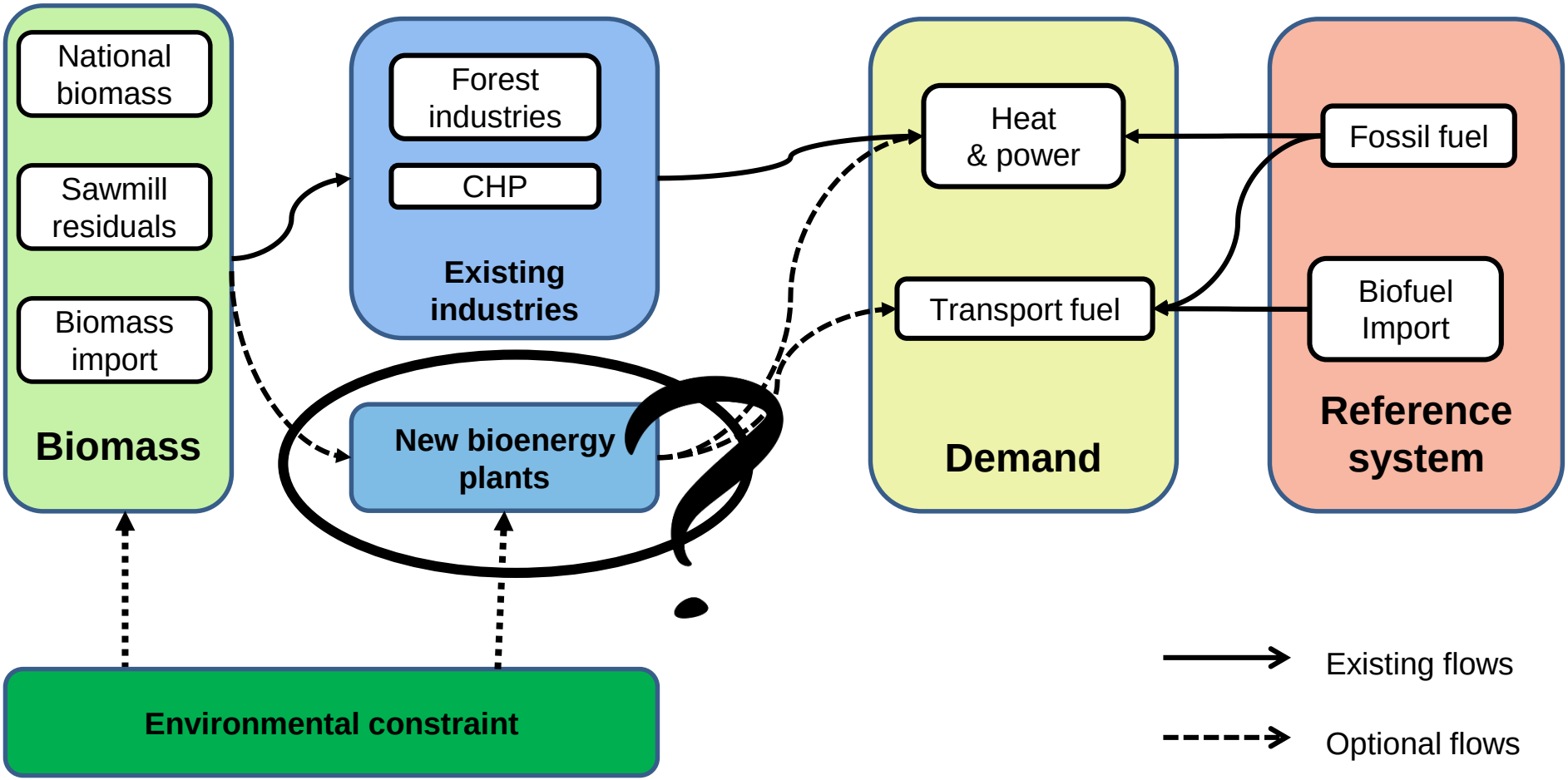
General BeWhere structure



BeWhere Model

- **Techno-economical model, geographic explicit**
- **Spatially explicit - 0.2 ˚ to 0.5˚grid cell**
- **Mixed integer linear program (GAMS)**
- 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**

BeWhere answers…

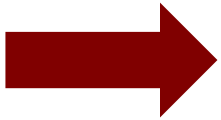
Size and locations

Technology mix

Biomass flow

Biofuel trade

Total costs and emissions



Policy tool

Economic incentives

Carbon penalty

RES potential

Economic potential

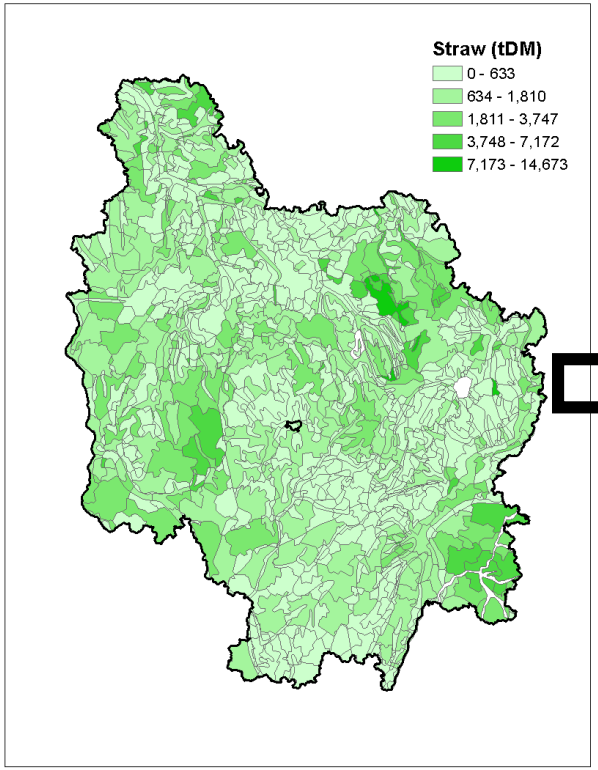
The BeWhere Umbrella

Input: biomass

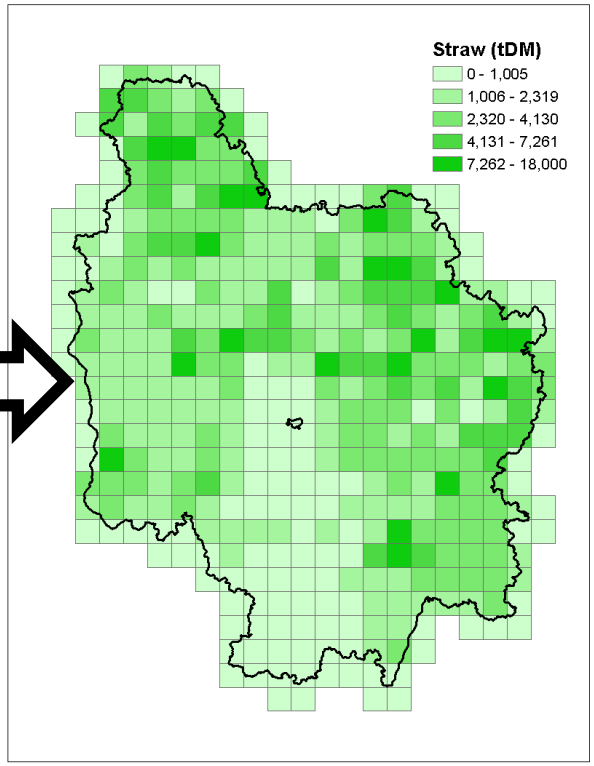
WP 1

S2Biom

Straw availability



Aggregation

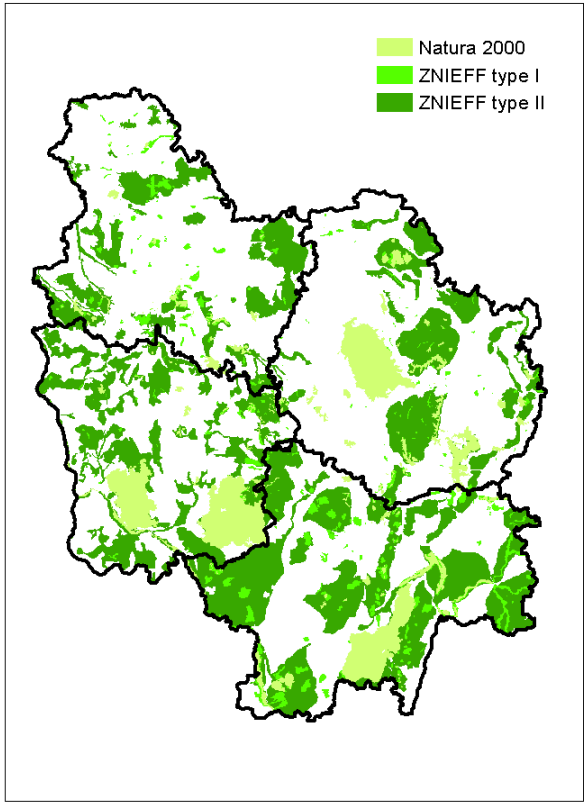


Source: INRA

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

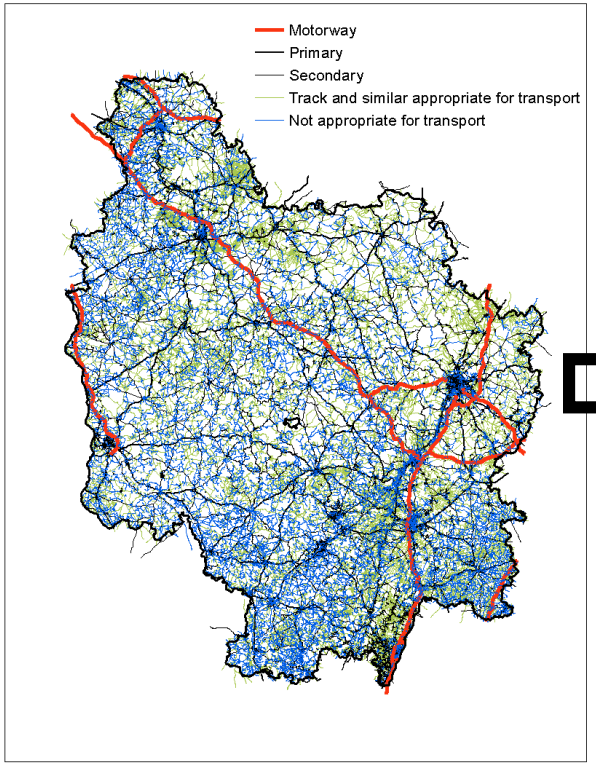
- type I: areas of great biological or ecological interest
- type II: large, rich and slightly modified natural landscapes, providing significant biological potential

Assumptions for Natura 2000 areas

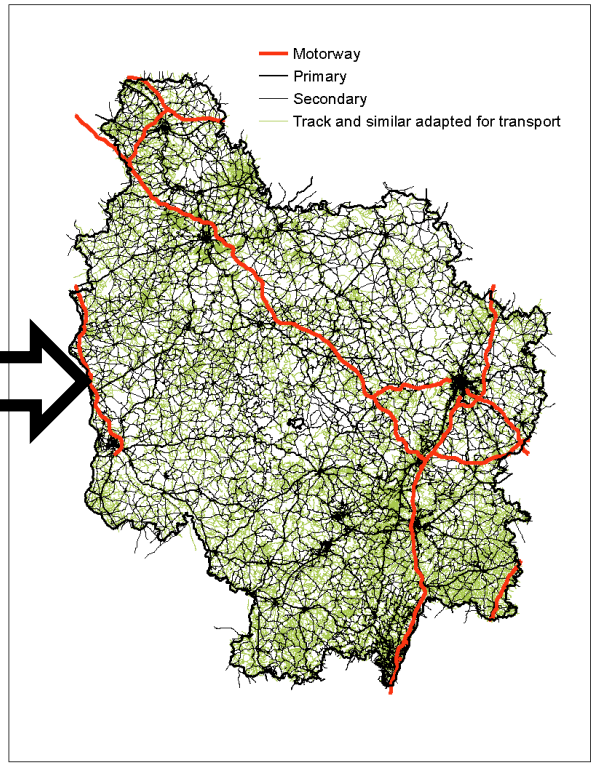
- No extraction of biomass
- No power plants can be installed

BeWhere input: logistics

Road Network



Used road network



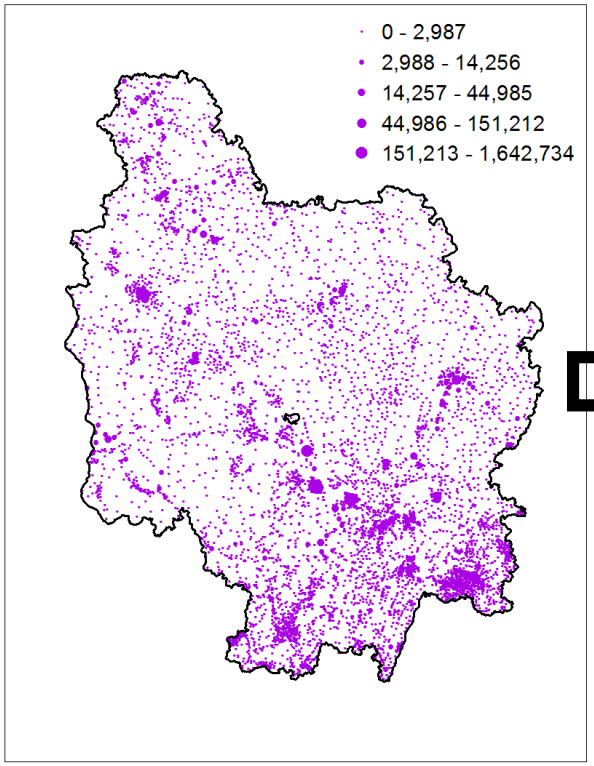
Source: OpenStreetMap.org

Input

- Transport cost
- Emissions
- Terminals / pretreatment

BeWhere input: demand

Population



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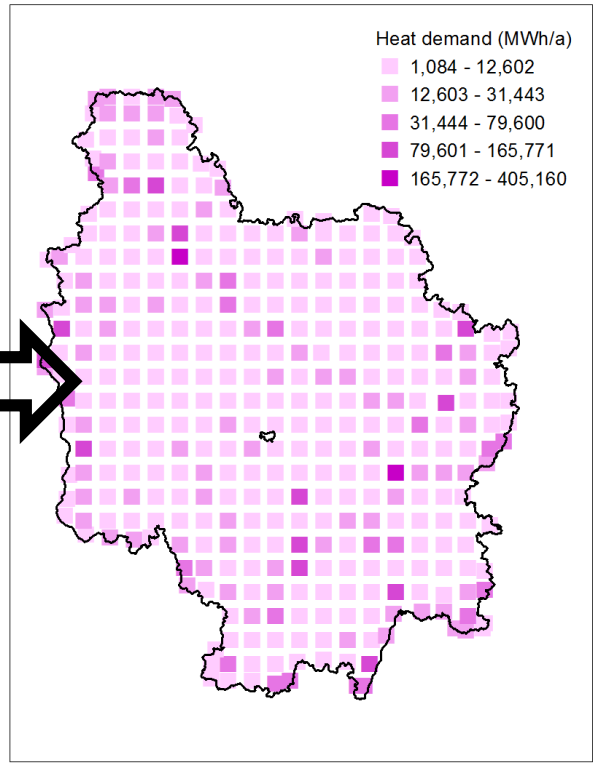


