OPEUS

Shift2Rail energy simulation tool for rolling stock

Future Improvements Noise & Energy

Tony LETROUVE, Clément DEPATURE

13rd November 2019

Grant Agreement Number: 730818

Presentation objectives :

- Demonstrate the interest and the positionning of the OPEUS tool to choose the most relevant train technology on one cycle.

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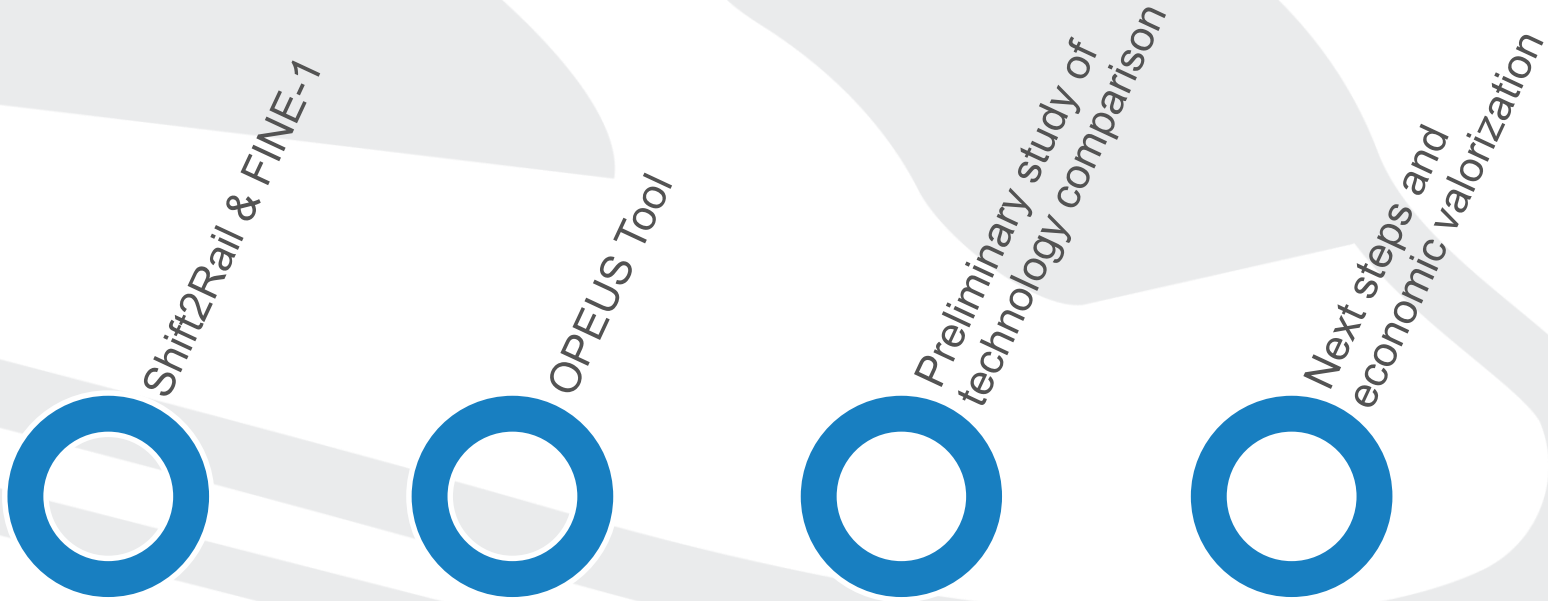

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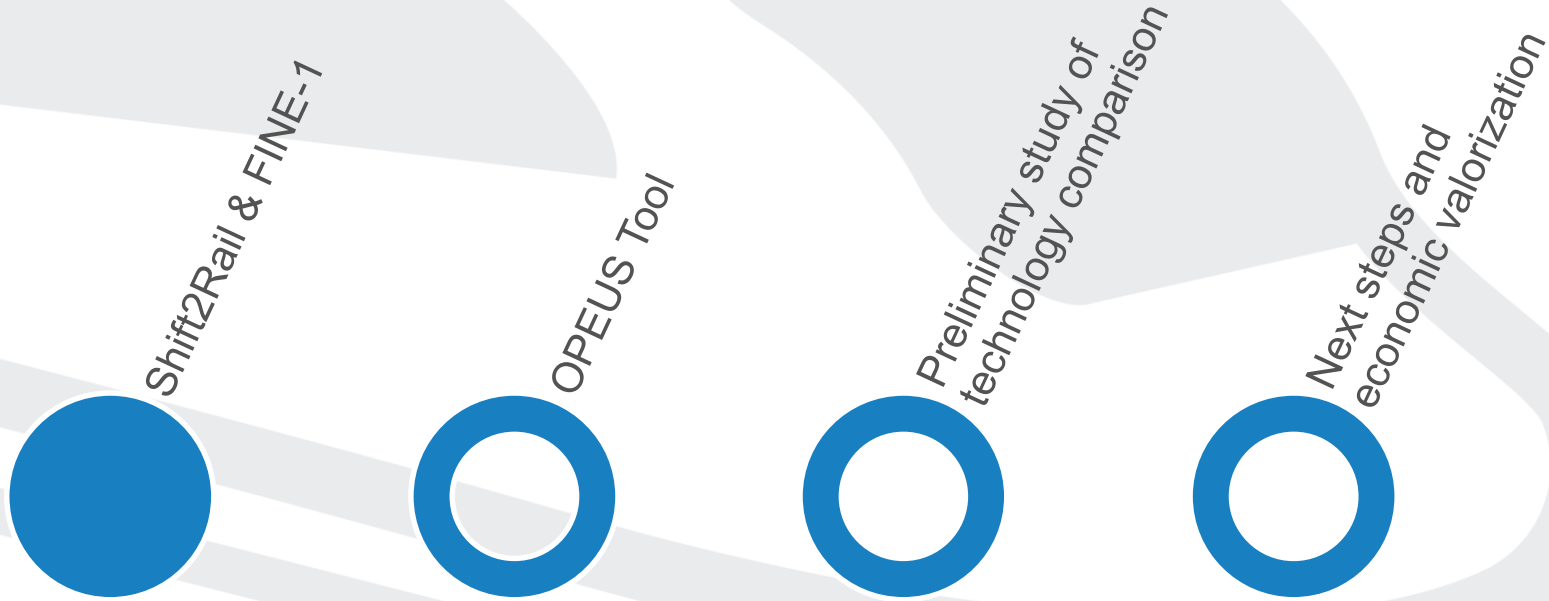

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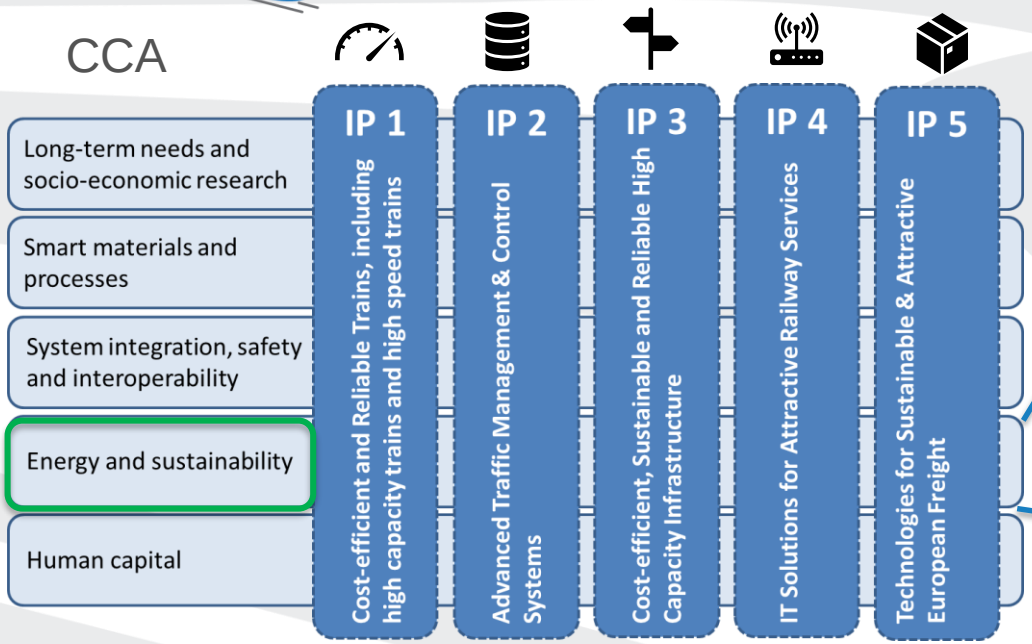
Locating FINE1 inside Shift2Rail



CCA Working Area 5.1

CCA = Cross Cutting Activity / IP = Innovation Programme

The purpose is to identify all energy-relevant TDs and SPDs, to quantify and follow up energy savings to support increasing cost-effectiveness and sustainability through energy-efficiency.

Energy Simulation

Energy Methodology

Gathering of technical data (TDs)

Support energy-related work in Shift2Rail

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FINE1 Energy Members & Timeline

Start: 01/09/2016

36 months

Finish: 31/10/2019

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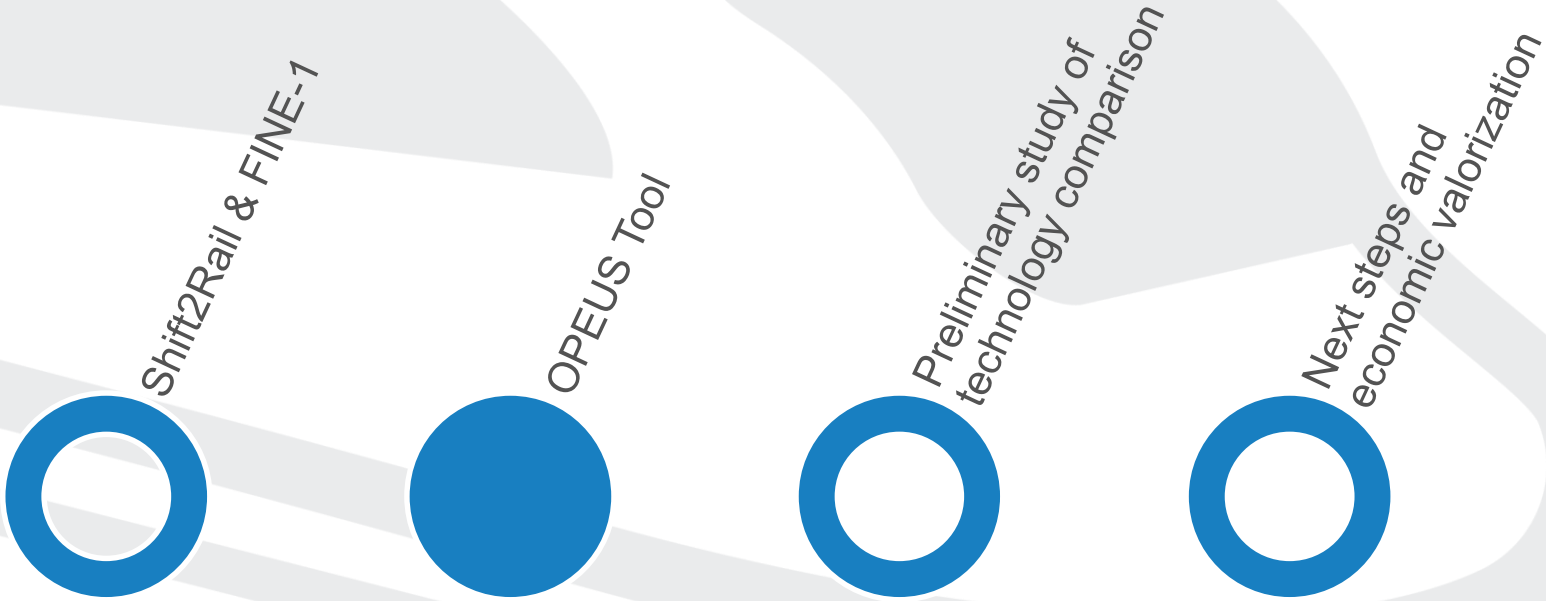

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Overview

Objective

What is the OPEUS-tool for?

