Energy Assessment in Shift2Rail European Rail Research Program

Holger DITTUS\textsuperscript{1}, Henry VÖLKER\textsuperscript{2}, Lukas PRÖHL\textsuperscript{3}, Harald ASCHEMANN\textsuperscript{3}, Stefan HEIBL\textsuperscript{4}, Roberto PALACIN\textsuperscript{5}

\textsuperscript{1}Deutsches Zentrum für Luft- und Raumfahrt e.V., Institut für Fahrzeugkonzepte, Stuttgart, Germany; holger.dittus@dlr.de
\textsuperscript{2}Bombardier Transportation GmbH, Center of Expertise Energy Performance, Hennigsdorf, Germany
\textsuperscript{3}University of Rostock, Chair of Mechatronics, Germany
\textsuperscript{4}DB Systemtechnik GmbH, München, Germany
\textsuperscript{5}Newcastle University, NewRail - Newcastle Centre for Railway Research, United Kingdom

2019-10-30
# Table of Content

1. **Overview: Shift2Rail and FINE1**
2. **FINE1 Energy Baseline**
3. **OPEUS Energy Simulation Tool**
4. **Energy KPI Evaluation**
5. **Conclusion**
Shift2Rail Programme

S2R OBJECTIVES

+50%
INCREASE RELIABILITY & PUNCTUALITY BY 50%

x2
DOUBLE RAILWAY CAPACITY

HALVE LIFE-CYCLE COSTS OF RAILWAY TRANSPORTS

CONTRIBUTE TO REDUCTION OF NEGATIVE EXTERNALITIES, SUCH AS NOISE, VIBRATIONS, EMISSIONS & OTHER ENVIRONMENTAL IMPACTS

CONTRIBUTE TO THE ACHIEVEMENT OF THE SINGLE EUROPEAN RAILWAY AREA

28 MEMBERS

375 PARTICIPANTS INVOLVED FROM 28 COUNTRIES

101 SMEs

103 RESEARCH CENTRES AND UNIVERSITIES

2015 - € 52 M
SHIFT2RAIL INITIATIVE LIGHTHOUSE PROJECTS

2016 - € 168 M
27 PROJECTS

2017 - € 112 M
17 PROJECTS

2018 - € 153 M
19 PROJECTS & 3 TENDERS

2019 - € 152 M
18 TOPICS & 4 TENDERS

ABOUT € 1BLN and A NEW APPROACH TO R&I IN RAILWAY
working together & driving innovation

2019-10-30 Energy Assessment in Shift2Rail
European Rail Research Program

Grant Agreement Number: 730818
FINE1 Main facts:

- 9 partners from 5 countries
- 38 months runtime (09/2016 – 10/2019)
- 3,017 M€ budget
- Coordinator: Bombardier Transportation Germany

FINE1 was supported by the complementary projects:

- OPEUS for Energy (Coordinator: University of Newcastle)
- DESTINATE for Noise (Coordinator: TU Berlin)
FINE1 Objectives

• 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)
1. Overview: Shift2Rail and FINE1
2. FINE1 Energy Baseline
3. OPEUS Energy Simulation Tool
4. Energy KPI Evaluation
5. Conclusion
The energy baseline is used as state-of-the-art reference to quantify energy savings achieved in S2R.

It consists of the following main parts:

- **Service profiles for high speed, regional, urban and freight traffic segments** including line parameters such as timetables, gradients, speed limits, etc. (see EN50591)

- **Definition of reference simulation data** for the traffic segments, consisting of vehicle, line and traction component parameters
# FINE1 Energy Baseline: Service Profiles

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

*CleanER-D [8]*

**Baseline: Service Profiles**

Energy Assessment in Shift2Rail European Rail Research Program
FINE1 Energy Baseline: >200 technical Parameters

Energy Assessment in Shift2Rail European Rail Research Program
Table of Content

1. Overview: Shift2Rail and FINE1
2. FINE1 Energy Baseline
3. OPEUS Energy Simulation Tool
4. Energy KPI Evaluation
5. Conclusion
OPEUS Tool: Development Process

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

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 Dittrich, Deutsches Zentrum für Luft- und Raumfahrt

Future Improvement for Energy and Noise
Grant Agreement Number: 730818
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.