Input needed

- 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

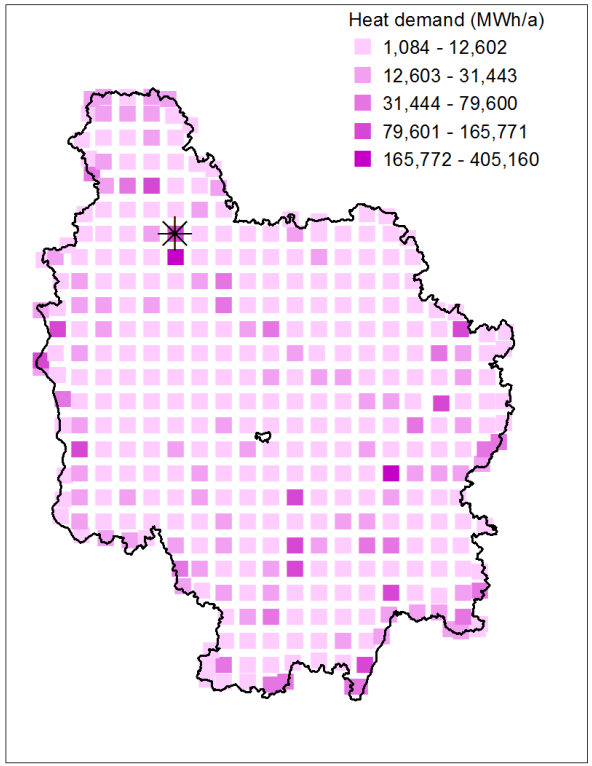
BeWhere input: technology

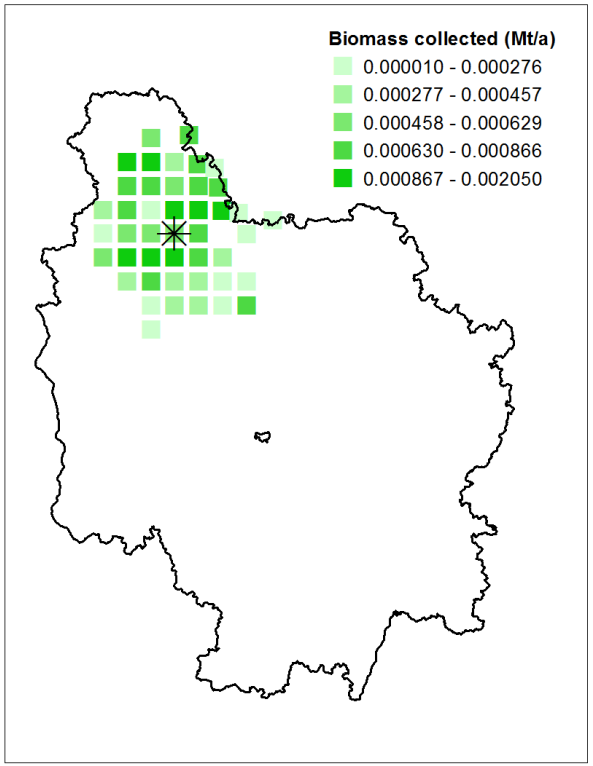
Technology	Operating hours hours/year	Investment cost MEUR	Heat MWth	Power MWe	Heat efficiency	Power efficiency
Fixed bed for CHP	7,200	0.2	0.1	0.05	0.5	0.23
Pyrolysis combustion engine (compression-ignition)	7,500	0.7	0.25	0.25	0.4	0.4
Fixed bed, direct combustion	8,500	2.5	5		0.88	
BFB for CHP	8,500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

Source: S2Biom, WP2

Result Example

First plant



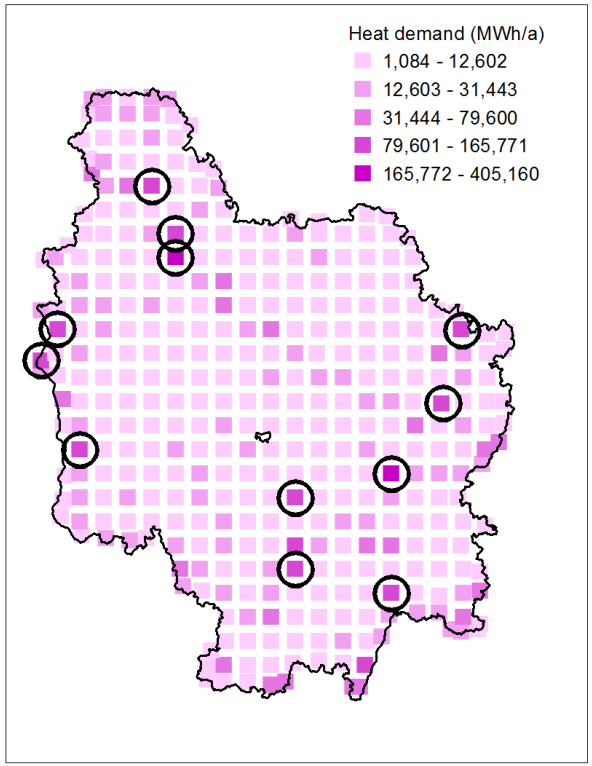


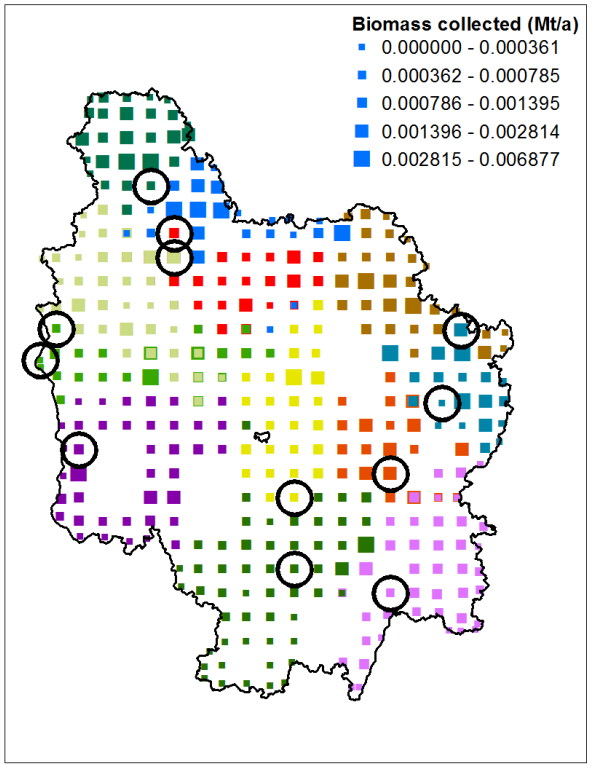
Radius (km)	65
Straw (t/a)	0
Miscanthus (t/a)	30,000
Power (MWh)	35,417
Heat (MWh)	85,000

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

Result Example

Maximize the fossil fuel substitution



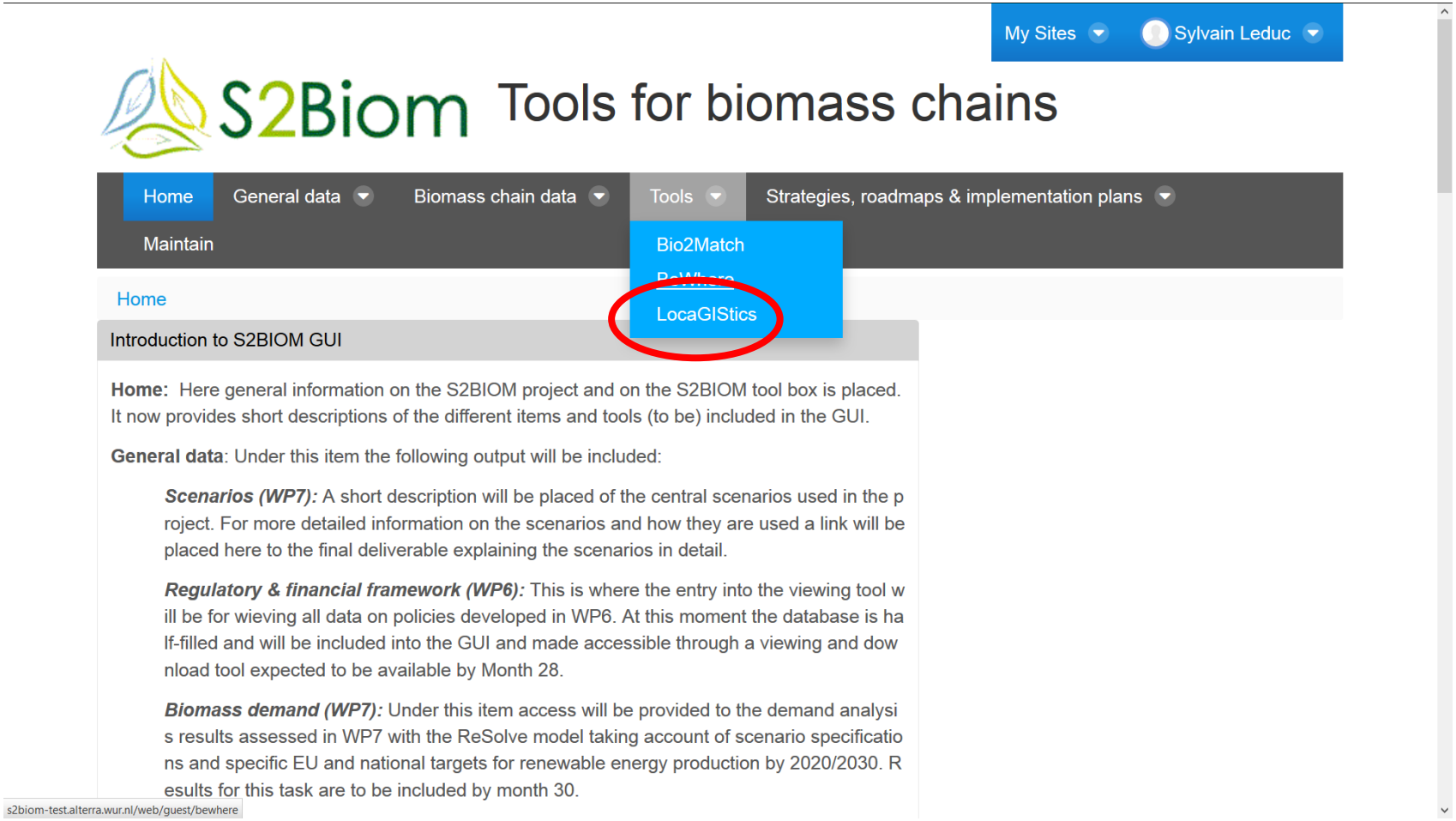


	Min	Max
Radius (km)	70	158
Straw (t/a)	6,412	20,377
Miscanthus (t/a)	9,623	18,400
Power (MWh)	24,792	35,417
Heat (MWh)	59,500	85,000

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

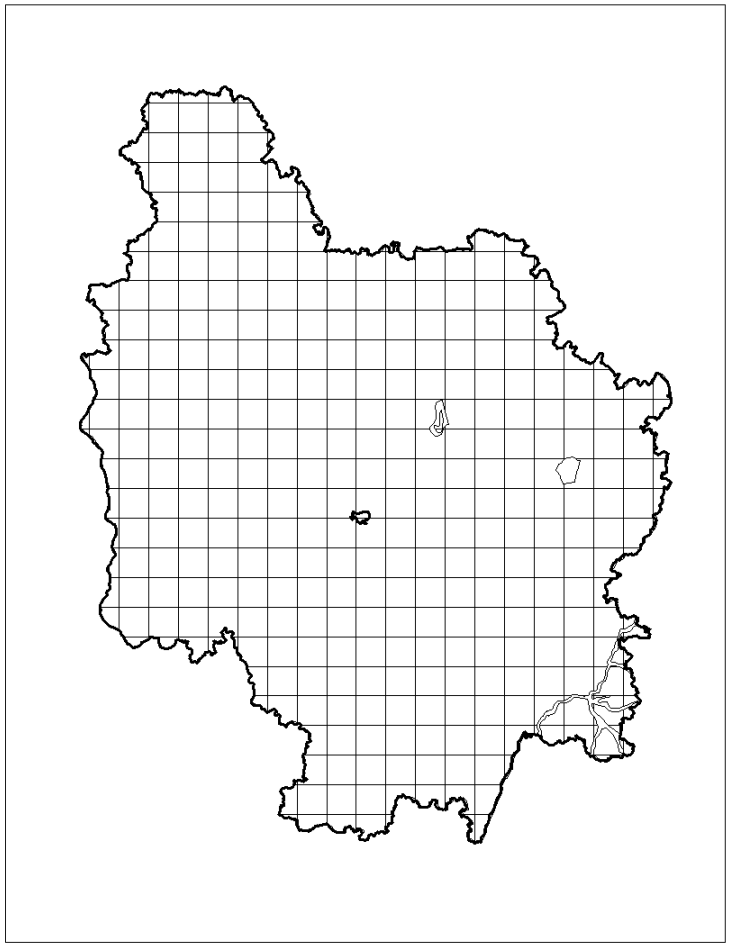
Heat demand has stronger impact on the location than the distribution of biomass

