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Europe's Rail

Development of energy assessment methodology and simulation tool in Shift2Rail projects FINE1 and OPEUS

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[1]German Aerospace Center (DLR)
[2]University of Rostock, Chair of Mechatronics, Rostock

FINE2

This project has received funding from Shift2Rail Joint Undertaking (JU) under grant agreement No 881791. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Shift2Rail JU members other than the Union.

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1. Overview: FINE1 and OPEUS
2. Development of Energy Simulation Tool
3. Energy Baseline
4. Energy KPI Evaluation
5. Conclusion

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FINE1 - *Future Improvements on Noise and Energy*

FINE1 Main facts:

- 9 partners from 5 countries
- 38 months runtime (09/2016 – 10/2019)
- CCA for noise and energy
- Coordinator: Bombardier Transportation

FINE1 high level objectives related to energy:

- **Assess energy demand and support the quantification of energy improvements of new technologies with a standardized approach**

FINE1 was supported by the complementary projects:

- OPEUS for Energy (Coordinator: University of Newcastle)
- DESTINATE for Noise (Coordinator: TU Berlin)

ALSTOM
BOMBARDIER
the evolution of mobility
CAF
SIEMENS
Talgo
DB
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TRAFIKVERKET
SWEDISH TRANSPORT ADMINISTRATION
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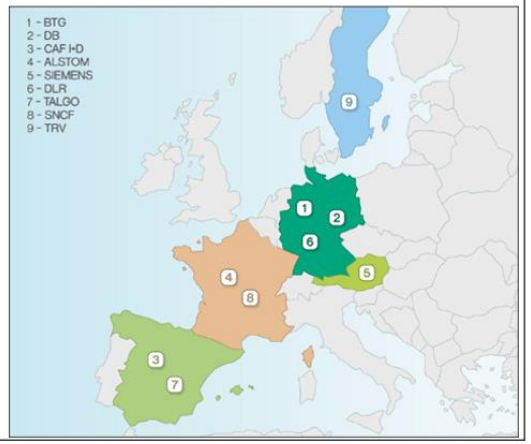
German Aerospace Center



OPEUS
Newcastle University
Universität Rostock
UITP ADVANCING PUBLIC TRANSPORT
uic
saft
STADLER

FINE2

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FINE-1 Main Objectives (related to energy)

- Develop and implement **energy calculation methodology** to quantify S2R energy savings
- Develop **energy baseline** as a reference for the analysis of energy savings of new S2R technologies.
- **Define operational scenarios** for the traffic segments high speed, regional, urban and freight traffic
- Evaluate and document S2R energy savings (➔ **Energy KPI**)

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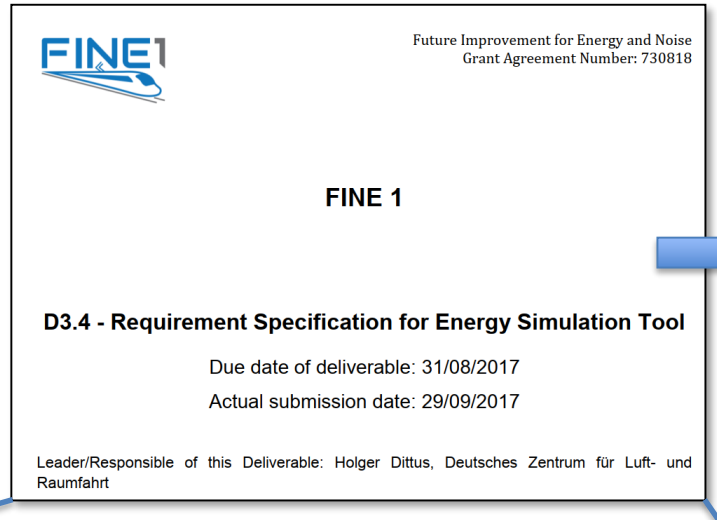
OPEUS Energy Simulation Tool: Development Process



Future Improvement for Energy and Noise
Grant Agreement Number: 730818

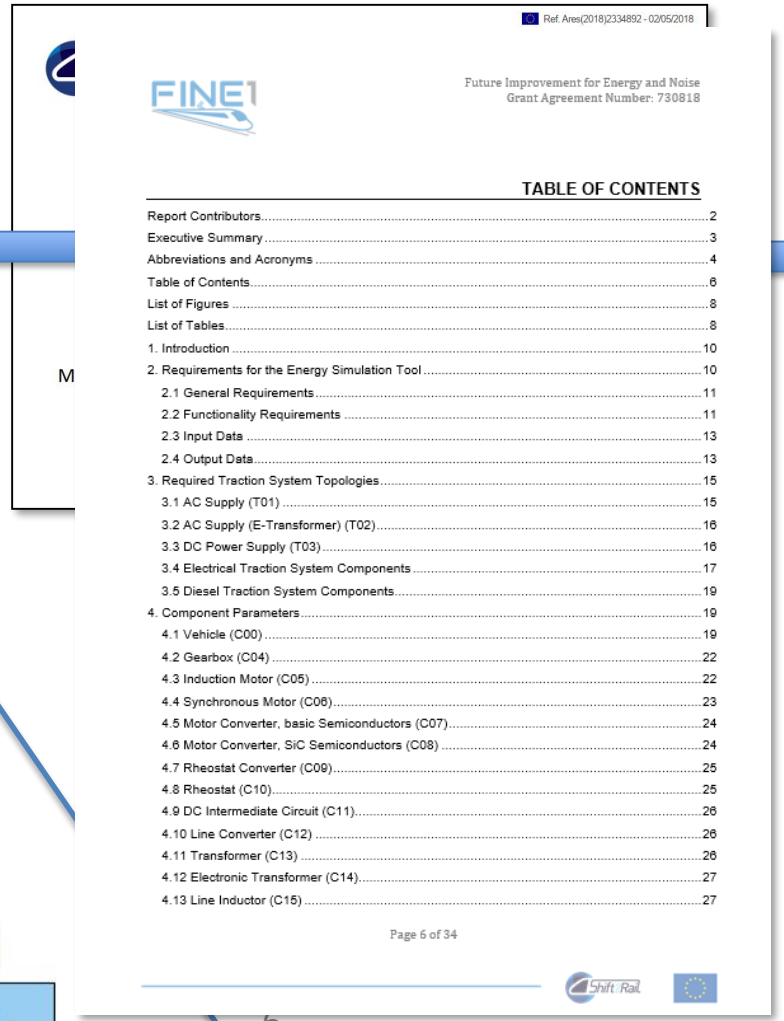
FINE 1

D3.4 - Requirement Specification for Energy Simulation Tool

Due date of deliverable: 31/08/2017

Actual submission date: 29/09/2017

Leader/Responsible of this Deliverable: Holger Dittus, Deutsches Zentrum für Luft- und Raumfahrt



