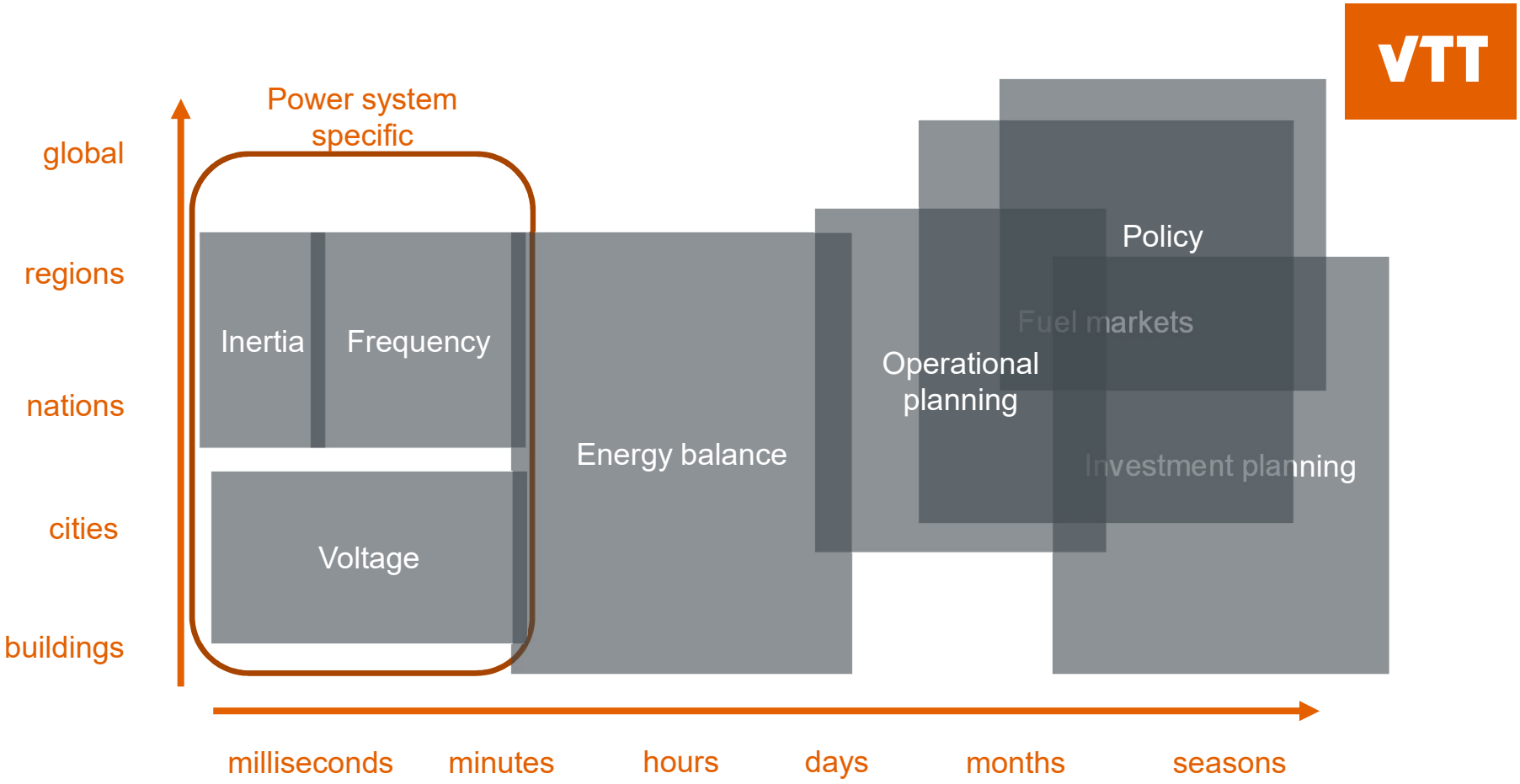
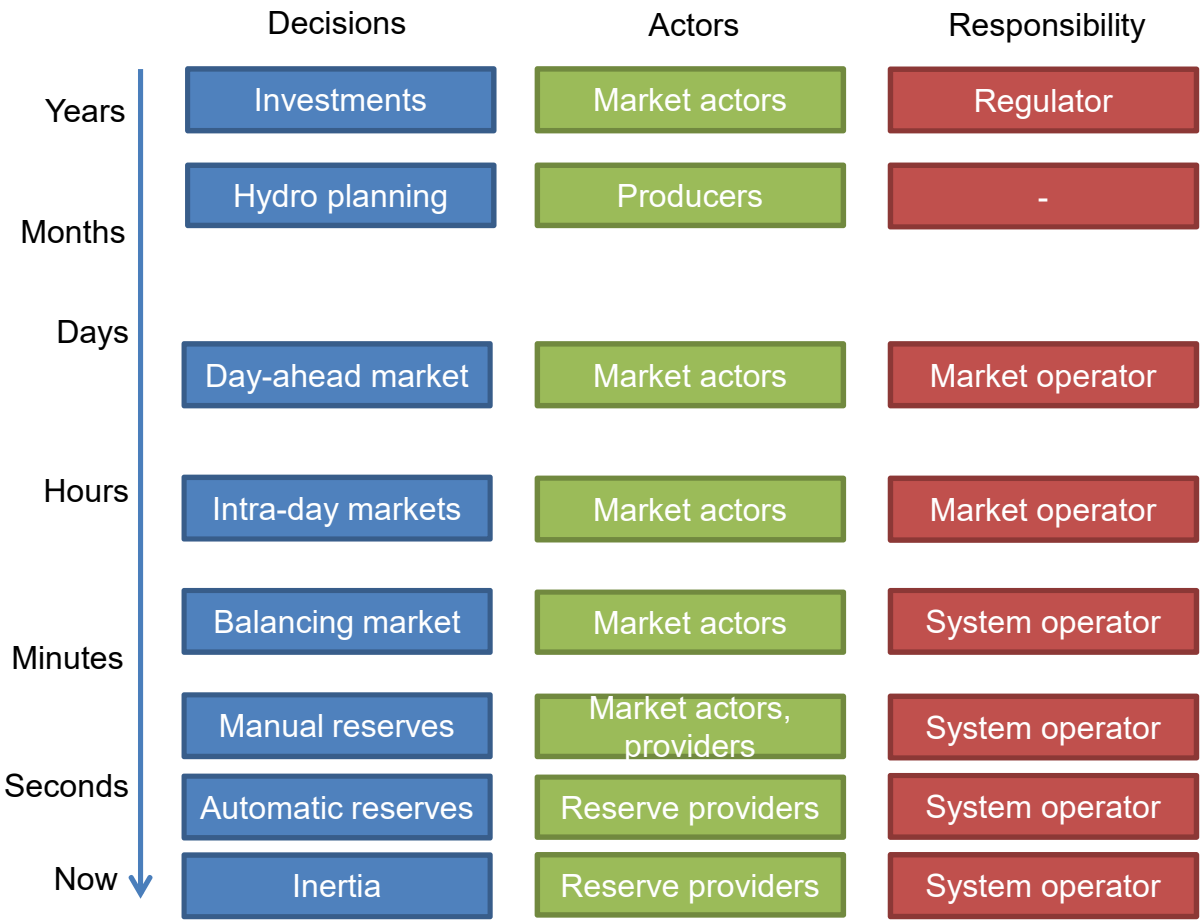
Moniskaalaiset energiajärjestelmämallit päätöksenteon tukena