LocaGIStics

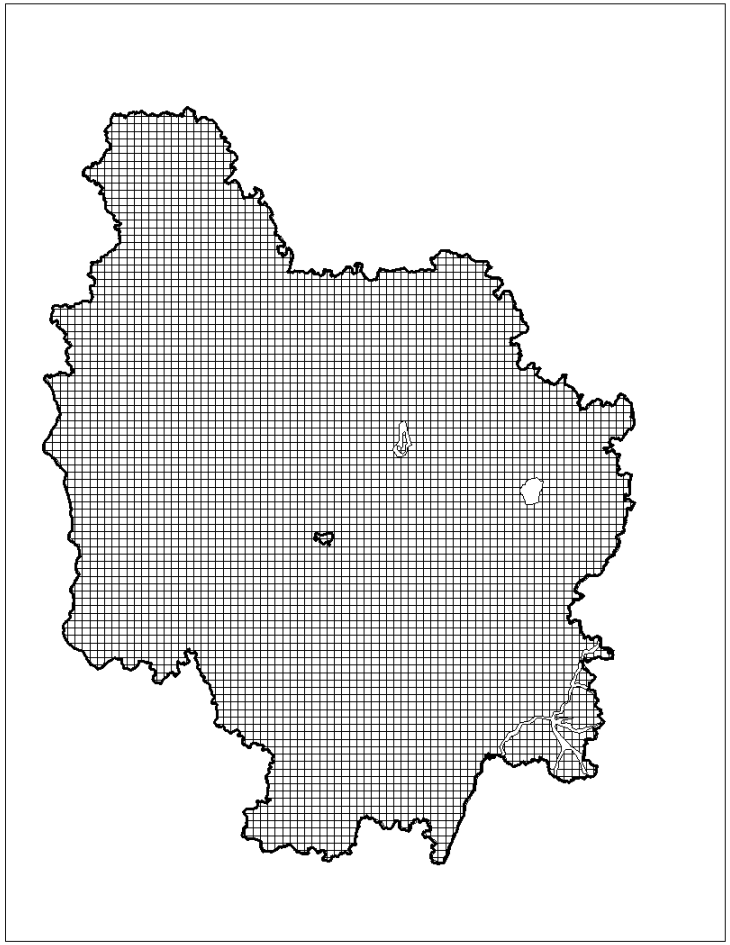


Burgundy case study

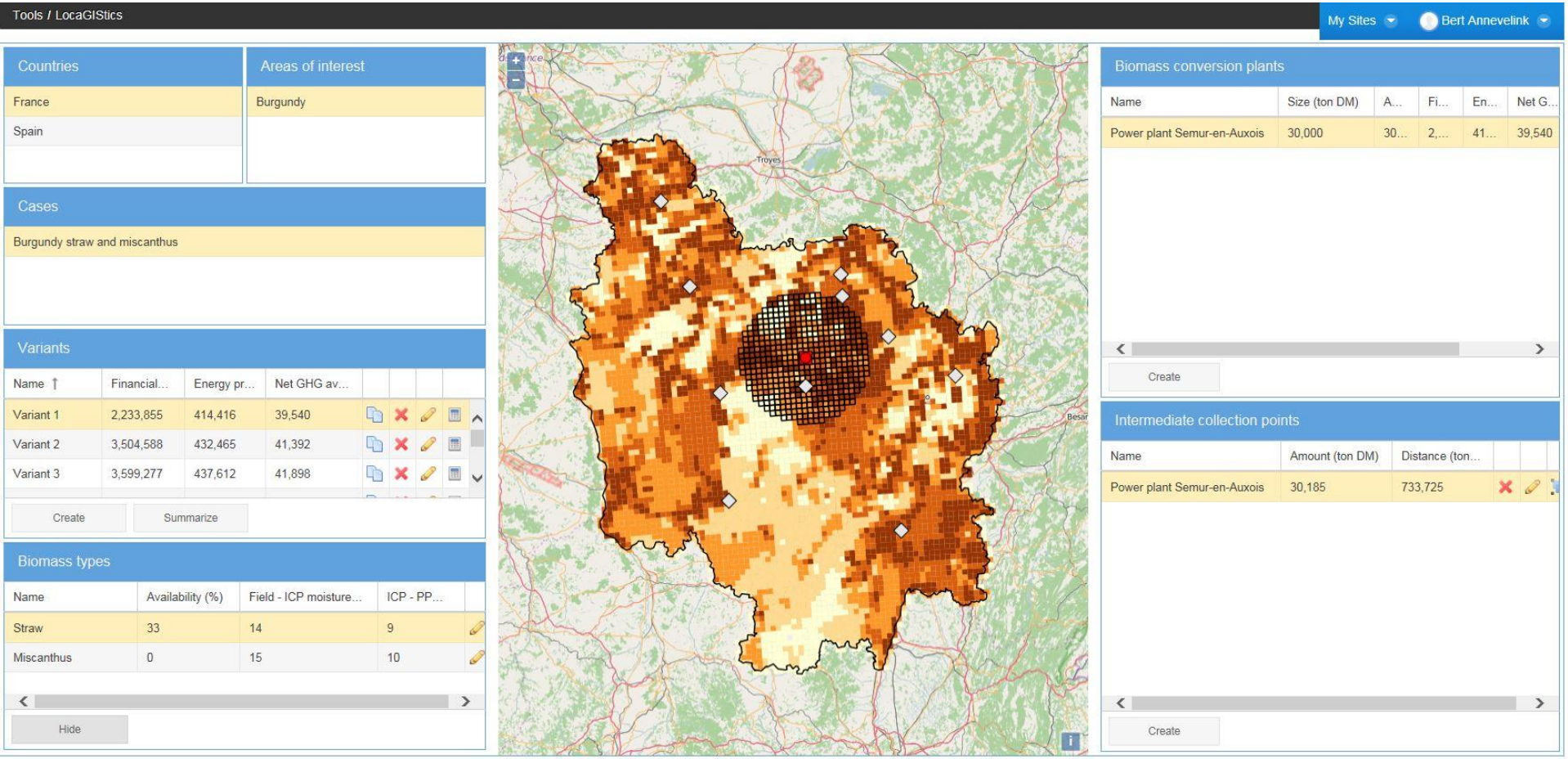
BeWhere 377 grid points



LOCAgistics - 5,357 grid points

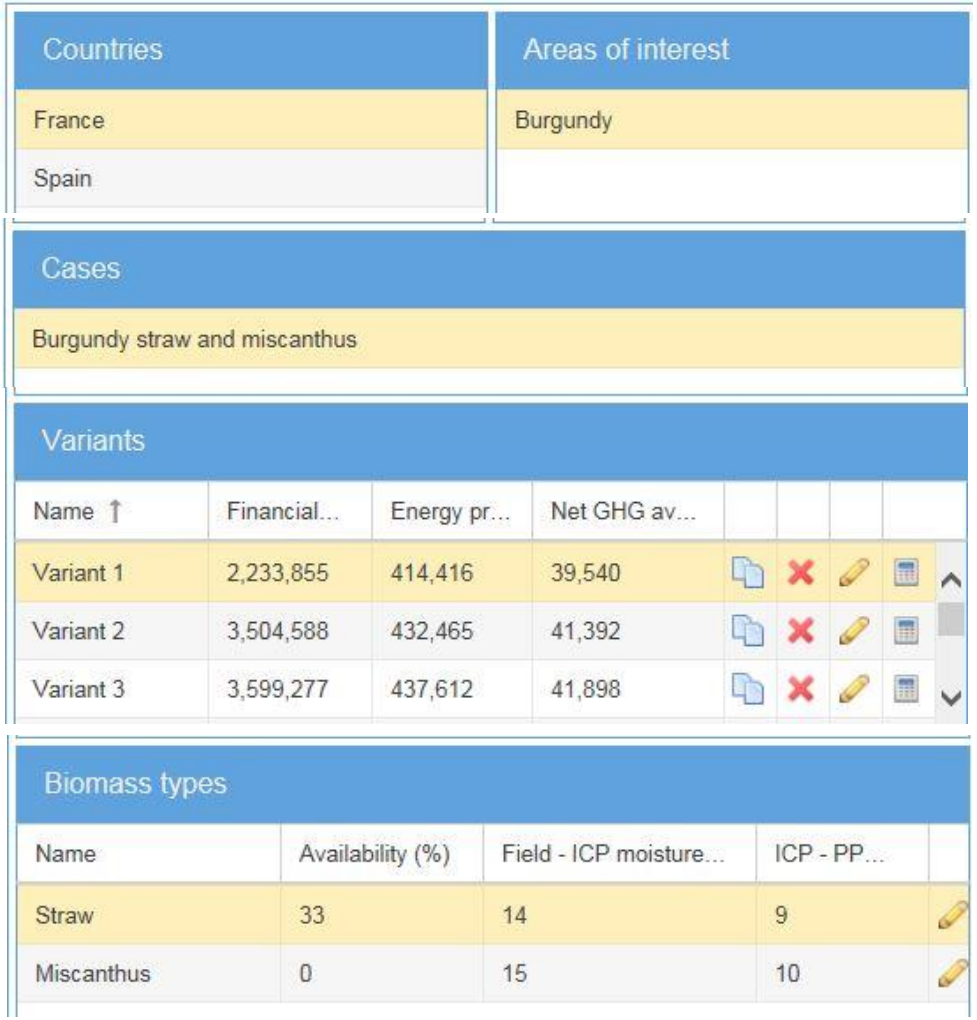


LocaGIStics - User interface



User interface - left hand side

- country & area of interest
- cases
- variants
- biomass types



Countries	Areas of interest
France	Burgundy
Spain	

Cases

Cases
Burgundy straw and miscanthus

Variants

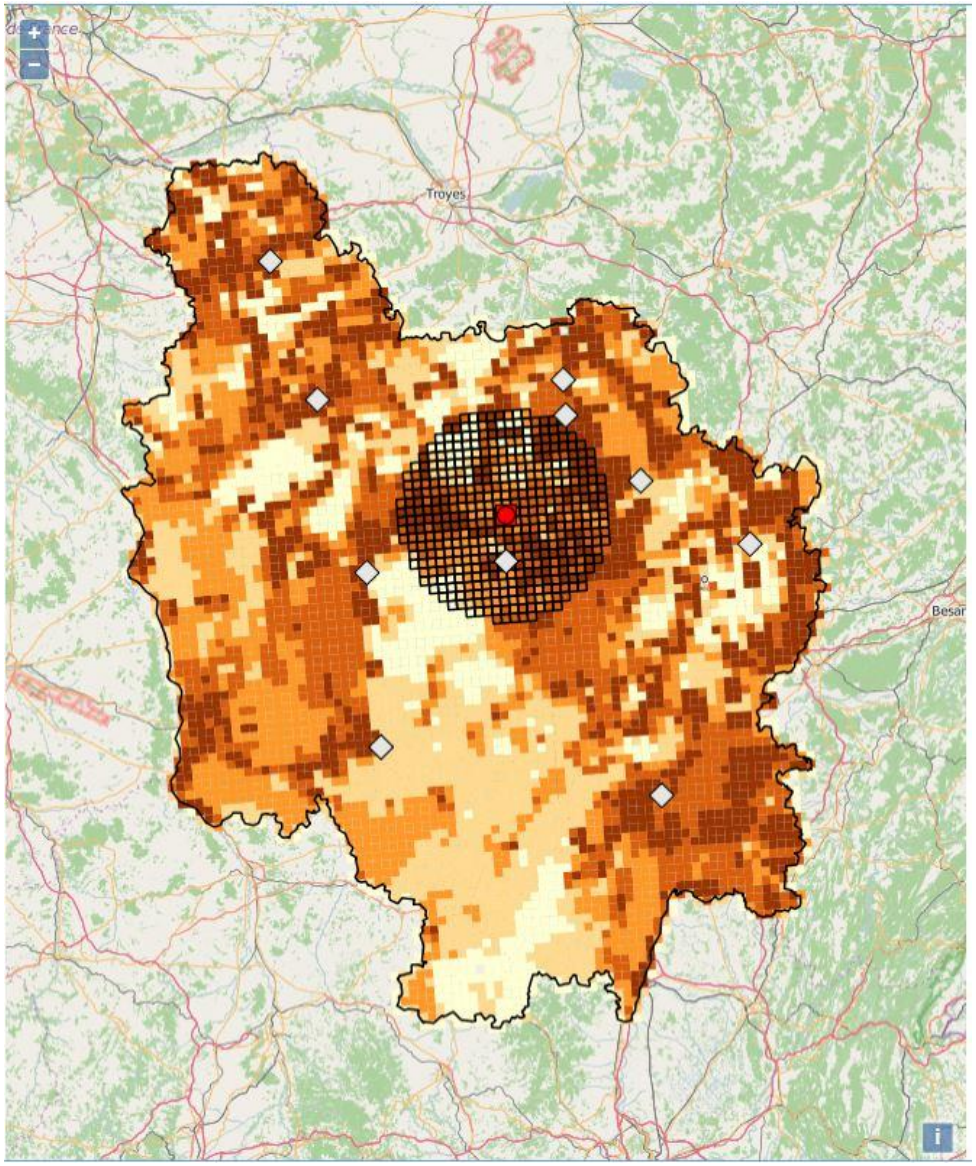
Name	Financial...	Energy pr...	Net GHG av...
Variant 1	2,233,855	414,416	39,540
Variant 2	3,504,588	432,465	41,392
Variant 3	3,599,277	437,612	41,898

Biomass types

Name	Availability (%)	Field - ICP moisture...	ICP - PP...
Straw	33	14	9
Miscanthus	0	15	10

User interface - middle

- regional biomass availability per grid cell
- powerplant locations suggested for the whole Burgundy region based on calculations of BeWhere (white points)
- LOCAgistics will further analyse chain towards one power plant in more detail (red square)



User interface - right hand side

- **power plant**

Biomass conversion plants

Name	Size (ton DM)	A...	Fi...	En...	Net G...
Power plant Semur-en-Auxois	30,000	30...	2,...	41...	39,540

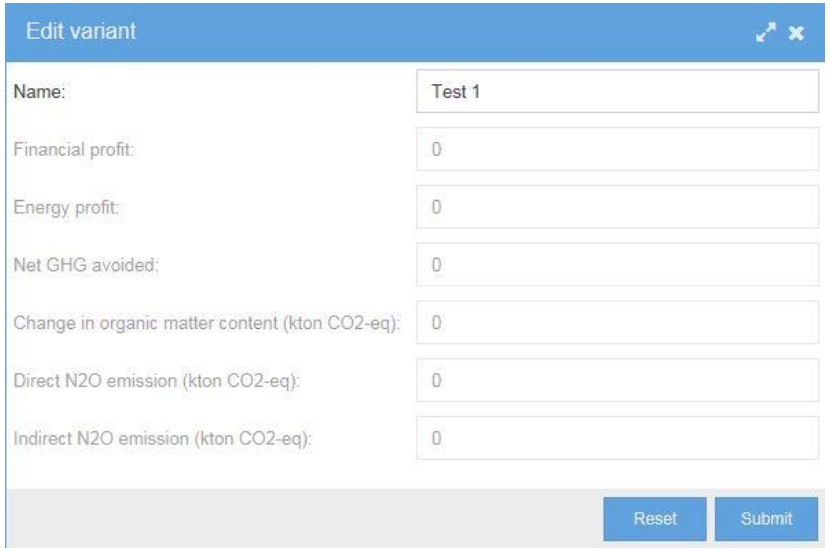
- **intermediate collection point**

Intermediate collection points

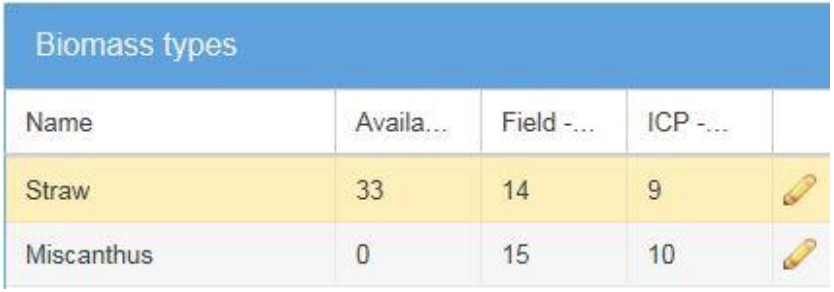
Name	Amount (ton DM)	Distance (ton...			
Power plant Semur-en-Auxois	30,185	733,725			

Specify a case study (1)

