A Domain-Specific Language for Simulation Composition

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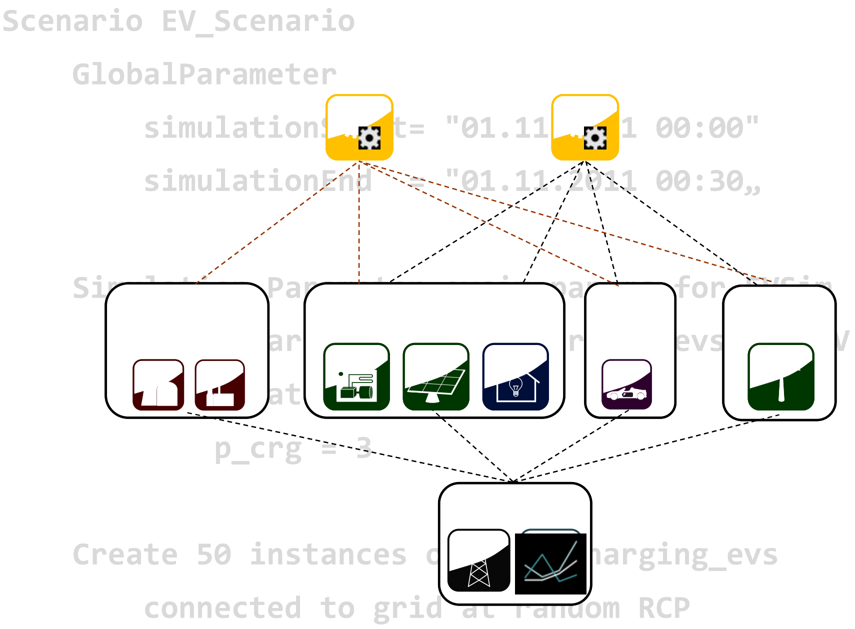


Scenario EV_Scenario
GlobalParameter
simulationS t= "01.11 1 00:00"
simulationEnd = "01.11.2011 00:30„
Si Par for EVSim
ar evs
at
p_crg = 3
Create 50 instances o harging_evs
connected to grid at random RCP

06/08/2011

Motivation

Approach

Domain Modelling

Example

Conclusion

3 Project GridSurfer 1/2

- Funded by Federal Ministry of Economics and Technology
- E-Mobility in northern Germany (rural area, high share of wind power)
- OFFIS: Simulation based analysis
  - Grid friendly EV charging strategies
  - Increased PV integration in the low voltage grid
  - …

4 Project GridSurfer 2/2

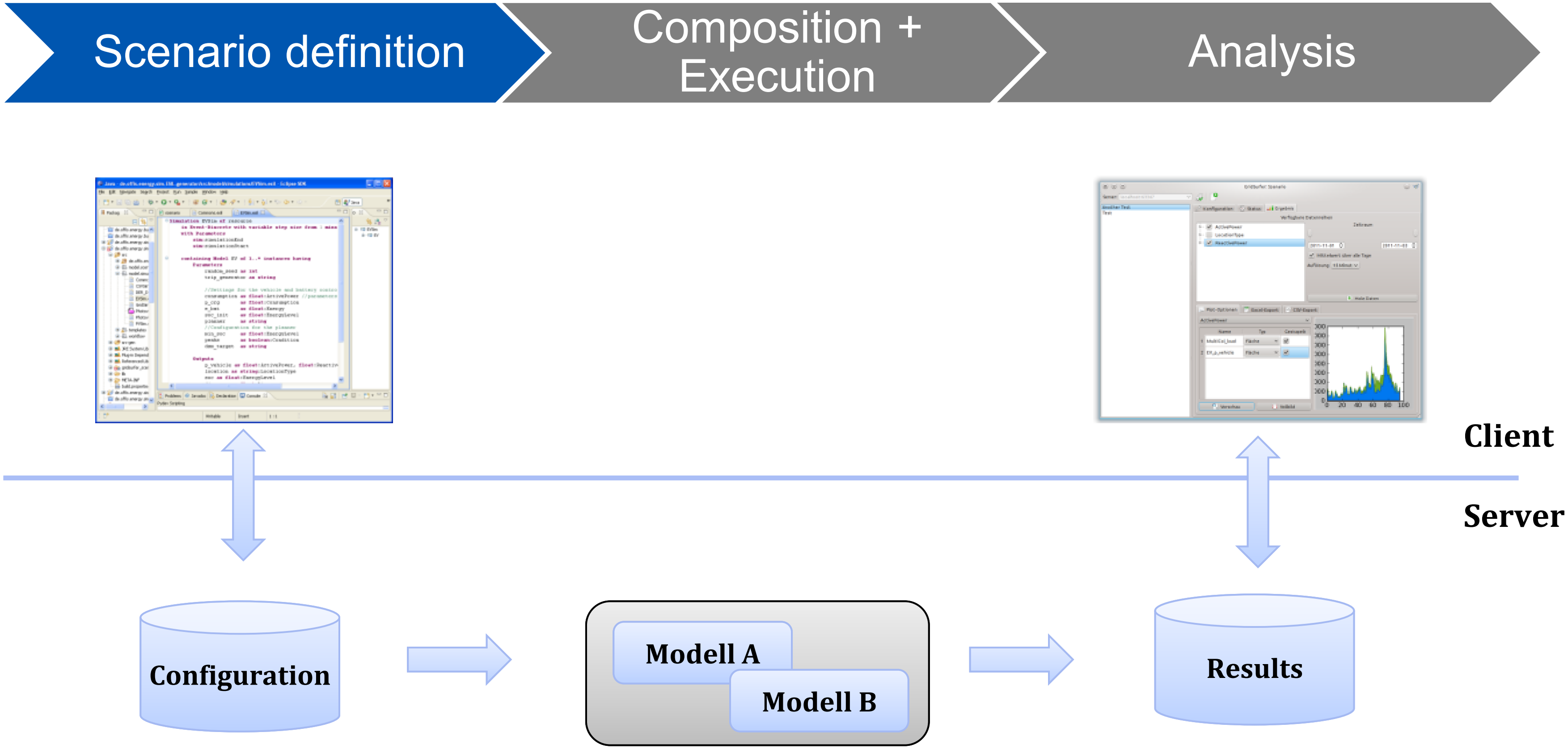
- Models for
  - Electric vehicles (EV)
  - Industrial and residential loads
  - Photo-voltaic systems (PV)
  - Different power grids

- Vehicle charging strategies must be developed and tested in different scenarios with varying…
  - model configurations (e.g. EV charging power, …)
  - numbers of models
  - placement of models in the power grid

5 Objective

Find a solution that allows to specify the different scenarios in a flexible and understandable way.