21.11.2019, FORS

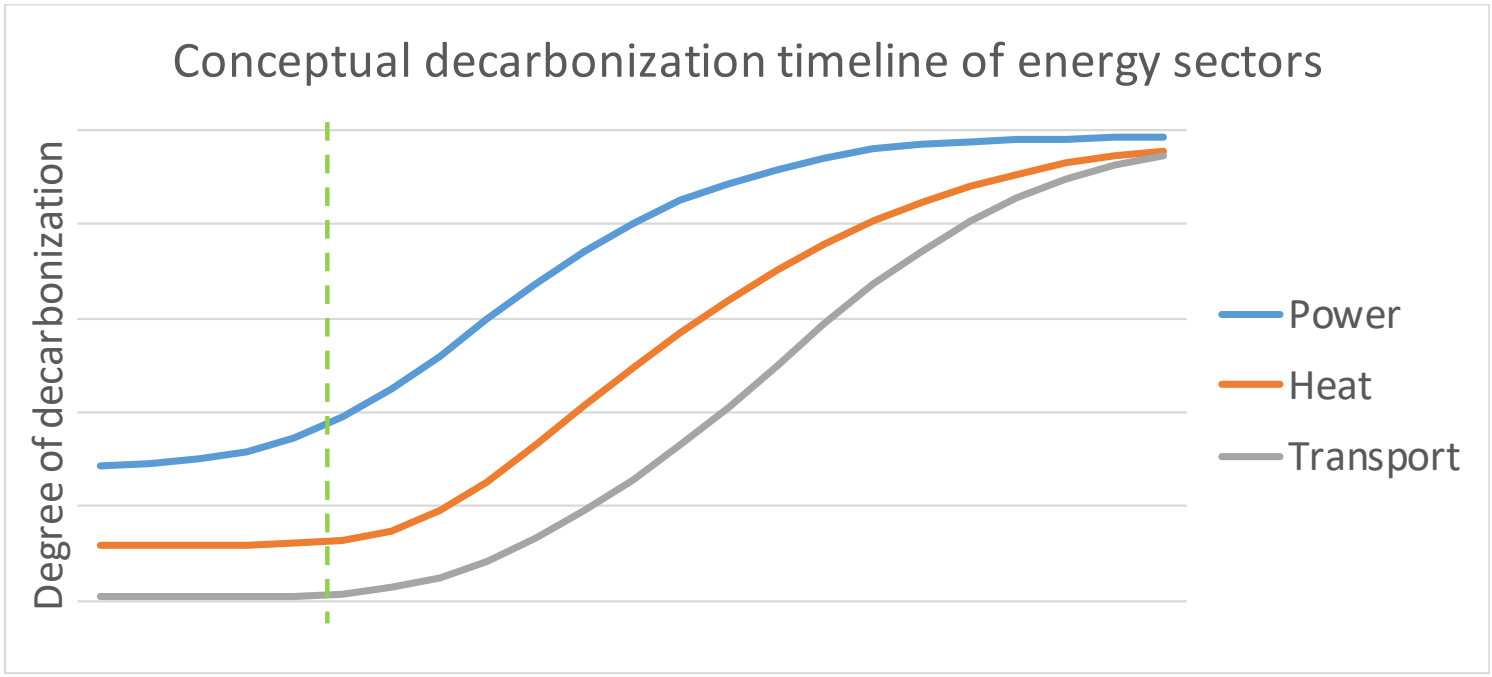
Juha Kiviluoma, erikoistutkija


Power system specific
global
regions
nations
cities
buildings
Inertia
Frequency
Voltage
Energy balance
Operational planning
Fuel markets
Policy
Investment planning
milliseconds
minutes
hours
days
months
seasons

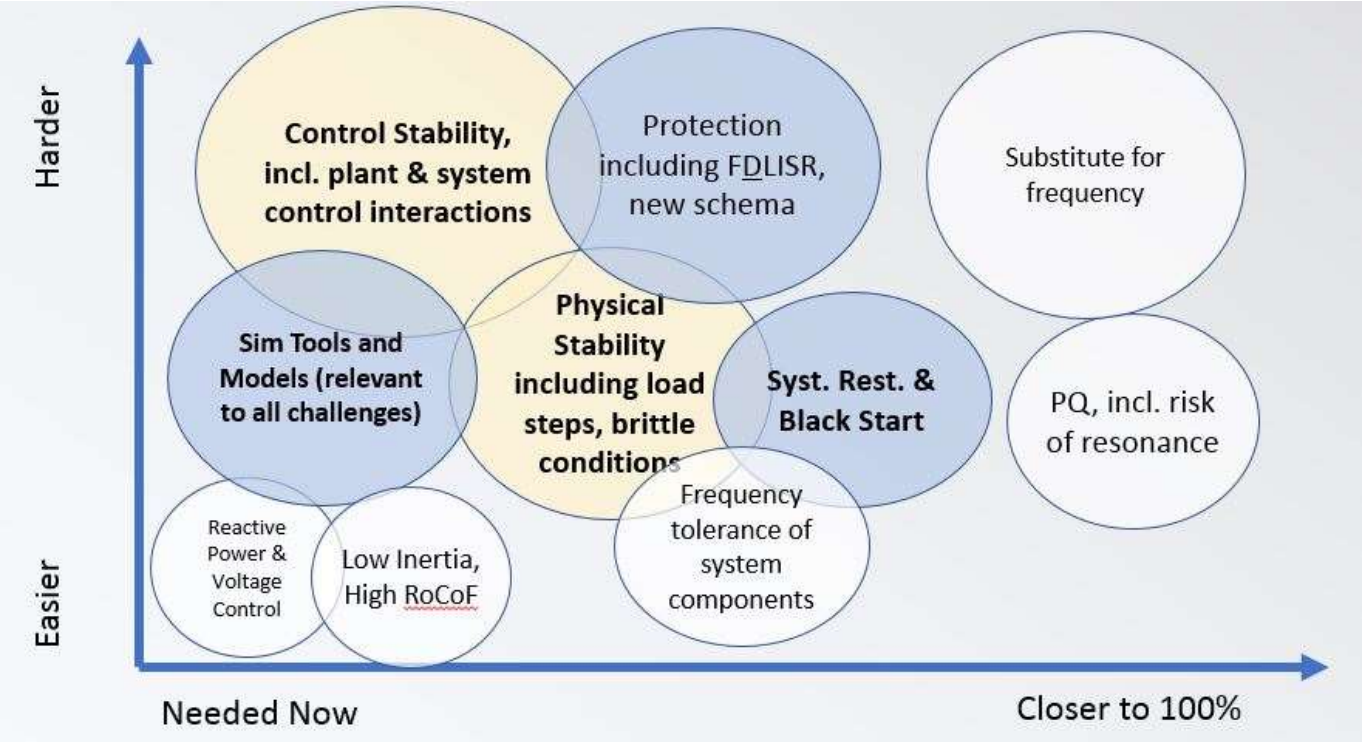

Decisions
Actors
Responsibility
Years
Months
Days
Hours
Minutes
Seconds
Now
Investments
Market actors
Regulator
Hydro planning
Producers
-
Day-ahead market
Market actors
Market operator
Intra-day markets
Market actors
Market operator
Balancing market
Market actors
System operator
Manual reserves
Market actors, providers
System operator
Automatic reserves
Reserve providers
System operator
Inertia
Reserve providers
System operator

There are lots of models

- Physics
  - Power: transient stability, dynamic stability
  - Gas: linepack
  - Heat: thermal simulations
  - Industries: process specific models
- Operational
  - Power: unit commitment with power flows
  - Heat: thermal simulations
  - Industries: control software
  - Transport: dynamic simulations
- Planning
  - Power and gas: investment models, macro-economic models
  - Heat: Building stock models
  - Transport: transport sector models


Conceptual decarbonization timeline of energy sectors
Degree of decarbonization
Power
Heat
Transport

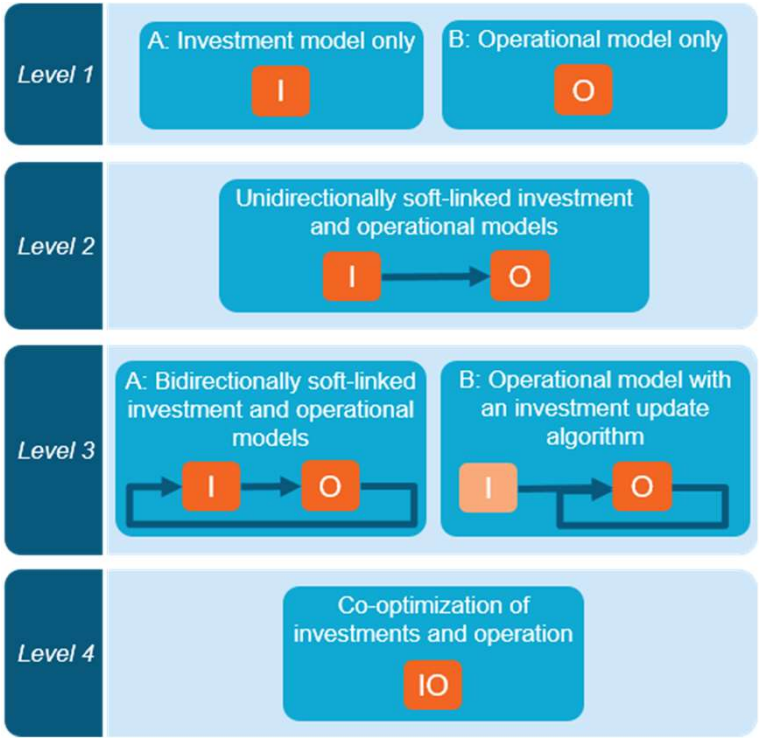
New challenges generated by ‘VIBRES’