Ref. Ares(2018)2334892 - 02/05/2018

Future Improvement for Energy and Noise
Grant Agreement Number: 730818

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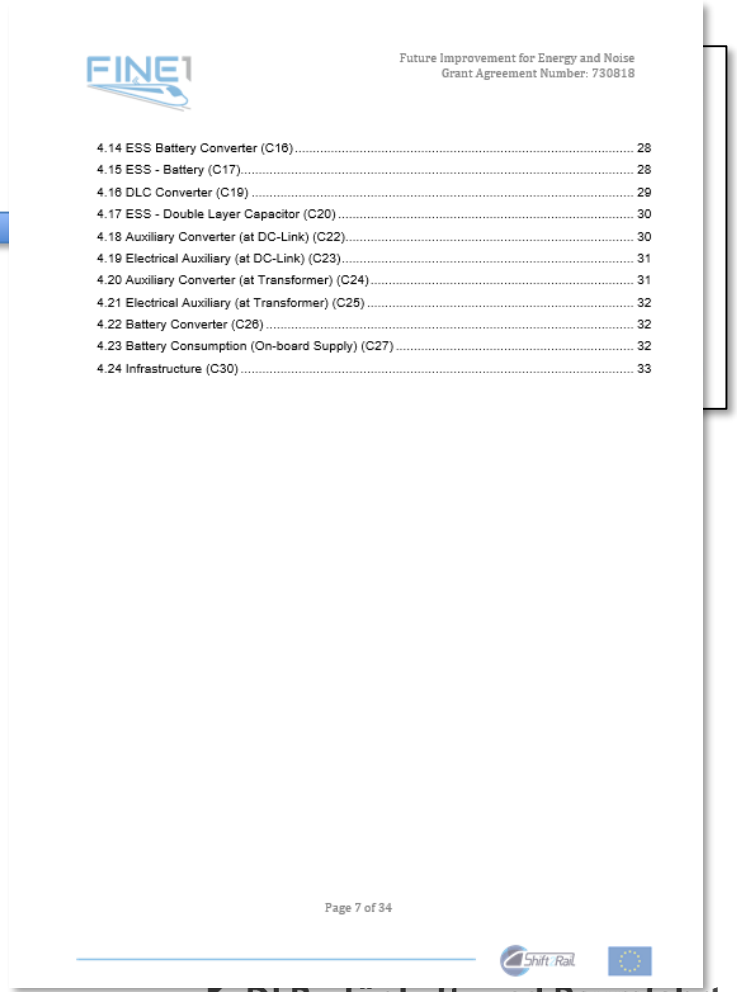

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- **Calculation of the energy usage** of railway vehicles over defined duty cycles
- Calculation of **power requirements** and prediction of **component performance** in the **time-domain**
- **Single Train Simulation** (STS)-based concept
- **Interface of STS**: Wheel-rail contact to AC or DC catenary
- **Integrated** trajectory planning and powertrain simulation
- **Re-configurability** for various powertrain architectures
- Low simulation running times for quick **sensitivity analysis**

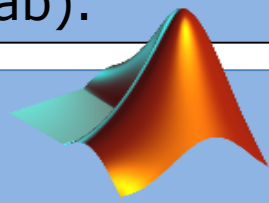
OPEUS Tool: General Set Up

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 simulate;
- Easy processing of the output data.

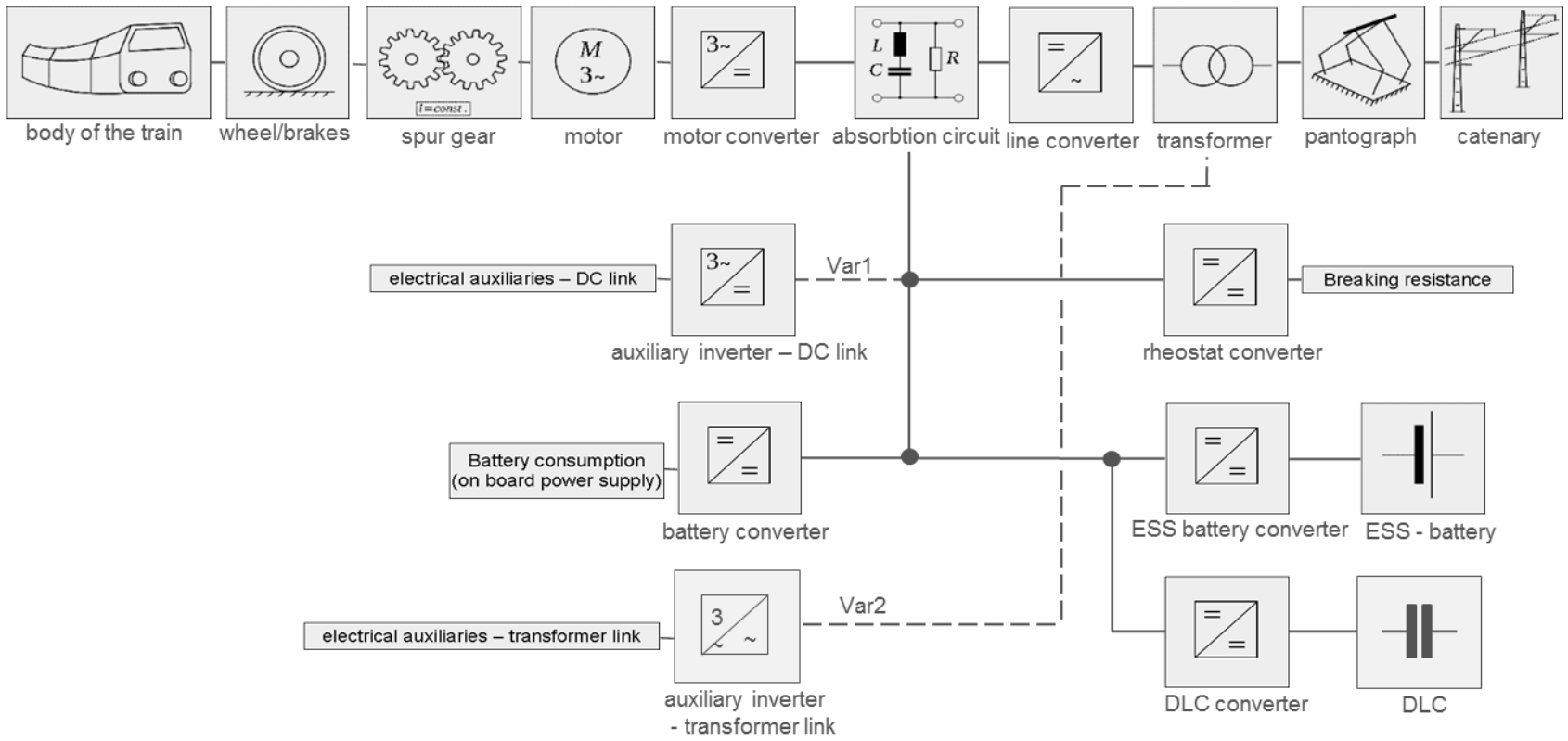
Track data and **train data** is organized in Excel libraries:
- Clear handling of data;
- Easy possibility to extend the library with own data.