6 Simulation platform



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8 Domain Specific Language (DSL)

A DSL is a language that has been designed for a specific problem domain

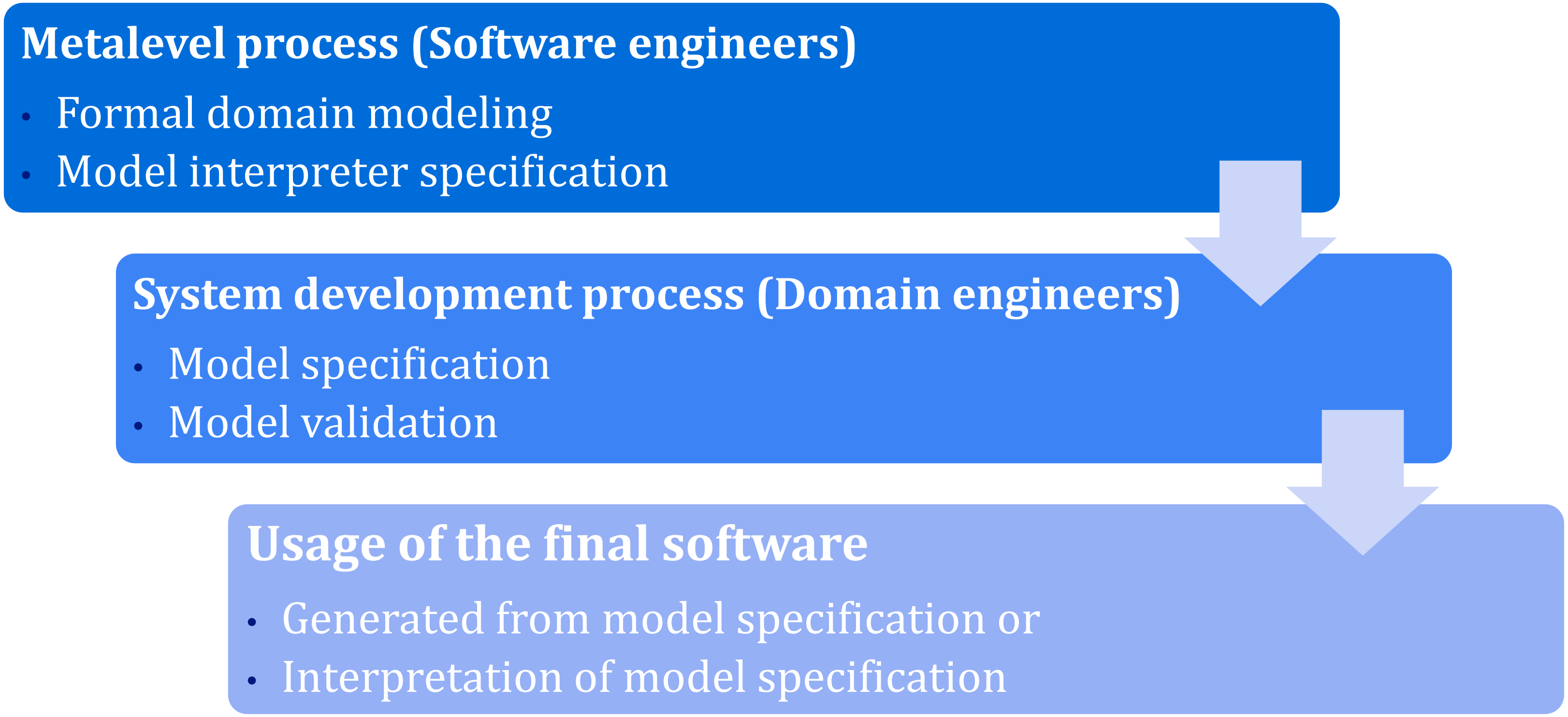
(in contrast to a general purpose language)

DSL: What are the benefits?

- Reduced code size and complexity due to specificness
- Increased productivity
- (Easy to understand for domain experts)
- Domain aspects can be implemented independently of the actual system (or its language)

DSL: Modelling

3-level process similar to Model-Integrated Computing [SK 97]



Metalevel process (Software engineers)

- Formal domain modeling
- Model interpreter specification

System development process (Domain engineers)

- Model specification
- Model validation

Usage of the final software

- Generated from model specification or
- Interpretation of model specification

[SK 97] Sztipanovitz, J. and Karsai, G. (1997). Model-Integrated Computing. Computer, 30(4): 110-111.

DSL: XText

- Xtext is an **open-source** framework for developing DSLs
- Widely **established**, **easy** to use but still very flexible/powerful
- DSL specific editor with syntax highlighting and auto-completion automatically generated as Eclipse-plugin

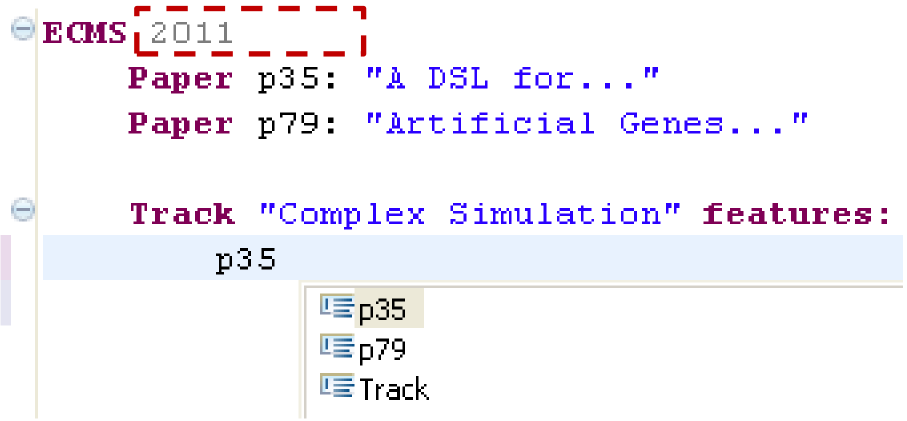
DSL Definition

```
ECMS:
'ECMS' year=INT
(papers+=Paper)+
(tracks+=Track)*;

Paper:
'Paper' name=INT ':' title=STRING;

Track:
'Track' name=STRING 'features:'
(papers+=[Paper])+;
```

Generated Editor



```
ECMS 2011
    Paper p35: "A DSL for..."
    Paper p79: "Artificial Genes..."

    Track "Complex Simulation" features:
        p35
```

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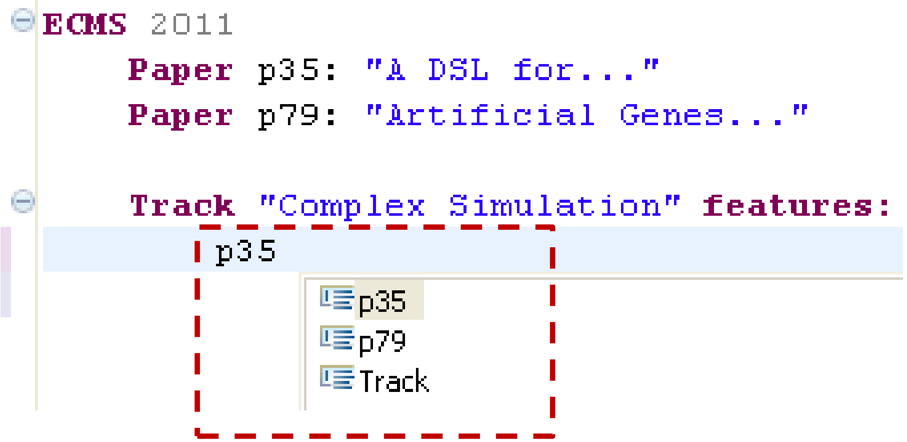

