

Solution Architect for Global
Bioeconomy & Cleantech Opportunities



Sustainable Bioenergy
Solutions for Tomorrow

Seminar on Sustainable
Bioenergy Solutions for
Tomorrow

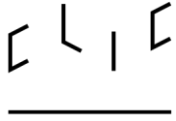
29 Nov 2016
Helsinki, Finland

Olli-Jussi Korpinen
Lappeenranta University
of Technology (LUT)

Dynamic simulation tools for evaluation of biomass supply systems



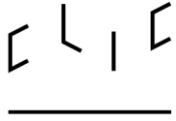
Open your mind. LUT.
Lappeenranta University of Technology



Contents

1. Introduction
2. Modelling of biomass supply systems
3. Dynamic simulation modelling
4. Dynamic simulation tools created in BEST
5. Conclusions





Introduction

- Biomass procurement takes place in both **ecological** and **industrial** environment
- Ecological environment includes
 - Geography
 - Meteorology
 - Seasonality
 - Randomness
 - Unpredictability



Himmanen 2016



Himmanen 2016



Karttunen et al. 2010



Kärki et al. 2014



Seasonality, randomness, unpredictability?



Year 2015 was the warmest in records

12.1.2016 11:43

According to the Finnish Meteorological Institute statistics, 2015 was a record warm year in the most parts of the country.

Lapland was the only province in which the year was not quite the warmest but in the shared second place. The mean temperature in 2015 was 4.2°C, which is about 1.9°C warmer than the long-term average i.e. the period 1981–2010. As regards the whole country, only June and July were colder than average. February and March as well as November and December were proportionally the warmest periods as the mean temperature in the whole country was 4-6°C warmer than normal.



Photo: Eija Vallinheimo

Warm weather records were broken in both November and December. The new weather record for November, 14.3°C, was measured on 3 November in Kemiöns. The record for December was 11.3°C, which was measured in Pori and Kokemäki 20 December.

The highest temperature of the year, 31.4°C, was recorded on 3 July in Kouvola. There were only 19 hot days during the entire summer, which is about half the normal number of hot days. The first hot day was as late as on 29 June, which makes it the second latest first hot day recorded since 1961. The majority of hot days were not until in August. Because of the bleak summer weather, the number of thunderstorms was record low this year. The lowest temperature of the year, -39 was recorded in Utsjoki on 11 January.

The new record for annual precipitation measured in Puolanka

The level of annual precipitation varied between the 500mm in Northern Lapland just over 1,000mm in Kainuu. The highest level of rainfall was measured in Puolanka, where 1,242mm of rain was received at the Paljakka station. This exceeds clearly the previous record for annual precipitation, which was 1,109mm measured in Nupuri in Espoo in 1981.

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STATISTICS

Energy

Energy consumption in households

Changes in these statistics

Future releases

Releases

Reviews

Tables

Figures

Press releases

Available products and services

Description

Quality descriptions

Methodological descriptions

Concepts and definitions

Classifications

Further information

RELATED TOPICS

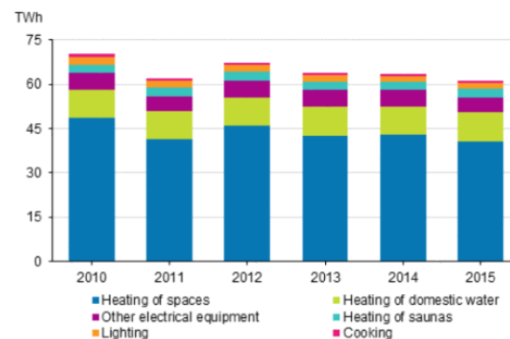
Energy 2015 table service

Published: 18 November 2016

Warm weather decreased energy consumption in households in 2015

In 2015, electricity used in housing amounted to 61 terawatt hours (TWh). Consumption decreased by four per cent from the previous year. The record warm weather diminished the consumption of heating energy for spaces by five per cent. The energy consumption of household appliances went down by six per cent due to, for example, the decreased need to heat car interiors. The data are based on Statistics Finland's statistics on energy consumption in households.