Holttinen et al. submitted

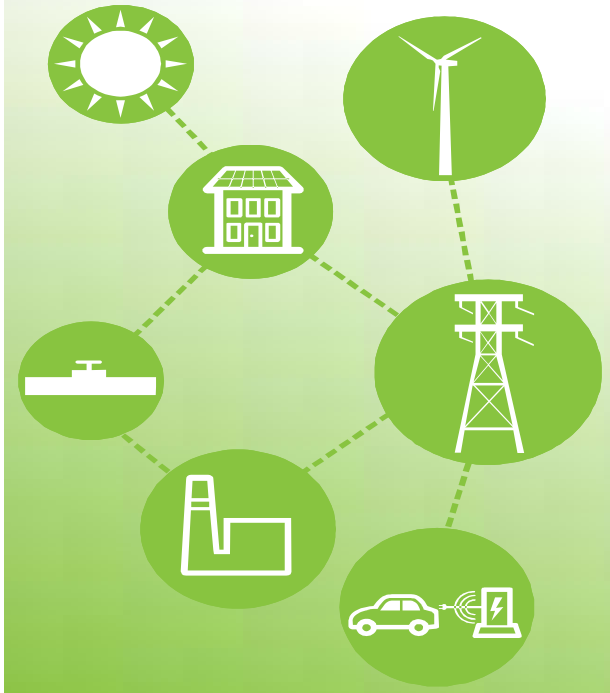
Approaches to the multiscale problem

- Each works on their own
  - Results and lessons diffuse over time
  - Approximations at higher level models
- Soft-link models
  - Results get passed between independent models either one-way or as iteration
- Co-optimization
  - Simplifications required



Helistö et al. “Including operational aspects in the planning of power systems with large amounts of variable generation: A review of modeling approaches”, *WIREs Energy Environ*. 2019

Spine



Manage modelling with Spine Toolbox

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18th Sep. 2019, NREL
OpenMod workshop

VTT UCD DUBLIN KU LEUVEN KTH VETENSKAP OCH KONST ENERGY REFORM CONSULTING SERVICES

Starting points

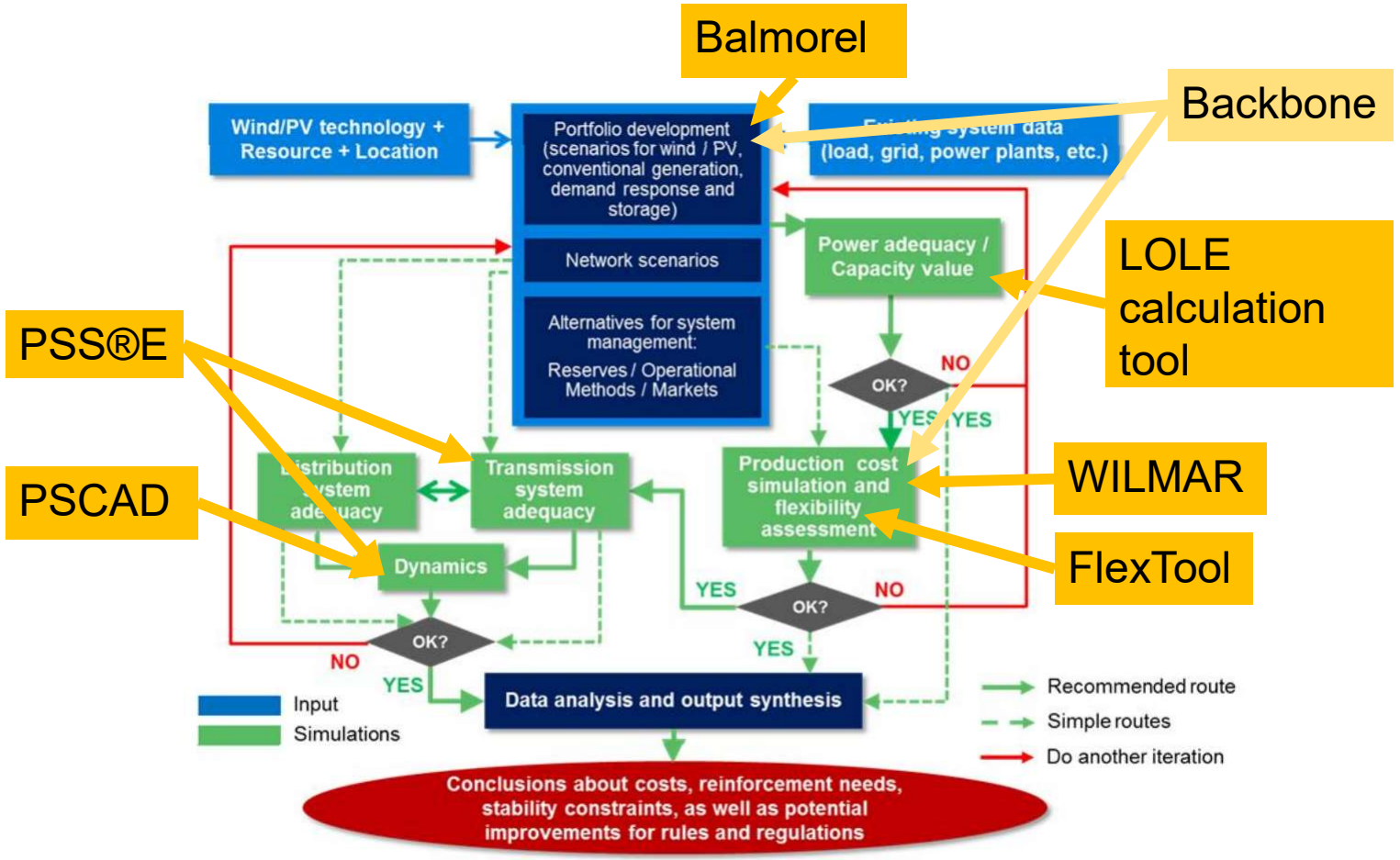
- Some aims
  - Co-operation instead of competition
  - Build tools together
  - Replicable results → scientific progress and more reliable policy support
- Some means
  - Open source
  - Python based Spine Toolbox

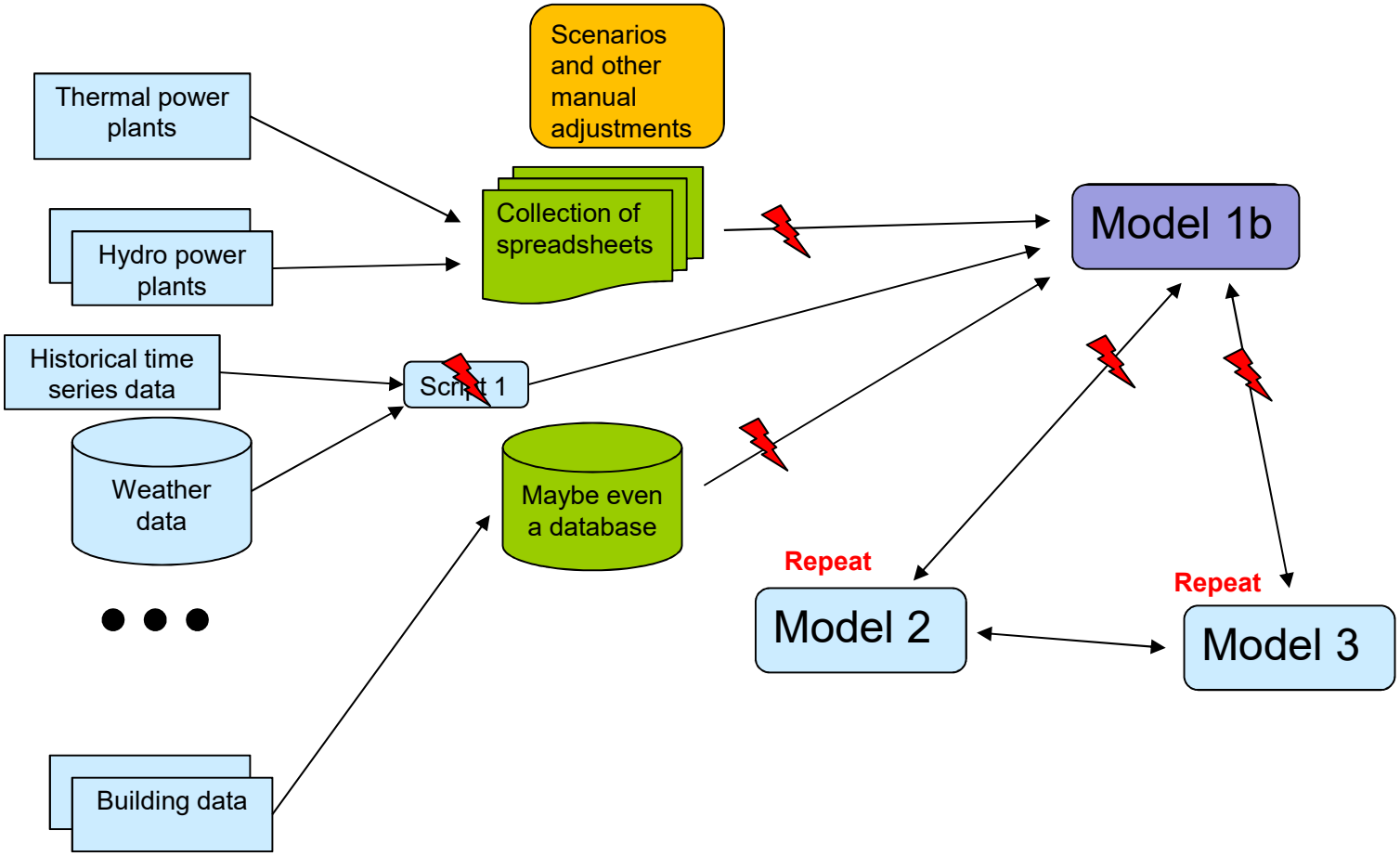
- Spine Model in Julia (https://github.com/Spine-project)
- Backbone in GAMS (https://gitlab.vtt.fi/backbone)
- IRENA FlexTool in Excel/Mathprog (https://www.irena.org/energytransition/Energy-System-Models-and-Data/IRENA-FlexTool)