- **make new variant of biomass value chain design**

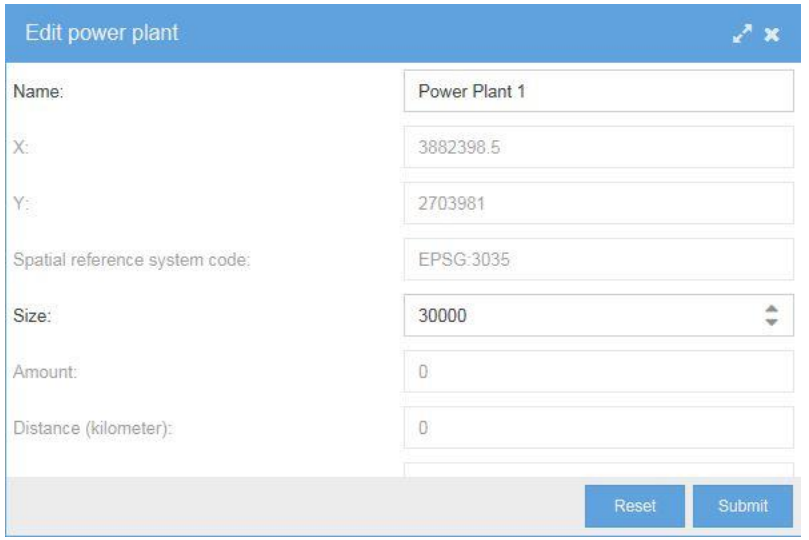


- **specify share of biomass types**

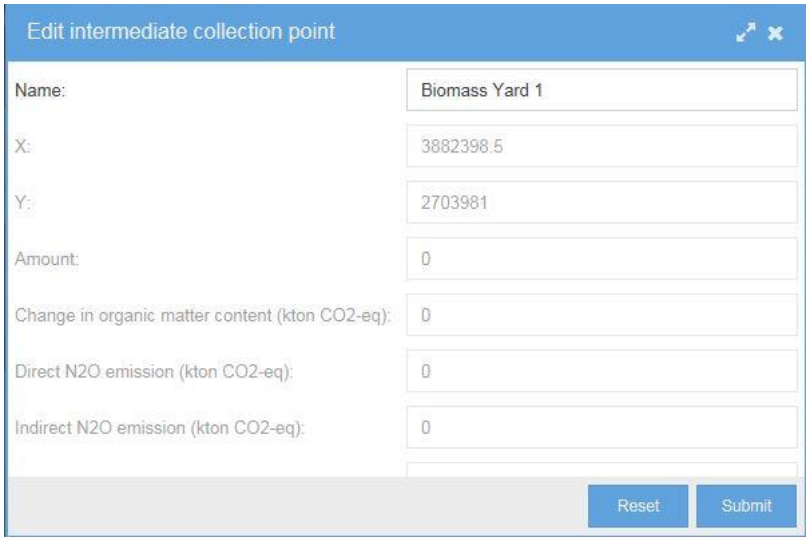


Specify a case study (2)

- **create biomass conversion plant**

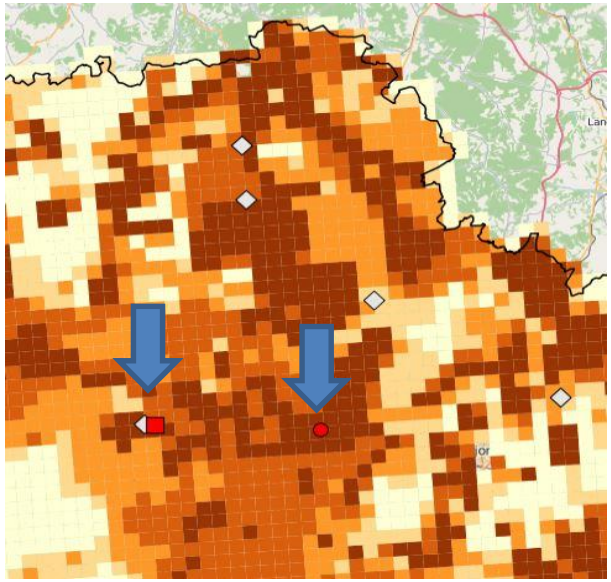


- **create intermediate collection point**

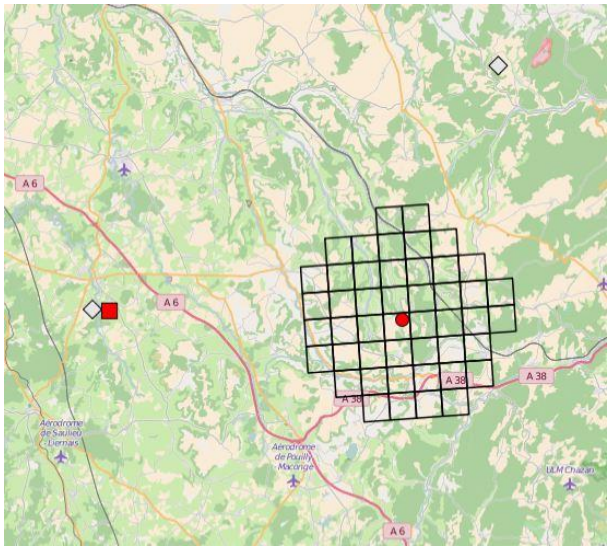


Specify a case study (3)

- **position on the map**
  - biomass conversion plant (■)
  - intermediate collection point (●)



- **hide biomass maps to see surface map of the area**



Specify a case study (4)

- **start calculation**

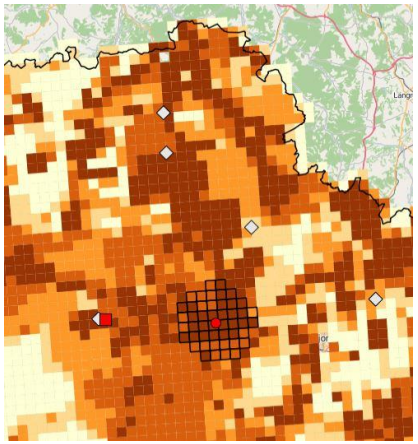
Variants

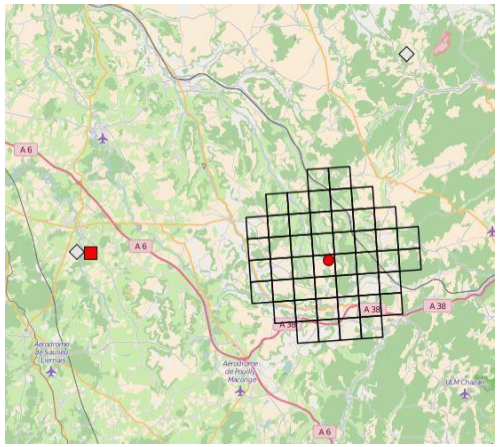
Name	Financial profit	Energy profit	Net GHG avoided
Test 1	0	0	0

- **based on biomass availability, a GIS based 'peeling heuristic' determines**
  - biomass used (ton dm)
  - transport distances (ton.km)
- **analyse results**

Variants

Name	Financial profit	Energy profit	Net GHG avoided
Test 1	3,598,124	436,487	41,790





Specify a case study (5)

- **analyse results**

Variants

Task	Financial profit	Energy profit	Net GHG avoided	Ton fresh	Ton dry matter
Variant 1	2,233,855	414,416	39,540	35,099	30,185
Variant 2	3,504,588	432,465	41,392	35,267	30,080
Variant 3	3,599,277	437,612	41,898	35,571	30,316
Variant 3b	2,165,579	412,817	39,389	34,971	30,075

Variants

Task	F...	E...	N..	T...	T...	Change in organic matter content (kton CO2-eq)	Direct N2O emission (kton CO2-eq)	Indirect N2O emission (kton CO2-eq)
Variant 1	2...	4...	3...	3...	3...	0	0	0
Variant 2	3...	4...	4...	3...	3...	4,752,850	155,665	130,748
Variant 3	3...	4...	4...	3...	3...	3,949,717	105,818	126,148
Variant 3b	2...	4...	3...	3...	3...	0	0	0

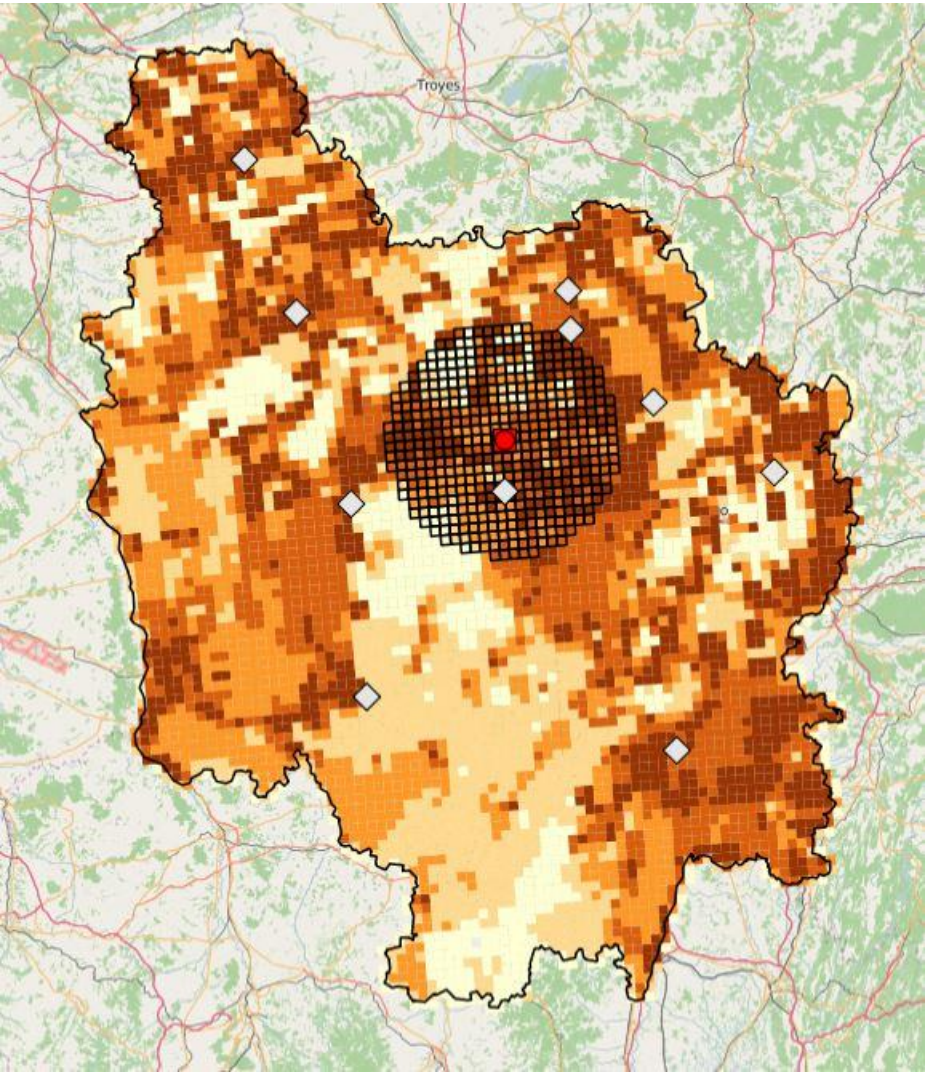
Variants

Task	F...	E...	N..	T...	T...	C..	D..	I...	Distance ICP -> BCP (km.)	Distance ICP -> BCP (ton km.)	Distance field -> ICP (km.)	Distance field -> ICP -> BCP (ton km.)
Variant 1	2...	4...	3...	3...	3...	0	0	0	3,833	148,159	18,192	733,725
Variant 2	3...	4...	4...	3...	3...	4...	1...	1...	1,124	151,265	2,820	415,223
Variant 3	3...	4...	4...	3...	3...	3...	1...	1...	3,973	1,643,259	530	207,798
Variant 3b	2...	4...	3...	3...	3...	0	0	0	31,321	1,615,525	11,739	554,167
Variant 4	3...	4...	4...	3...	3...	4...	9...	1...	2,459	1,673,339	178	116,308
Variant 5	2...	4...	3...	3...	3...	0	0	0	26,668	1,653,065	6,296	332,567

Five variants as an example

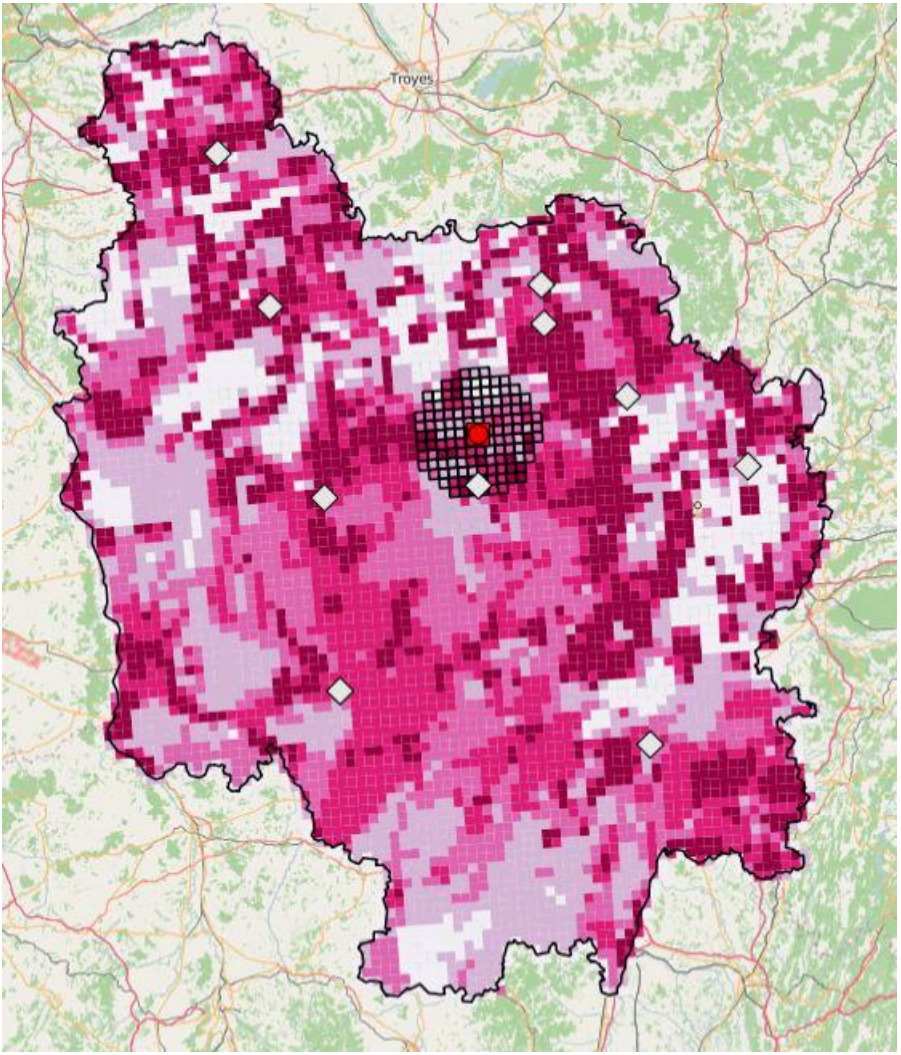
1. powerplant & no biomass yard; only straw
2. powerplant & no biomass yard; straw & Miscanthus
3. powerplant & one biomass yard; straw & Miscanthus