- Calculation of the energy consumption of various railway vehicles and their components.

Input

What does the OPEUS-tool need as input data?

- Parameter sets of vehicles and their components, including:
  - Parameter sets of the various components;
  - Track data (time tables, speed limits, altitude,...).

Usage

What does the OPEUS-tool allow users to do?

- Create and simulate a variety of traction topologies by rearranging/exchanging the component blocks.
- Investigation and assessment of technical innovations based on the simulated power profiles and simulated energy consumption.
- Easy implementation and comparison of various train parameters.

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General Set Up

Simulation structure is implemented in **Matlab and Simulink**
- Common software for engineering tasks;

Component models are organized in a Simulink library:
- Avoid ambiguity;
- Easy to implement changes at the component models.

Input data and **Output data** of the tool are implemented as Microsoft Excel files:
- Easy and familiar interface;
- Even users with less background in Matlab/Simulink are able to execute the simulations;
- Easy processing of the output data.

Track data and **train data** is organized in Excel libraries:
- Clear handling of data;
- Easy possibility to extend the library with own data.

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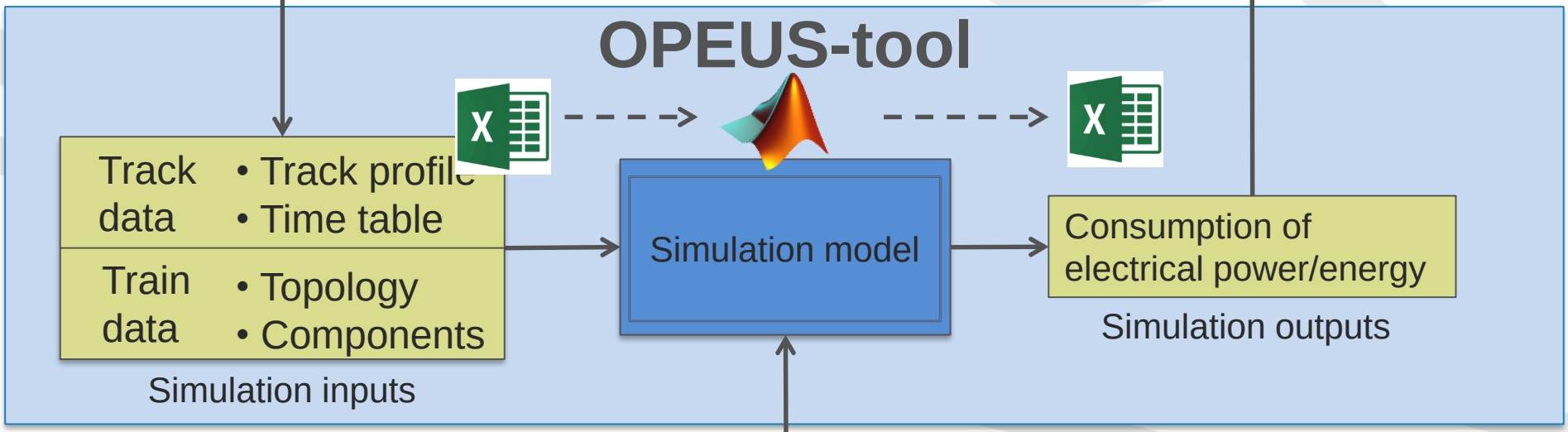
General Set Up

Different service categories:
- Urban
- Regional
- High Speed
- Freight

Assessment of innovative technologies:
- ESS
- SiC converter
- Synchronous motor
- ...



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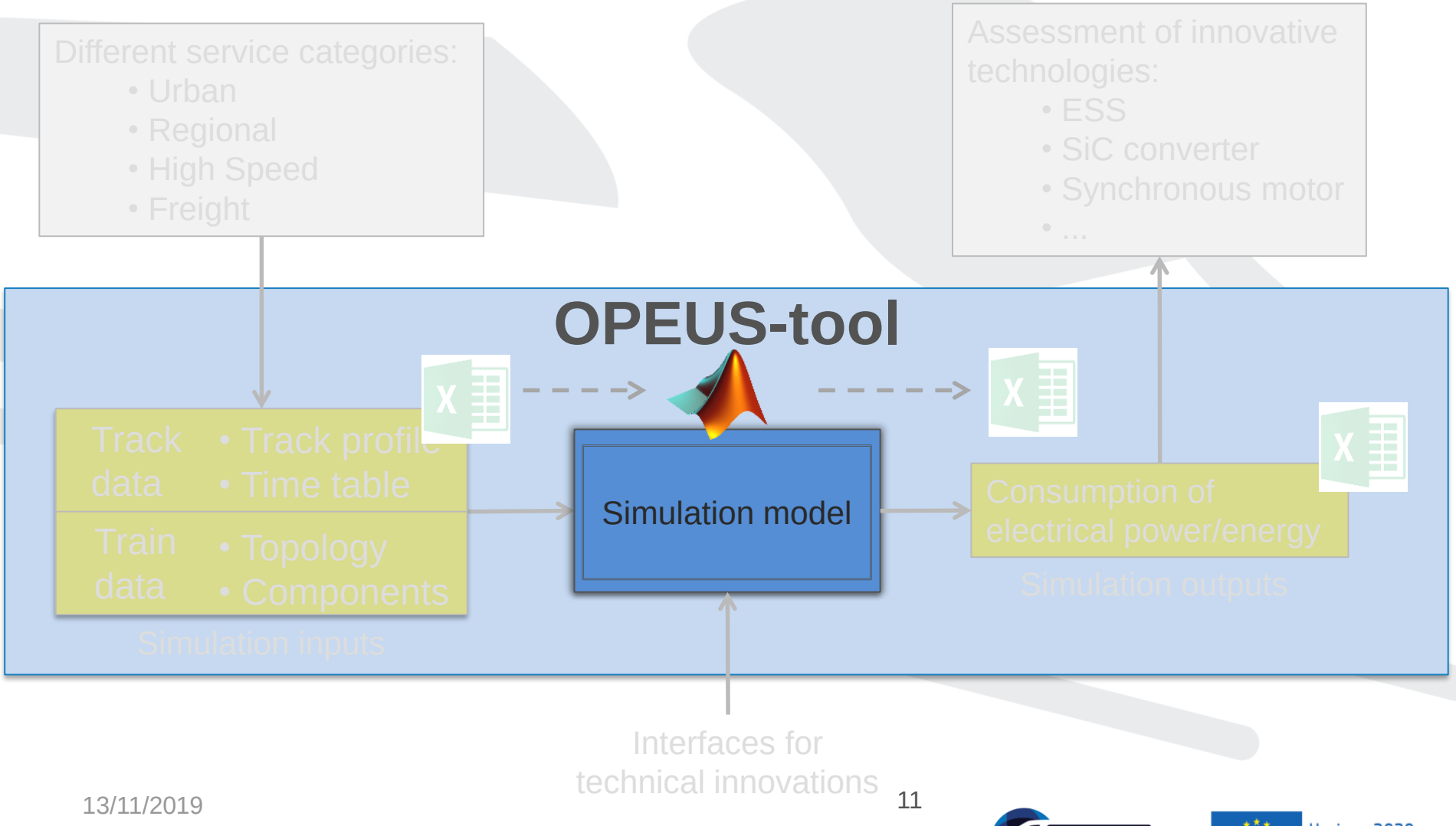
Simulation model



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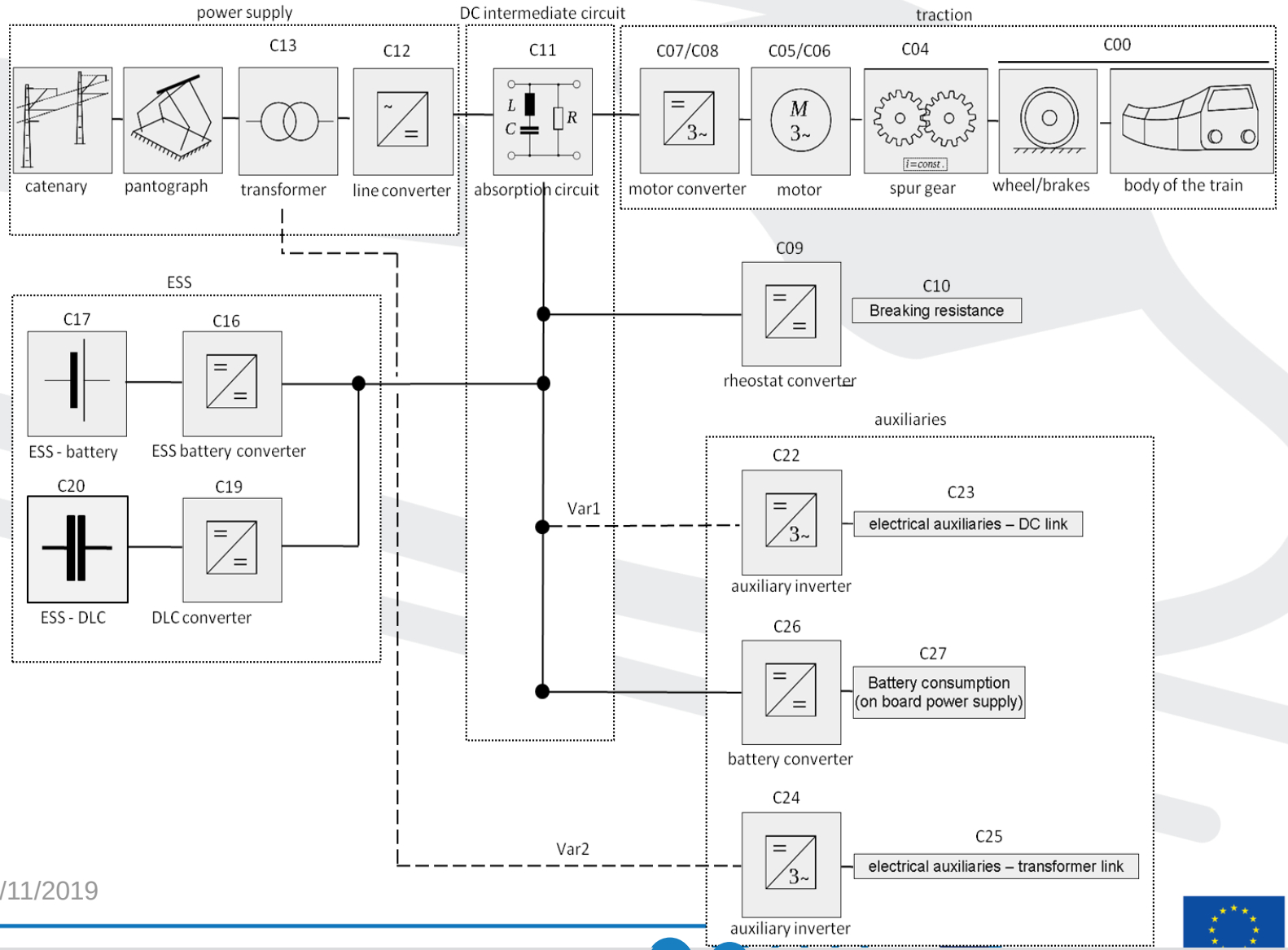
Traction System Topologies

