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open energy modelling framework

A modular open source framework to model energy supply systems

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Outline

- Idea of an open framework
- Status quo and quick overview
  - Current projects
  - Possible applications
- How to build an application
  - Basic components
  - Extended applications
- Getting involved
- Conclusion

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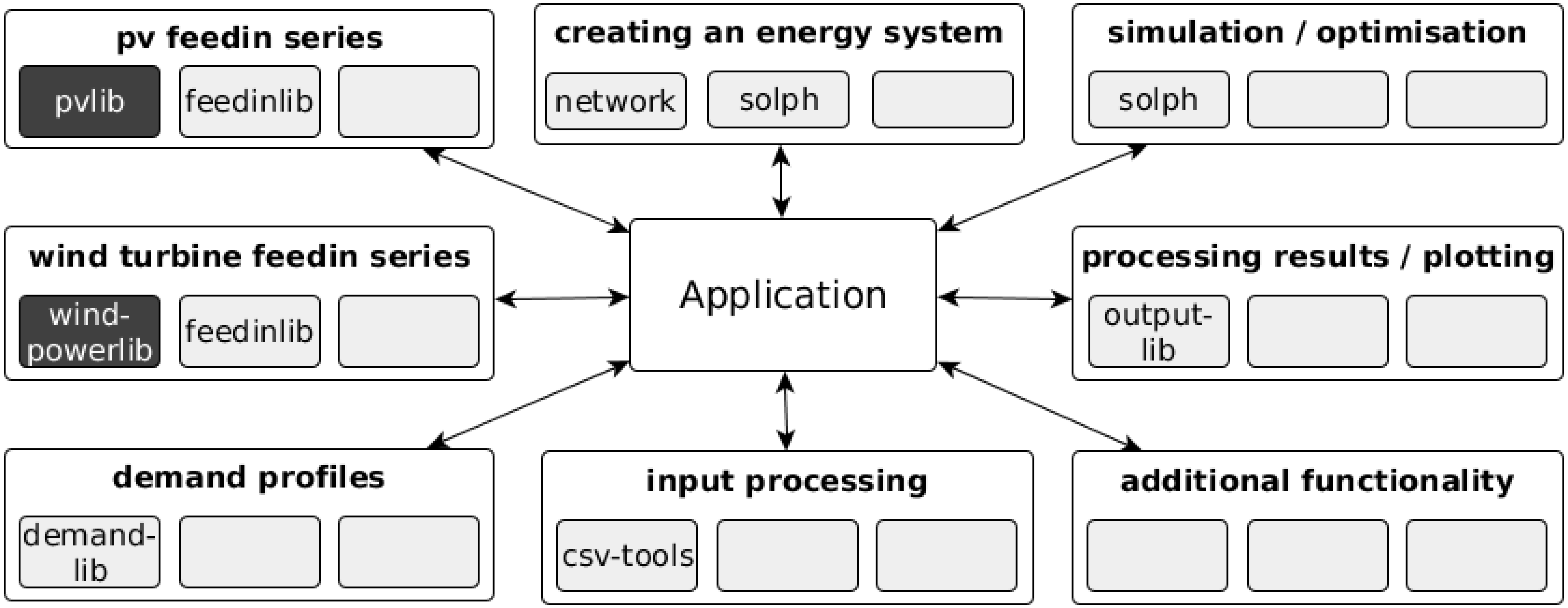
oemof – Initial idea

- People from different institutions
  - Center for Sustainable Energy Systems (ZNES), Flensburg
  - Reiner Lemoine Institut, Berlin
  - Otto-von-Guericke-Universität, Magdeburg
- Individual energy modelling requirements in
  - Research projects
  - Dissertations
  - Student projects
- Tired of repeatedly redundant work concerning data and model development → Join forces
- Open to new members and modellers

oemof – Initial idea

- Collaborative development of an open and effective framework for energy system analysis
- Generic graph based foundation G := (N, E)
- The Set of Nodes N consists of
  - Busses
  - Components
    - Sinks
    - Sources
    - Transformer
- Object-oriented implementation in python
- Usage of existing packages for scientific computing