Variant 1 - powerplant & no biomass yard; only straw



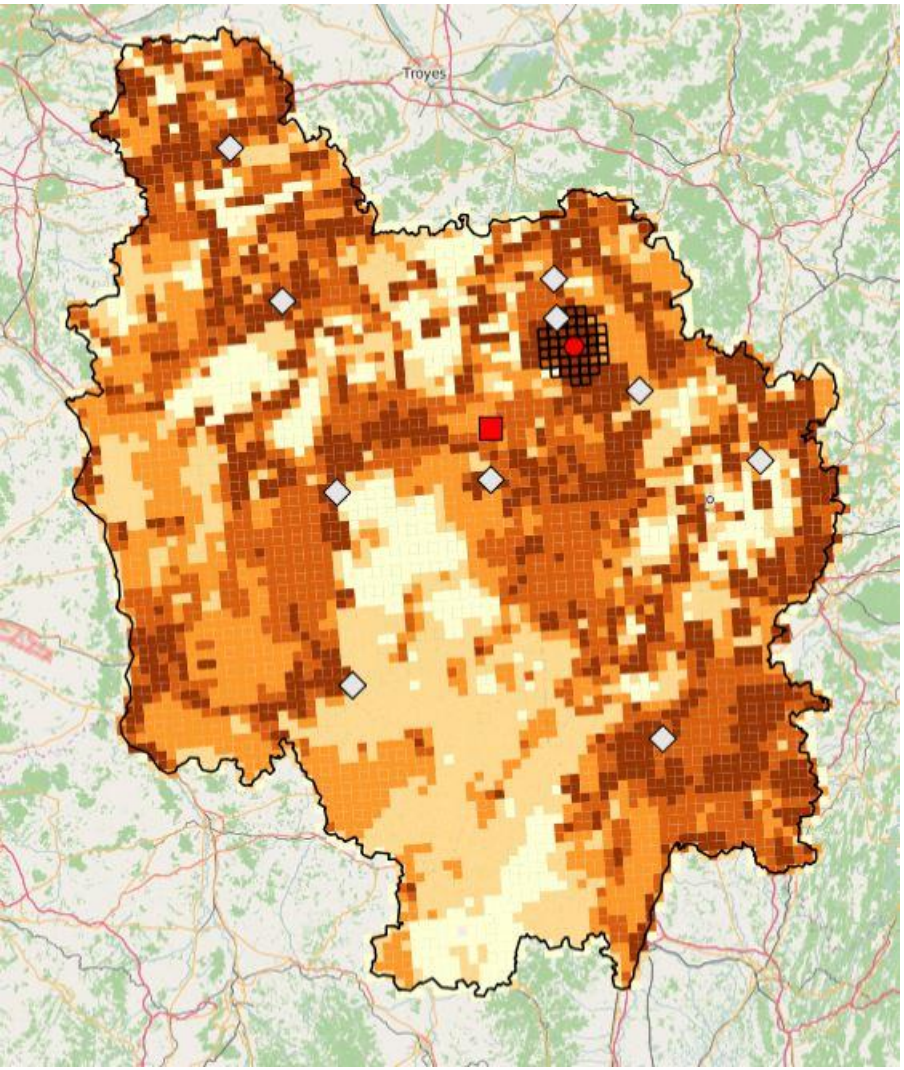
- **map is shown for available straw**
- **only 33% straw available, no Miscanthus (0%)**
- **the size of the collection circle can be influenced:**
  - by assuming a higher or lower biomass availability % for a certain biomass type
  - but also by adding more biomass types (e.g. also include Miscanthus in variant 2)

Variant 2 - powerplant & no biomass yard; straw & Miscanthus



- map for Miscanthus (purple)
- smaller supply circle, because Miscanthus available at closer distance
- !! calculation results are different (e.g. profit)

Variant 3 - powerplant & one biomass yard; straw & Miscanthus

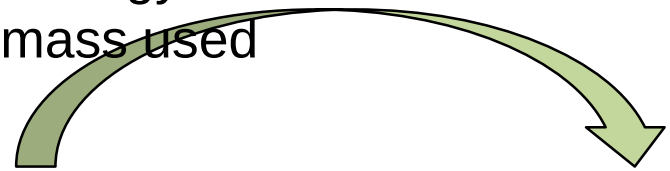


- intermediate collection point (●) located near area with a high biomass availability
- power plant (■) located near area with a high energy demand

BeWhere / LocaGIStics

- Plants location, size and technology
- Biomass used

- Costs
- Emissions avoided

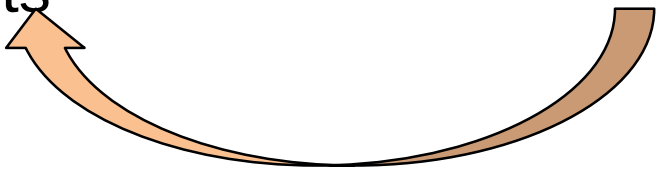


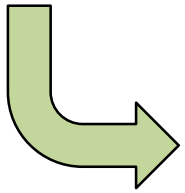
BeWhere

Determine the optimal location of plants

LocaGIStics

Calculations at the plant level



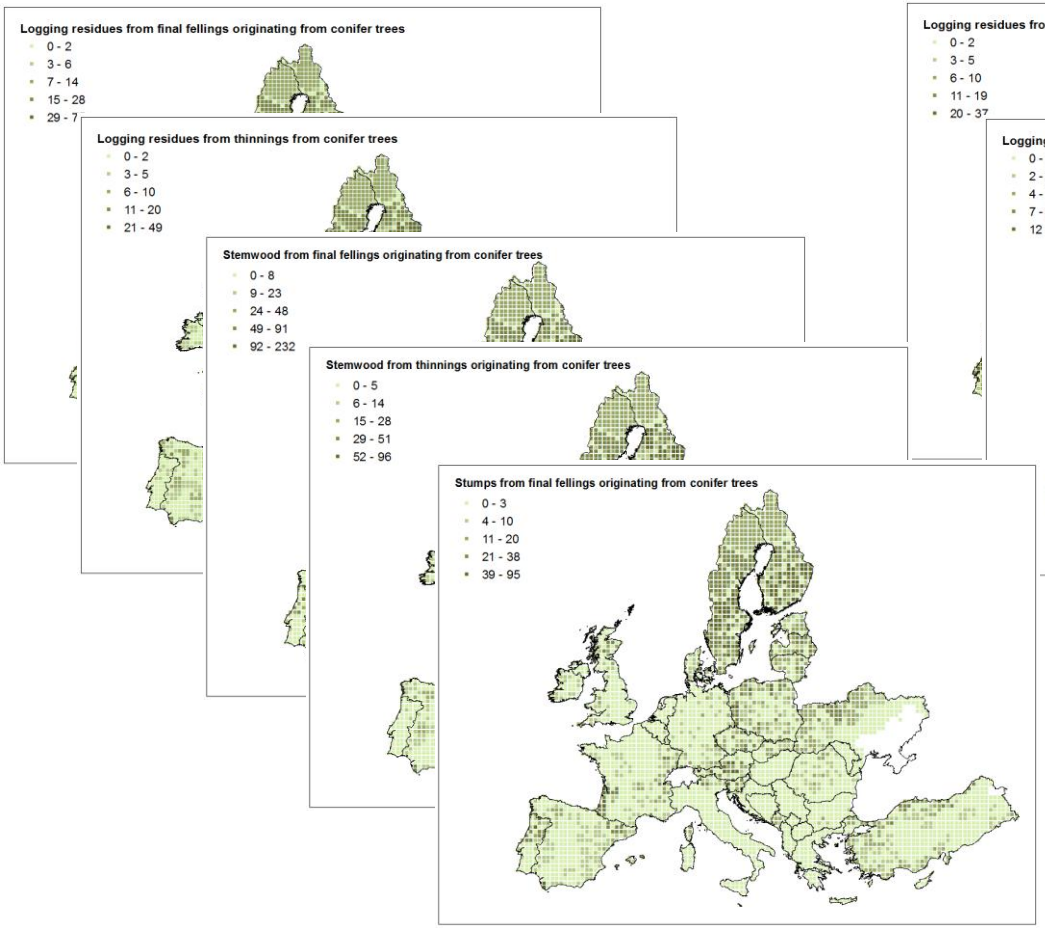


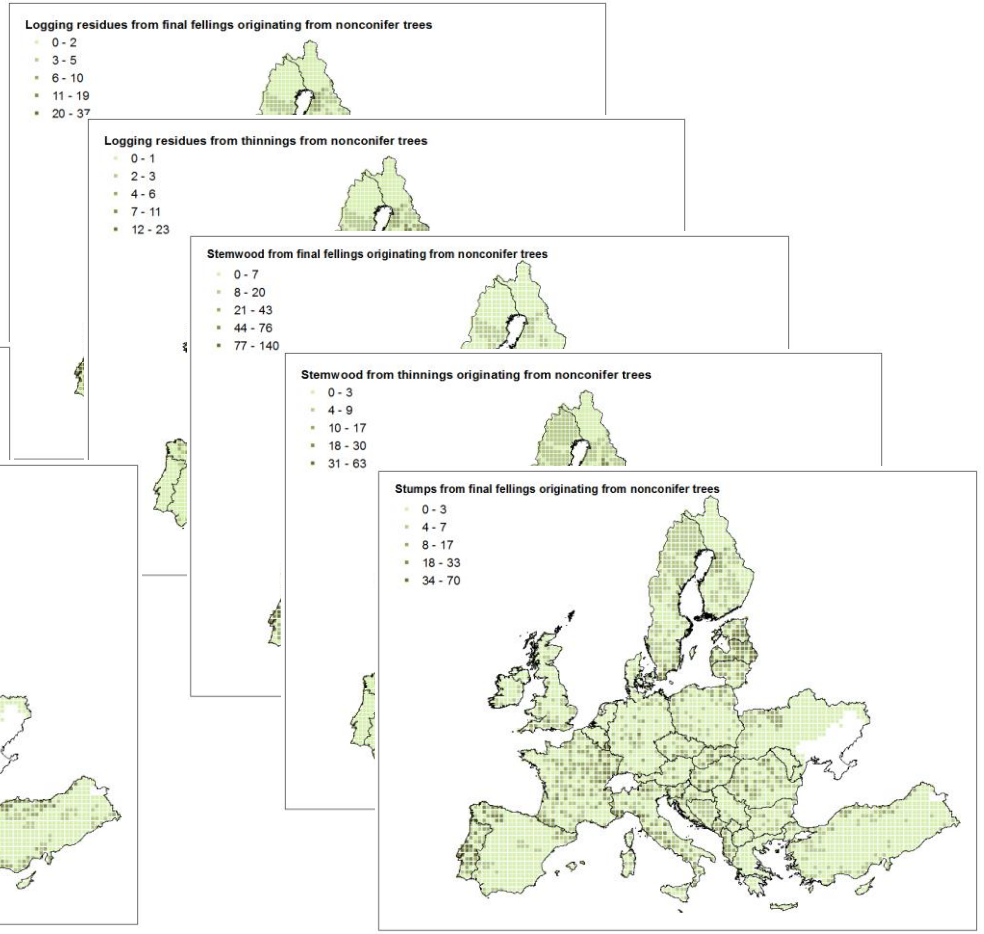
Final results

Quality check!

European model

Woody biomass feedstock (WP1)





Conifers

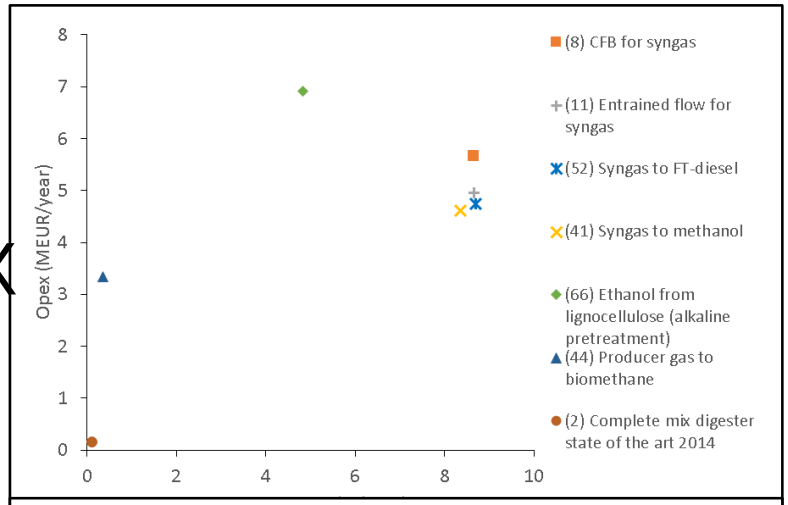
Nonconifers

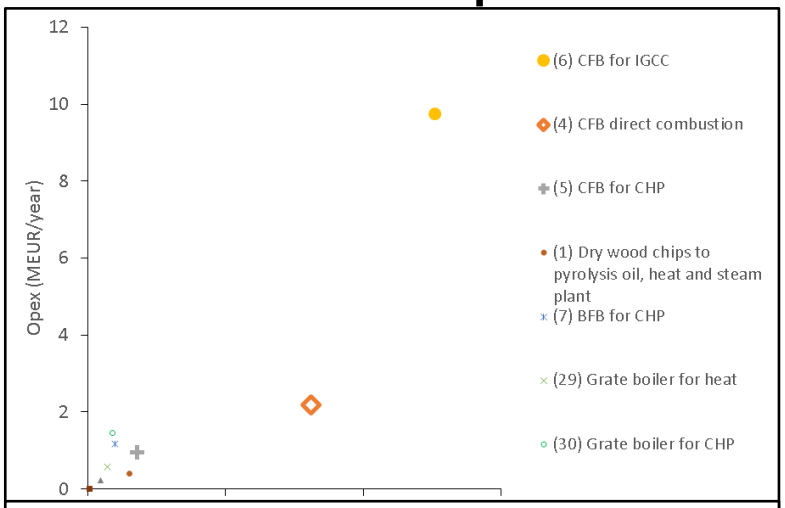
Technology Input (WP2)