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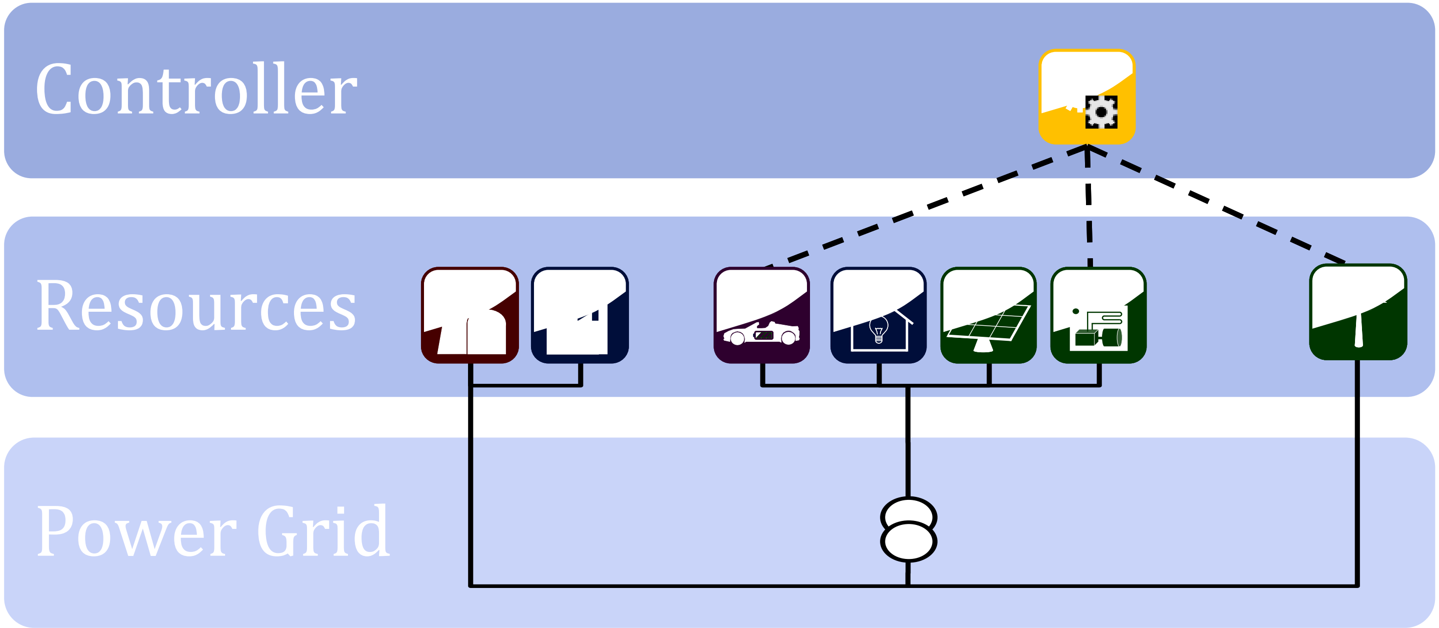
Domain analysis

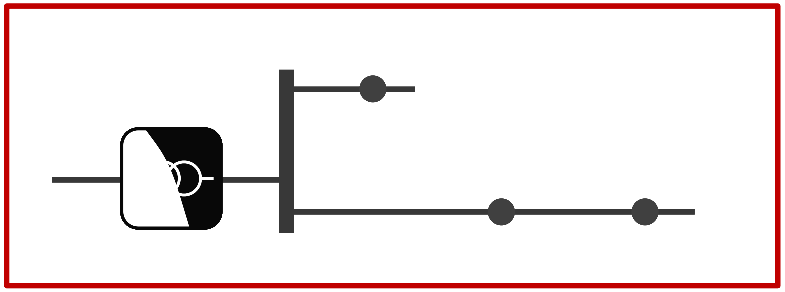
1. Collection of scenarios that need to be simulated
2. Classification contained objects
3. Analysis of object and scenario characteristics



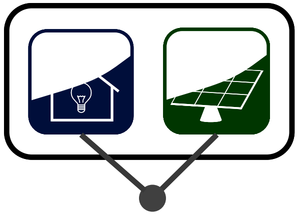
Scenario object characteristics

Key aspects identified:

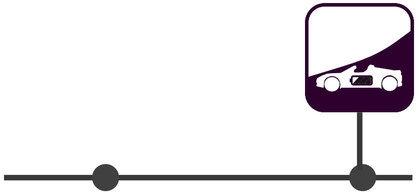
- Connection points
  - Specific or randomly chosen



- Resource groups

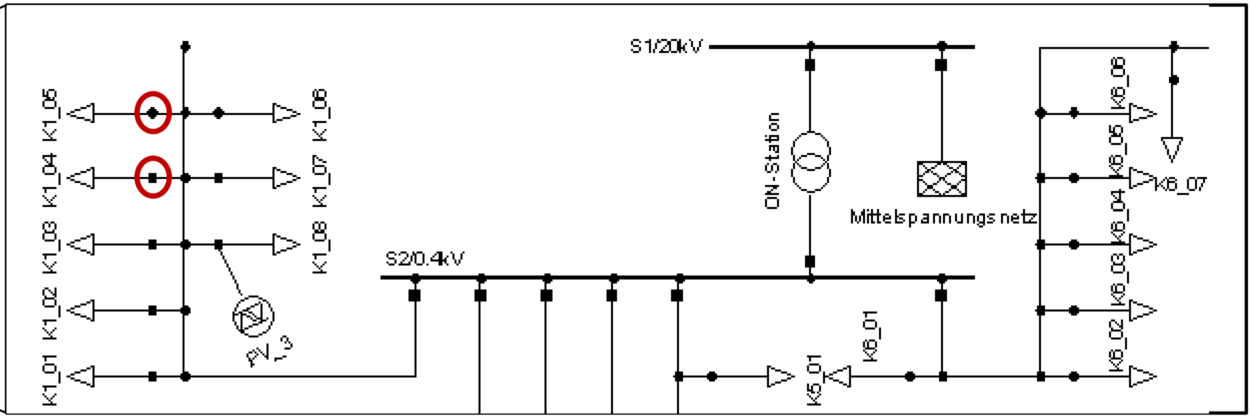


- Moving resources (EVs)

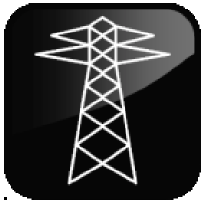


16 Power grid topology

CIM Topology File



Extract connection points



Power Grid Model

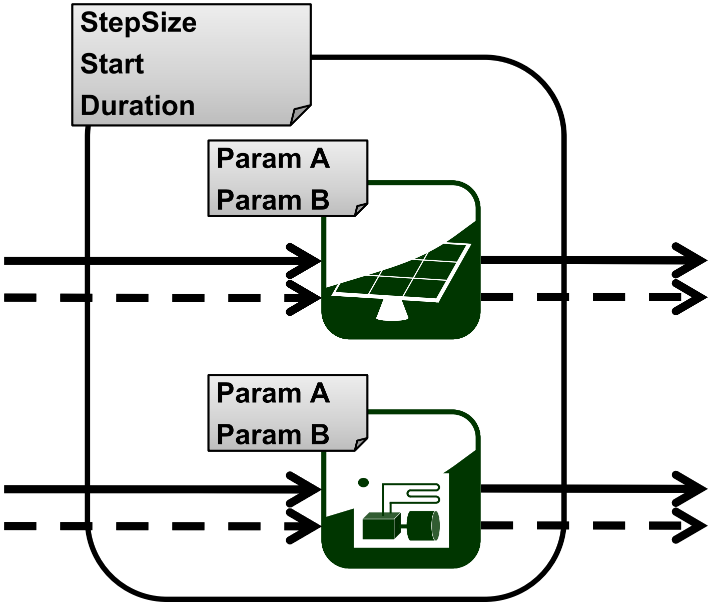
```
#Topology
Name: TestCaseB
RCPs:
- Bus1_C
- Bus2_C
- Bus3_C
- Transformer20kV_C
```

Topology meta model

Topology definition

Simulation definition

- Treated as „black box“
- Can have configuration parameters
- Can contain 1..* models that have
  - configuration parameters
  - 0..* in-/outputs