Spine

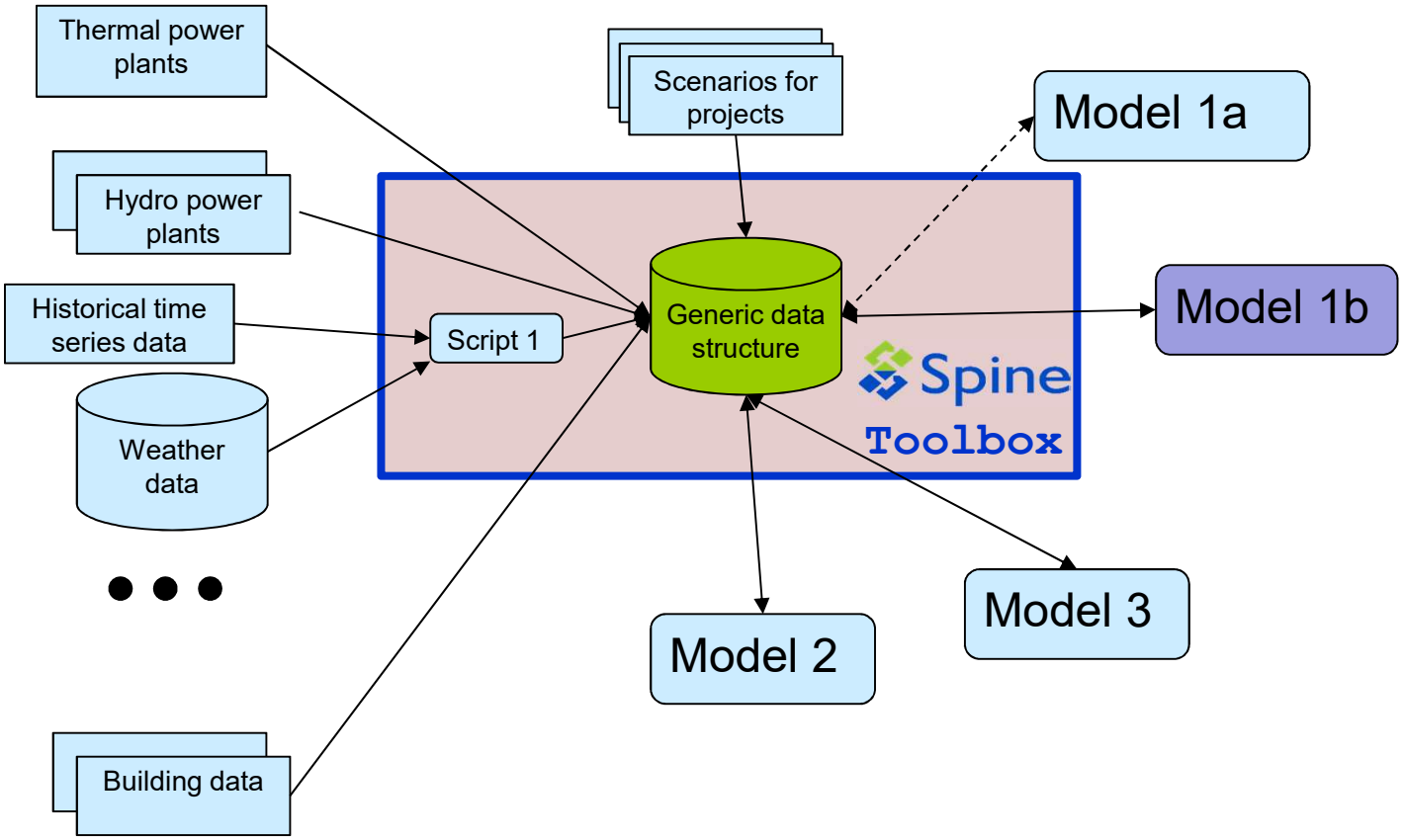
Design and Operation of Energy Systems models

Spine

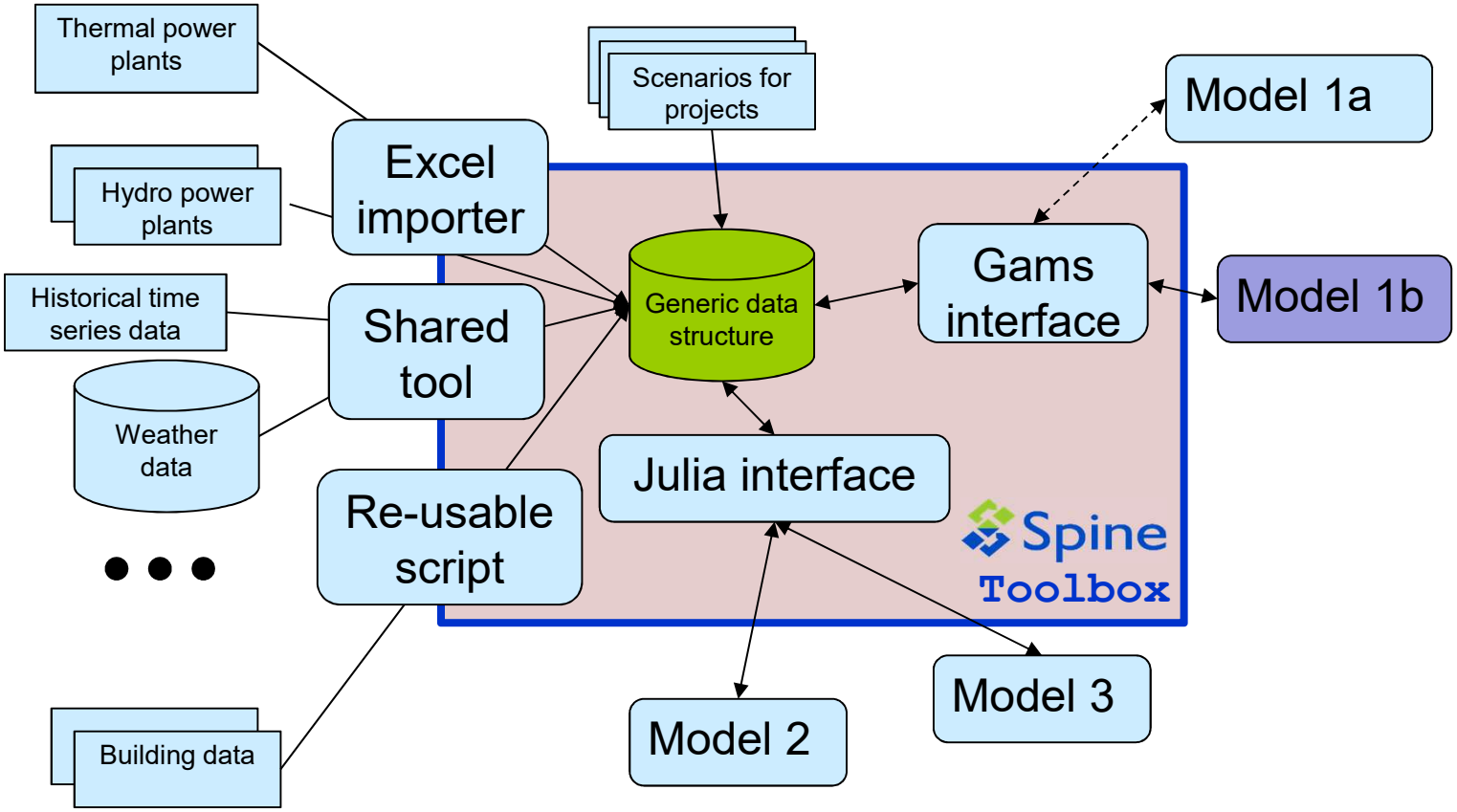



Thermal power plants
Hydro power plants
Historical time series data
Weather data
Building data
Scenarios and other manual adjustments
Collection of spreadsheets
Script 1
Maybe even a database
Model 1b
Repeat
Model 2
Repeat
Model 3