oemof – Toolbox and applications



- You need an application to combine the existing libraries
- You can add you own library to the oemof framework and make it available for the growing oemof community
- Help us to fill the gaps, talk to the actual contributors

oemof – Toolbox

feedinlib

- Generates feedin timeseries of photovoltaic and wind power plants from weather data
- Provides interface to pvlib and windpowerlib

demandlib

- Generates power and heat load profiles for various sectors

windpowerlib

- Generates feedin time series of wind power plants
- Provides power (coefficient) curves for numerous wind turbine types

oemof – Toolbox

solph

- Creates and solves LP/MILP optimization models of energy systems
- Based on pyomo-package

db

- Provides tools for oemof related databases or data APIs (experimental)

outputlib

- Delivers data structures and plots results
- Based on pandas-package

oemof – Applications

renpassG!S

- Bottom up energy system model for Central Europe (LP, welfare maximization with inelastic demand and transshipment)
- More information: https://github.com/znes/renpass_gis

HESYSOPT

- Tool for modelling district heatings systems (MILP, operational optimization with exogenous prices)
- More information: https://github.com/znes/HESYSOPT

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oemof – Applications

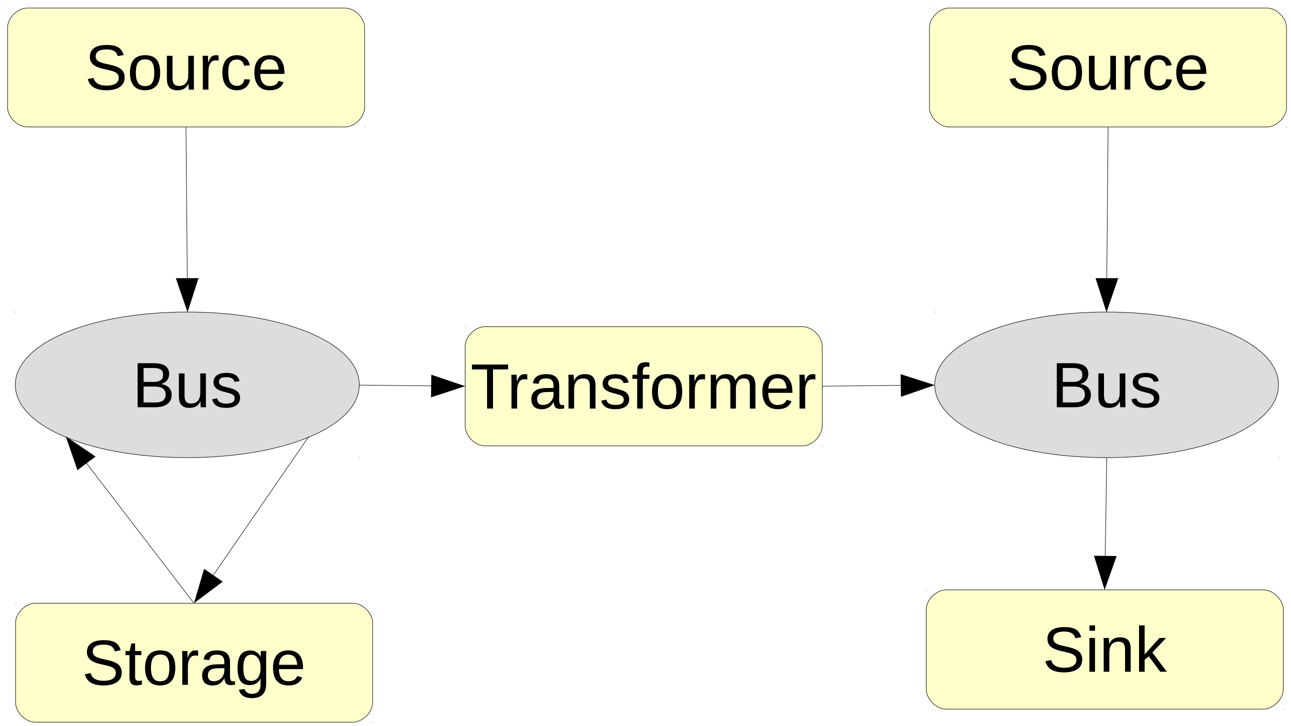
reegis_HP

- Ecological and economic evaluation of district heating and combined heat and power in an energy system based on renewable sources (LP, welfare maximization with inelastic demand)
- More information: http://reiner-lemoine-institut.de/en/ecological-and-economic-evaluation-of-district-heating-and-combined-heat-and-power-in-a-energy-system-based-on-renewable-sources/

MicroPower

- Small micro grids with spinning reserve and minimal power

oemof.network



- Use the flexible structure to define your own energy system
- See the documentation to learn how to use the classes http://oemof.readthedocs.io/en/stable/oemof_solph.html

How to build an application

You can build an application...

... from scratch using the python classes

... using a specfic layouted spreadsheet (libreoffice, openoffice, MS Excel, ...)

... using scripts creating objects from a database or data file.

The following examples will show how to create a welfare maximization example from scratch using **oemof.network** and **oemof.solph** as currently prominent packages.

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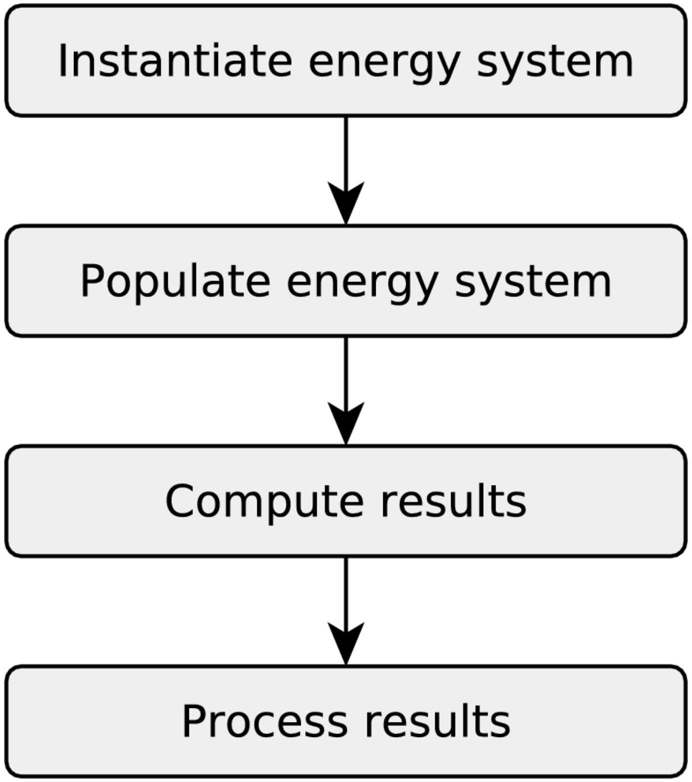
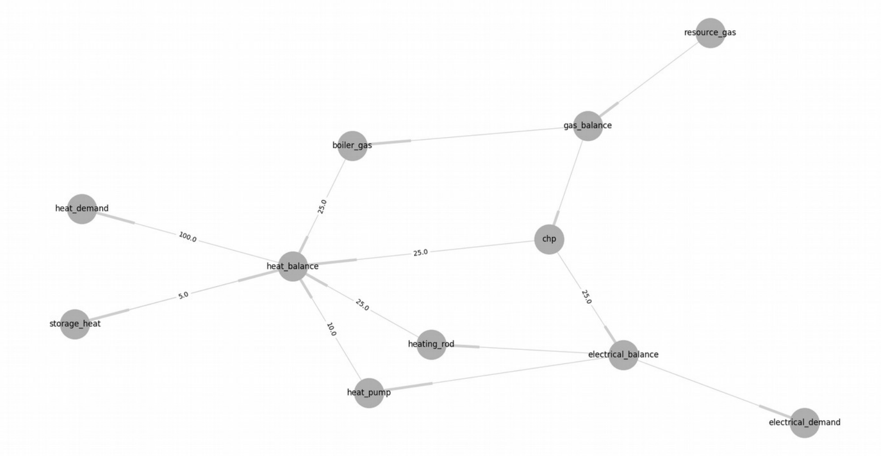
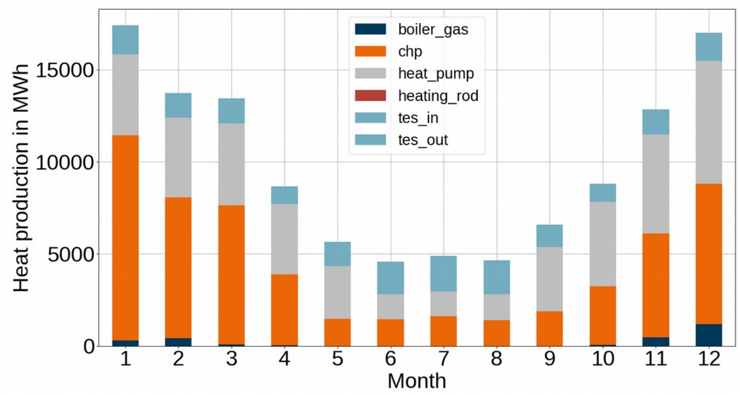
How to build an application - Workflow