Simulation definition

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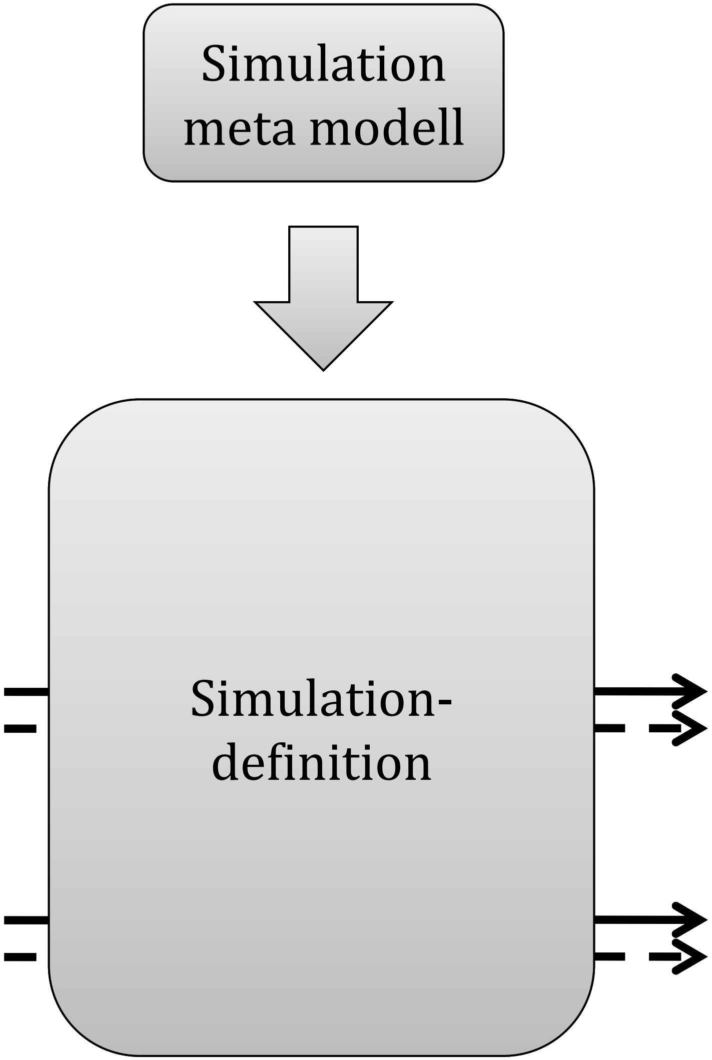
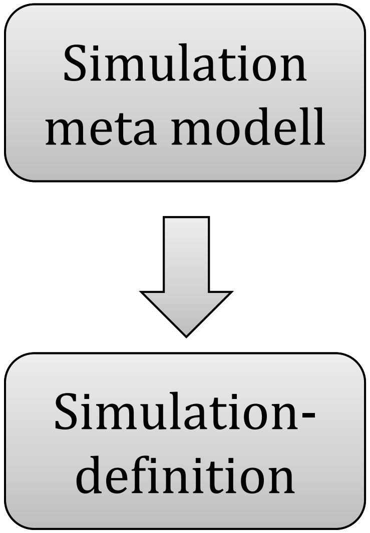
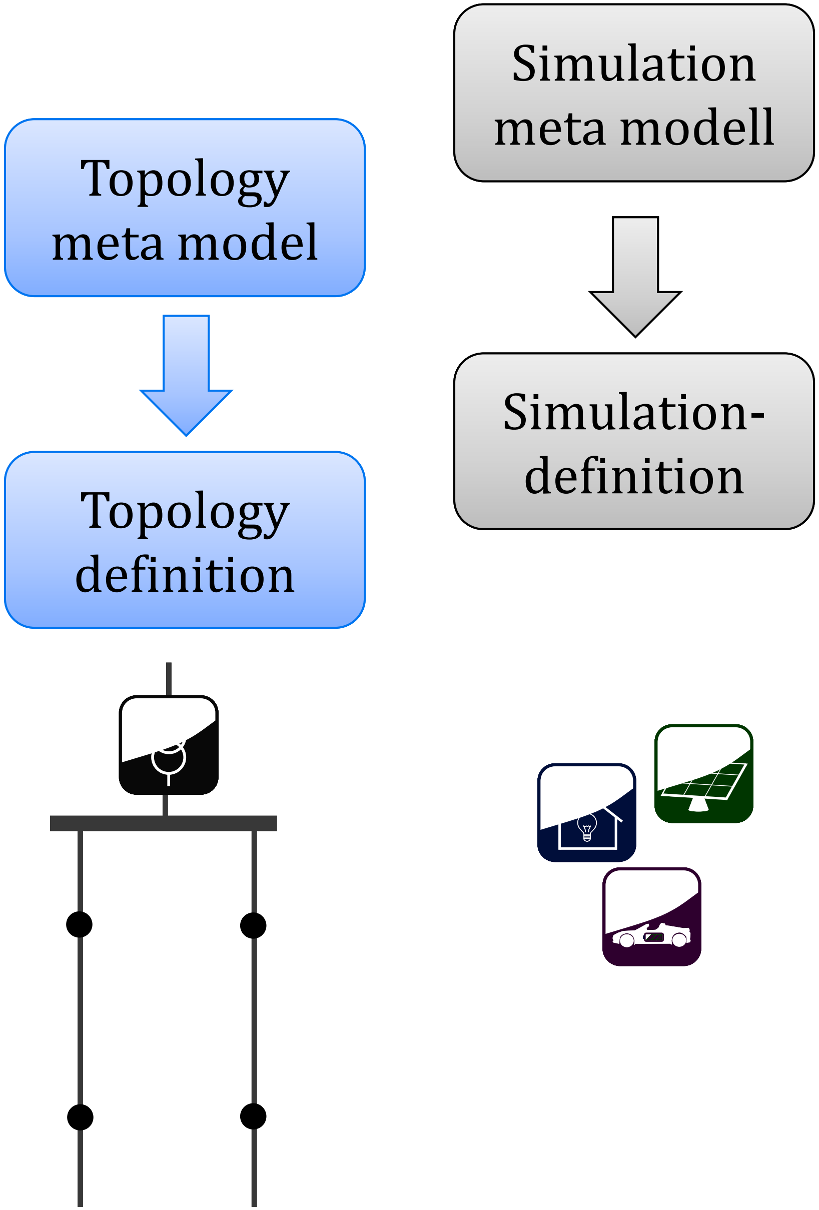