Spine


Thermal power plants
Hydro power plants
Historical time series data
Weather data
Building data
Scenarios for projects
Script 1
Generic data structure
Spine Toolbox
Model 1a
Model 1b
Model 2
Model 3

Spine


Thermal power plants
Hydro power plants
Historical time series data
Weather data
Building data
Excel importer
Shared tool
Re-usable script
Scenarios for projects
Generic data structure
Julia interface
Gams interface
Model 1a
Model 1b
Model 2
Model 3
Spine Toolbox

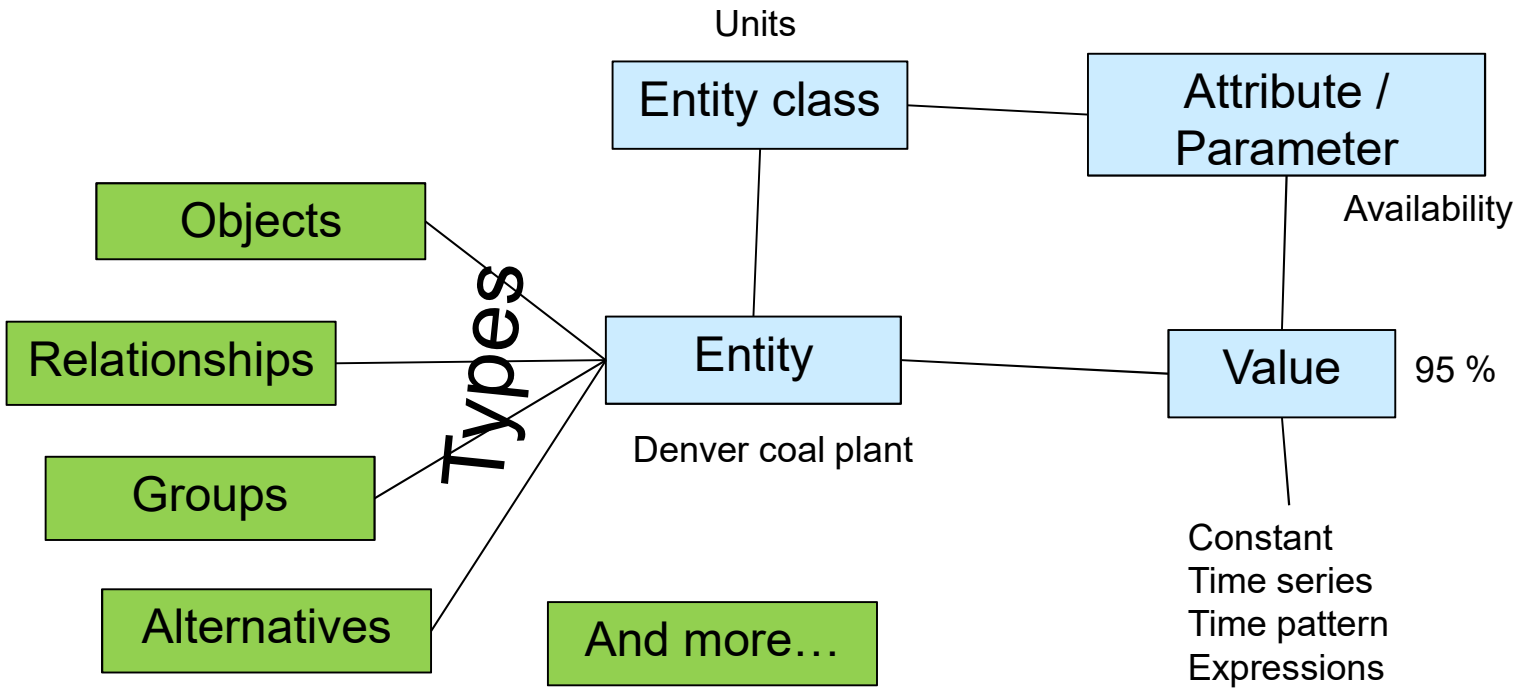
Spine

Remedies

- Interface!
  - Connect through a shared, generic, data structure
  - Each tool needs to maintain only one connection
  - Easy to add new tools and swap old tools
- Non-documented spreadsheets → Re-usable scripts
- Local files → Server based databases (one version)
- Version control (know what happened) and open source (share the effort)
  - Data acquisition and data processing
  - Models
- Project based workflow
  - Keep project specific modifications separate
- Separate design and execution
  - Work on your laptop, execute in cloud

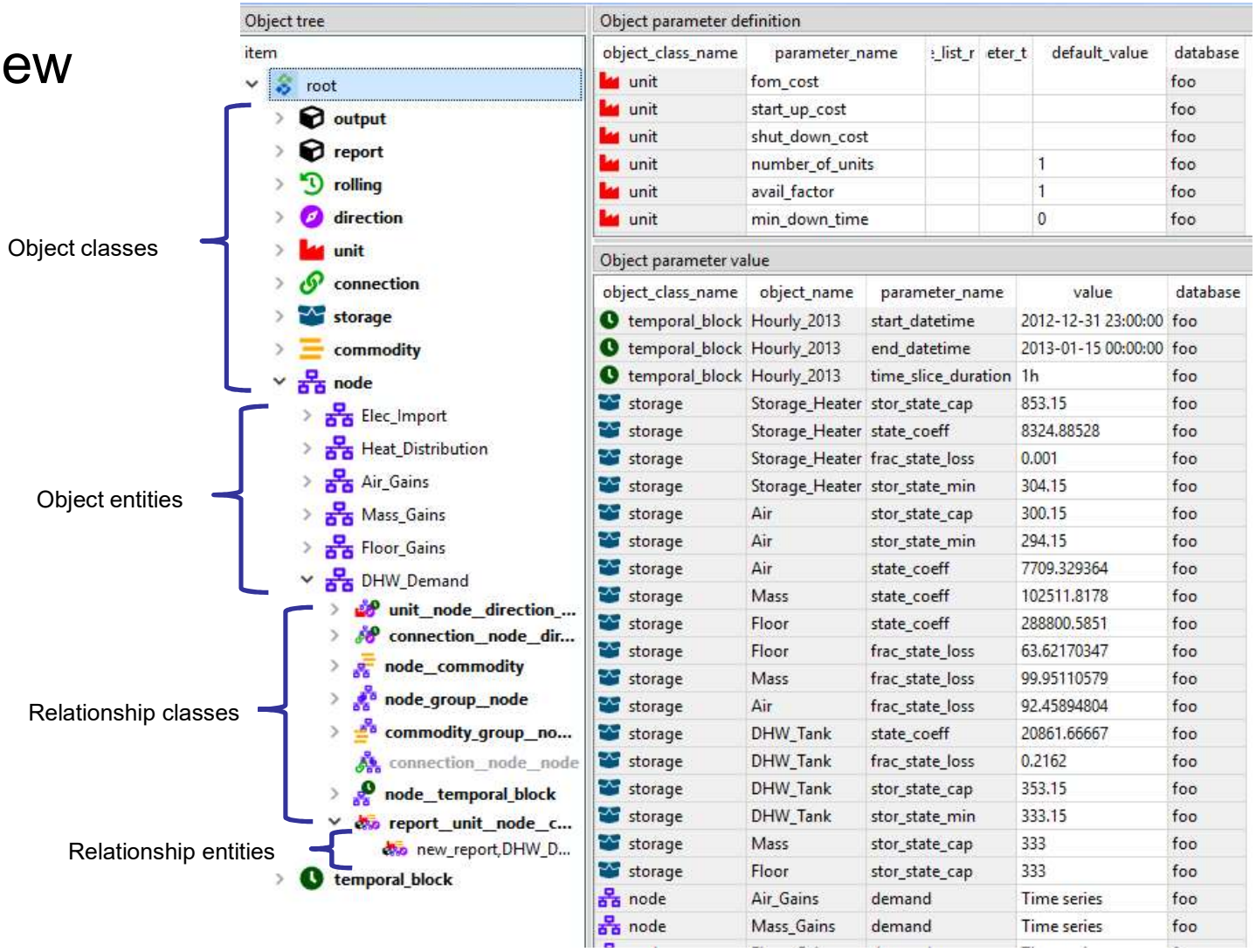
Spine

Generic data structure (EAV with classes and entity types)