Energy consumption in households 2010-2015



Sixty-seven per cent of energy consumption in households concerned heating of residential buildings, 16 per cent heating of domestic water, and five per cent heating of saunas. In domestic

Electricity consumption exceeded 15,000 MW for the first time on 7 Jan 2016

1/7/2016 5:25 PM - Current News

According to Fingrid's operational control measurements, the average hourly power of Finnish electricity consumption reached a new record, 15,100 megawatts, on 7 January 2016 around 5-6 pm. 10,800 megawatts of electricity were produced in Finland, and the remaining 4,300 megawatts were imported from neighbouring countries. The adequacy of electricity was not threatened during the peak consumption.

The average hourly power of Finnish electricity consumption first rose to around 14,900 megawatts on Thursday morning 7 January 2016, but this top figure was exceeded in the evening of the same day. Consumption has reached its highest figures this winter due to the very low sub-zero temperatures at the start of the year. Power plants have been operating without significant disturbances. Nearly all available power plants are already in use, but so far, the peak

Sources: Finnish Meteorological Institute, Statistics Finland, Fingrid

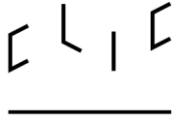
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Modelling of biomass supply systems

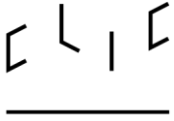
Performance
evaluation
models

- Cost-calculation models
- GIS-based models
- Simulation models

Optimization
models

- Deterministic models
- Stochastic models
- Multi-objective models



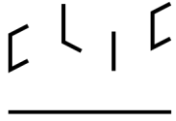


Why simulation?