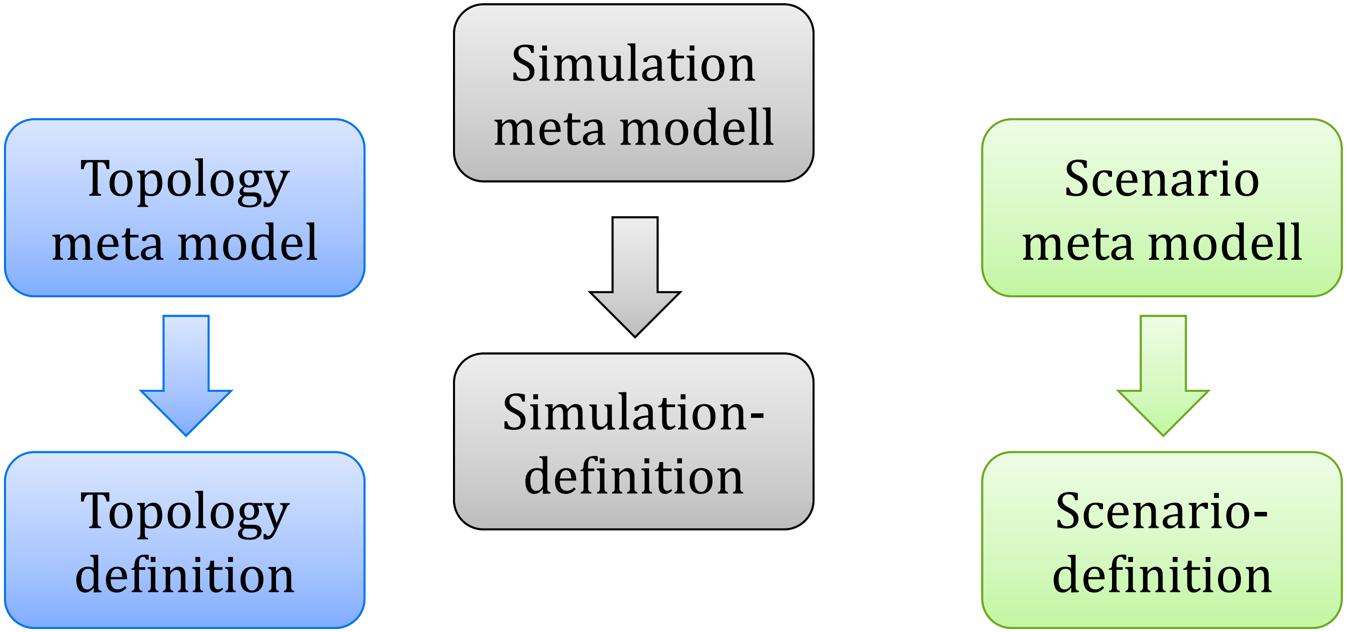
DSL Overview



DSL Overview



DSL Overview



Topology meta model

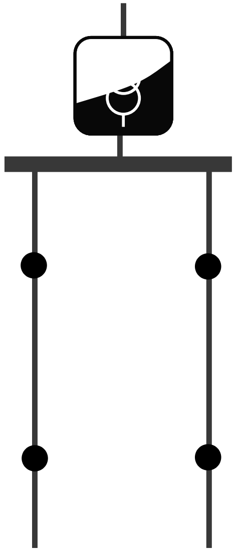
Topology definition

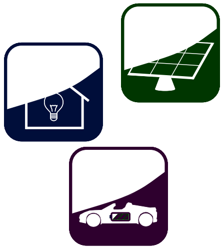
Simulation meta modell

Simulation-definition

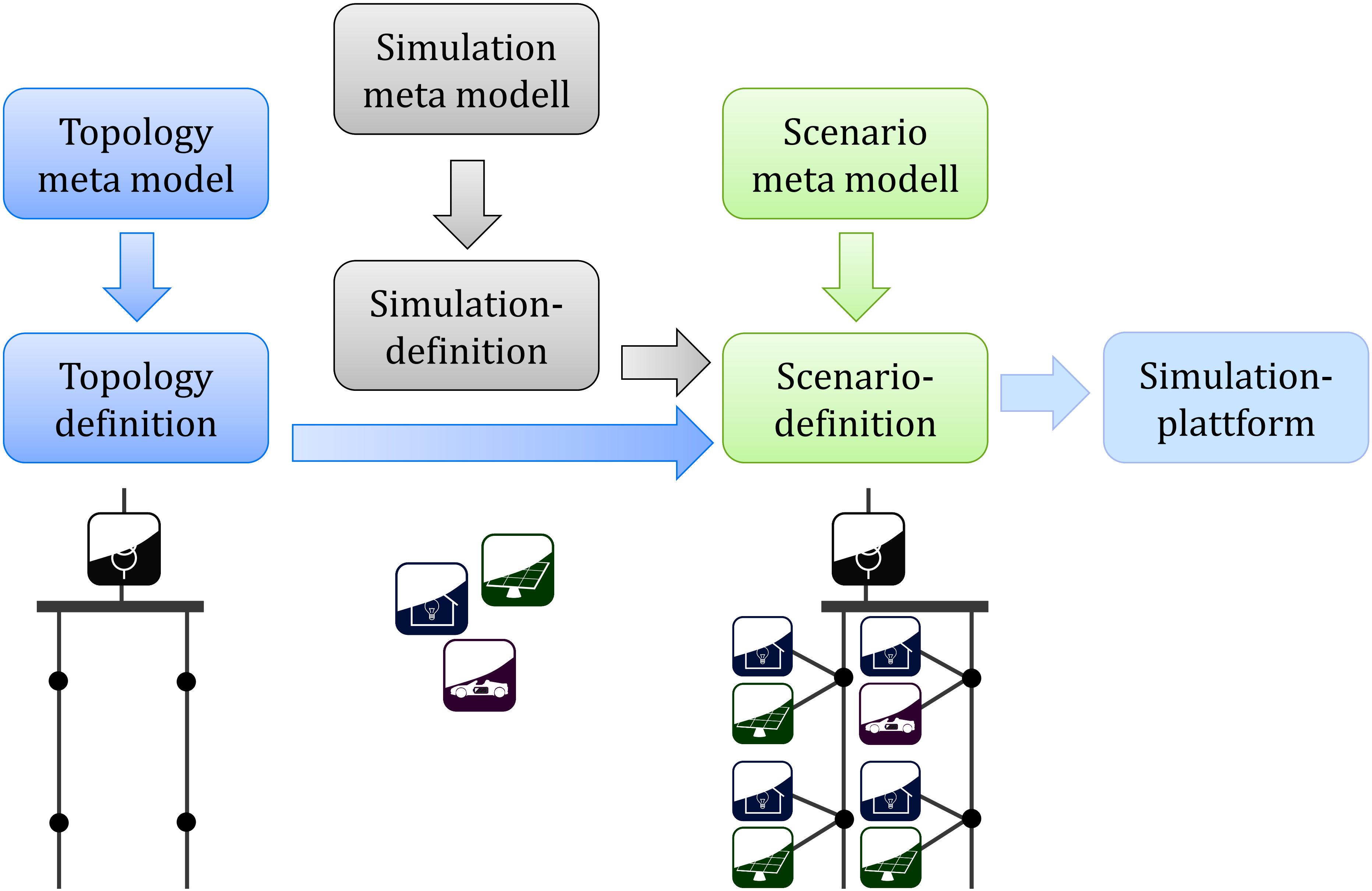
Scenario meta modell