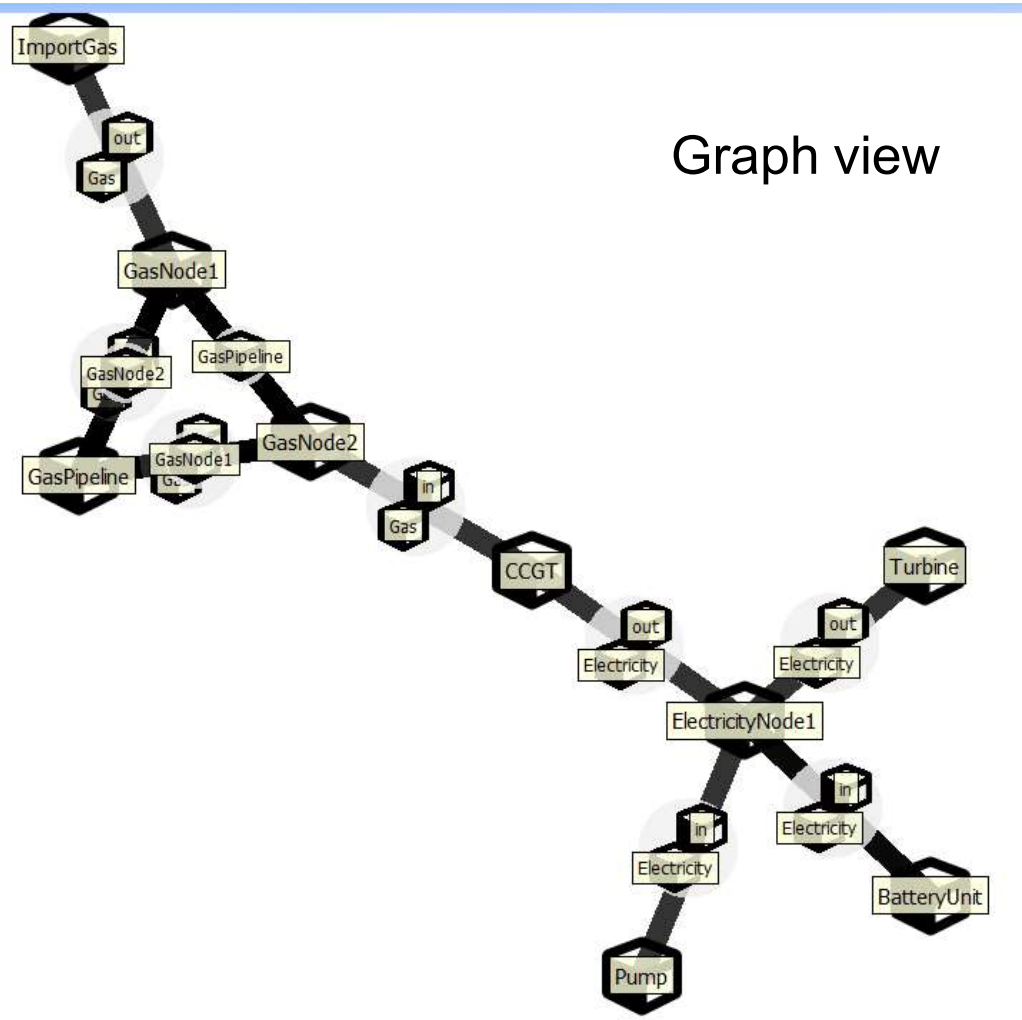


Spine

Tree view


Object classes
Object entities
Relationship classes
Relationship entities
Object tree
item
root
output
report
rolling
direction
unit
connection
storage
commodity
node
Elec_Import
Heat_Distribution
Air_Gains
Mass_Gains
Floor_Gains
DHW_Demand
unit__node__direction_...
connection__node__dir...
node__commodity
node_group__node
commodity_group__no...
connection__node__node
node__temporal_block
report__unit__node__c...
new_report,DHW_D...
temporal_block
Object parameter definition
object_class_name | parameter_name | _list_r | eter_t | default_value | database
unit | fom_cost | | | | foo
unit | start_up_cost | | | | foo
unit | shut_down_cost | | | | foo
unit | number_of_units | | | 1 | foo
unit | avail_factor | | | 1 | foo
unit | min_down_time | | | 0 | foo
Object parameter value
object_class_name | object_name | parameter_name | value | database
temporal_block | Hourly_2013 | start_datetime | 2012-12-31 23:00:00 | foo
temporal_block | Hourly_2013 | end_datetime | 2013-01-15 00:00:00 | foo
temporal_block | Hourly_2013 | time_slice_duration | 1h | foo
storage | Storage_Heater | stor_state_cap | 853.15 | foo
storage | Storage_Heater | state_coeff | 8324.88528 | foo
storage | Storage_Heater | frac_state_loss | 0.001 | foo
storage | Storage_Heater | stor_state_min | 304.15 | foo
storage | Air | stor_state_cap | 300.15 | foo
storage | Air | stor_state_min | 294.15 | foo
storage | Air | state_coeff | 7709.329364 | foo
storage | Mass | state_coeff | 102511.8178 | foo
storage | Floor | state_coeff | 288800.5851 | foo
storage | Floor | frac_state_loss | 63.62170347 | foo
storage | Mass | frac_state_loss | 99.95110579 | foo
storage | Air | frac_state_loss | 92.45894804 | foo
storage | DHW_Tank | state_coeff | 20861.66667 | foo
storage | DHW_Tank | frac_state_loss | 0.2162 | foo
storage | DHW_Tank | stor_state_cap | 353.15 | foo
storage | DHW_Tank | stor_state_min | 333.15 | foo
storage | Mass | stor_state_cap | 333 | foo
storage | Floor | stor_state_cap | 333 | foo
node | Air_Gains | demand | Time series | foo
node | Mass_Gains | demand | Time series | foo