Simulation structure is implemented in **Matlab and Simulink:**
- Common software for engineering tasks;
- Based on CleanER-D tool (also implemented in Matlab).

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



OPEUS Tool: Traction Topology T01 – AC Traction



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OPEUS Tool: 2-Step Validation and Approval

1) Functional design requirements:
checked against FINE1 deliverable *D3.4 Requirement Specification for Energy Simulation Tool*

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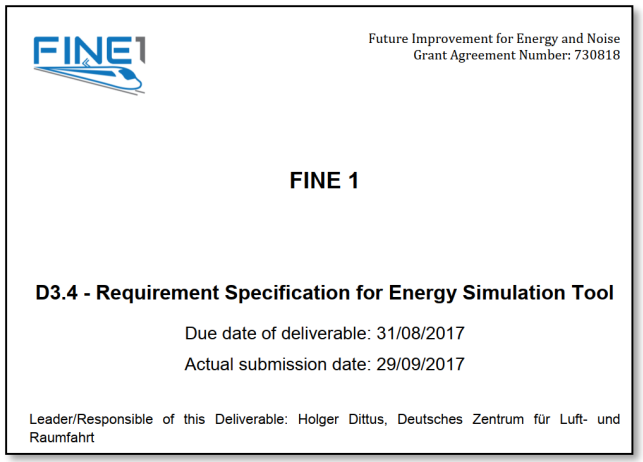
German Aerospace Center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FINE 1

D3.4 - Requirement Specification for Energy Simulation Tool

Due date of deliverable: 31/08/2017

Actual submission date: 29/09/2017

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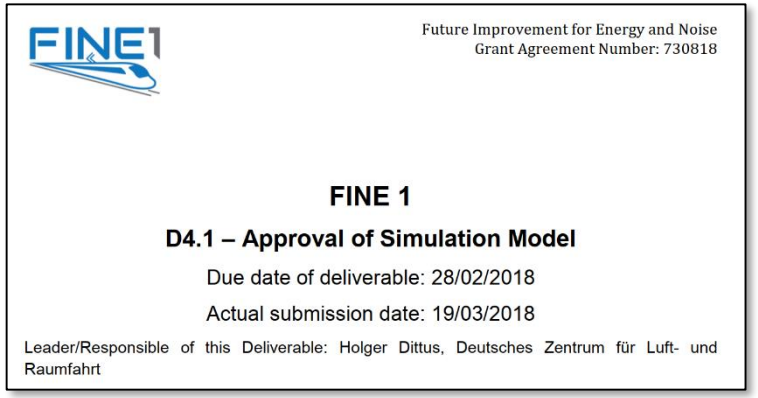
2) calculation results:
checked via simulation of pre-defined train configurations and comparison of the results against established tools and measurements of the individual project partners:

SIEMENS CAF SNCF DB STADLER

RESULT:


FINE1

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FINE 1

D4.1 – Approval of Simulation Model

Due date of deliverable: 28/02/2018

Actual submission date: 19/03/2018

Leader/Responsible of this Deliverable: Holger Dittus, Deutsches Zentrum für Luft- und Raumfahrt

FINE2

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1. Overview: FINE1 and OPEUS
2. Development of Energy Simulation Tool
3. Energy Baseline
4. Energy KPI Evaluation
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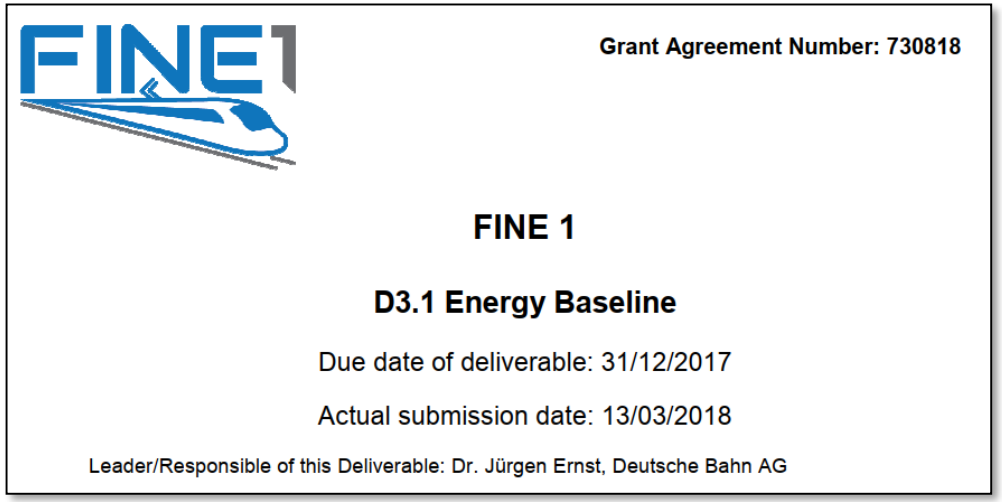
Energy Baseline