Biofuel

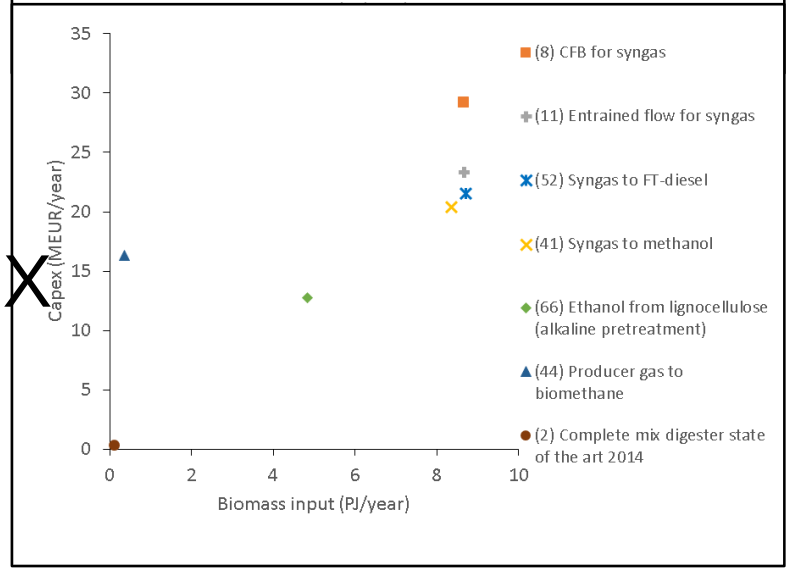
Heat and power

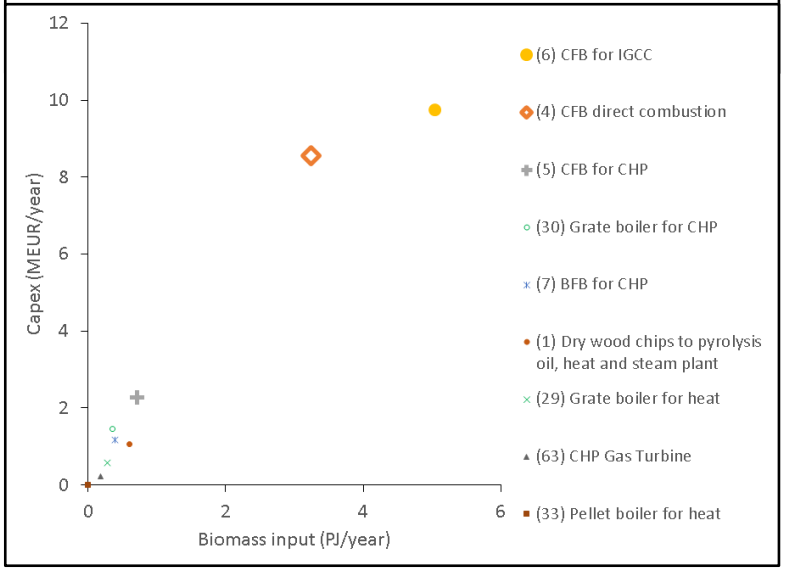
OPEX



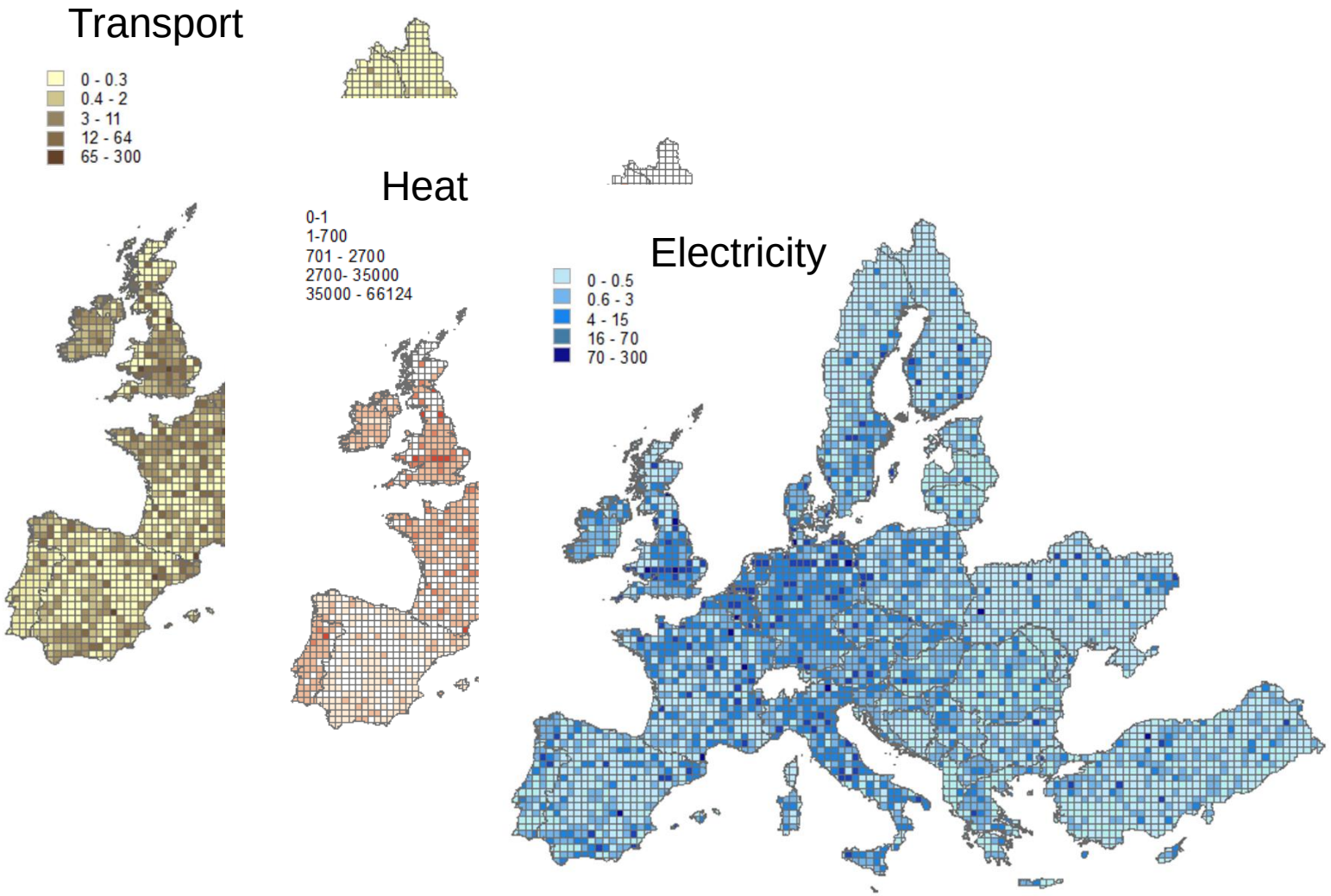


CAPEX

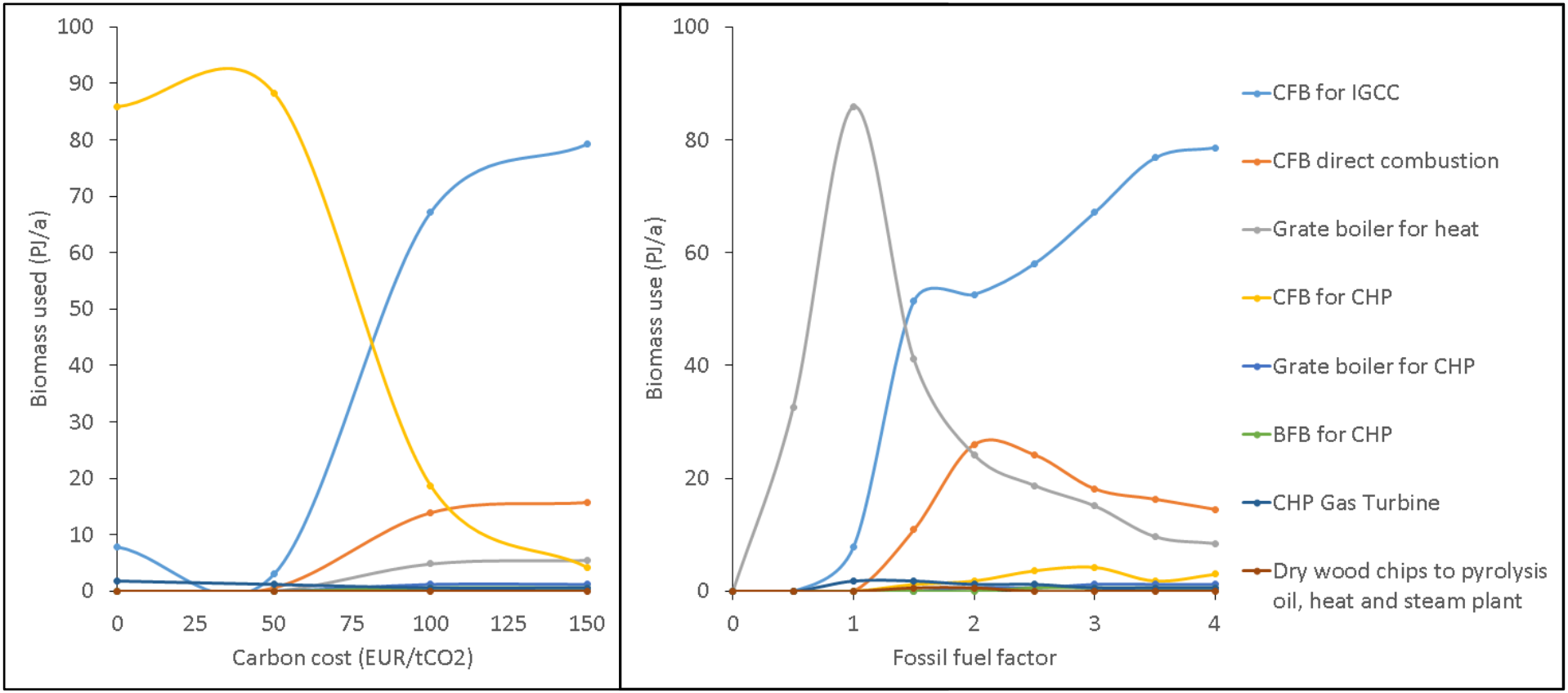




Demand (PJ/a)


Transport
0 - 0.3
0.4 - 2
3 - 11
12 - 64
65 - 300
Heat
0-1
1-700
701 - 2700
2700- 35000
35000 - 66124
Electricity
0 - 0.5
0.6 - 3
4 - 15
16 - 70
70 - 300

CHP: Carbon cost or subsidy?



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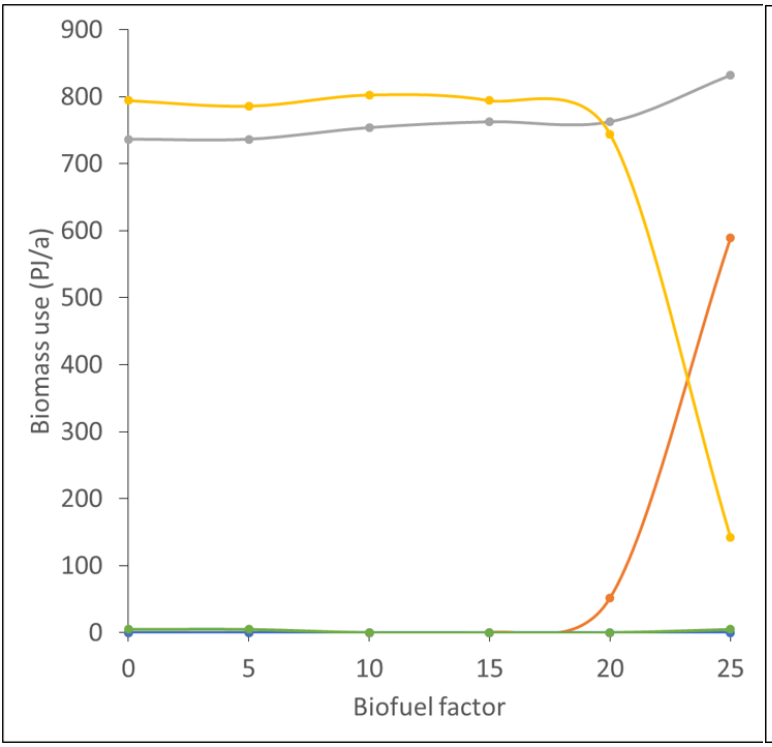
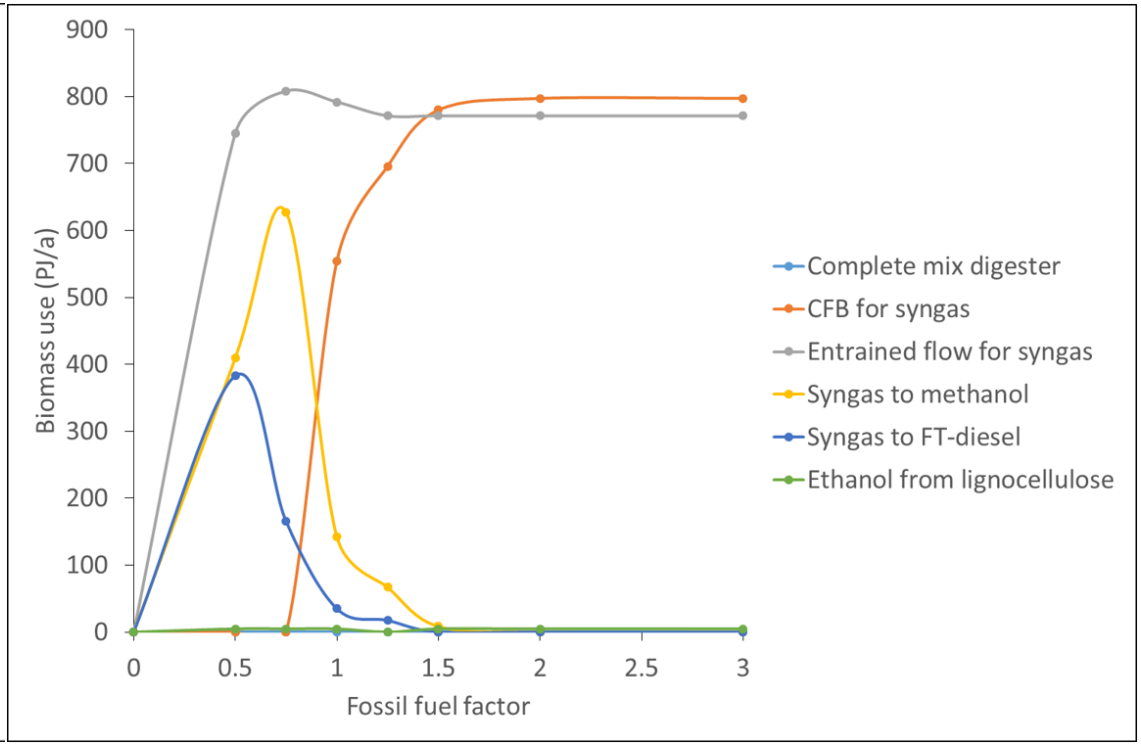
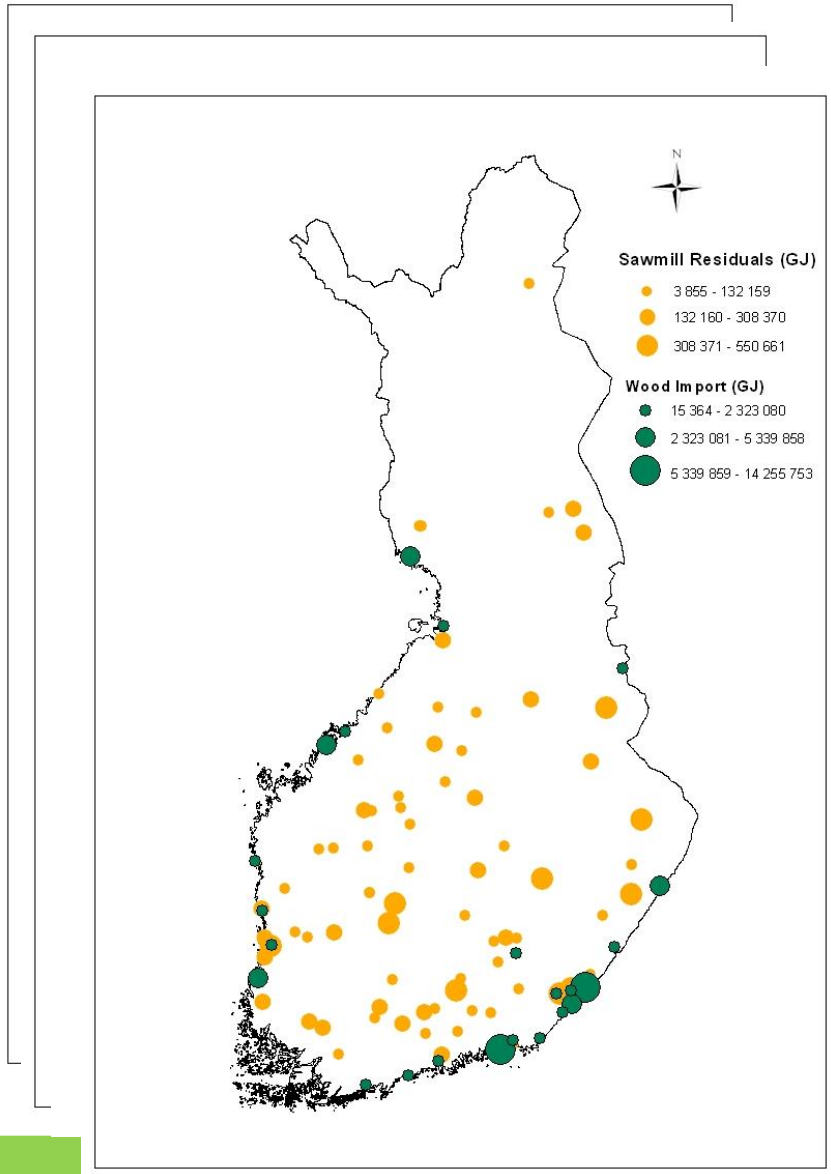
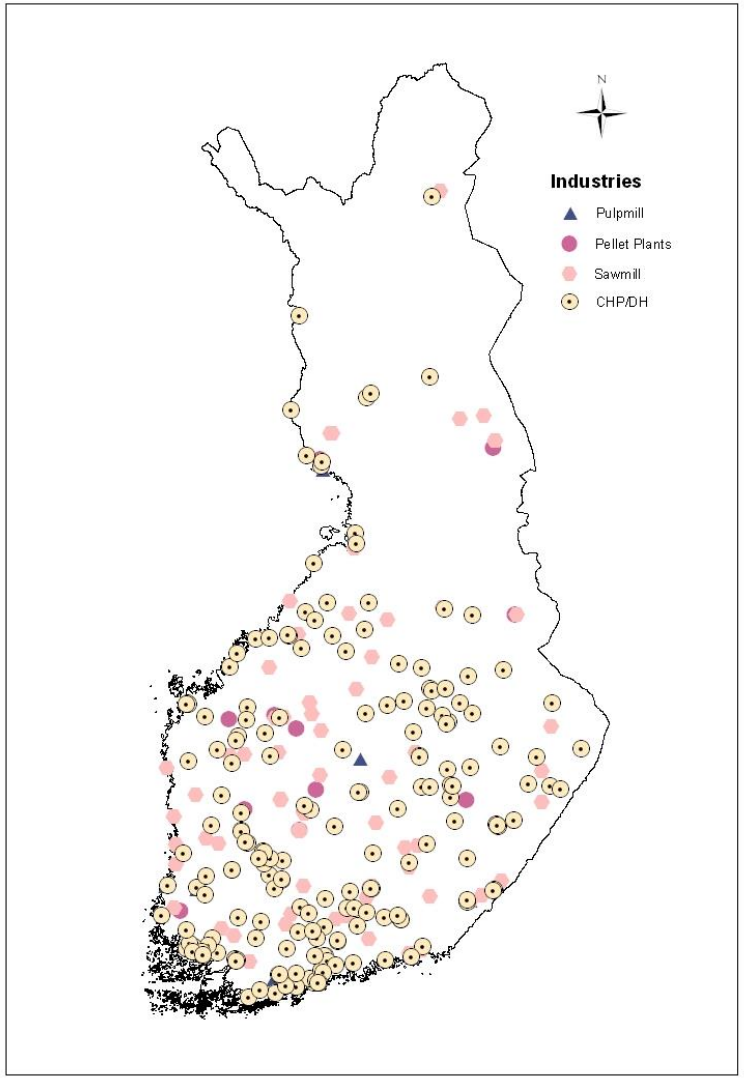
Biofuel: support or subsidy?