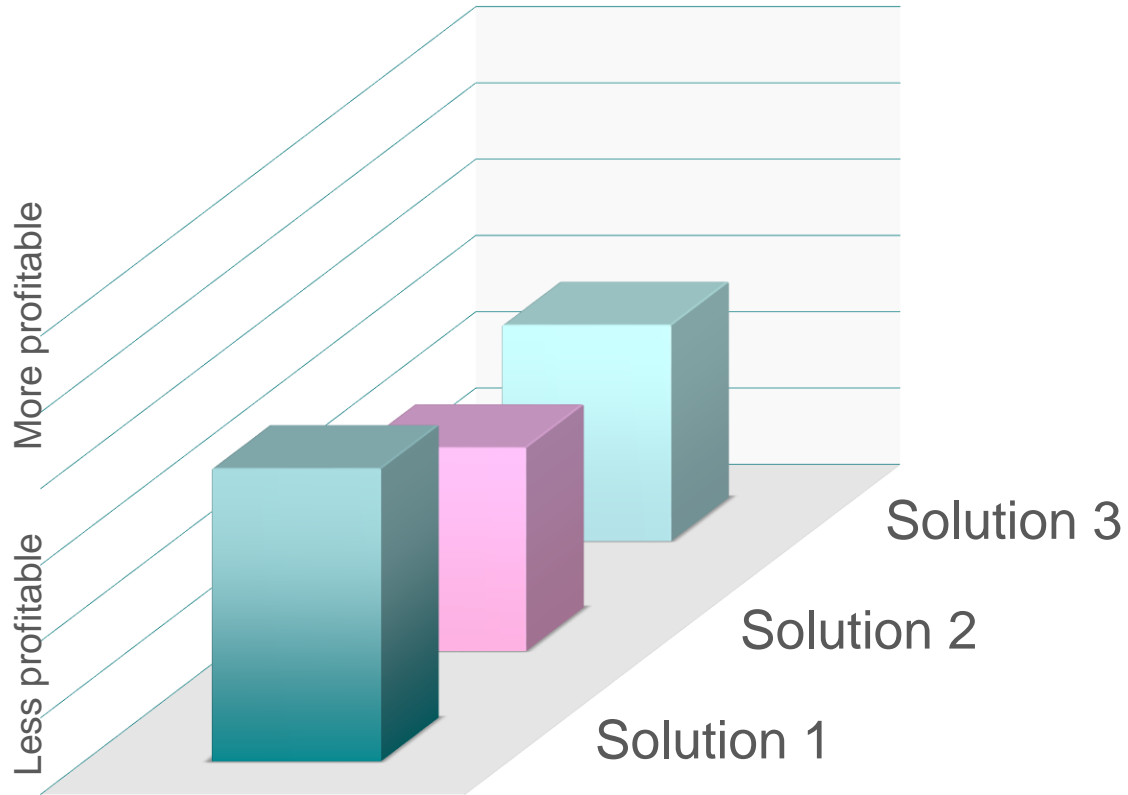
Simulation can be used to

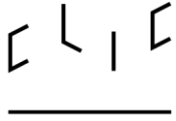
- evaluate the performance of
 - ✓ an existing logistics system
 - ✓ a new system based on heuristic decision-making
 - ✓ a new system suggested by **static analyses** (from e.g. optimization model)
- account for seasonality and stochasticity
- account for strong system interactions
 - ✓ usually too complex for analytic models



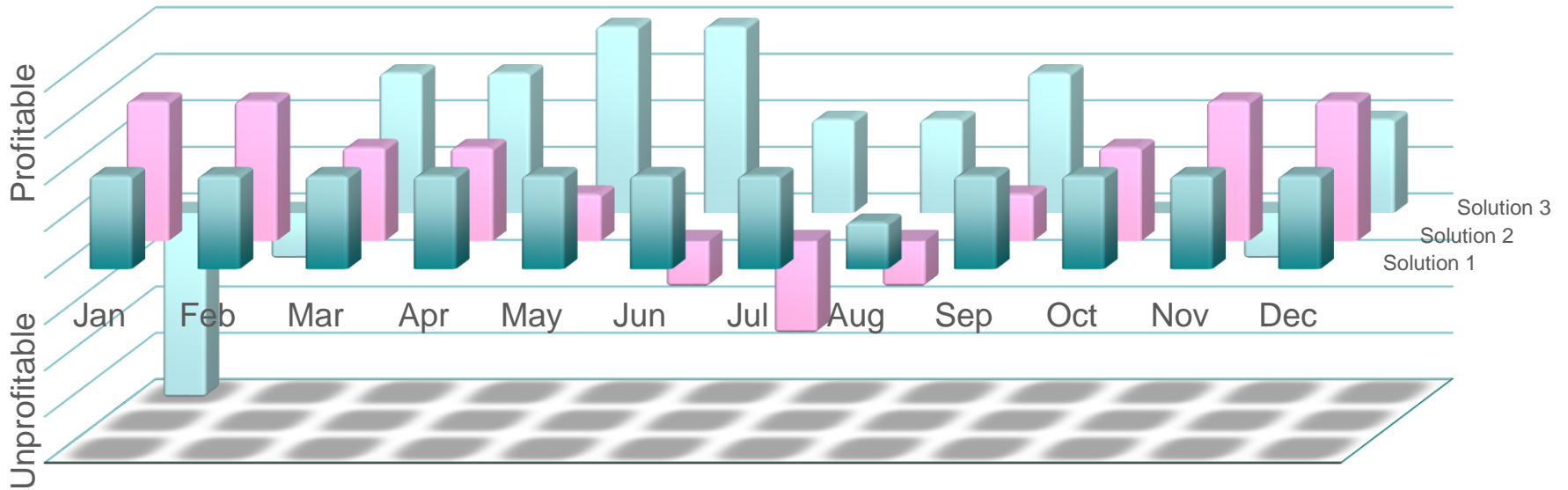


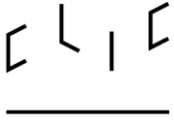
Example: profitability of logistics solutions