How to build an application - Logger

- Use the oemof default logger
- All messages are stored in a file
- You can switch between different levels
- Returns oemof version or branch

```
# Default logger of oemof
import logging
from oemof.tools import logger
logger.define_logging()

logging.info(“The program started”)
logging.debug(“This message is only for debugging”)
logging.warning(“Something odd happened.”)
logging.error(“That shouldn't happen.”)
```

How to build an application - EnergySystem

- The EnergySystem class is the container for your energy model and holds the network, time series, ...
- Pass a time index to initialise it

```
import pandas as pd
from oemof import solph

date_time_index = pd.date_range('1/1/2017', periods=8760,
                                freq='H')

energysystem = solph.EnergySystem(timeindex=date_time_index)
```

How to build an application - Bus

- A Bus class can be seen as a balance for connected components with its respective inputs and outputs
- Every component has to be connected to a bus

```
from oemof import solph

# create a natural gas bus
bgas = solph.Bus(label="natural_gas")

# create an electricity bus
bel = solph.Bus(label="electricity")

# create a thermal bus
bth = solph.Bus(label="heat")
```

How to build an application - Flow

- Can be interpreted as weight of directed edge between two nodes (Bus and Component)
- No obligatory parameters are needed
- A Flow object has various optional parameters like costs or

```
from oemof import solph

my_first_flow = solph.Flow()
```

How to build an application - Source

- A component with no input and one output
- A source has different additional parameters

```
from oemof import solph

# renewable sources (windpower, pv)
solph.Source(label='pv', outputs={bel: solph.Flow(fixed=True,
    actual_value=data['pv'], nominal_value=5400)})

# commodity source (gas, oil, lignite,...)
solph.Source(label='rgas', outputs={bgas: solph.Flow(
    nominal_value=194397000, summed_max=1000000)})

# shortage source
solph.Source(label='shortage', outputs={bel: solph.Flow(
        variable_costs=5000)})
```

How to build an application - Sink

- A component with no input and one output
- A sink has different additional parameters
- **data['demand']** is a normalised demand series

```
from oemof import solph

# demand sink
solph.Sink(label='demand', outputs={bel: solph.Flow(
    fixed=True, actual_value=data['demand'],
    nominal_value=5460)})

# excess sink
solph.Sink(label='excess', inputs={bel: solph.Flow()})
```

How to build an application - Transformer

- A component representing different possibilities for the number of inputs/outputs (currently renamed)
- There are 1xN and Nx1 transformers

```
from oemof import solph

# gas fired power plant (output related definition)
solph.LinearTransformer(
    label='pp_gas',
    inputs={bgas: solph.Flow()},
    outputs={bel: solph.Flow(nominal_value=4711,
                             variable_costs=50,
                             fixed_costs=1000)},
    conversion_factors={bel: 0.58})
```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How to build an application - CHP