The energy baseline is used as state-of-the-art reference to quantify energy savings achieved in S2R. It consists of:

- **Service profiles** for high speed, regional, urban and freight including line parameters such as timetables, gradients, speed limits, etc. (see EN50591)
- Definition of **reference simulation data** consisting of **vehicle, line and traction component parameters**
- Energy Baseline data is available for SPDs:
  - HST300, HST250
  - Intercity
  - Regional 160, Regional 140
  - Suburban (Metro, Tram)
  - Freight


FINE1

Grant Agreement Number: 730818

FINE 1

D3.1 Energy Baseline

Due date of deliverable: 31/12/2017

Actual submission date: 13/03/2018

Leader/Responsible of this Deliverable: Dr. Jürgen Ernst, Deutsche Bahn AG

FINE1 Energy Baseline: Service Profiles

Main Service Category	Sub Service Category	Max. profile speed [km/h]	Average Station Distance [km]	Station standstill time [min]	Route length [km]	Operational travel time [hh:mm:ss]	Source of profile
High Speed	High Speed 300	300	150	3	300	01:47:00	prEN 50591
	High Speed 250	250	100	3	300	02:03:00	High speed from prEN 50591, but limited to 250km/h, 2 additional stops
	Intercity	200	28	2 – 3	250	02:39:00	prEN 50591
Regional	Regional 160	160	15	1 – 2	250	02:57:00	Intercity from prEN 50591, but limited to 160km/h 7 additional stops
	Regional 140	140	5	1 – 2	70	01:09:00	prEN 50591
Urban	Suburban	120	3,6	1	40	00:43:00	prEN 50591
	Metro	80	1,0	0,5	21,5	00:41:00	based on EU-project OSIRIS [7]
	Tram	50	0,5	0,5	10,7	00:29:40	based on EU-project OSIRIS [7] incl. UITP suggestions
Freight	Freight Mainline	100	50	1 – 5	300	04:17:15	prEN 50591
	Freight Shunting	42	-	-	37	04:32:00	CleanER-D [8] Pmax 870 kW

SPD Energy Baseline: >200 technical Parameters

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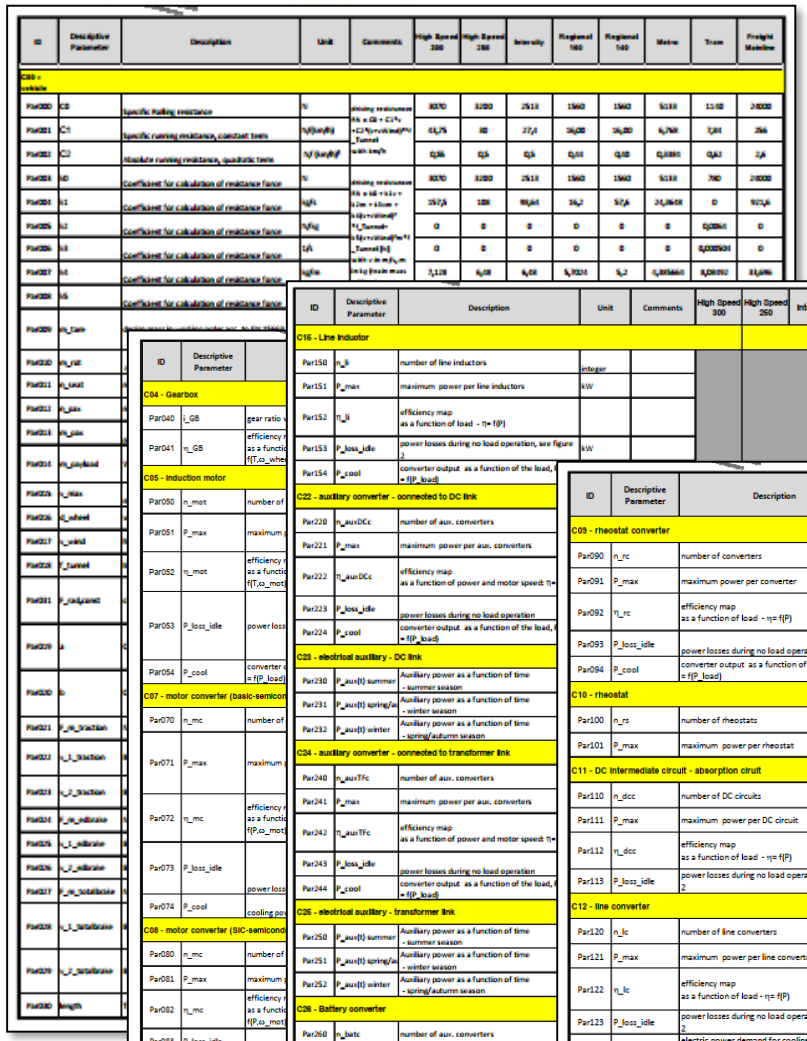