Graph view



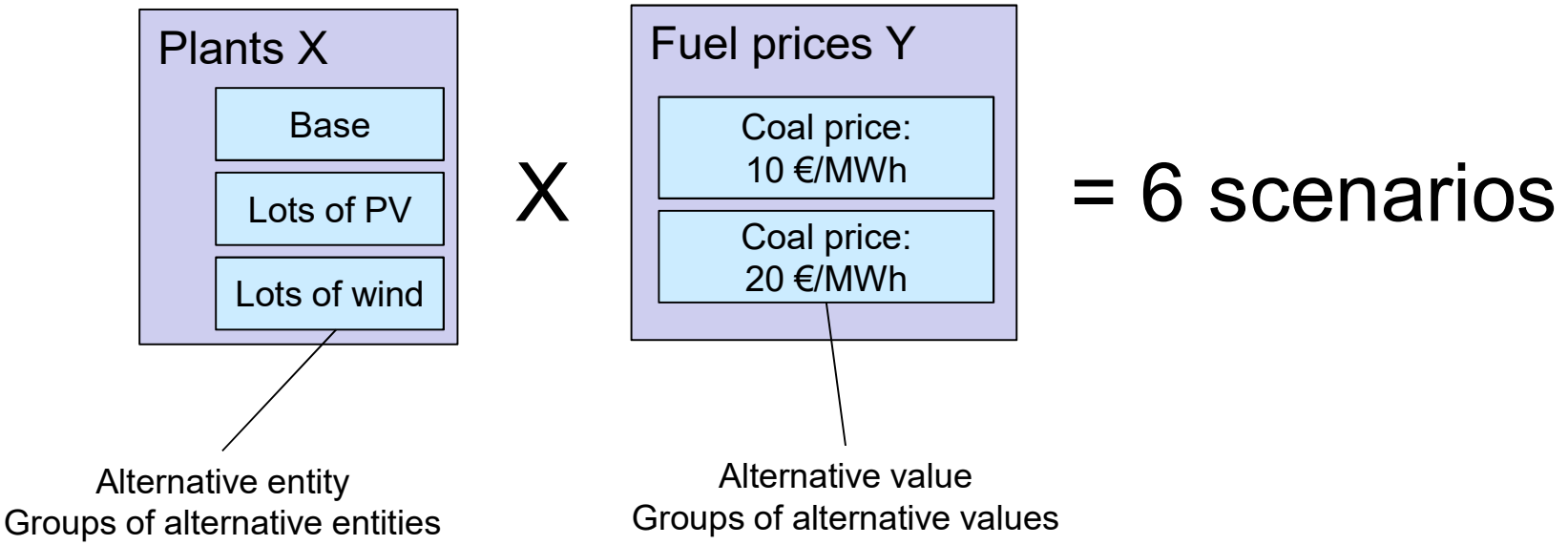
Spine

Tabular view

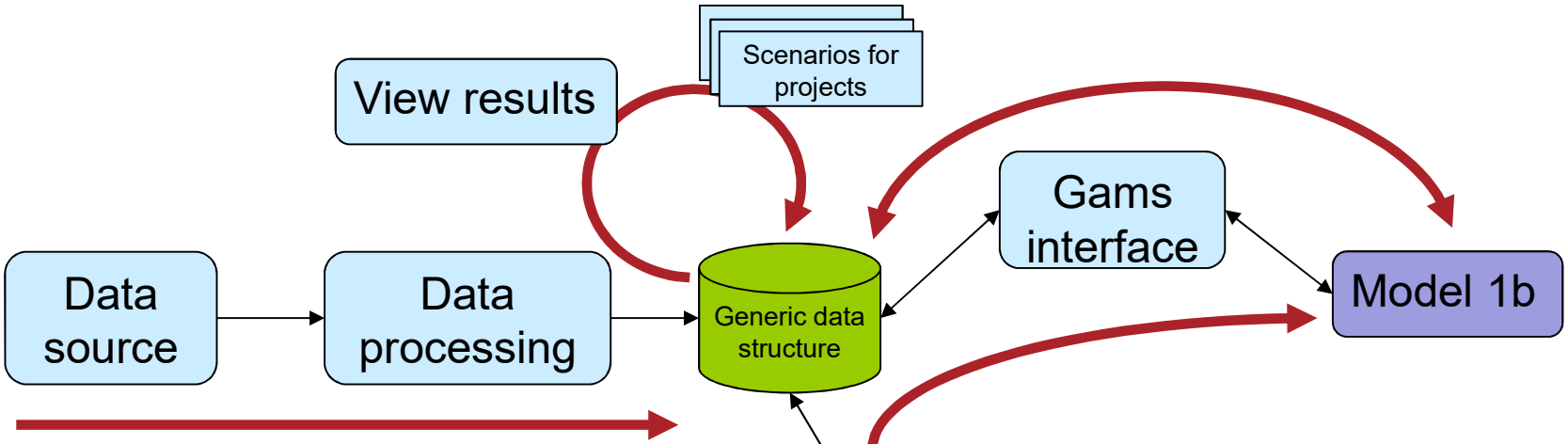
	db parameter	conversion_cost	unit_capacity	unit_conv_cap_...	
unit	**commodity**				
BatteryUnit	Electricity		100	1	
CCGT	Gas		50	1	
ImportGas	Gas	[100.0, 100.0, 10...		1	
Pump	Electricity		200	1	
Turbine	Electricity		200	1	
Turbine	Water				

Spine

Alternatives, scenarios and recipes



Spine



- Establish workflows
  - Common workflow language
- Separate design and execution
  - Spine Toolbox for design
  - Spine Engine for execution
    - Direct acyclic graphs
    - Scheduling, workers,…

Spine

Spine: Open source toolbox for modelling ~~integrated energy systems~~

- Project part funded by the Horizon 2020 program of the European Union
- LCE-05-2017 - Tools and technologies for coordination and integration of the European energy system
- 4 year project commenced October 2017 with a €3.7m budget
- 5 Partners, collaboration with NREL & DTU

www.spine-model.org

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Spine

beyond
the obvious

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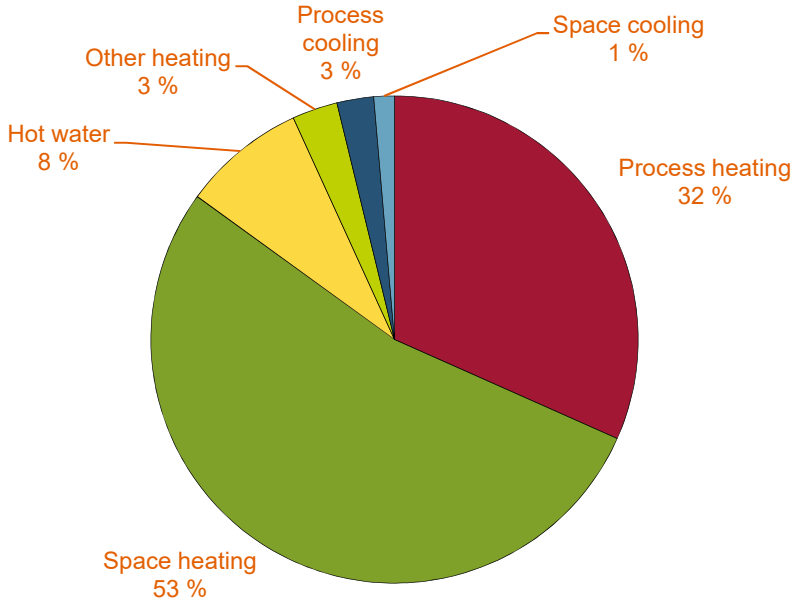
28/11/2019

Power to space heating

- Heat pumps often profitable already
  - Challenge: Heat source
  - Opportunity: Boreholes
- Resistance heating is cheap
  - Can rapidly replace fuel fully or partially
  - If electricity grids can take it
- Inflexible electric heating
  - Problem for power system
  - Heat is inexpensive to store – especially in new builds
  - Maybe even more important than energy efficiency in buildings

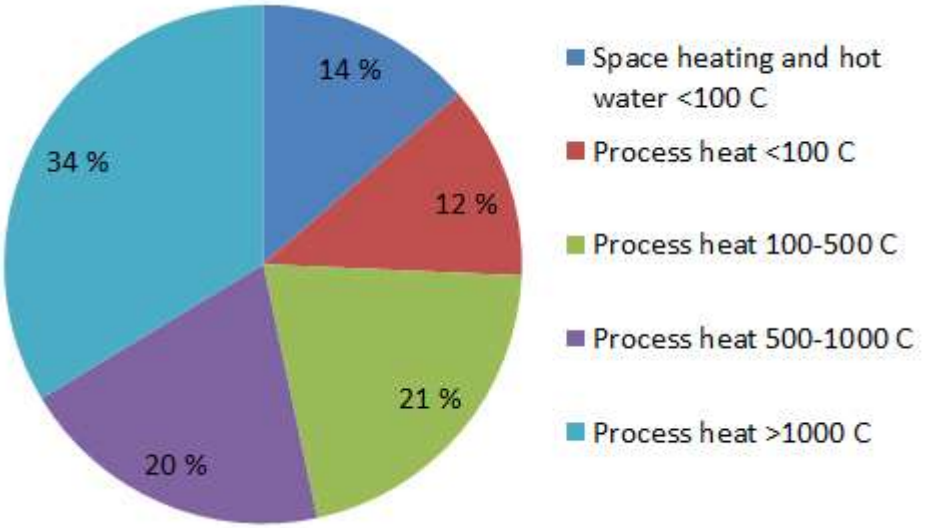


EU-28 heating and cooling in final energy use

Power to industries

- Processes are diverse
- Heat pumps can do only so much
- Direct conversion can yield high temperatures
- …but portion of the processes are difficult to electrify

- Biggest barrier is price
- Fossil fuels are cheap in heating
- …but 2035 goals



T. Naegler, S. Simon, M. Klein, H. C. Gils, "Quantification of the European industrial heat demand by branch and temperature level"

Power to molecules

- Part of energy demand in industries
- Raw materials (molecules) for some industries
- Power to fuels

Power to transport

- Electric vehicles
- Some forms of transport are difficult to electrify

Challenges and opportunities

- Don’t waste electricity
- Distribution grids
- Large amounts of wind power and the transmission grid
- Heating of buildings
- Opportunities
  - Power to heat
  - Power to molecules
  - Smart utilization of the biomass resources
- Challenges
  - Stranded assets (electricity, heat, transport)
  - Peak capacity
  - Power system stability