- Use the 1xN transformer
- The VariableFractionTransformer can be used to model an extraction turbine
- Heat pumps can be modelled similarly using the Nx1 transformer

```
from oemof import solph

# gas fired chp (input related definition)
LinearTransformer(
    label='pp_chp',
    inputs={bgas: solph.Flow(nominal_value=110,
                             variable_costs=42)},
    outputs={bel: solph.Flow(), bth: Flow()},
    conversion_factors={bel: 0.3, bth: 0.4})
```

How to build an application - Storage

- capacity_loss: relative loss per time step
- inflow_/outflow_conversion_factor: efficiency of charging and discharging
- nominal_capacity: Maximum effective storage capacity

```
from oemof import solph

solph.Storage(
    label='storage', nominal_capacity=6000,
    inputs={bel: solph.Flow(nominal_value=1000)},
    outputs={bel: solph.Flow(nominal_value=1000)},
    capacity_loss=0.01,
    inflow_conversion_factor=1,
    outflow_conversion_factor=0.8)
```

How to build an application – Optimisation

- Pass your EnergySystem instance to the OperationalModel class
- Solve the problem using your favoured solver

```
from oemof import solph

# initialise the operational model (create problem)
om = solph.OperationalModel(energysystem)

# optionally write lp file to disc (debugging)
om.write(filename, io_options={'symbolic_solver_labels': True})

# set tee to True to get the solver output
om.solve(solver='cbc', solve_kwargs={'tee': True})

results = ResultsDataFrame(energy_system=es)
```


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How to build an application – Options

- The **investment object** can be used to have a variable nominal_value. Periodical costs per installed capacity have to be defined. Useful to compare alternative capacities (e.g. storage vs. grid capacity expansion)
- **BinaryFlows** can be used to represent load ranges or up- and downtime restrictions (MILP)
- **DiscreteFlows** can be used to force flows to integer e.g. for discrete power blocks (MILP)

How to build an application – Own extensions

- You can **add your own components** with some fancy internal behaviour in your application
- You can **add additional constraints** e.g. connecting two flows
- There are existing examples how to add constraints and components
- We are currently trying to simplify the process of adding constraints and components

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Getting started - Examples

- test_installation: Test solph and solver
- storage_investment: Basic usage, investment
- simple_dispatch: Basic usage, chp
- csv_reader_investment: csv-read, investment
- csv_reader_dispatch: csv-reader, basic
- add_constraints: adding constraints and components
- variable_chp: Modelling an extraction turbine

Getting started - Documentation

- Homepage
  - General information, Newsletter, ...
  - URL: http://www.oemof.org
- General Documentation
  - API (docstrings)
  - Installation guide
  - Overall documentation
  - URL: http://oemof.readthedocs.io
- Docstrings (source code)
  - Parameter
  - Attributes
  - Constraints, sets and variables