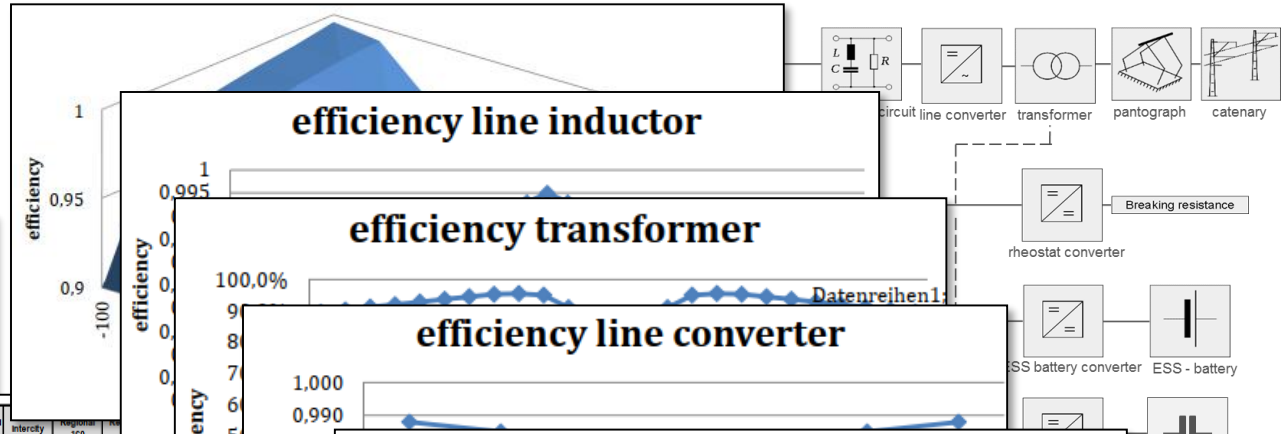

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1. Overview: FINE1 and OPEUS
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4. Energy KPI Evaluation
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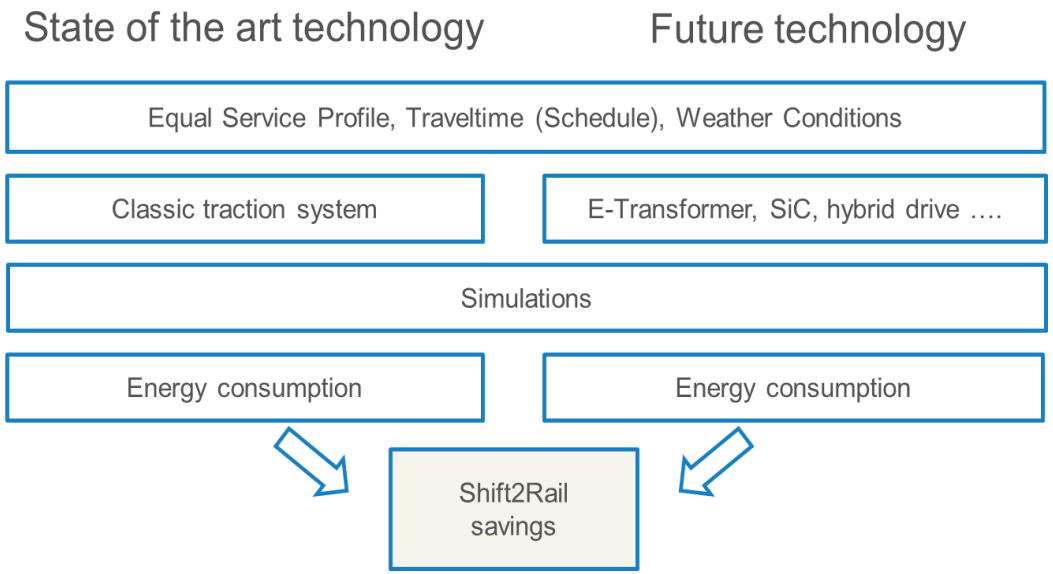
Evaluation of Energy KPIs



➔ **Energy KPI quantifies relative savings** of the TD innovations compared to the energy baseline

➔ The **Energy KPI summarizes overall savings per SPD**, assuming technical improvements reported by the TDs are applied

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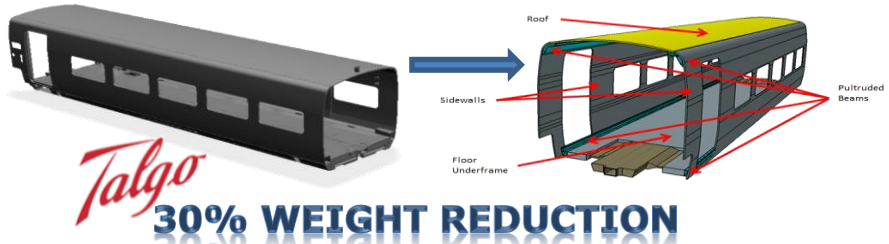
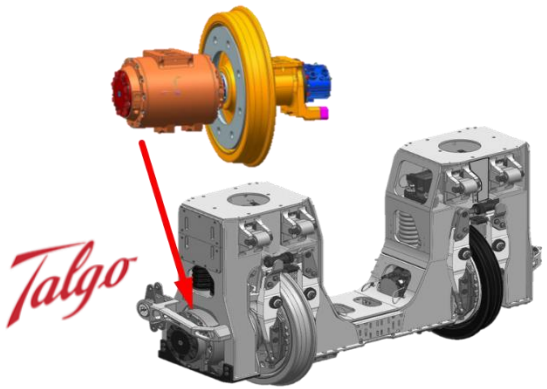
Data Gathering: Improved technologies from S2R-TDs