Simulation Topology (AC Traction Chain –T01)



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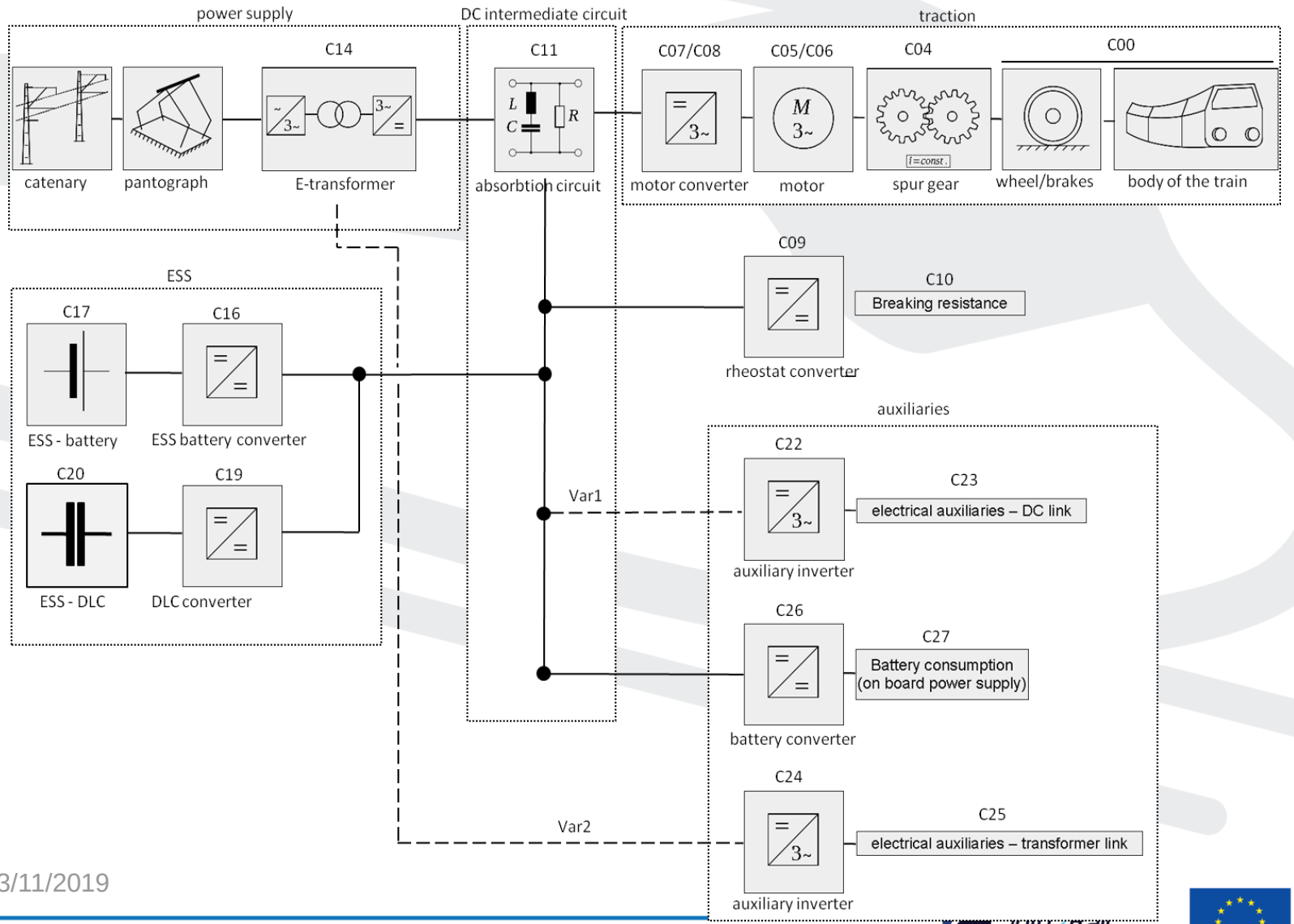
Traction System Topologies

Simulation Topology (AC Traction Chain – E-transformer –T02)



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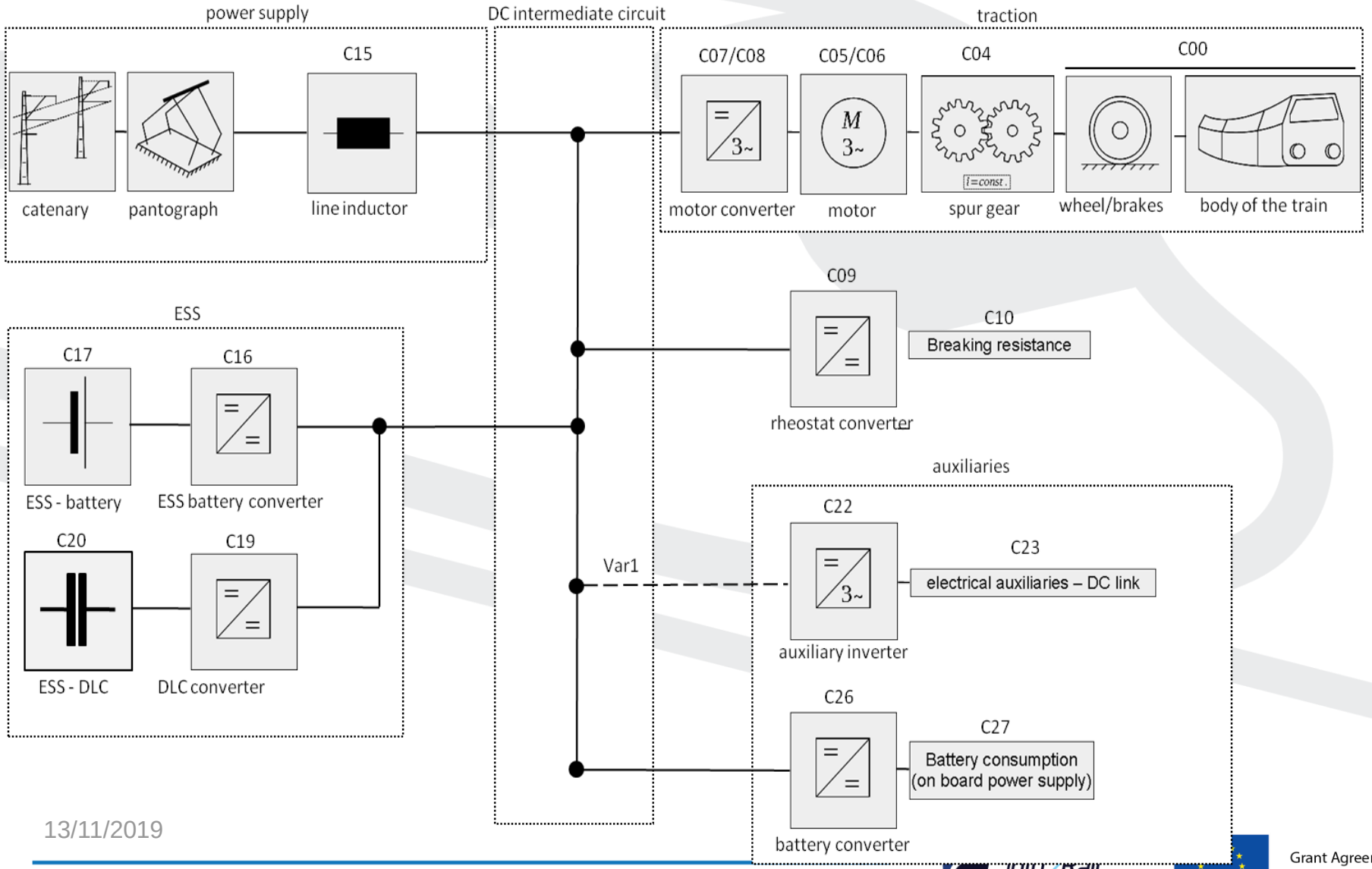
Traction System Topologies

Simulation Topology (DC Traction Chain –T03)



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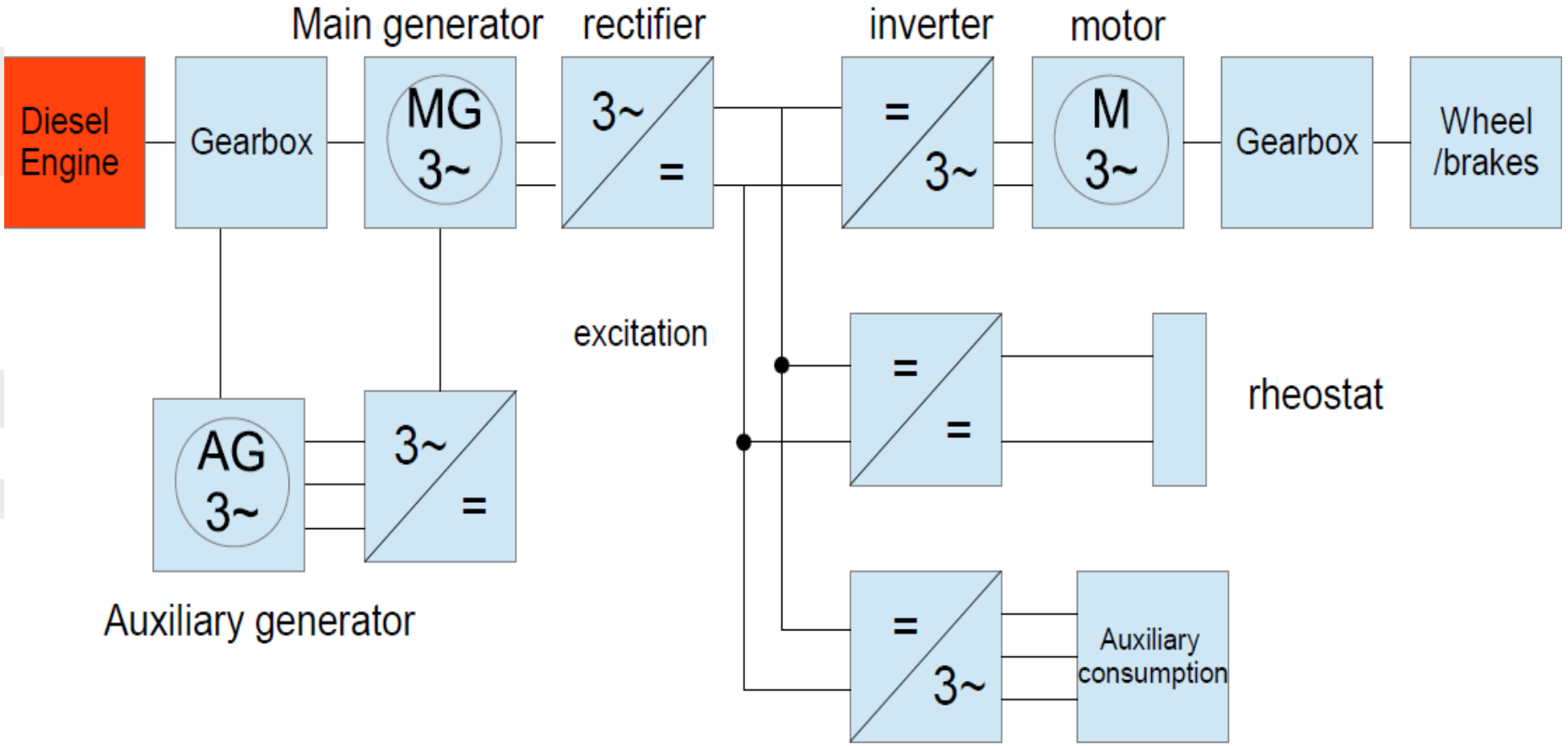
Traction System Topologies