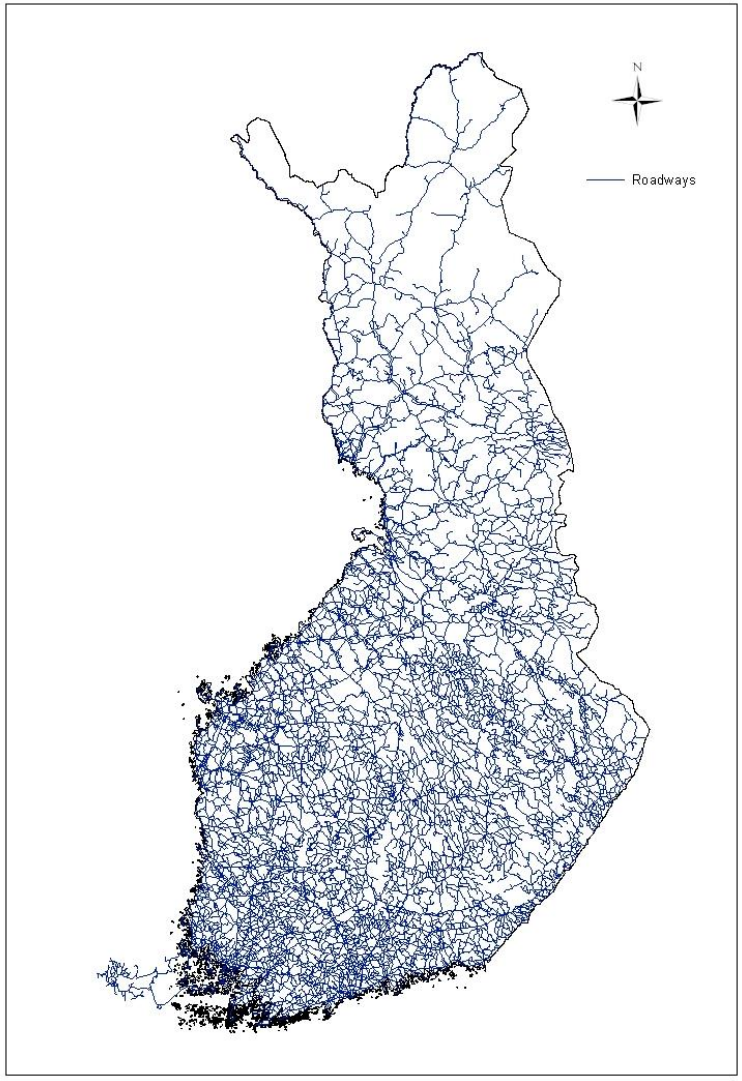


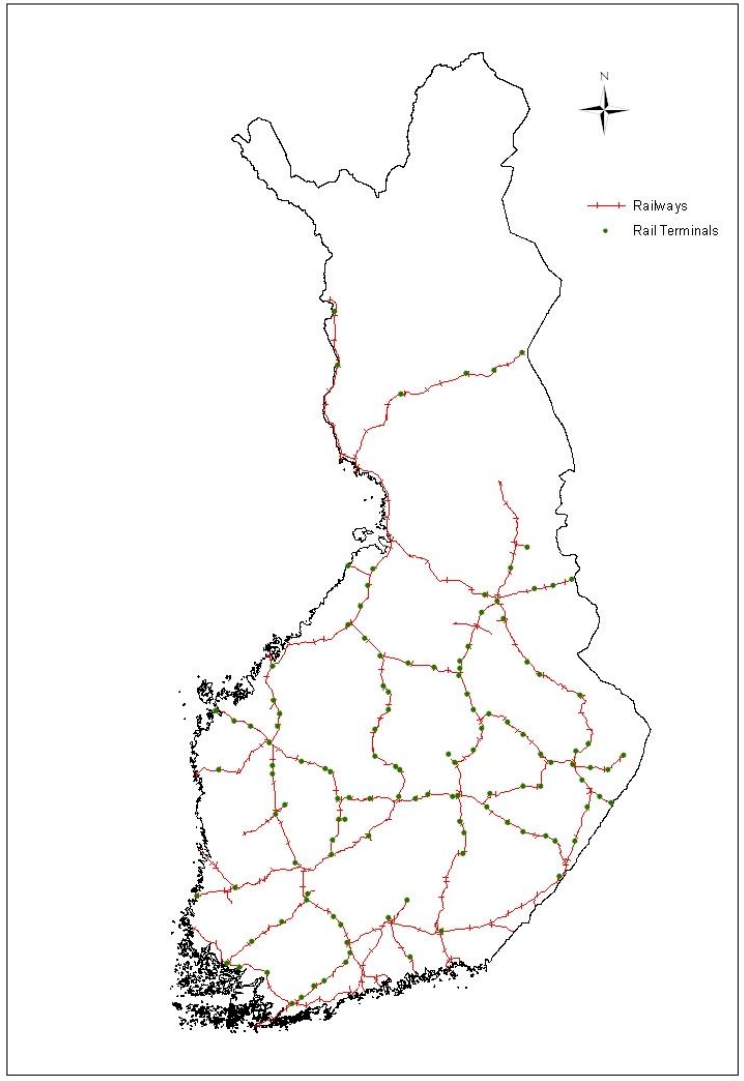
Spatial distribution of feedstock resources





Transport Network





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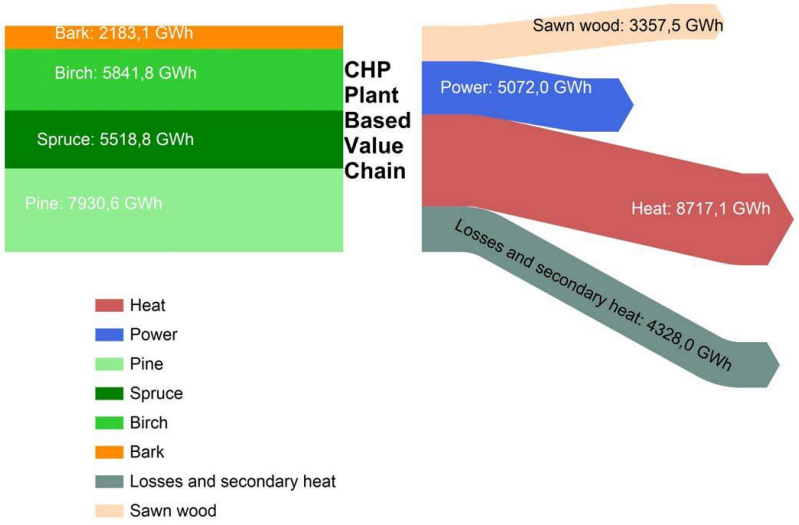
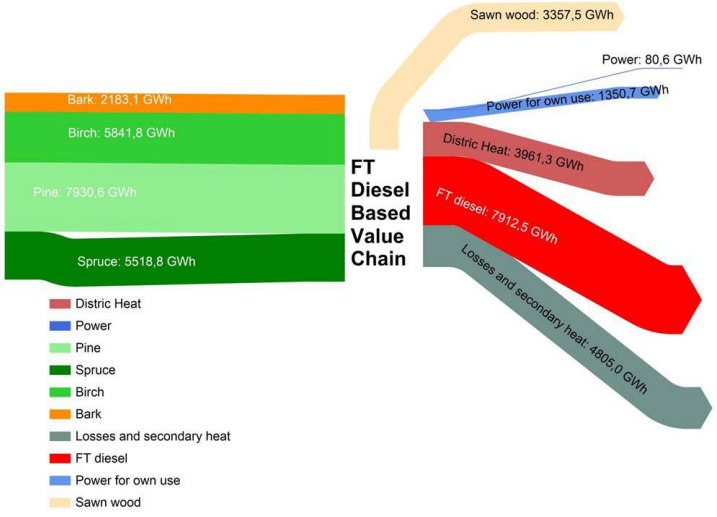
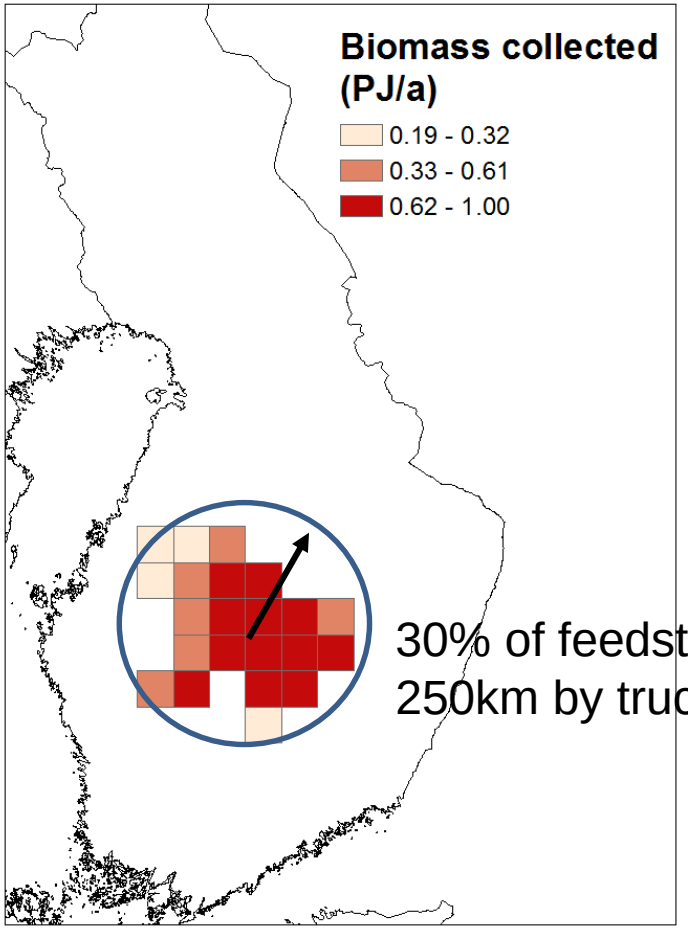
Äänekoski