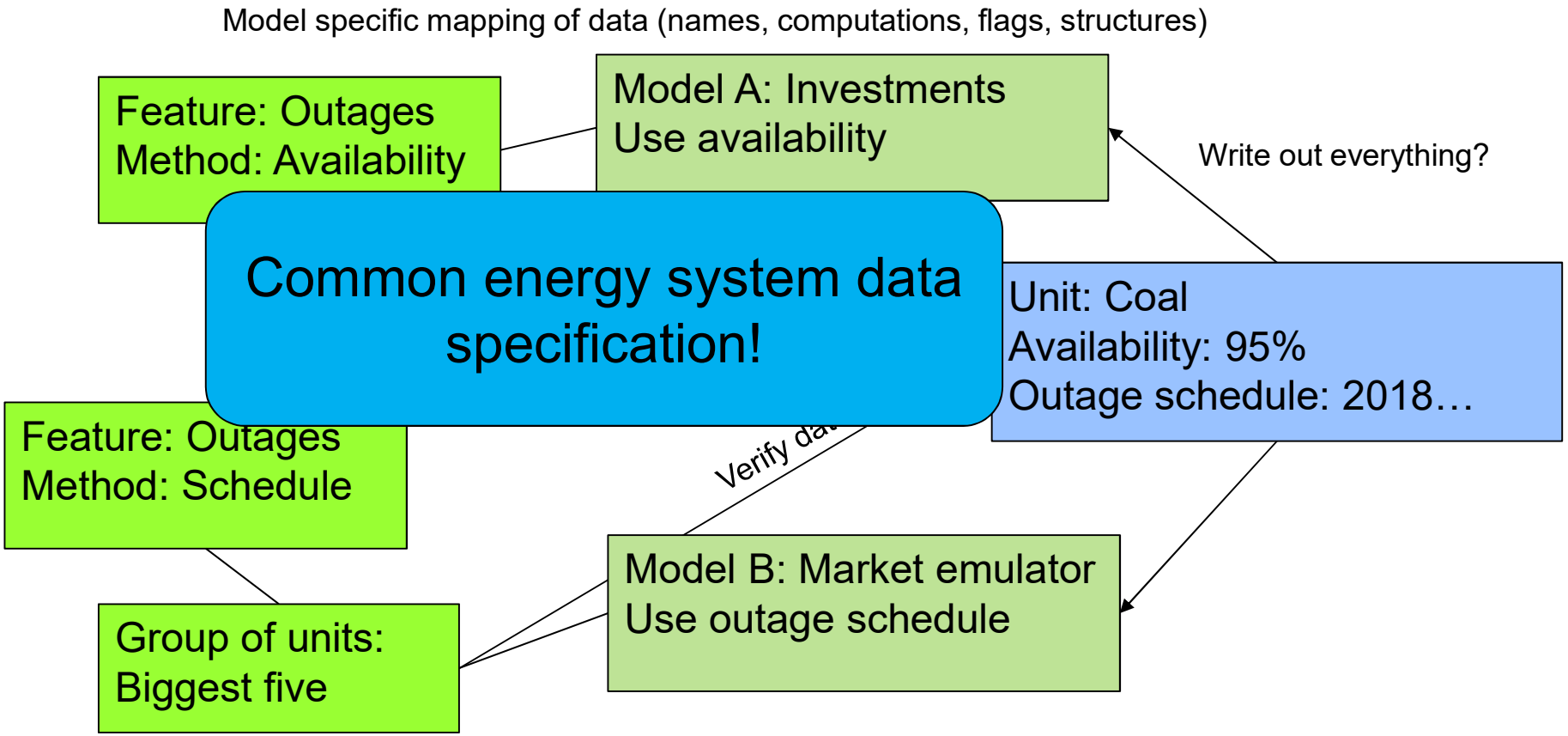
Types of entities

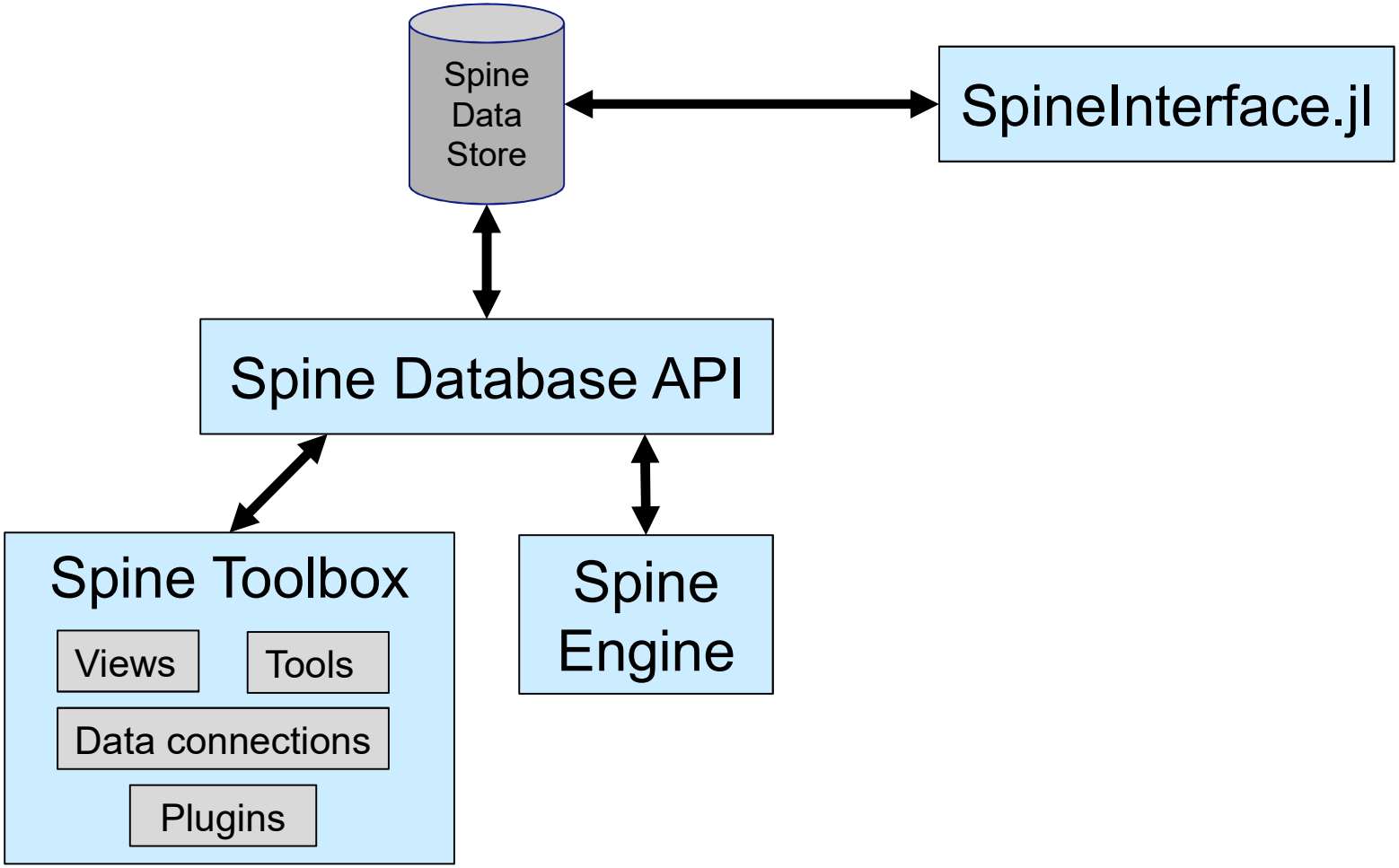
- Objects
  - Regular
  - Template (relationships could also have templates)
  - Archetype (relationships could also have archetypes)
  - Scenario
  - Tool
- Relationships
  - Dimensional sets
  - Groups / Collections
  - ‘Bags’ (single object can appear multiple times)
  - Hierarchical
  - Composition
  - Connection (arc in a graph)
- Entities with external reference
- Entities with code

Metadata and commit messages

- Automatic metadata from tools/models that process data
- User can also input metadata
- Follow best metadata practices
- Commits
  - Push users to improve documentation
  - Changes to the database will be accompanied by a commit message
  - Logs time and user, but hopefully also a helpful message about the data edits in that session

Many tools and models, but one data set?




Spine
Data
Store
SpineInterface.jl
Spine Database API
Spine Toolbox
Views
Tools
Data connections
Plugins
Spine
Engine

Philosophical notes

- Try to use the generic data structure as far as reasonable
- Don’t allow screw ups
  - Data validation
  - Explicit selection
  - Archetypes – features – methods
- Open interfaces – can grow and accommodate new things
  - Databases through SQLAlchemy (db agnostic)
  - Direct connection to Julia/JuMP (Spine Model)
  - Plug-in infrastructure