Simulation Topology (Diesel-electric Traction Chain –T05)



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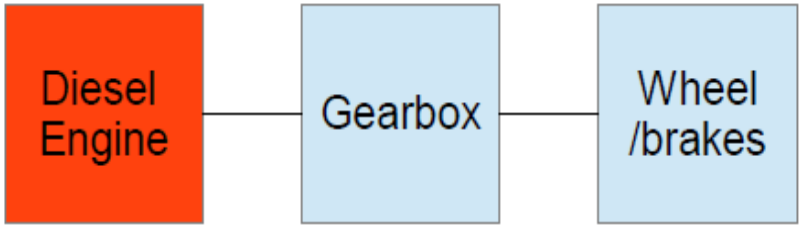
Traction System Topologies

Simulation Topology (Diesel mechanic/hydraulic Traction Chain –T05)



Hydraulic/mechanical gearbox

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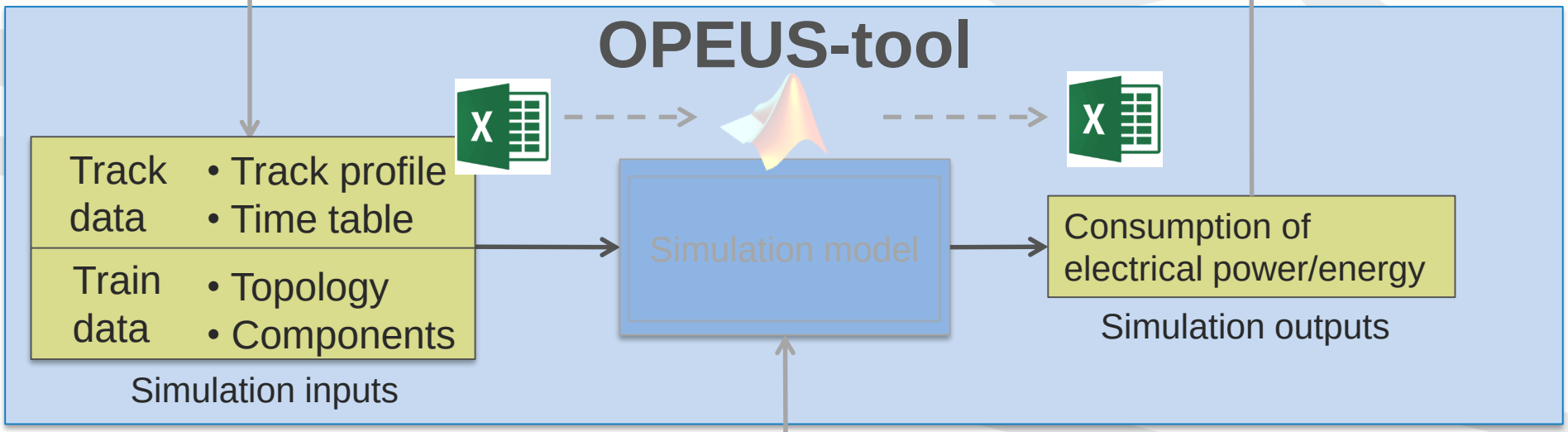
Inputs and Outputs

Different service categories:
- Urban
- Regional
- High Speed
- Freight

Assessment of innovative technologies:
- ESS
- SiC converter
- Synchronous motor
- ...



Interfaces for technical innovations

Inputs

OPEUS-Tool
Input data

Input table: general inputs

Please **select train data** to be simulated:
-synthetic train, defined for service category - select the corresp. abbrevation from the drowdown list
- own train data - select "own" from the drowdown list

Note: If you pick one of the synthetic vehicles, the tool will copy the data to the "Simulation_Input" folder by itself. If you want to simulate some other data, the tool will request a directory of the data in the further proceeding.

Reg160

Please **select a topology** by enter the corresponding abbrevation:
- predefined topologies - select the corresp. abbrevation from the drowdown list
- own topology - enter "own" from the drowdown list

Note: If you pick one of the synthetic vehicles, the tool will copy the data to the "Simulation_Input" folder by itself. If you want to simulate some other data, please copy the train data file into the "Simulation_Input" folder.

Please take into account the assignment between the topology and the pre-defined service categories:
T01/T02 - AC power supply: HS300, HS250, Intercity, Reg160, Reg140, Suburb, FrMain, FrSh
T03 - DC power supply: Metro, Tram

T01

legend - vehicle data/ track data

abbrevation	service category
HS300	High Speed 300
HS250	High Speed 250
Intercity	Intercity
Reg160	Regional 160
Reg140	Regional 140
Suburb	Sub-Urban
Metro	Metro
Tram	Tram
FrMain	Freight Mainline
FrSh	Freight Shuntig

legend - traction topology

abbrevation	topology
T01	AC power supply
T02	AC power supply - E-transformer
T03	DC power supply
T05	Diesel-Electric
T06	Diesel

Please **select track profile** to be simulated:
- track profile defined for service category -select the corresp. abbrevation from the drowdown list
- own track profile - enter "own" from the drowdown list

Note: If you pick one of the synthetic vehicles, the tool will copy the data to the "Simulation_Input" folder by itself. If you want to simulate some other data, the tool will request a directory of the data in the further proceeding.

Reg160

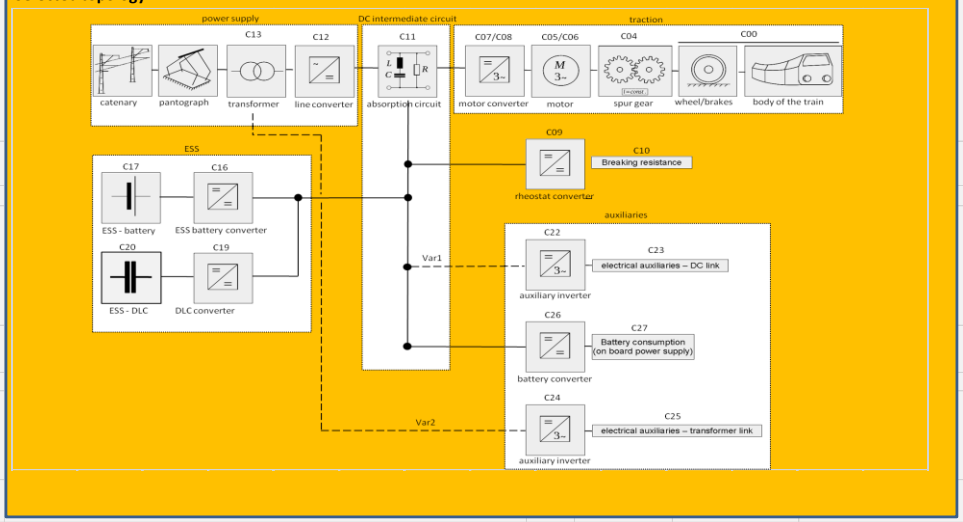
Please **select the trajectory mode**:
-allout trajectory - enter "allout"
-fullfill timetables (accord. to selected track profile), with coasting - enter "timetable"
-fullfill timetables(accord. to selected track profile), without coasting - enter "timetableNoCoast"
- own trajectory - enter "own"

timetable

Please select if a **pre-calculated speed profile** shall be used for the simulation:
- pre-calculated speed profile - enter "pre-calculated trajectory"
- calculate a new speed profile from the time table - enter "calculate trajectory"
WARNING: The calculation of the speed profile could last up to a few minutes.

calculate trajectory

Selected topology



Outputs

Summarized results:

Energy values for total trip and station by station.

Out table: summary of the simulation results

Simulated service category	Simulated topology
Reg160	T01

Integrated Values for journey				Simulation date and time
total time	10800	s	03:00:00 (hh:mm:ss)	20-Mar-2018 12:07:15
total distance	250001	m	250,001 km	
operational speed (total distance per total time)	83	km/h		
traction energy at the wheel	697,4367	kWh		
total braking energy at the wheel	156,6757	kWh		
ED-braking energy at the wheel	146,9196	kWh		
braking energy at the mechanical brakes	9,7561	kWh		
traction energy of motor converters at DC link	912,4825	kWh		
recuperated energy of motor converters at DC link	119,1614	kWh		
auxiliary energy at the DC link	546,9983	kWh		
rheostat braking energy at DC link	0	kWh		
traction energy at the catenary	1647,1644	kWh		
recuperated energy at the catenary	93,8406	kWh		
difference of energy stored in onboard energy storage system(s) (if applicable)	0	kWh		
fuel consumption (if applicable)		kg		
energy equivalent for 1l diesel	9,8	kWh/l		
energy equivalent for fuel consumption	0	kWh		

Specified topology	
component	**included in simulation**
ESS-battery	No
ESS-DLC	No
auxiliary at transformer	No
auxiliary at DC intermediate circuit	Yes

Performance indicators	
number of seats	230
number of pax	180
payload (tonne)	0
consumption per kilometre (Wh/km)	6213,270347
consumption per passenger-kilometre (Wh/pkm)	34,51816859
consumption per seat-kilometre (Wh/skm)	27,0142189
kilometre (Wh/tkm)	#DIV/0!