TD1.5: Mass reduction by new braking systems

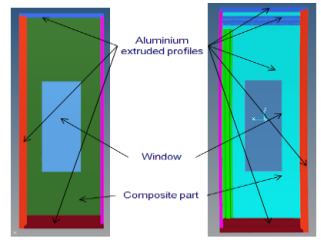


TD1.3: Carbody mass reduction

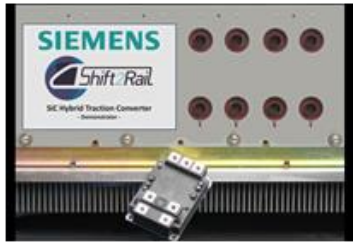


TD1.1: direct PM motor-wheel-system ➔ improved gearbox efficiency

TD3.9: Smart power supply avoids separation sections



TD1.6: Mass reduction doors



TD1.1: SiC converters

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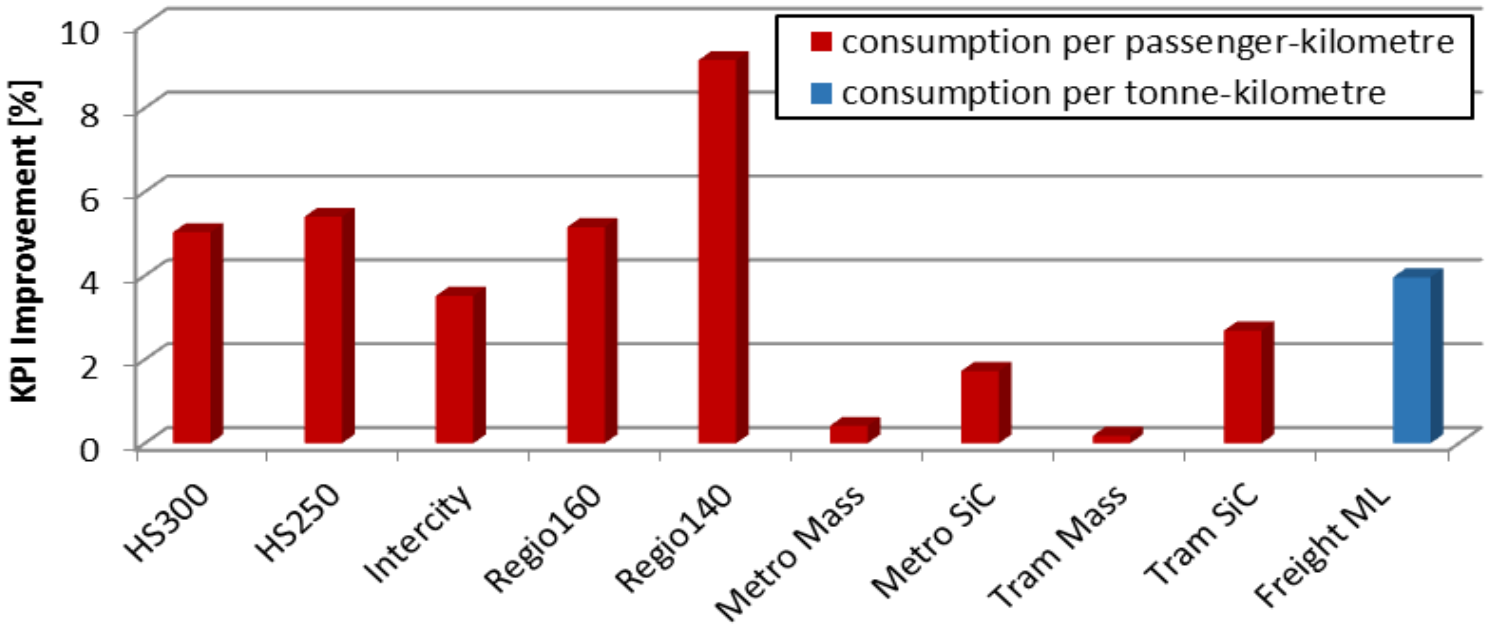
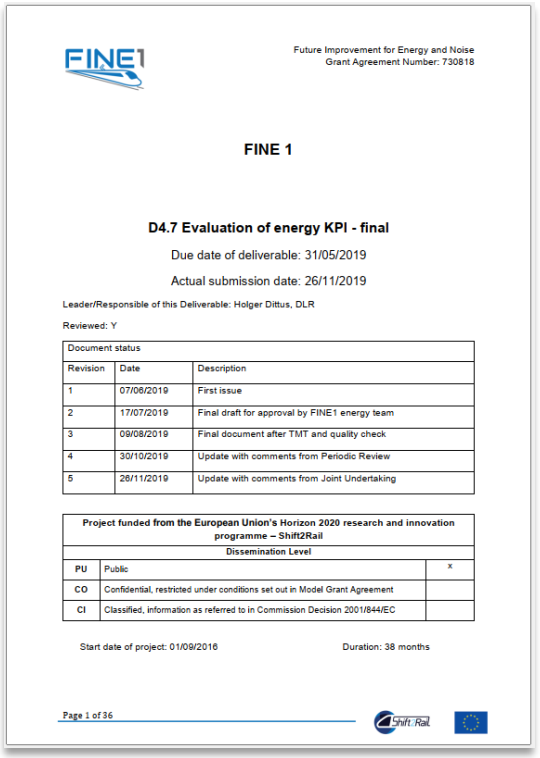
Mapping of Technologies and SPDs

SPD	Mass reduction carbody	Mass reduction doors	Mass reduction brakes	Improved line converter (SiC)	Improved motor converter (SiC)	Direct drive with improved gearbox
HST300	X	X	X	X	X	X
HST250	X	X	X	X	X	X
Intercity		X	X	X	X	
Regional 160		X	X	X	X	
Regional 140		X	X	X	X	
Metro*		X	X	n.a.	X*	
Tram*		X	X	n.a.	X*	
Freight				X	X	

*no integrated calculation possible

FINE-1: Energy KPI results





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Grant Agreement Number: 730818

FINE 1

D4.7 Evaluation of energy KPI - final

Due date of deliverable: 31/05/2019

Actual submission date: 26/11/2019

Leader/Responsible of this Deliverable: Holger Dittus, DLR

Reviewed: Y

Document status		
Revision	Date	Description
1	07/06/2019	First issue
2	17/07/2019	Final draft for approval by FINE1 energy team
3	09/08/2019	Final document after TMT and quality check
4	30/10/2019	Update with comments from Periodic Review
5	26/11/2019	Update with comments from Joint Undertaking

Project funded from the European Union's Horizon 2020 research and innovation programme – Shift2Rail		
Dissemination Level		
PU	Public	x
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

Start date of project: 01/09/2016 Duration: 38 months

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➔ Improvements of energy KPI between 3.5% (Intercity) and 9.1% (Regional140)

OPEUS Tool in FINE2 WP3 – Update Energy KPI (pending)

In FINE2 WP3…

- Data gathering process of FINE1 with TDs is repeated
- OPEUS tool is applied to update the energy KPIs

➔ Update of energy KPI is available with D3.1 Evaluation of Energy KPI (Now?)

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Evaluation of Energy KPI	12 - SNCF	Report	Public	34

Description of deliverables

D3.1 : Evaluation of Energy KPI [34]
The result of the work carried out in task T3.1 including S2R energy KPI is documented.