Scenario-definition





DSL Overview



Topology meta model

Simulation meta modell

Scenario meta modell

Topology definition

Simulation-definition

Scenario-definition

Simulation-plattform

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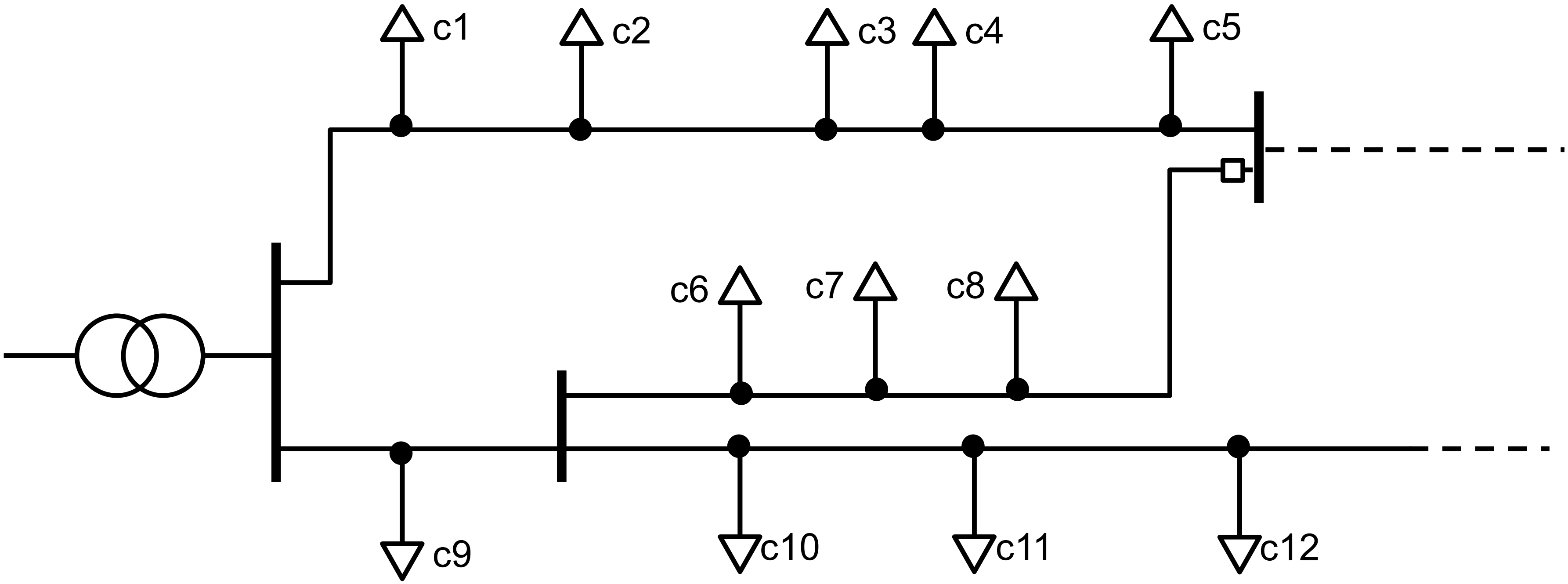
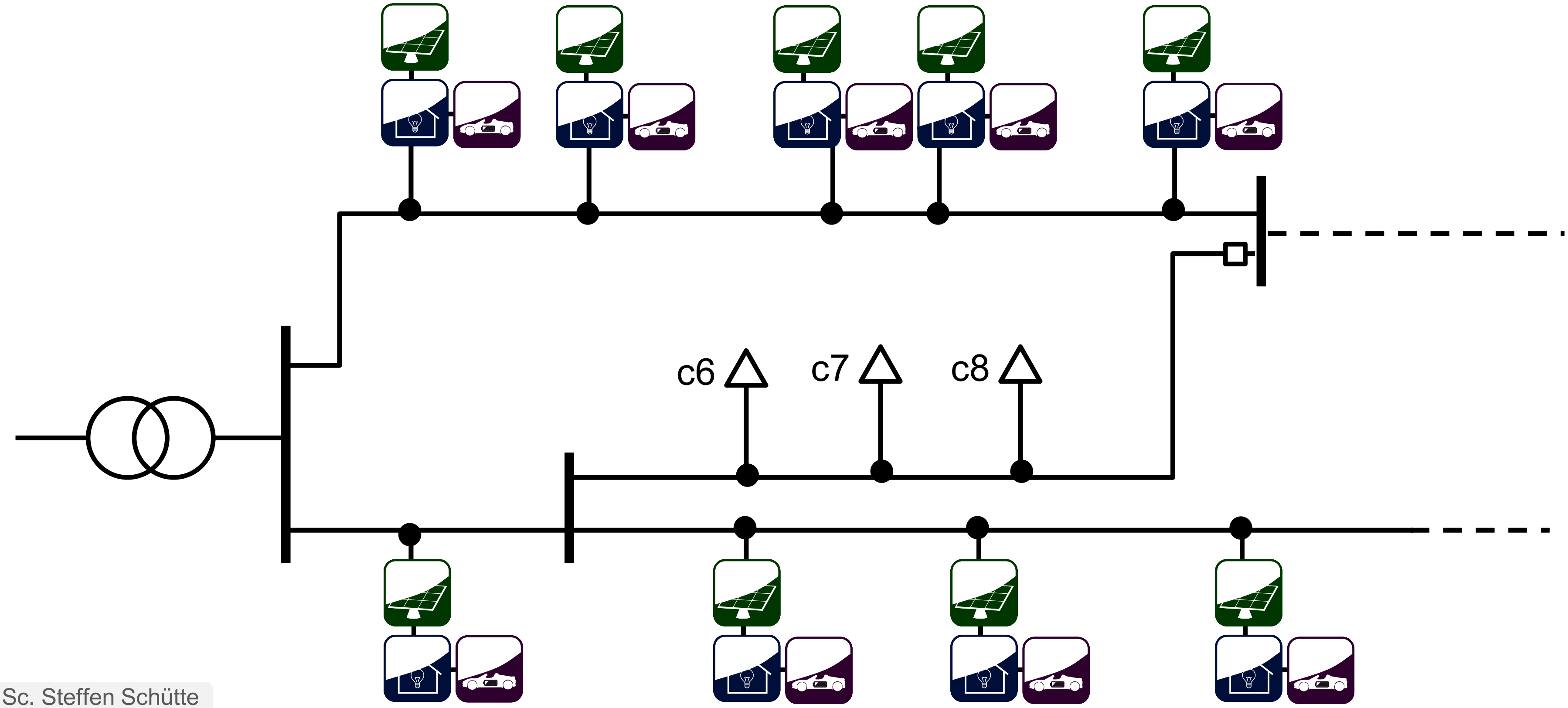
Example