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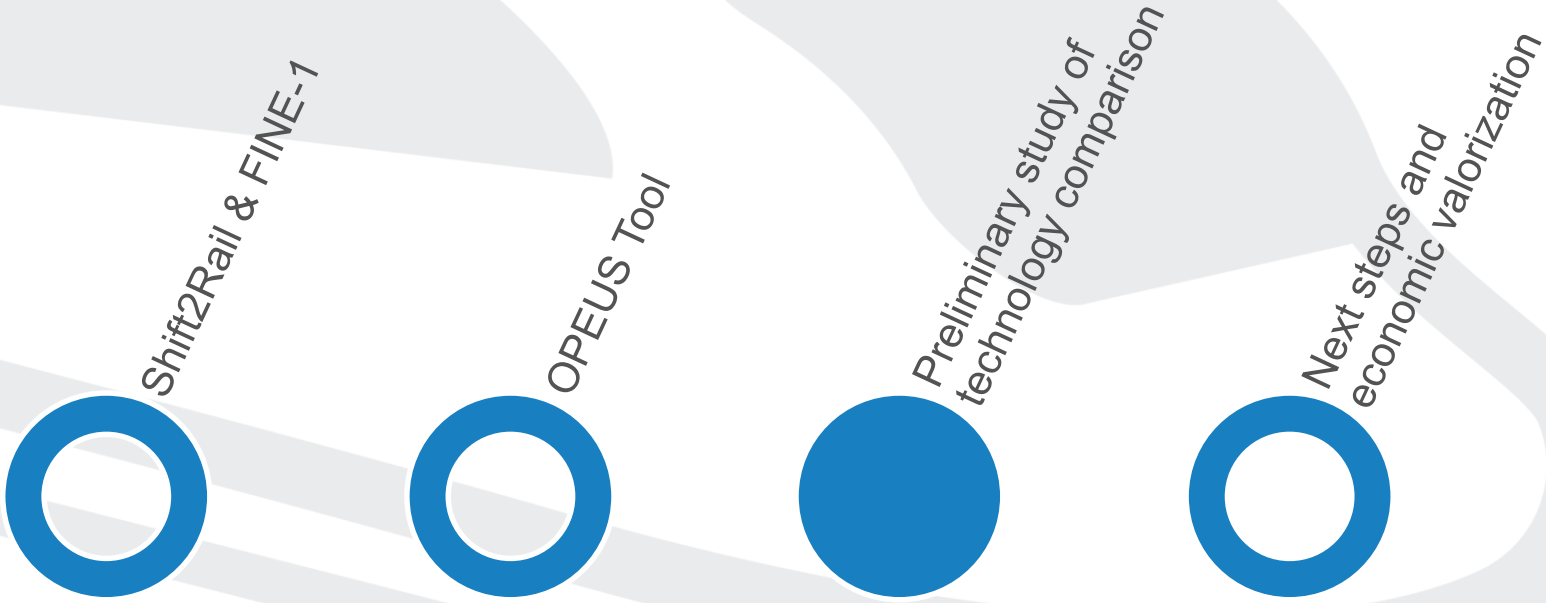

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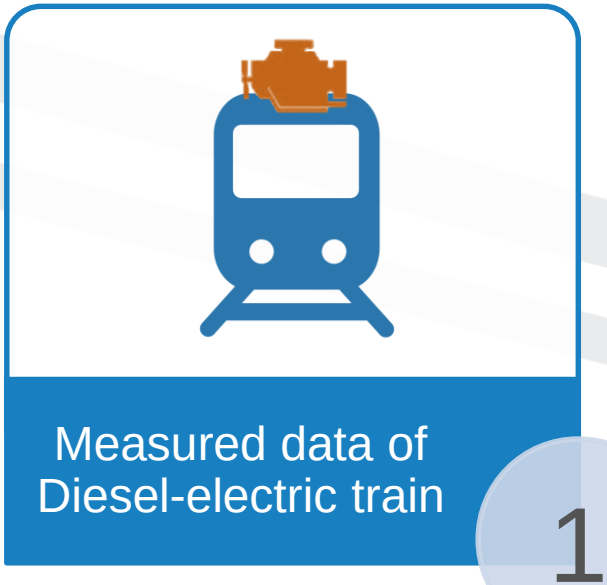
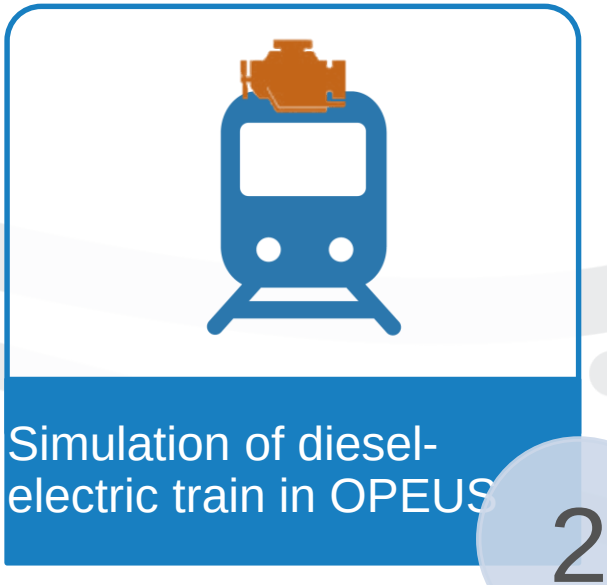
Study cases and simulations done : Simulation tool validation

Simulation context:

- all data used in this study come from library delivered with OPEUS tool
- Train data: Reg160
- Track profile: Measured data (Duration: 96 min / Distance: 105 km)
- Season mode: Winter
- Topology: Diesel electric

1 simulation done





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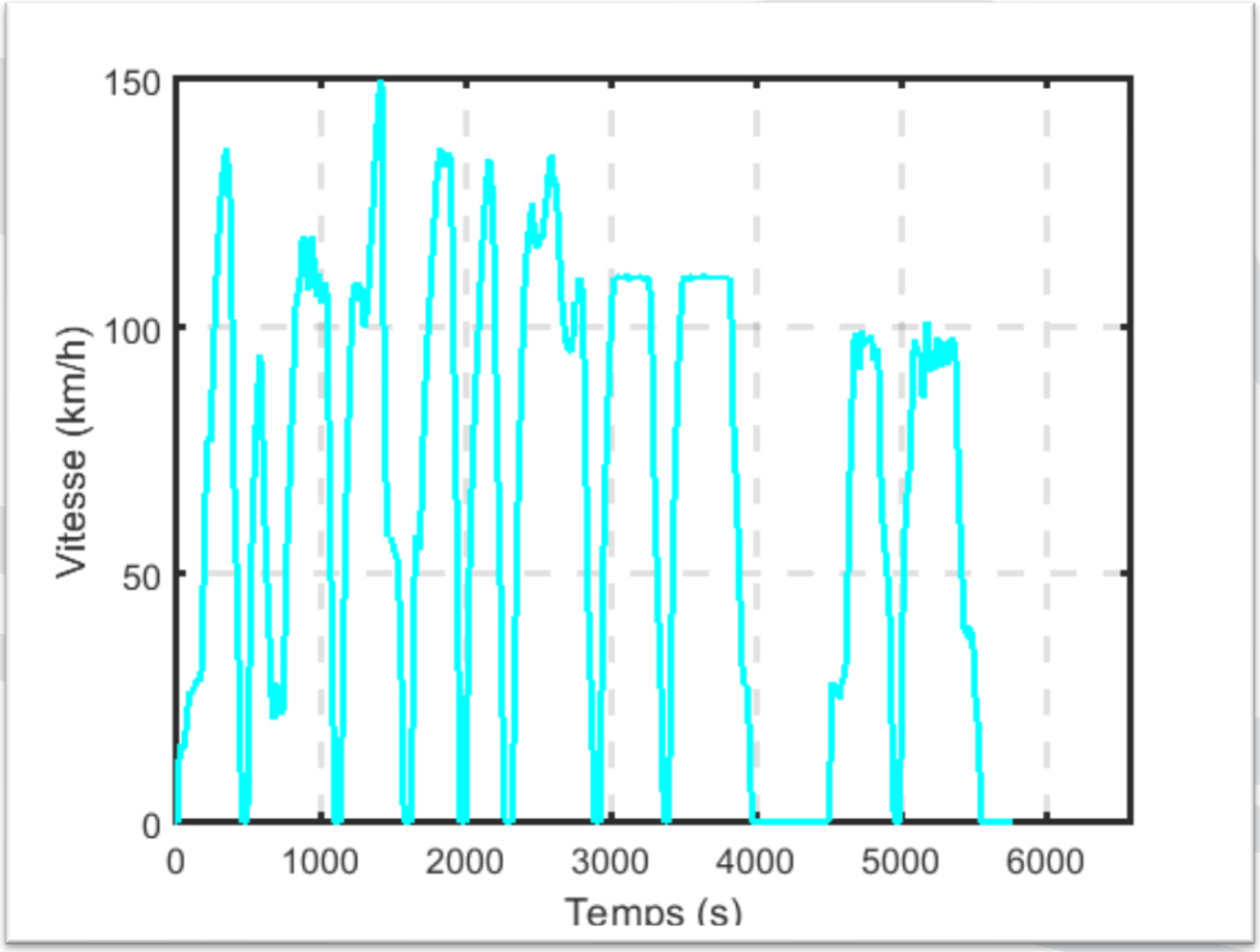
Study cases and simulations done : Simulation tool validation



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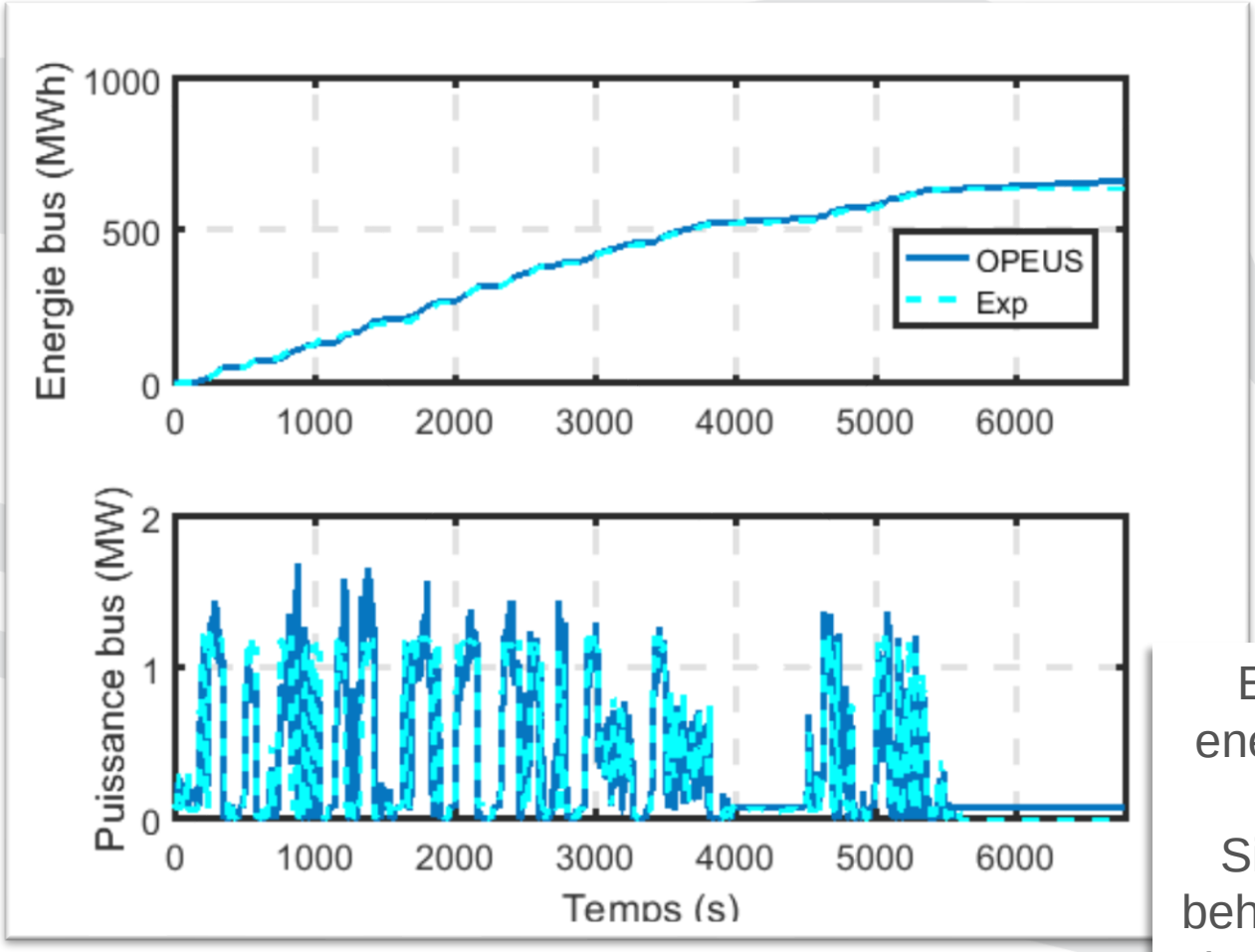
Study cases and simulations done : Simulation tool validation