Example: profitability of logistics solutions



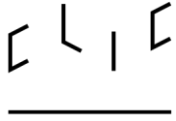


Dynamic simulation modelling



- Dynamic: able to change over **time**
 - ✓ We need to account for the **quality changes of biomass** on its way to the end-user
- Dynamic: possibility to change parameters
 - ✓ We need to provide different logistical options and possibility to change initial data because **of case-specific features** and **randomness** in actual cases





Application 1: Feed-in terminal (partial simulation approach)

The objective of the simulation run is to secure a typical demand by nearby power plant(s)

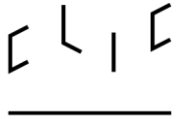
- Runtime 1 year (Jul-Jun)
- Scalable and flexible model
- Spatial, but non-geographical
- Model user has liberties and responsibilities
- Input parameters are imported from spreadsheets



Himmanen 2016



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Feed-in terminal: Input data

Truck properties

1 = yes 0 = no

| Truck type | m ³ | Unloading, min | ± min | Stationar Crusher | Weighing | Sampling |
|------------|----------------|----------------|-------|-------------------|----------|----------|
| Woodchip 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Woodchip | | | | | | |

| | dry CV | bulk density | Storage capacity | Unloading place | Waiting place |
|------|---------|------------------------|----------------------|-----------------|---------------|
| Fuel | [MJ/kg] | t/m ³ loose | m ³ loose | # | # |
| Chip | 0 | 0 | 0 | 4 | 2 |

| |
|-------------|
| Woodchip |
| ForestRes |
| ForestRes |
| Stem 1 |
| Stem 2 |
| Stem 3 |
| Whole Three |
| Whole Three |
| Stump |
| Agro 1 |
| Agro 2 |
| Other |

| |
|-----------|
| ForestRes |
| Stem |
| Whole Thr |
| Stump |
| Agro |
| Other |
| Crusher |

Plant utilization

| Month | Needed fuel amount [MWh] | # of trucks | # of mobile crusher | Shift |
|-------|--------------------------|-------------|---------------------|-------|
| 1 | 49000 | 2 | 2 | 2 |
| 2 | 45000 | 2 | 2 | 2 |
| 3 | 49000 | 2 | 2 | 2 |
| 4 | 42000 | 3 | 2 | 2 |
| 5 | 39000 | 3 | 2 | 2 |
| 6 | 23000 | 1 | 2 | 2 |
| 7 | 0 | 0 | 0 | 1 |
| 8 | 0 | 0 | 0 | 1 |
| 9 | 18000 | 2 | 2 | 1 |
| 10 | 43000 | 2 | 2 | 2 |
| 11 | 42000 | 2 | 2 | 2 |
| 12 | 44000 | 2 | 2 | 2 |

Distance between plant and terminal 5000 m
Average speed of terminal trucks 60 km/h

Routing features

| | Distance, m | Speed, km/h |
|----------------------------------------|-------------|-------------|
| 1 Gate >> Waiting (for weighing) | 50 | 20 |
| 2 Waiting area >> Weighing scales 1 | 25 | 8 |
| 3 Gate >> Passing weighing | 75 | 20 |
| 4 Weighing >> Waiting (Sampling) | 10 | 5 |
| 5 Waiting area >> sampling | 20 | 5 |
| 6 Weighing >> Pass sampling | 30 | 20 |
| 7 Waiting area >> Weighing out | 20 | 5 |
| 8 Weighing out >> Gate | 75 | 15 |
| 9 waiting area >> gate (pass weighing) | 50 | 15 |