- Low voltage distribution grid



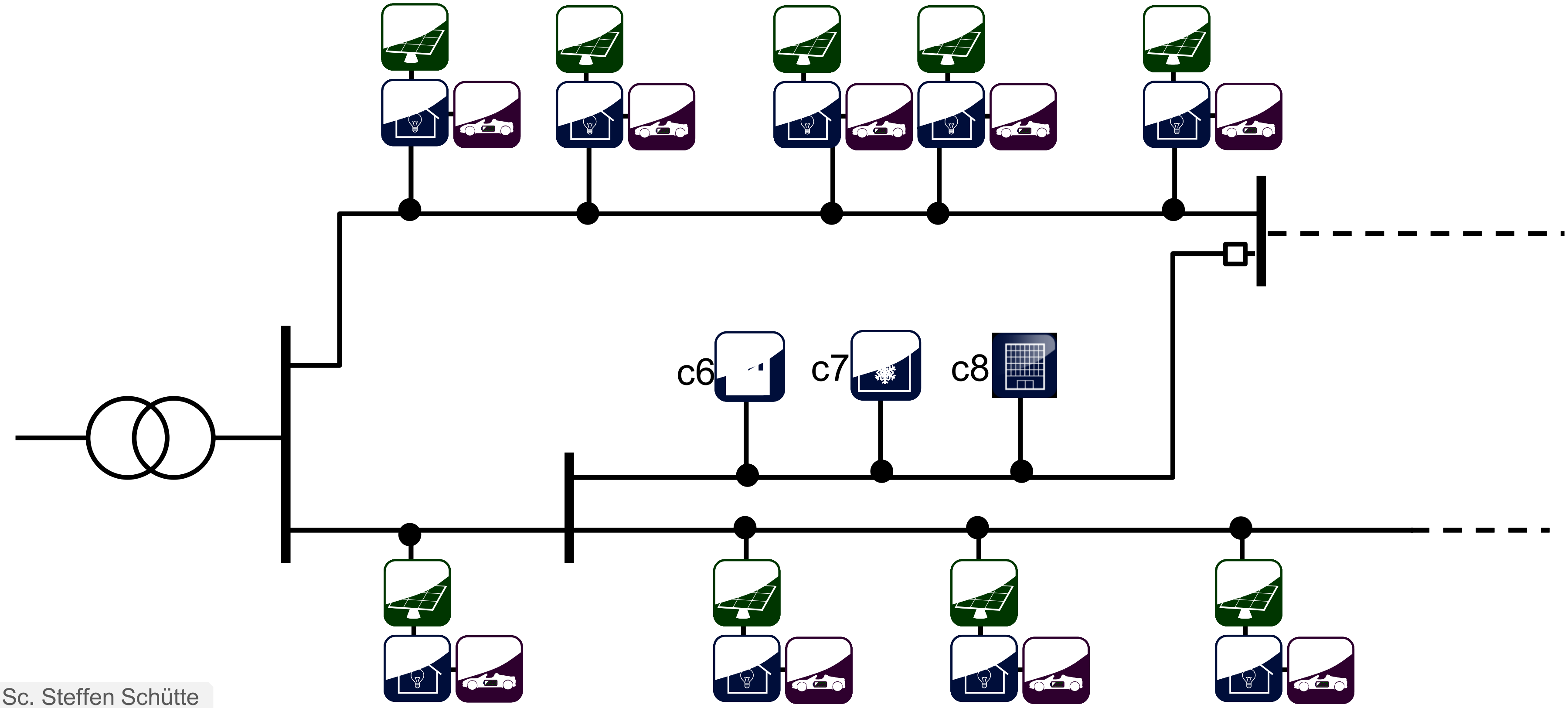
Example

- Low voltage distribution grid
- Groups of private homes with photovoltaics and an EV
- EVs leave grid when driving to work

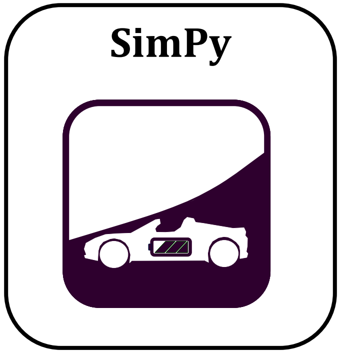


Example

- Low voltage distribution grid
- Groups of private homes with photovoltaics and an EV
- EVs leave grid when driving to work
- Some business loads



Example: Simulation & Model definition

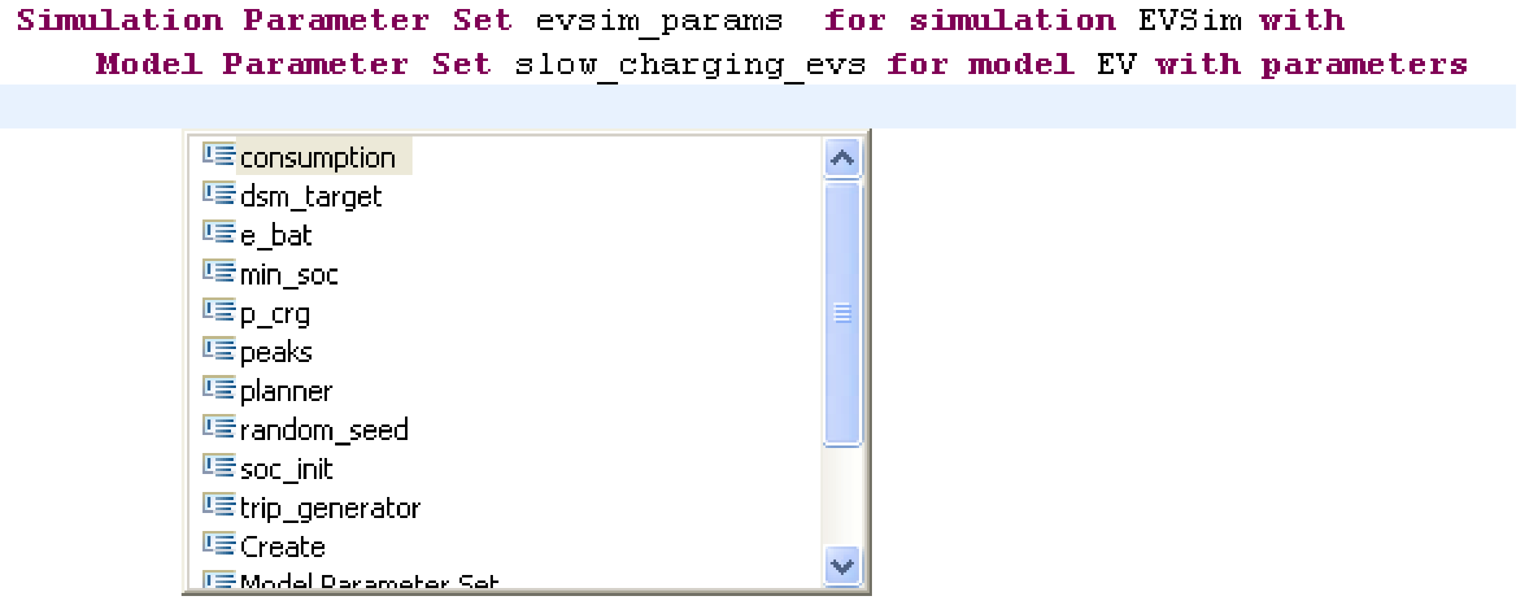


```
Simulation EVSim of resource
    with Parameters
        sim:simulationEnd
        sim:simulationStart

    containing Model EV of 1..* instances
        Parameters
            random_seed    as int
            trip_generator as string
            p_crg          as float:Consumption  //kWh/100km
            e_bat          as float:Energy        //kWh
            soc_init       as float:EnergyLevel  //%

        Outputs
            p_vehicle      as float:ActivePower,  //kW
                              float:ReactivePower //kW
            location       as string:LocationType
            soc            as float:EnergyLevel   //%
            distance       as float:Distance      //km
            plugged_in     as boolean
```

Example: Scenario definition

```
Scenario example1
  GlobalParameter
     simulationStart= "01.11.2009"
     simulationEnd= "08.11.2009"

   [Parameter specification (see next slide)]
```

Example: Parameter specification



```
Simulation Parameter Set evsim_params  for simulation EVSim with
    Model Parameter Set slow_charging_evs for model EV with parameters
```

Example: Parameter specification

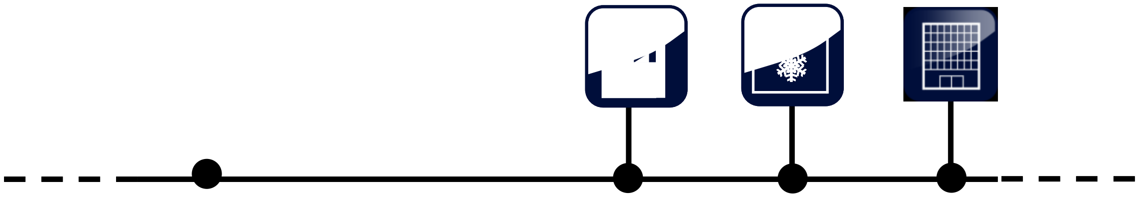
```
Simulation Parameter Set evsim_params  for simulation EVSim with
    Model Parameter Set slow_charging_evs for model EV with parameters
         e_bat = 31
         p_crg = 3
         trip_generator = "Simple“

Simulation Parameter Set pv_params for simulation PVSim with
    Model Parameter Set private_pv for model Photovoltaic with parameters
          PV_Angle = 30
          PV_IMPP = <var_impp>
          PV_Inverter_maxActivePower = 900
          PV_NOCT = 48
          PV_NumberOfModulesPerString = 6
          PV_NumberOfStrings = 1
          PV_UMPP = 23.8
          PV_aP = -0.48


 . . .
```