Error calculating energy consumption by 1%.
Similar bus power behaviors. Up to 30% instantaneous error

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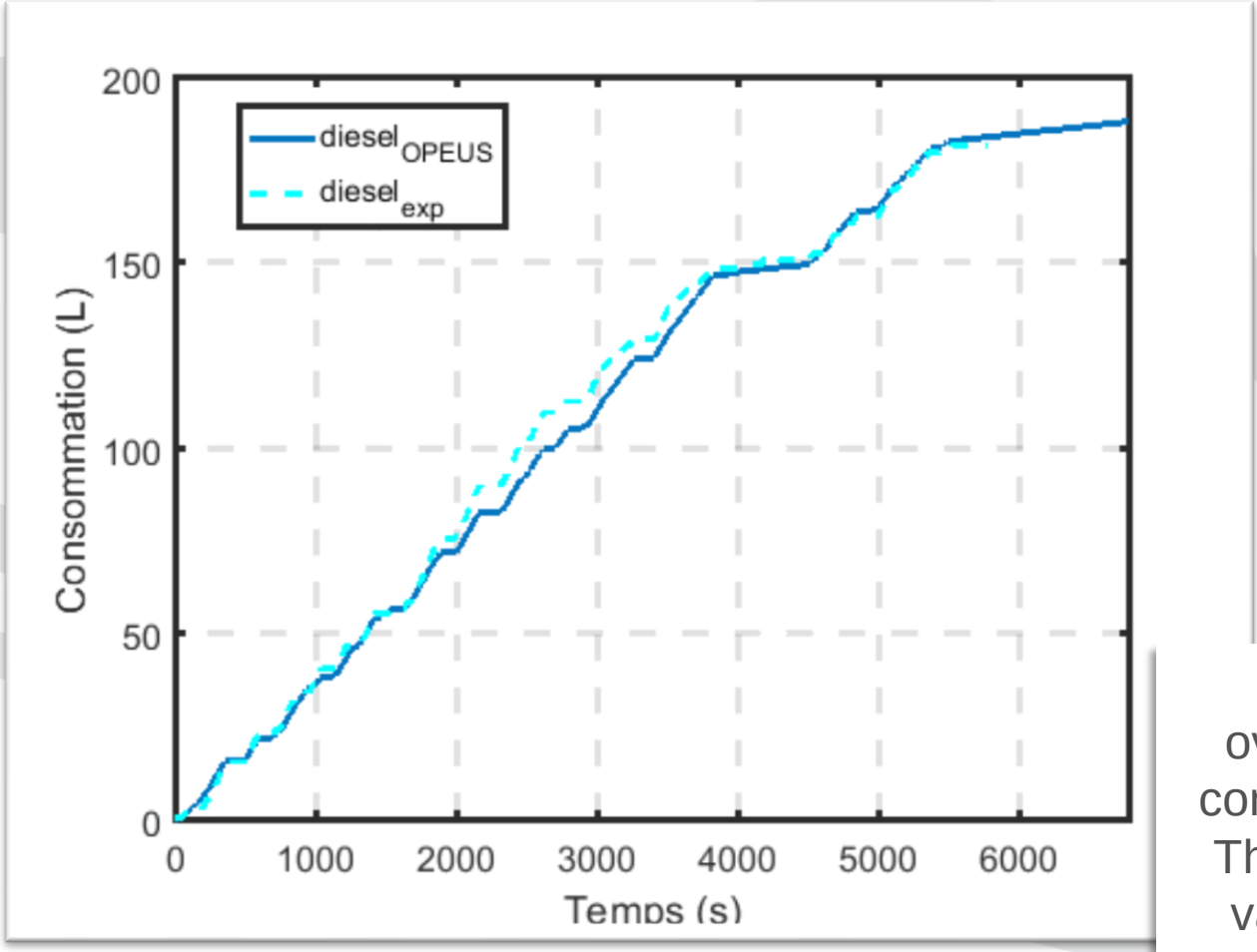
Study cases and simulations done : Simulation tool validation



The simulation overestimates the consumption by 1%. The OPEUS tool is validated from an energy point of view.

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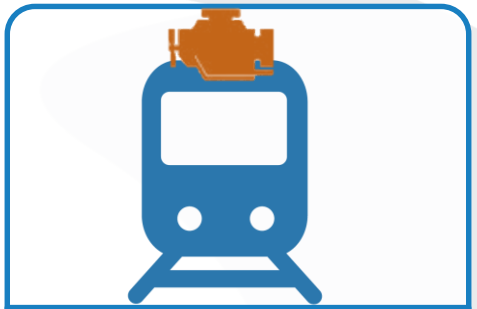
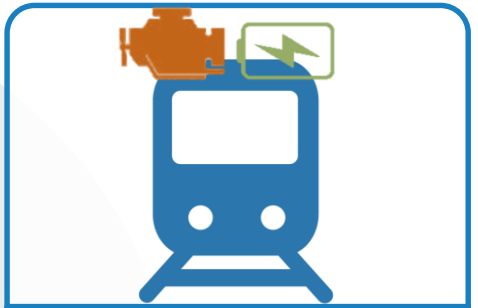
Study cases and simulations done : Which consumption for one track

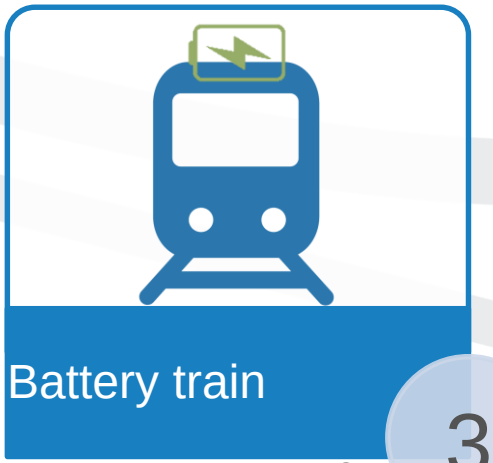
Simulation context:

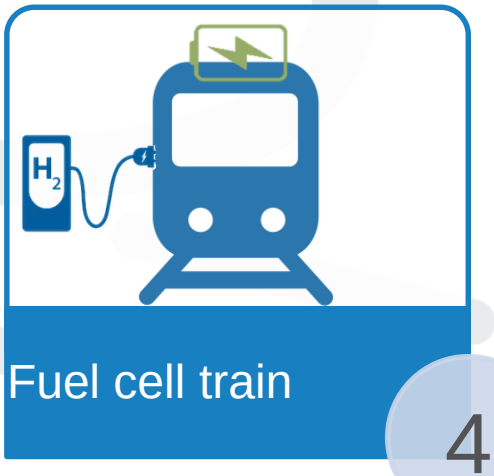
- all data used in this study come from library delivered with OPEUS tool
- Train data: Reg160
- Track profile: Estimated
- Season mode: Winter
- Topology: Diesel electric

4 simulations done in OPEUS tool









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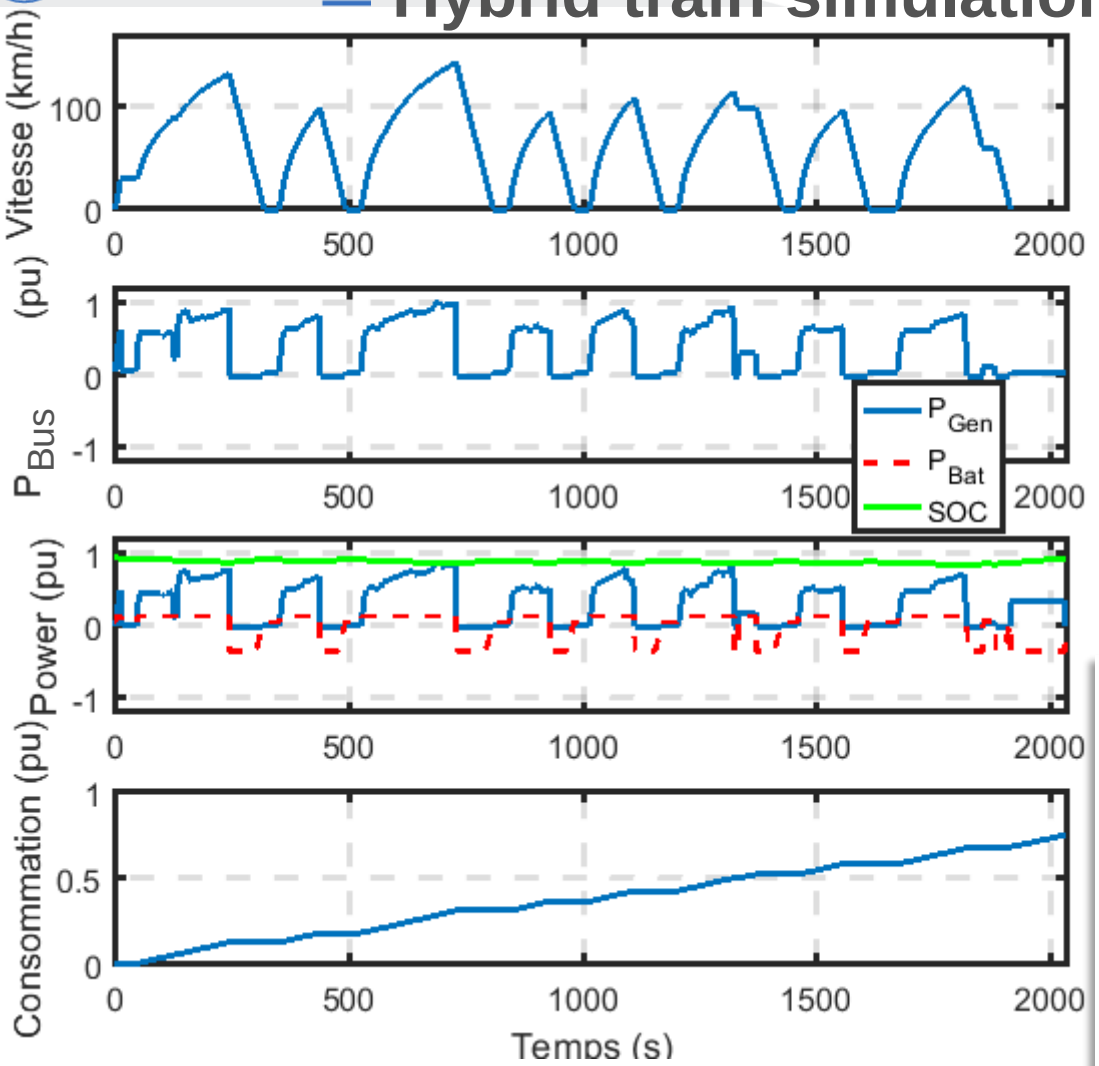
Study cases and simulations done : Hybrid train simulation with OPEUS



Hybridization with batteries allow to : Recover part of braking energy and Reduce the fuel consumption by 20 % on this driving cycle.