Yard properties

| | | |
|------------------------------------------------|----------------|----------|
| Total storage capacity in the terminal | m ² | 10000000 |
| Feeder truck capacity | | 150 |
| Max vehicle count allowed at plant | | 100 |
| Max vehicle count allowed to wait weighing | | 5 |
| Max vehicle count allowed to wait weighing out | | 5 |
| Max vehicle count allowed to wait Sampling | | 5 |

| | | |
|--------------------------|-----|-----|
| Weighing time (in), min | min | 1 |
| Weighing time (out), min | min | 0,5 |
| Sampling time | min | 10 |

| | | |
|----------------------------|-------------------|------|
| Number of wheel loaders | # | 1 |
| Wheel loader loading speed | m ³ /s | 0,1 |
| mobile crusher | m ³ /s | 0,04 |
| Stationary crusher | m ³ /s | 0,06 |

Routing features For fuel storage

| Route | Chip | ForestResec | Stem | ... |
|------------------------------------|----------|-------------|------|-----|
| Sampling >> Waiting area to unload | Distance | 1 | 1 | 260 |
| | Speed | 1 | 1 | 20 |
| Waiting >> unloading | Distance | 1 | 1 | 35 |
| | Speed | 1 | 1 | 10 |
| Unloading >> weighing out | Distance | 1 | 1 | 430 |
| | Speed | 1 | 1 | 30 |

| Month |
|-------|
| 1 |
| 2 |
| 3 |
| 4 |
| 5 |
| 6 |
| 7 |
| 8 |
| 9 |
| 10 |
| 11 |
| 12 |

| Month | Chip |
|-------|------|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| 12 | |



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5%
5%
5%
5%
5%
5%
5%

FEED-IN TERMINAL - Simulation model

Remember to set input values in input.xlsm file and save file.
Non-numeric value in a numeric cell will cause error.
In the end of the run, the model will save results to output.xlsx file.
This file shall not be opened during saving (end of the run).


Fixed seed (reproducible model runs)


Top level agent

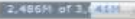
Run: 6  Running

Time: 52433.67

Experiment:  100%

Simulation:  100%

Date: Aug 6, 2015 9:53:40 AM 

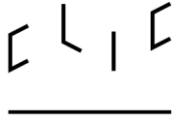
Memory:  2,466M of 3,433M 

best

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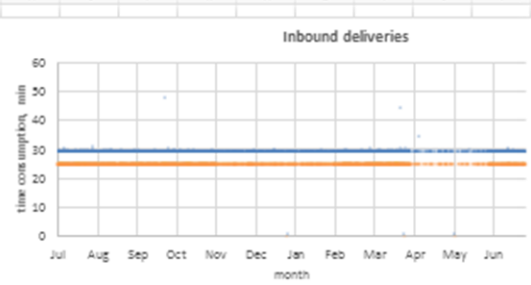
best

100% of 100%
100% of 100%

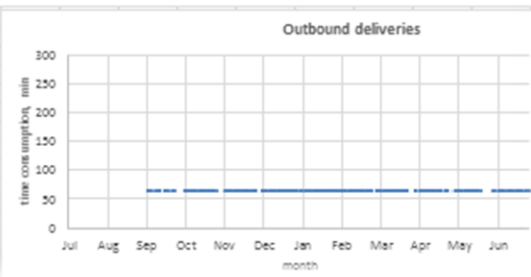


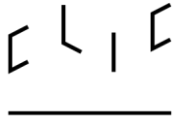
Feed-in terminal: Result data

| Arriving truck | Month | # trucks | min visit | avg visit | max visit |
|----------------|-------|----------|-----------|-----------|-----------|
| | 1 | 178 | 29,2 | 29,2 | 30 |
| | 2 | 294 | 29,2 | 29,2 | 30,1 |
| | 3 | 408 | 29,2 | 29,3 | 44,6 |
| | 4 | 61 | 29,2 | 29,3 | 34,4 |
| | 5 | 61 | 29,2 | 29,2 | 30,2 |
| | 6 | 247 | 29,2 | 29,2 | 30,3 |
| | 7 | 409 | 29,2 | 29,2 | 31,2 |
| | 8 | 344 | 29,2 | 29,2 | 30,2 |
| | 9 | 365 | 29,2 | 29,3 | 48 |
| | 10 | 364 | 29,2 | 29,2 | 30,2 |
| | 11 | 186 | 29,2 | 29,2 | 29,7 |
| | 12 | 130 | 0,8 | 29,2 | 30,2 |
| | | 3107 | 0,8 | 29,2 | 48 |