Case 2



Case 3



30% of feedstock
250km by truck

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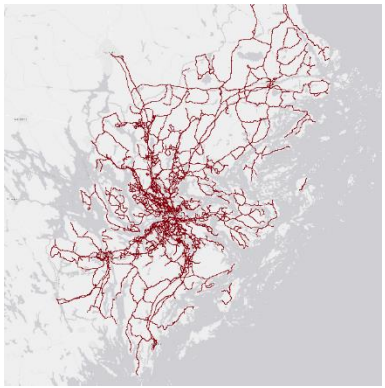
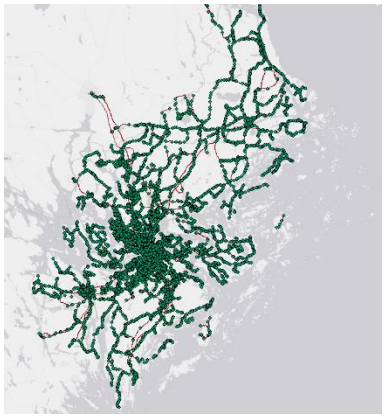
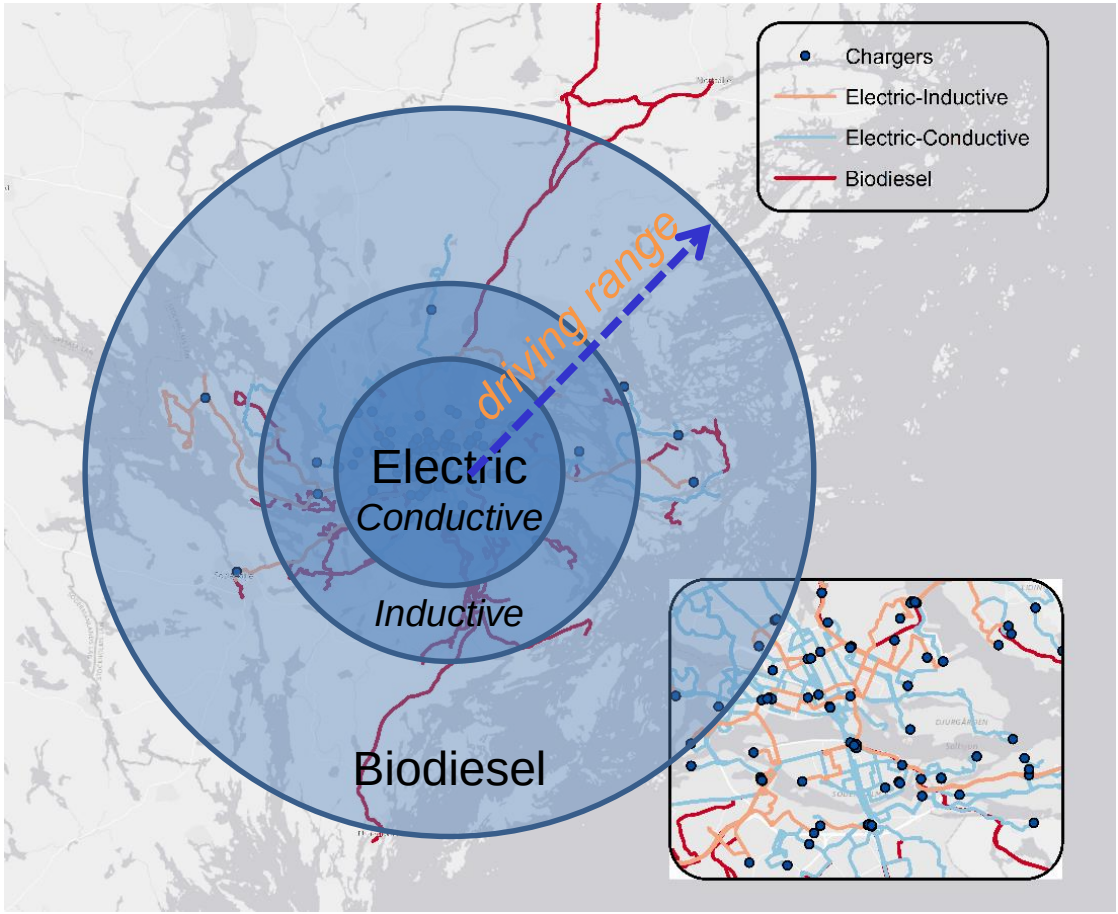
Electro-bus



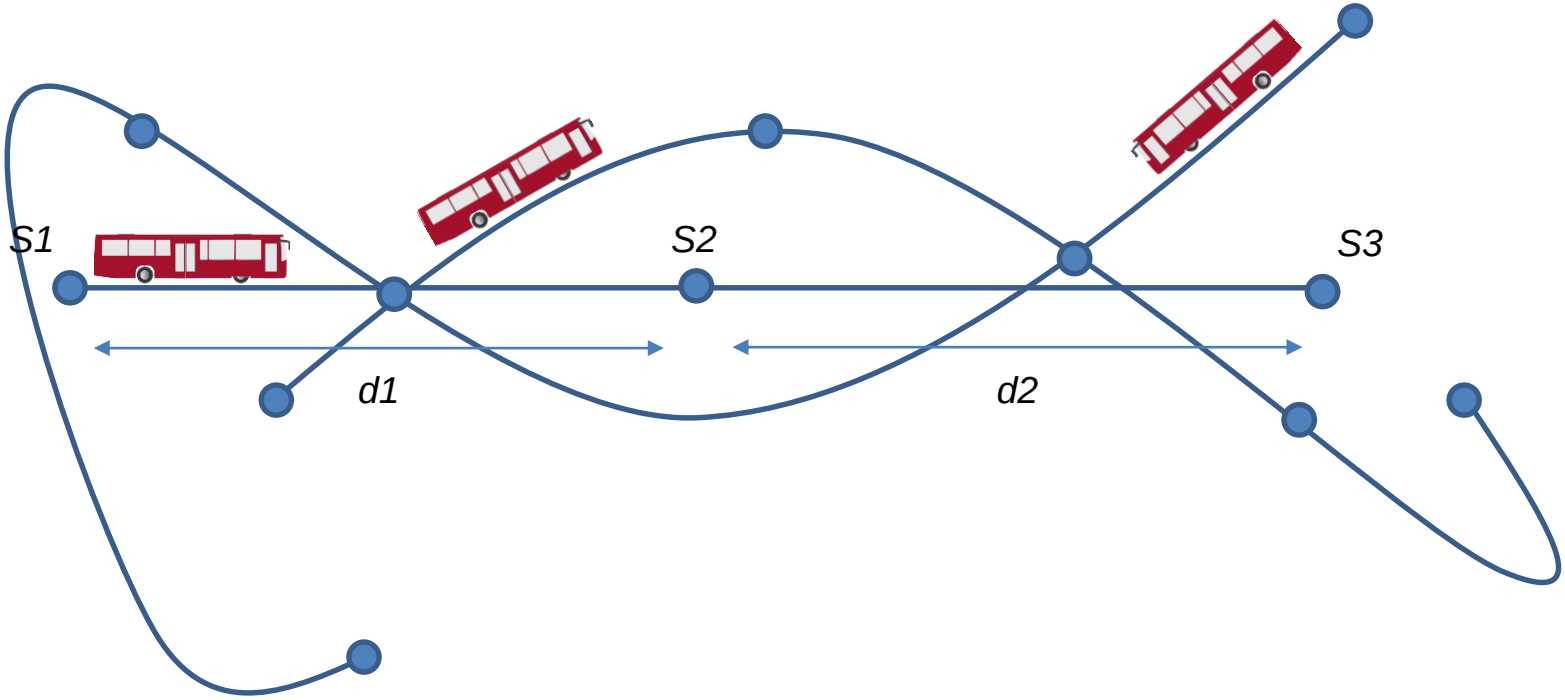
526 lines



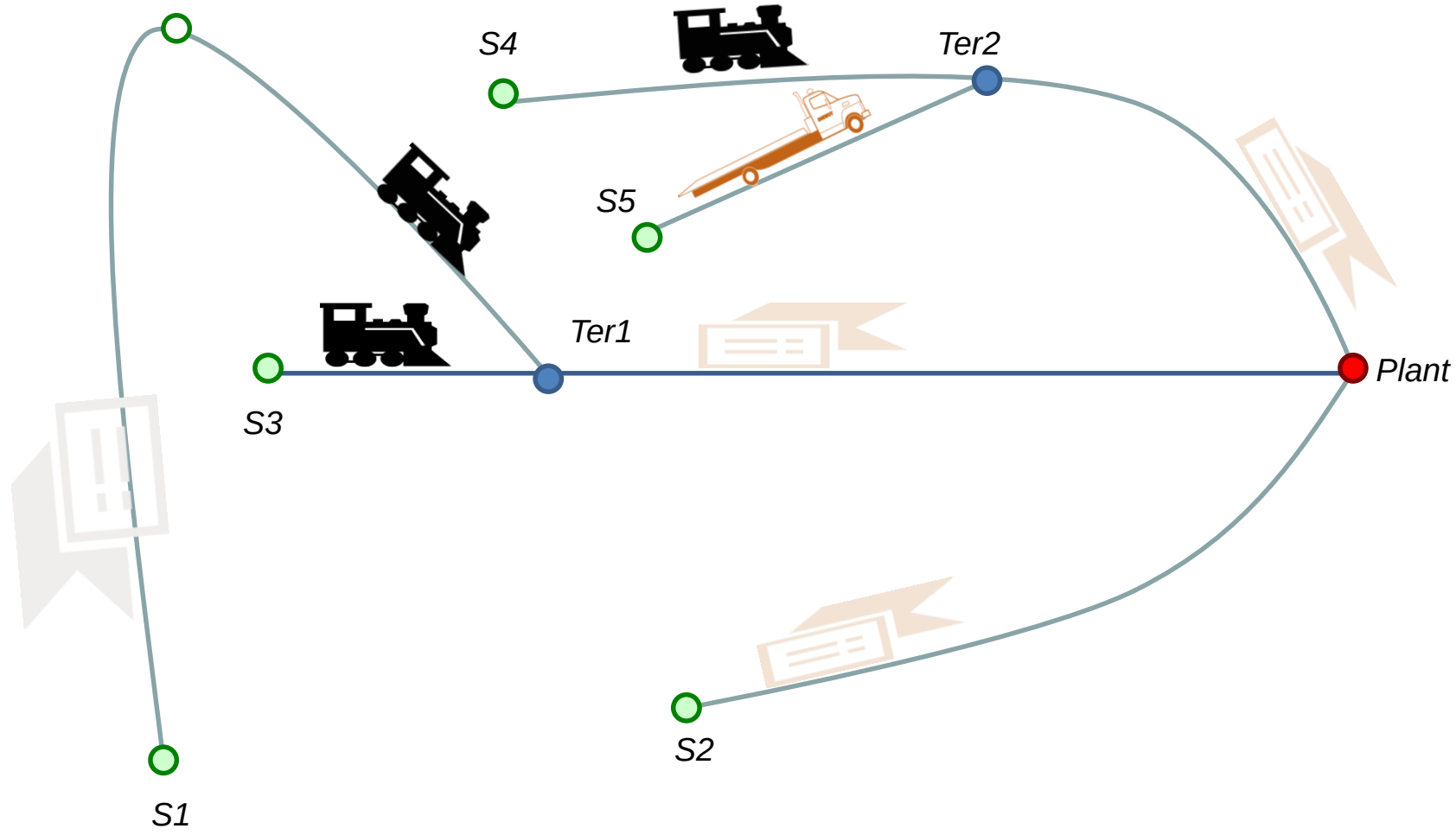
11,436 stations



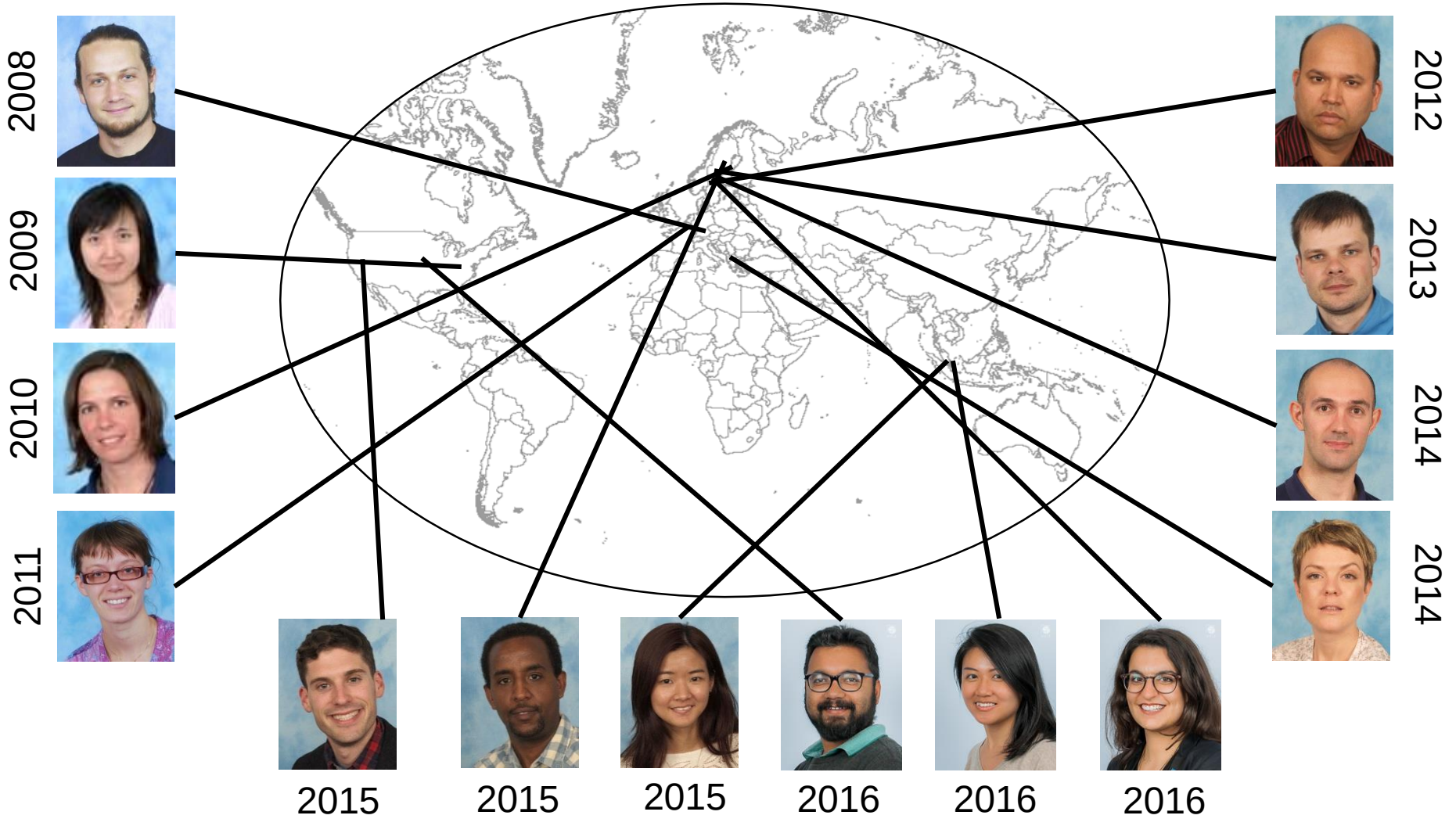
Bus station…as biomass terminals?



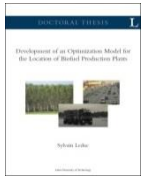
Biomass terminals?



BeWhere and YSSP



BeWhere Thesis

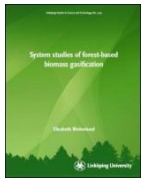


Leduc, S. (2009)

Development of an optimization model for the location of biofuel production plants.

Schmidt, J. (2009)

Cost-effective CO_2 emission reduction and fossil fuel substitution through bioenergy production in Austria: a spatially explicit modeling approach.

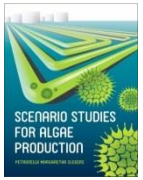


Wetterlund, E. (2012)

System studies of forest-based biomass gasification.

Khatiwada, D. (2013)

Assessing the sustainability of bioethanol production in different development contexts a systems approach.



Slegers, PM (2014)

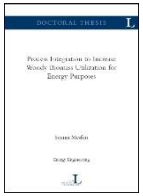
Scenario studies for algae production.

Campana, PE (2015)

PV water pumping systems for agricultural applications.

Patrizio, P (2016)

Prospects for agricultural biogas as a vehicle fuel in Northern Italy



Mesfun, S (2016)

Process integration to increase woody biomass utilization for energy purposes

2016

Karthikeyan, K (2016)

Potential of forest based bioenergy in Finland.

-17
-18

Electric buses,
MSW in Malaysia,
Biofuel from algae…

Thank you for your attention!!

Sylvain Leduc

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More about BeWhere

www.iiasa.ac.at/bewhere




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