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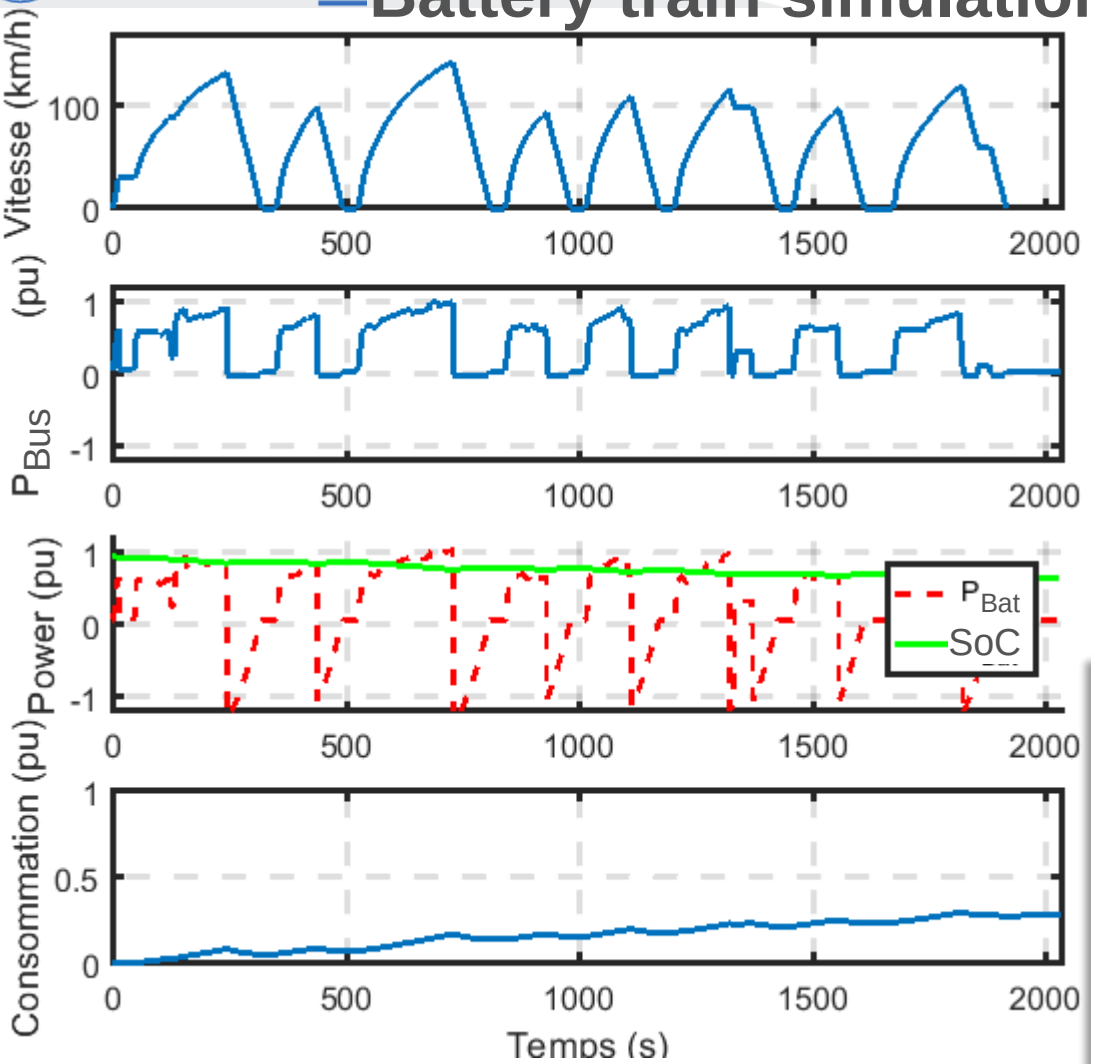
Study cases and simulations done : Battery train simulation with OPEUS



Use a battery allow to Recover a large part of braking energy Reduce the energy consumption by 70 % on this driving cycle.

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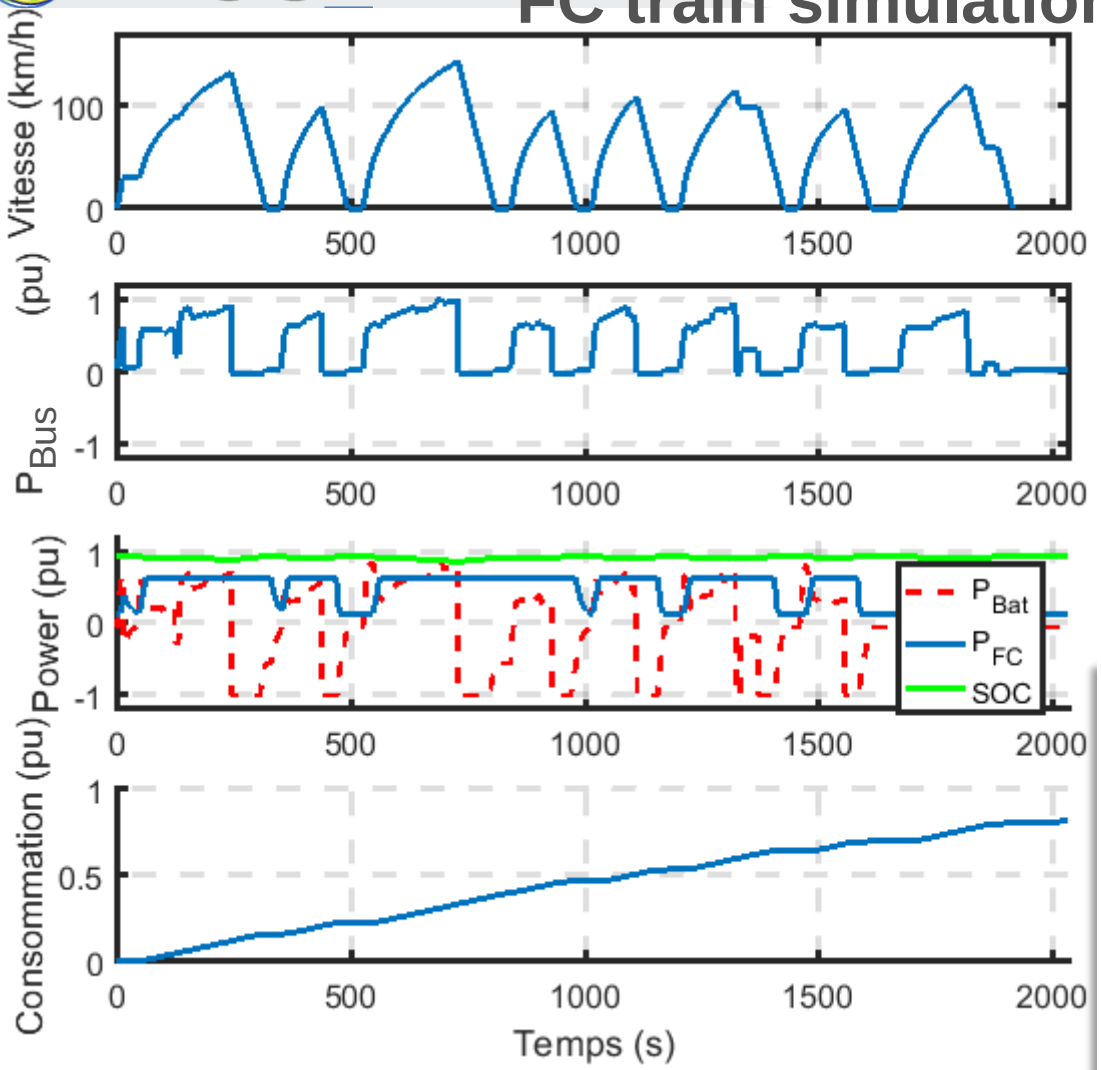
Study cases and simulations done : FC train simulation with OPEUS



Use FC – bat. allow to
- Recover a part of braking energy
- Reduce the energy consumption by 18 % on this driving cycle.

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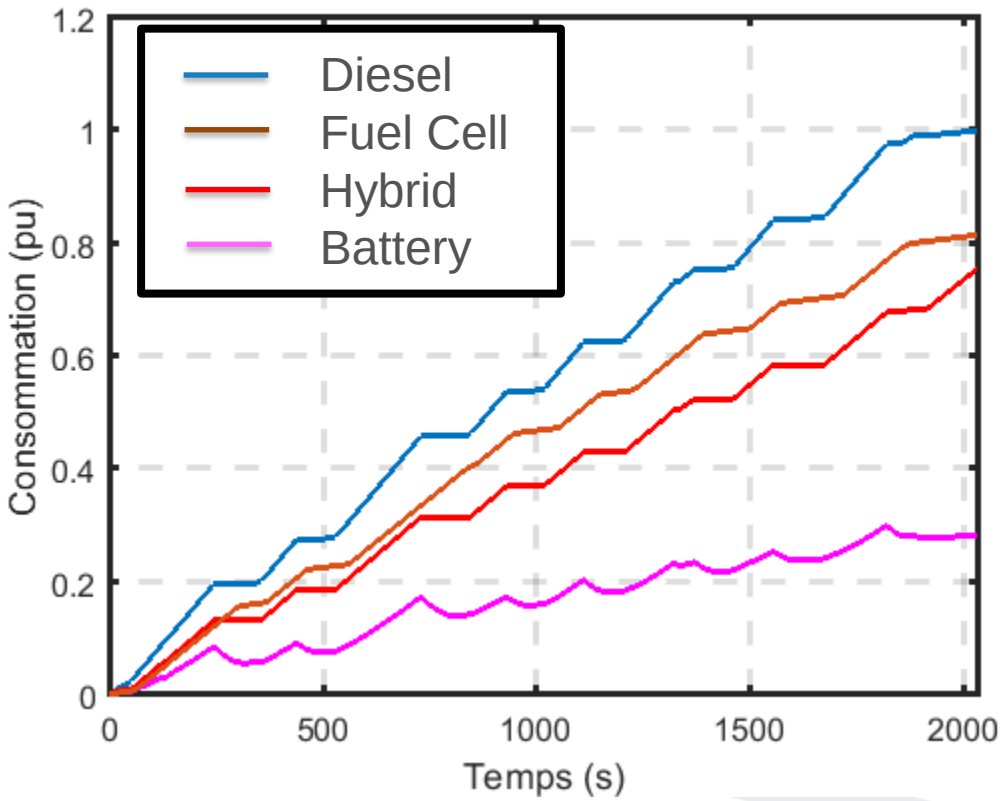
Study cases and simulations done :