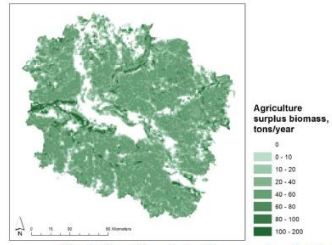
| Departing truck | Month | # trucks | min visit | avg visit | max visit |
|-----------------|-------|----------|-----------|-----------|-----------|
| | 1 | 345 | 64,2 | 64,2 | 64,2 |
| | 2 | 316 | 64,2 | 64,2 | 64,2 |
| | 3 | 344 | 64,2 | 64,2 | 64,2 |
| | 4 | 296 | 64,2 | 64,2 | 64,2 |
| | 5 | 274 | 64,2 | 64,2 | 64,2 |
| | 6 | 188 | 64,2 | 64,2 | 64,2 |
| | 7 | 0 | | | |
| | 8 | 0 | | | |
| | 9 | 128 | 64,2 | 64,2 | 64,2 |
| | 10 | 302 | 64,2 | 64,2 | 64,2 |
| | 11 | 295 | 64,2 | 64,2 | 64,2 |
| | 12 | 303 | 64,2 | 64,2 | 64,2 |
| | | 2797 | 64,2 | 64,2 | 64,2 |



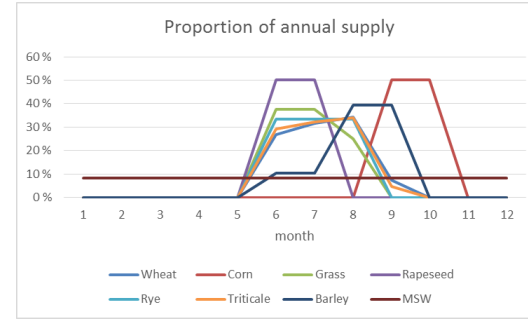
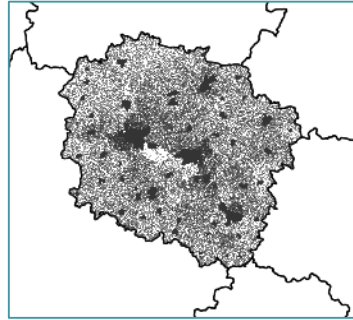


Application 2: Case Poland (holistic simulation approach)

Biomass resource assessment
Latva-Kajrā, Natarajan & Zyadin



Kujawsko-Pomorskie agriculture biomass surplus estimate in tons per year.



Fixed input parameters

Data input for biomass supply logistics simulation in Silesian Voivodeship, Poland

Select geospatial level for feedstock availability assessment

- Voivodeship
- Powiat
- Gmina

Municipal solid waste (MSW) production per capita: 300 kg/a = Theoretic MSW supply potential

Quick guide

- Select the geospatial resolution (above) where the data about available feedstock per annum is given
- Select the corresponding tab ("Województwa", "Powiaty" or "Gminy")
- Fill the estimates of feedstock availability for each geographical unit (i.e. row)
- Custom [T]: your own value [tons] will be used
- % (Theor.): your own estimate, % of theoretic harvest potential, will be used if "Custom [T] is blank"
- Both "Custom [T]" and "% (Theor.)" are blank, theoretic harvest potential is used.
- Theoretic harvest potential of feedstock (exc. MSW) is based on BEST research report No D14.2
- Default value for "% (Theor.)" is 30 (see Zyadin et al. 2016).
- Return to front page, save and close file. Run simulation.