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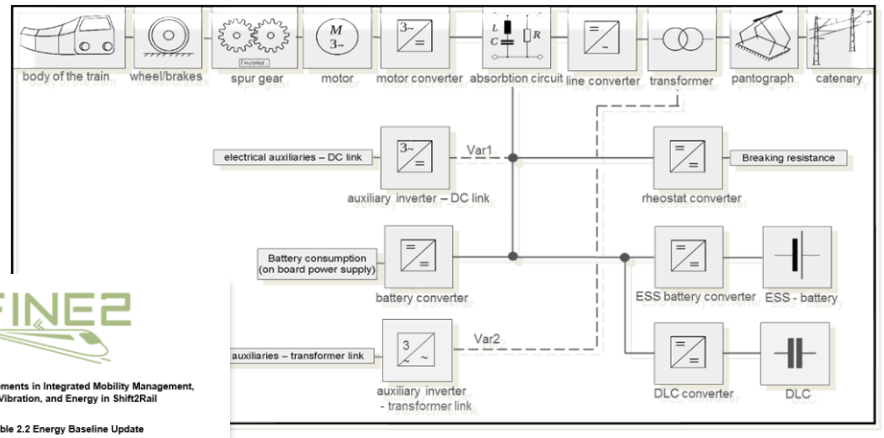
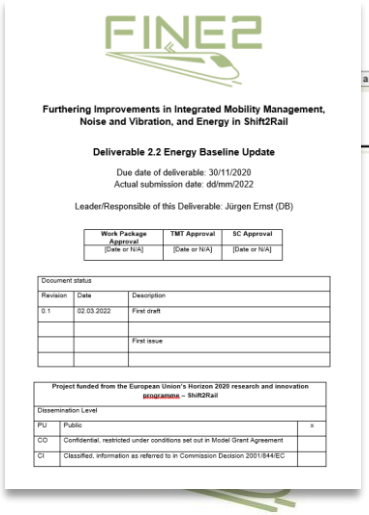
OPEUS Tool in FINE2 - WP4

Combined Traction and HVAC Simulations for BEMU

OPEUS Simulation Model, New BEMU Baseline




FINE2

Furthering Improvements in Integrated Mobility Management, Noise and Vibration, and Energy in Shift2Rail

Deliverable 2.2 Energy Baseline Update

Due date of deliverable: 30/11/2020
Actual submission date: dd/mm/2022

Leader/Responsible of this Deliverable: Jürgen Ernst (DB)

Work Package Approval	TMT Approval	SC Approval
[Date or N/A]	[Date or N/A]	[Date or N/A]

Document status

Revision	Date	Description
0.1	02.03.2022	First draft
		First issue

Project funded from the European Union's Horizon 2020 research and innovation programme – Shift2Rail

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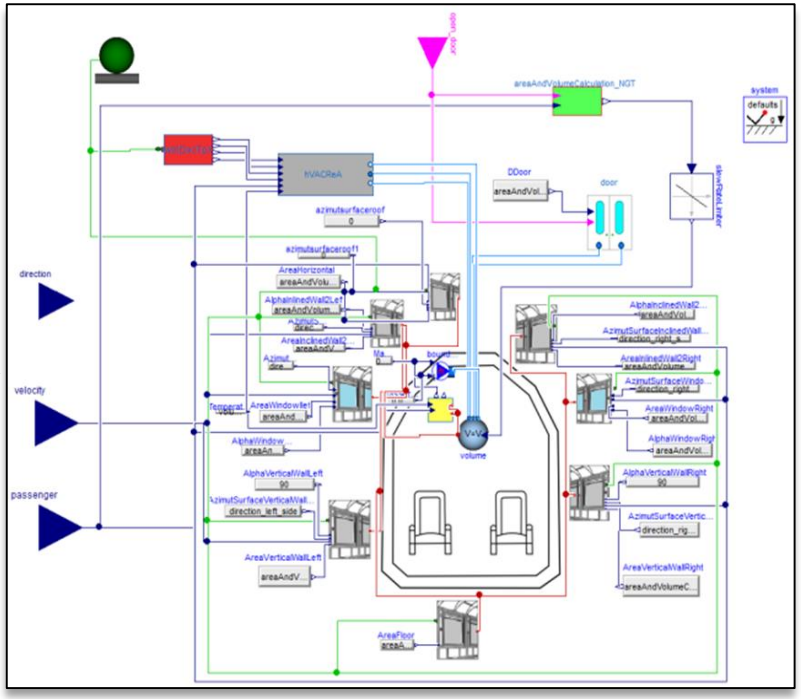
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

- dynamic HVAC power demand for 13 OP defined in EN50591

- OPEUS BEMU speed profile
- BEMU energy baseline carbody parameters

DLR Thermal Carbody Model



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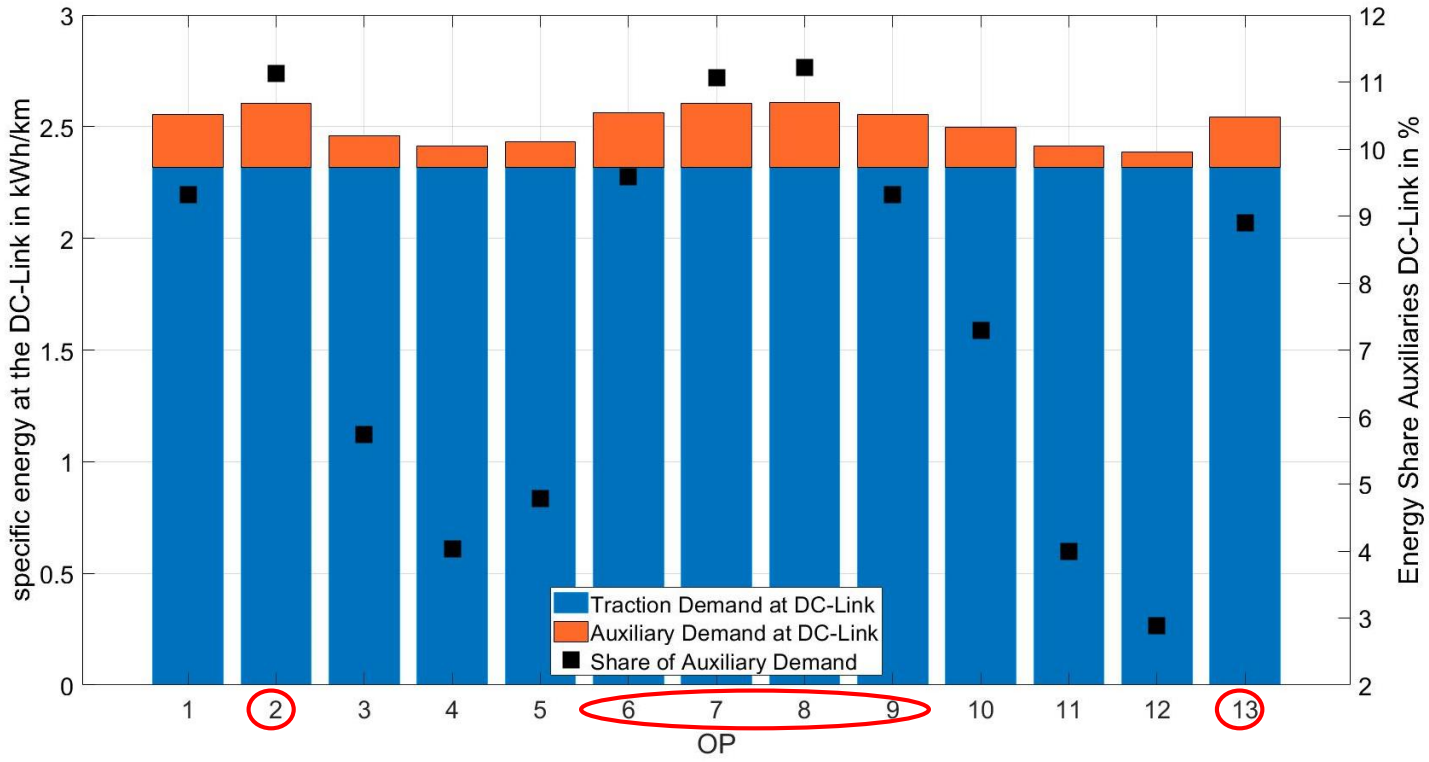
D4.3 Study on potential HVAC energy savings