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 result comparison:

- Siemens
- CAF
- Stadler
- SNCF

Comparison to measured data:

- DB

Functionality check:

- Deutsches Zentrum für Luft- und Raumfahrt
  German Aerospace Center

Implementation of feedback:

- Universität Rostock

OPEUS Tool: Validation and Approval

Energy Assessment in Shift2Rail European Rail Research Program
Table of Content

1. Overview: Shift2Rail and FINE1
2. FINE1 Energy Baseline
3. OPEUS Energy Simulation Tool
4. Energy KPI Evaluation
5. Conclusion
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.
Energy KPI: Improvements from S2R-TDs

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

TD1.3: Carbody mass reduction

TD1.5: Mass reduction by new braking systems

TD3.9: Smart power supply avoids separation sections

TD1.6: Mass reduction doors

TD1.1: SiC converters
## Mapping of Technologies and SPDs

<table>
<thead>
<tr>
<th>SPD</th>
<th>Smart Power Supply</th>
<th>Mass reduction carbody</th>
<th>Mass reduction doors</th>
<th>Mass reduction brakes</th>
<th>Improved line converter (SiC)</th>
<th>Improved motor converter (SiC)</th>
<th>Direct drive with improved gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>HST300</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HST250</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Intercity</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Regional 160</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Regional 140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Metro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
<td>X</td>
</tr>
<tr>
<td>Tram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
<td>X</td>
</tr>
<tr>
<td>Freight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Summary: KPI results

- Improvements of energy KPI between 3.5% (Intercity) and 9.1% (Regional140)
- Metro and Tram: SiC improves energy KPI by 1.7% (Metro) and 2.7% (Tram)
Mass reductions lead to significant reduction of brake wear
1. Overview: Shift2Rail and FINE1
2. FINE1 Energy Baseline
3. OPEUS Energy Simulation Tool
4. Energy KPI Evaluation
5. Conclusion
What FINE1 & OPEUS achieved:
• S2R energy expert network was established, connecting people and topics throughout S2R technological and cross-cutting activities;
• Development of methodology, process and tool to assess S2R technologies and their impact on energy demand;
• Reference scenarios and system platform datasets (energy baseline) have been defined and distributed in S2R;
• Validation and application of the OPEUS single train energy simulation tool for KPI analysis;
• Energy KPI evaluations indicated energy savings of up to 9% with future S2R technologies;

Thanks to FINE1 & OPEUS Team for 3 years of excellent team-work!
References / Deliverables from FINE1 and OPEUS

- [http://opeus-project.eu/](http://opeus-project.eu/)

- EN50591/2019-08: “Specification and verification of energy consumption for railway rolling stock”
- „Energy Baseline”, S2R FINE1 Deliverable 3.1, GA No.: 730818, 2018-03-13
- “Use cases for SPDs”, S2R IMPACT-1 Deliverable 3.3, GA No. 730816
- “Reference scenario”, S2R IMPACT-1 Deliverable 4.1, GA No. 730816
- “Scenarios Set Up and Description”, S2R OPEUS Deliverable 3.1, GA No. 730827, 2018-09-28
- “Requirement Specification for Energy Simulation Tool”, S2R FINE1 Deliverable 3.4, GA No.: 730818, 2017-09-29
- “Approval of Simulation Model”, S2R FINE1 Deliverable 4.1, GA No.: 730818, 2018-03-17
- „Evaluation of Energy KPI - interim”, S2R FINE1 Deliverable 4.5, GA No.: 730818, 2018-04-23