Time distributions

Supply by month

Demand by month

Clipboard | Font | Alignment | Number | Styles | Cell Styles | Insert | Delete

A1 | [179] Gminas

| ID | Name | MSW [t] | | Wheat [t] | | Corn [t] | | Own | % | | |
|----|-------------------------------|---------|------------|-----------|-------|------------|--------|----------|----------|--------|------------|
| | | Own | % (Theor.) | Used | Own | % (Theor.) | Used | | | Own | % (Theor.) |
| 1 | [179] Gminas | | | | | | | | | | |
| 3 | 040101_1 Aleksandrów Kujawski | 21 | 30 | 21 | 46583 | 10 | 46583 | 0 | 25 | 0 | 32089 |
| 4 | 040102_1 Ciechocinek | 1452 | 30 | 1452 | 31699 | 10 | 31699 | 0 | 25 | 0 | 44867 |
| 5 | 040103_1 Nieszawa | 1975 | 30 | 1975 | 80445 | 10 | 80445 | 0 | 25 | 0 | 59966 |
| 6 | 040104_2 Aleksandrów Kujawski | 11621 | 30 | 11621 | 83189 | 10 | 83189 | 0 | 25 | 0 | 15505 |
| 7 | 040105_2 Bądkowo | 4445 | 30 | 4445 | 29837 | 10 | 29837 | 0 | 25 | 0 | 34995 |
| 8 | 040106_2 Konec | 3259 | 30 | 3259 | 6823 | 10 | 6823 | 10 | 4232,2 | 70628 | |
| 9 | 040107_2 Raciążek | | 30 | 28242 | | 10 | 2368,1 | | 10 | 4616,4 | 71744 |
| 10 | 040108_2 Waganiec | 4562 | 30 | 4562 | 79154 | 10 | 79154 | 10 | 7357 | 11309 | |
| 11 | 040109_2 Zakrzewo | 3597 | 30 | 3597 | 72019 | 10 | 72019 | 10 | 4588,6 | 4126 | |
| 12 | 040201_1 Brodnica | 28579 | 30 | 28579 | | 10 | 61,6 | 10 | 7741,1 | 70969 | |
| 13 | 040206_2 Bartniczka | 4714 | 30 | 4714 | 10 | 4440,9 | 15 | 3802,35 | 677 | | |
| 14 | 040202_2 Bobrowo | 6328 | 30 | 6328 | 10 | 8222,4 | 15 | 11880 | 78135 | | |
| 15 | 040203_2 Brodnica | 7597 | 30 | 7597 | 10 | 1664,9 | 15 | 12271,8 | 31481 | | |
| 16 | 040204_2 Brzozie | 3766 | 30 | 3766 | 10 | 1097,4 | 15 | 11935,95 | 64759 | | |
| 17 | 040208_2 Osiek | 4098 | 30 | 4098 | 16202 | 10 | 16202 | 15 | 87 | 20771 | |
| 18 | 040209_2 Świdziebnia | 5209 | 30 | 5209 | 18702 | 10 | 18702 | 15 | 11853,75 | 89977 | |

Województwa | Powiaty | Gminy | Theoretic Biomass data

Modified by the user

Biomass supply in Poland logistics simulation

Annual demand

 tons

Plant location

 latitude longitude
 refresh points

Truck fleet

 cargo space number of units
(loose m³)

| | | |
|-----------------------------------------------------|---------------------------------|----------------------------------|
| Garbage trucks | <input type="text" value="10"/> | <input type="text" value="100"/> |
| Timber trucks | <input type="text" value="20"/> | <input type="text" value="10"/> |
| Trucks for other fuels | <input type="text" value="70"/> | <input type="text" value="50"/> |
| Terminal trucks (from feed-in terminal to plant) | <input type="text" value="80"/> | <input type="text" value="3"/> |

 Stationary crusher at feed-in terminal

Comminution

 Crusher capacity (m³ loose/h), same for plant and feed-in terminal

Compaction of material during loading at terminal

 Compaction used

 Set compaction rate for terminal trucks

 Cost of compaction €/m³ cargo space

Priority for pick-up from roadside storages

 weekly prioritization monthly prioritization always or not at all

Refresh point recalculates distances between demand and supply points. This procedure takes long time and it is not necessary if the plant location has not changed

Trucks run 05:30-21:30, Monday-Saturday.
Trucks between feed-in terminal and plant run 24/7 if needed.