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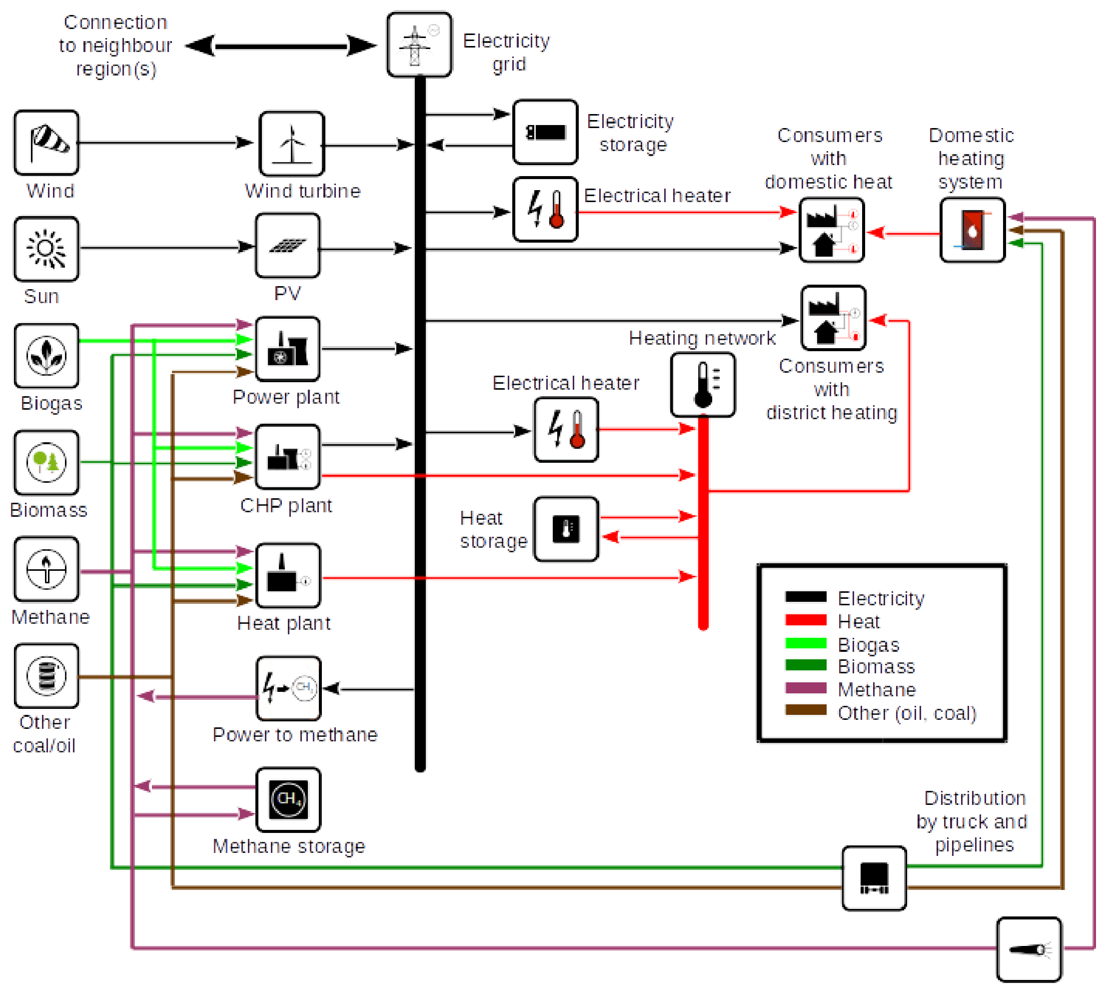
Flexible modelling within a single framework



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Ways to contribute

- Documentation
  - report or fix typos and grammar
  - clearify paragraphs
  - add additional explaination
- Code
  - report or fix Bugs
  - add features or take part in concept building
  - fix docstrings or code layout (e.g. pep8 rules)
- General
  - Improve our webpage or user forum
  - add or improve examples
  - write open and well documented applications
  - organise meetings or little workshops

How to contribute

These are the basic steps search for keywords to find tutorial

- Create an github account (github)
- Fork oemof (feedinlib...) (fork at github)
- Clone your fork to your system (clone from github)
- Fix bug/typo or add your feature (python)
- Create a Pull Request and tell us what you have done (pull request at github)
- Read developer rules (coding, tests,...)
- Ask a developer if you need help, we all once did our first Pull Request

Conclusion – oemof is..

- **Cross-Sectoral** – Include and link the heat, power and mobility sector
- **Multiregional** – Flexibly connect multiple regions
- **Time-step-flexible** – Choose the temporal resolution mostly suited for you application
- **Modular** – Choose from various python packages (libraries) with well defined interfaces for modelling and optimisation
- **Open Source and community driven** – It's free, transparent and well documented
- **Versatile** – Create applications and adapt components to your scope and purpose

Contact

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Official website and contact to all developers:

http://www.oemof.org/contact

github repositories:

http://github.com/oemof