For BEMU energy baseline parameters:

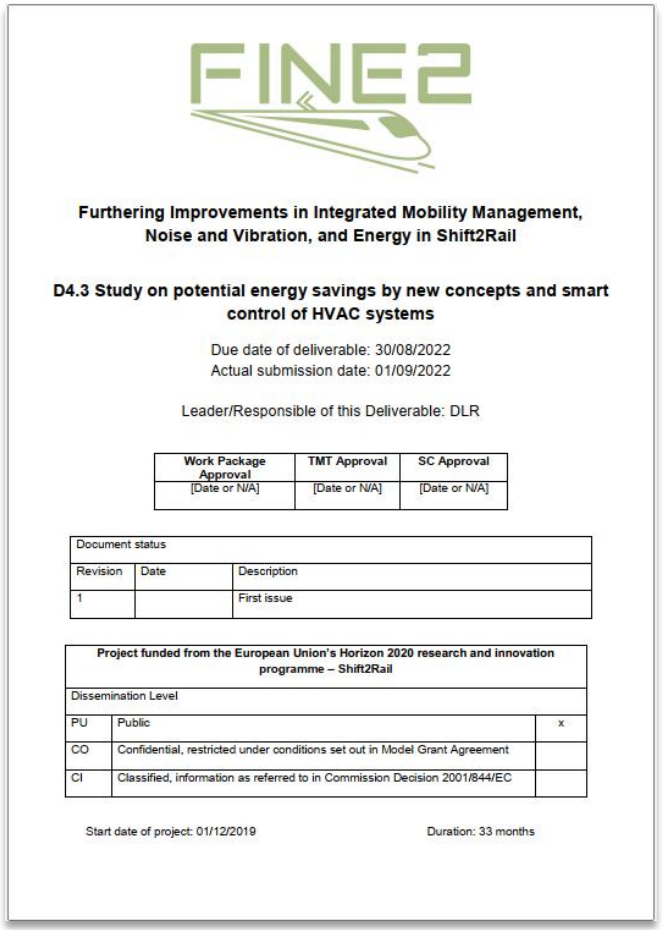
Comparison of traction and HVAC energy demand for 13 EN50591 OP

➔ Identification of high HVAC demand

Operation point	Temperature T_{amb} in °C	Humidity $H_{r,amb}$ in %	Sun radiation in W/m²	Passenger load in %
1	-10	90	0	0
2	0	90	0	100
3	10	90	0	50
4	15	90	0	50
5	22	80	0	100
6	28	70	600	100
7	35	50	700	100
8	-20	90	0	0
9	-10	90	0	0
10	0	90	0	0
11	15	80	0	0
12	22	80	0	0
13	35	50	700	0



D4.3 Study on potential HVAC energy savings



FINE2

Furthering Improvements in Integrated Mobility Management, Noise and Vibration, and Energy in Shift2Rail

D4.3 Study on potential energy savings by new concepts and smart control of HVAC systems

Due date of deliverable: 30/08/2022
Actual submission date: 01/09/2022

Leader/Responsible of this Deliverable: DLR

Work Package Approval	TMT Approval	SC Approval
[Date or N/A]	[Date or N/A]	[Date or N/A]

Document status		
Revision	Date	Description
1		First issue

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Dissemination Level		
PU	Public	x
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

Start date of project: 01/12/2019 Duration: 33 months

Study methodology:

1. Definition of HVAC energy saving measures
2. Analysis of the impact of these measure on HVAC energy demand and BEMU range

Results:

- Heat pump replacing conventional AC is most promising candidate for energy saving in regional BEMU
- Application of additional heat storage system is effective to reduce energy demand in heating OP.
- Modified passenger compartment temperature control recommended in particular for OP with cooling, low-effort measure
- Reduced heat transfer through the car body by improved insulation has good effect, but high effort.

1. Overview: FINE1 and OPEUS
2. Development of Energy Simulation Tool
3. Energy Baseline
4. Energy KPI Evaluation
5. Conclusion

Conclusion

- FINE1 and OPEUS have designed, implemented and applied an **energy simulation tool for single train runs**
- This OPEUS energy simulation tool has been **approved for energy KPI calculation in S2R** ➔ Very fruitful cooperation between CFM- and OC-Project
- The **state of the art with respect to energy demand** (energy baseline) of railway vehicles in different applications has been defined and documented
- In FINE-1 improvement of the **energy KPIs due to S2R technical solutions** (SiC, Mass reductions) have been assessed ➔ potential **energy savings range between 1% and 9%**
- **In FINE-2** the OPEUS energy simulation tool…
  - is in use to update energy KPI with improved technologies from the TD projects
  - has been used in combination with thermal carbody model to benchmark innovative HVAC measures for BEMU

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Thank you for your attention!

Feel free to ask questions

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