Example: Model instantiation

```
Scenario example1 using topology LowVoltageGrid_1
  GlobalParameter
     simulationStart= "01.11.2009"
     simulationEnd= "08.11.2009"

   [Parameter specification (see last slide)]
```

Example: Model instantiation

```
Scenario example1 using topology LowVoltageGrid_1
  GlobalParameter
     simulationStart= "01.11.2009"
     simulationEnd= "08.11.2009"

   [Parameter specification (see last slide)]

   Create 1 instances of csv.commercial1 connected to grid at rcp:6
   Create 1 instances of csv.commercial2 connected to grid at rcp:7
   Create 1 instances of csv.commercial3 connected to grid at rcp:8
```



Example: Model instantiation

```
Scenario example1 using topology LowVoltageGrid_1
  GlobalParameter
     simulationStart= "01.11.2009"
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   [Parameter specification (see last slide)]

   Create 1 instances of csv.commercial1 connected to grid at rcp:6
   Create 1 instances of csv.commercial2 connected to grid at rcp:7
   Create 1 instances of csv.commercial3 connected to grid at rcp:8

   Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
```

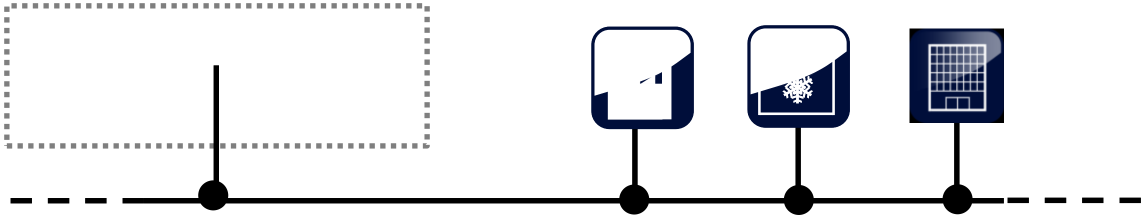

Example: Model instantiation

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  GlobalParameter
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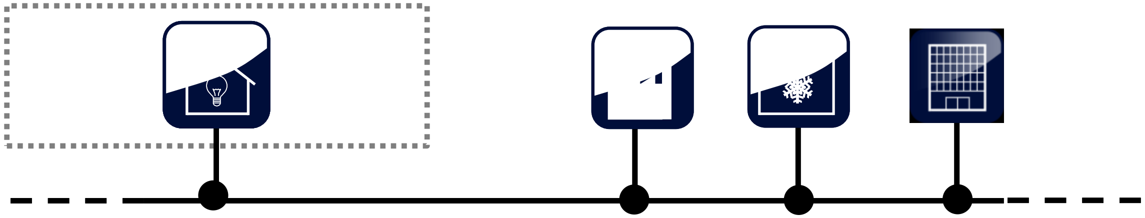
   Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
          Create 1 instances of csv.private connected to grid at group RCP
```



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   Create 9 instances of ModelGroup Home_EV_PV connected to grid at random RCP
          Create 1 instances of csv.private connected to grid at group RCP
          Create 1 instances of pv_params.private_pv connected to grid at group RCP
```

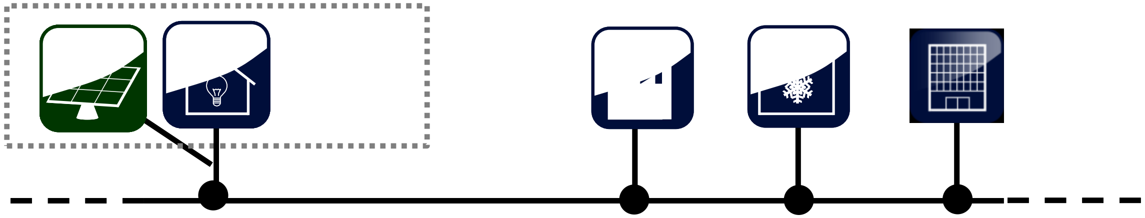

Example: Model instantiation

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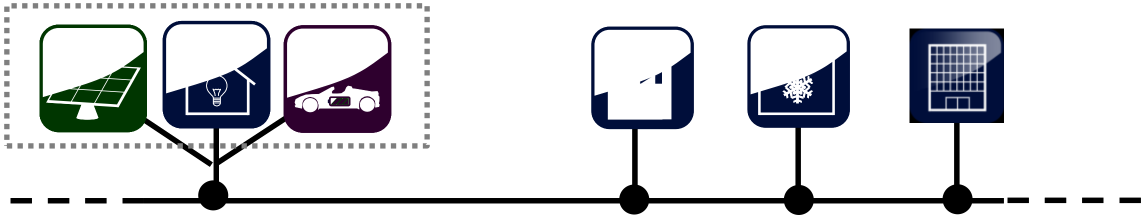
           Create 1 instances of csv.private connected to grid at group RCP
           Create 1 instances of pv_params.private_pv connected to grid at group RCP
           Create 1 instances of evsim_params.slow_charging_evs
               connected to grid at group RCP when location="home"
```



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          Create 1 instances of csv.private connected to grid at group_RCP
          Create 1 instances of pv_params.private_pv connected to grid at group_RCP
          Create 1 instances of evsim_params.slow_charging_evs
              connected to grid at group_RCP when location="home"
```

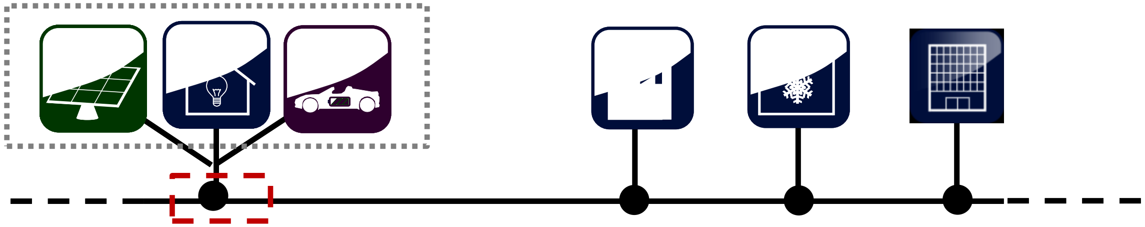

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- DSL based scenario description has been presented

Advantages

- Specification of **small and large scenarios** due to power grid topology references and/or random selection
- DSL can act as scenario **documentation**
- **Loose coupling** between scenario definition and simulation platform (via generator or interpreter)
- **Single point of truth** (no more distributed config files)

Limitations/Future work:

- Data and control flow implicit (based on model roles)
- No hierarchical scenarios

Literature

[Gu 10] Guntli, C. (2010). Create a DSL in Eclipse Open Source Tools to create DSLs. http://wiki.ifs.hsr.ch/SemProgAnTr/ChristopherGuntli

[IEA 2011] http://www.iea.org/papers/2011/smartgrids_roadmap.pdf

[SK 97] Sztipanovitz, J. and Karsai, G. (1997). Model-Integrated Computing. Computer, 30(4): 110-111.

Own publications:

Schütte, S. (2011). A domain-specific language for simulation composition. In T. Burczynski, J. Kolodziej, A. Byrski, & M. Carvalho (Eds.), *25th European Conference on modelling and Simulation* (pp. 146-152). Krakow.

Scherfke, S., Schütte, S., Wissing, C., Nieße, A., & Tröschel, M. (2010). Simulationsbasierte Untersuchungen zur Integration von Elektrofahrzeugen in das Stromnetz. *VDE Kongress - Smart Cities*.