To sum up



1

0,82

0,76

0,28

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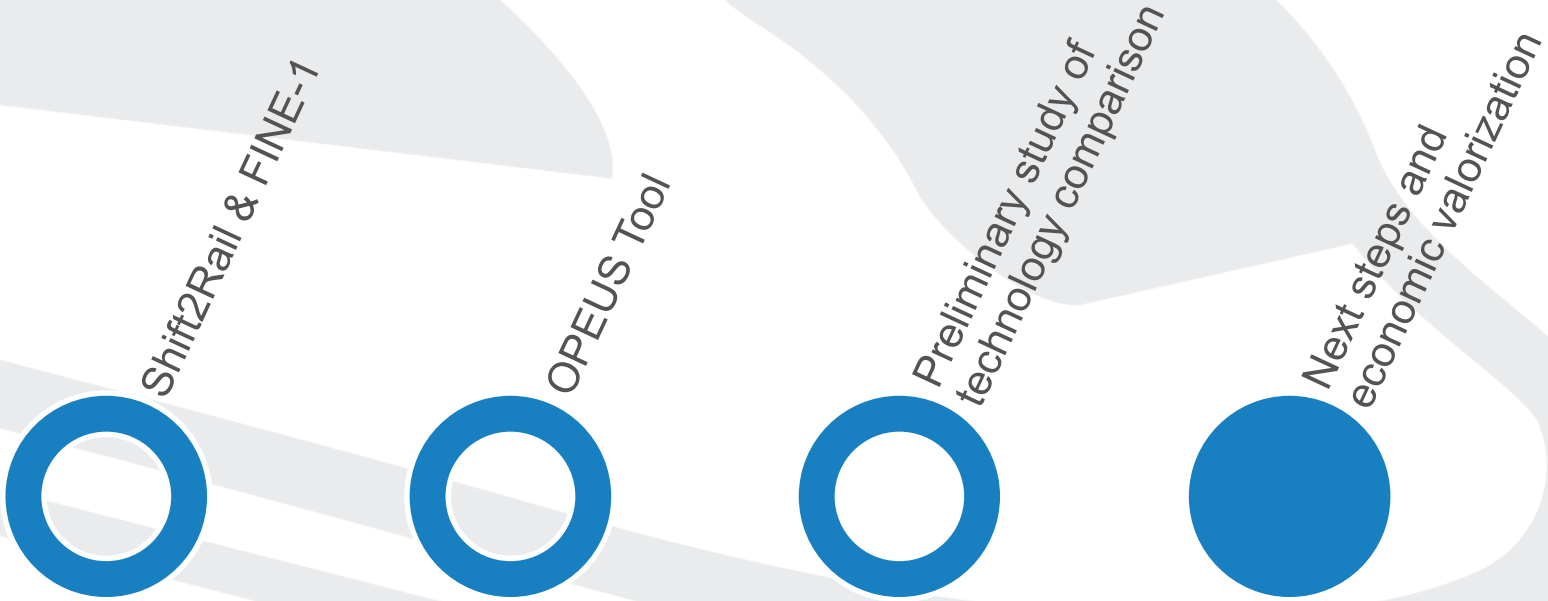

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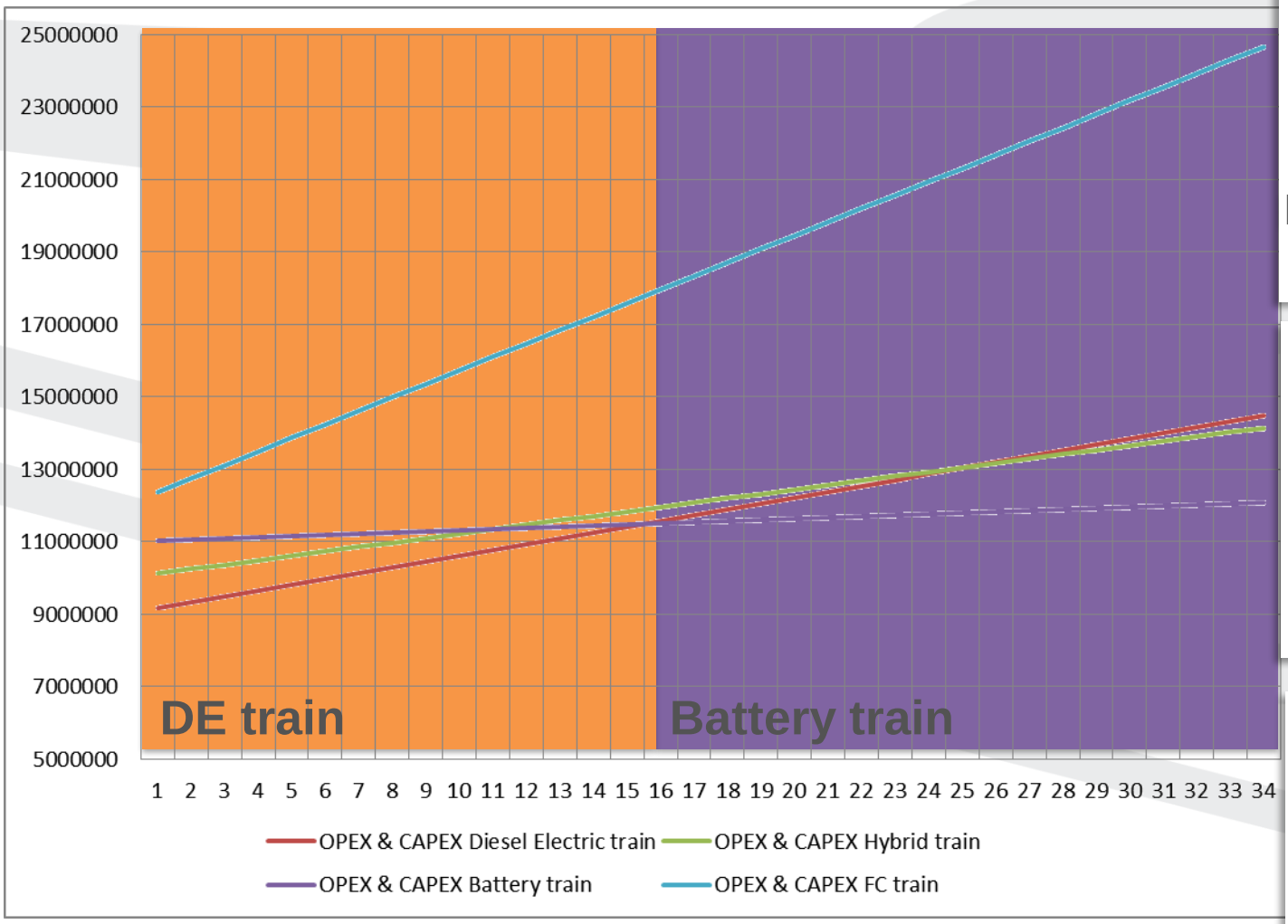
Next steps and economic valorization

Just with energy and train price



Assumption :
6 trips a days over the years
Average train price and combustible price
Batteries replacements are not taken into account

The diesel electric train seems to be the most relevant one during the first years.
At year 15 the battery train is more relevant.

What about infrastructure cost?

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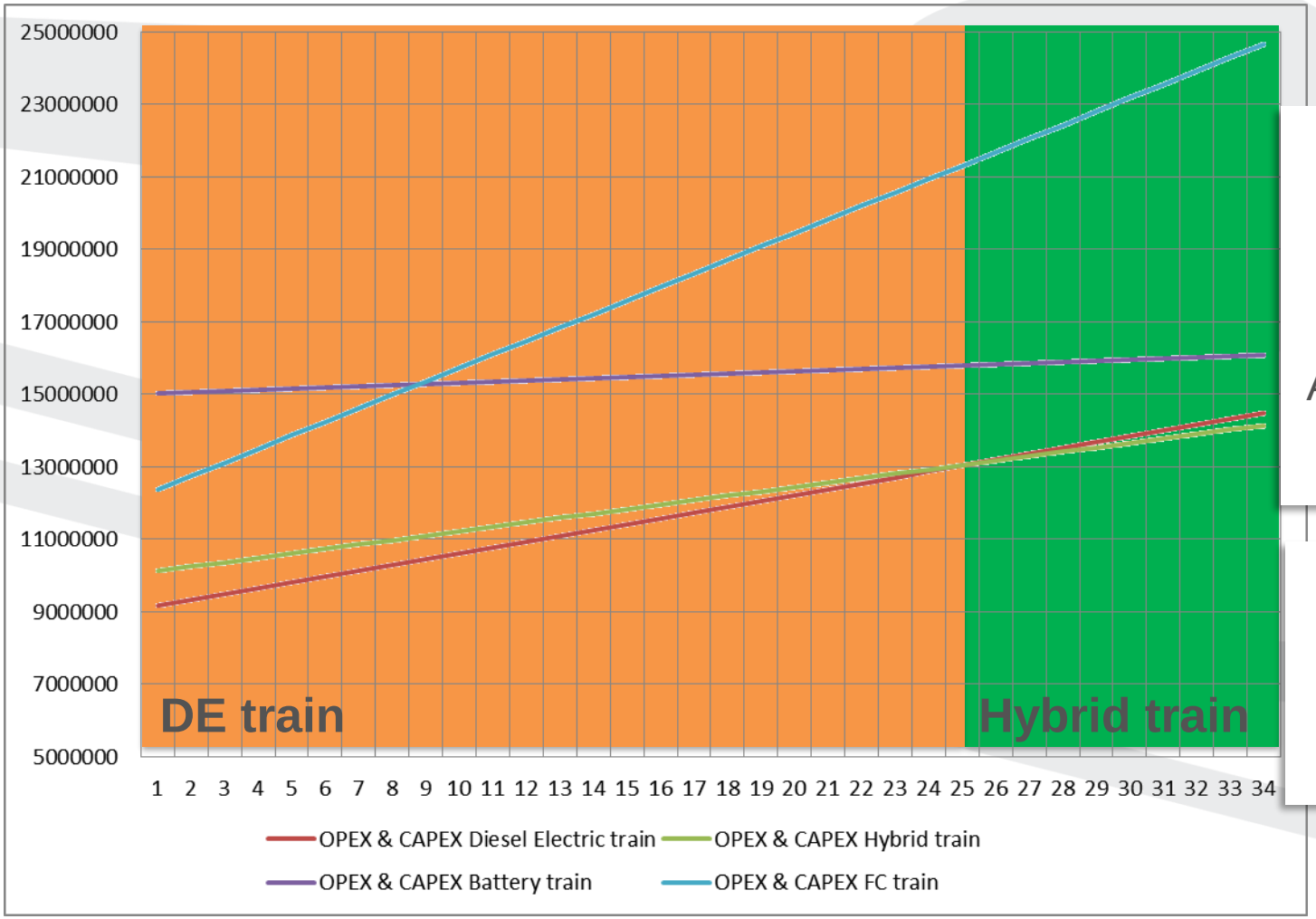
Next steps and economic valorization
Other parameters: infrastructure



The diesel electric train seems to be the most relevant one during the first years.
At year 25 the Hybrid train is more relevant.

Can energy be the lonely criteria to be taken into account?

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Next steps and economic valorization

Conclusion

There are plenty of other parameters that have to be taken into account such as:

- Are the maintenance cost is modifying?
- Are there any will from region or national government?
- Is the infrastructure suitable? Investment needs?
- Is the innovative architecture can suit actual exploitation planning? (eg. Charging time)
- Can we add other services with these trains? (Emergency supply, reduction of peak power, smartgrid…)
- …

A systemic approach has to be used in the deployment of a new technology!

Positioning of OPEUS FINE-1 Simulation tool :

- OPEUS tool should not be placed in the first step to choose a new architecture. This tool is suitable to define the energetic benefice and usages of new energetic component (eg. Number of cycle) of architecture but a more in-depth study taking into account government will, exploitation and infrastructure aspect has to be perform.

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More details, deliverables and OPEUS tools available at OPEUS-project.eu and FINE-1 website

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