If there is queue at the plant for unloading, the trucks wait to be unloaded even if it is outside working hours.

Capacity (m³ loose/h) means the produced output.

Compaction means pressing or squeezing comminuted fuel into the cargo space in order to increase payload.

Compaction rate represents the increased cargo density. It is assumed that after unloading at destination, the fuel gets back its original loose density.

Terminals and storage levels

 Use a feed-in terminal

 Direct deliveries to plant allowed

 Storage capacity at plant loose m³

 Initial amount of fuel in storage loose m³ loose m³

 Set minimum allowed storage size at plant (if stock is below this, reserve fuel is used) loose m³

 Set threshold for calling in more fuel to plant from feed-in terminal loose m³

 Truck transport cost feed-in (same for all) €/ton*km

 Annual fixed cost for using a feed-in terminal €/year

Reserve fuel

 Energy contents, (as received) MWh/ton

 Loose densities before comminution ton/m³loose

 Price €/ton

Long distance vehicles

 Delivery to plant

if uncheck goes to terminal

Background map © OpenStreetMap contributors, 2016

Run: 2 Paused

Time: 7.75

 Simulation:

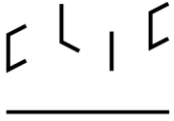
Date: Jun 1, 2016 7:45:00 AM

 Memory:

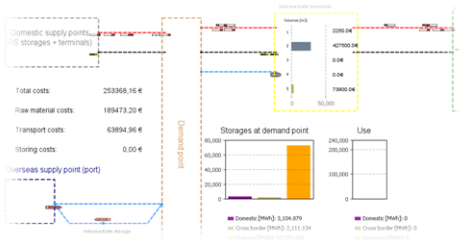
best

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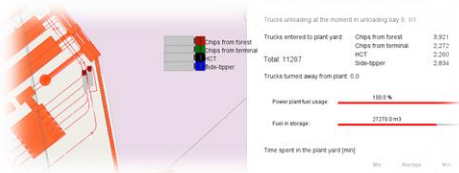
Note! The location of the demand point (plant) in this presentation has been determined by random WGS84 coordinates and is not based on any real plans to build a plant in this specific location.



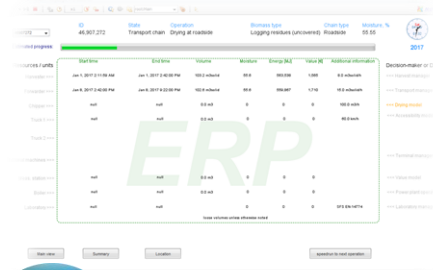
Other dynamic simulation applications



3) Simulation application for modelling **imported biomass deliveries**

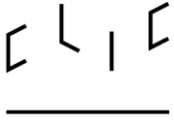


4) Simulation application for modelling **biomass reception** of the plant



5) Simulation application for modelling **information management** through ERP

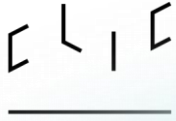




Conclusions

- Growing biomass volumes bring economies of scale benefits, but investments in logistics are also bigger than before
 - Who wants to try first?
 - A simulation model can try, with low costs
 - Vast amount of source data needed
 - Simulation model brings temporal dimension to logistics research
 - Seasonality, randomness, unpredictability
- The most feasible solution in logistics is usually the most sustainable
 - Now: analyzed from result data
 - Future: inclusion of runtime sustainability variables (e.g. fuel consumption, emissions)





Thank you!

Simulation modelling contacts

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mika.aalto@lut.fi

tapiio.ranta@lut.fi



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Open your mind. LUT.
Lappeenranta University of Technology