“the RekkE Vidde”

Assessing Range and Performance
of Electric Vehicles
in Nordic Driving Conditions
“the RekkEVidde” Objectives

• Produce realistic performance figures for EVs attributed to Nordic driving and weather conditions

• Agree what kind of additional testing is done for EV’s apart from the regulatory test (ECER No. 101)

Create market acceptance for EV’s
Consortium

Coordination

Laboratory testing

Field testing

Test Site Sweden
In-laboratory Testing Activities at VTT
EVs Tested at

Battery-Electric Vehicles

Citroën C-Zero
Nissan Leaf (’12 & ’13)
Renault Kangoo

Extended-Range Electric Vehicles
Plug-in Hybrid EVs

Chevrolet Volt
Opel Ampera
Toyota Prius PHEV

Not yet supported by the RekkEVidde protocol: Next Phase!
Citroën C-Zero in climatic test cell at VTT

Blower’s air speed max 100 km/h
Ambient temperature range from +25 down to -30 °C
Test Conditions

Normal ambient temperature: +23 °C
• Air resistance for normal temperature
• Road load for normal asphalt

Intermediate ambient temperature: ±0 °C
• Air resistance for intermediate temperature
• Road load for normal asphalt

Low ambient temperature: -20 °C
• Air resistance for low temperature (+16%)
• Road load for normal asphalt
• Road load for old snow (+6% rolling resistance)
• Road load for new snow (+9% rolling resistance)
## Energy Consumption (kWh) - Grid Electricity Uptake

<table>
<thead>
<tr>
<th>cycle</th>
<th>energy use (grid)</th>
<th>asphalt +23 °C kWh/km</th>
<th>asphalt 0 °C kWh/km</th>
<th>asphalt -20 °C kWh/km</th>
<th>old snow -20 °C kWh/km</th>
<th>new snow -20 °C kWh/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEDC</td>
<td>0.142</td>
<td>0.142</td>
<td>0.159</td>
<td>0.192</td>
<td>0.196</td>
<td>0.201</td>
</tr>
<tr>
<td>Helsinki City</td>
<td>0.141</td>
<td>0.137</td>
<td>0.148</td>
<td>0.173</td>
<td>0.211</td>
<td>0.207</td>
</tr>
<tr>
<td>Artemis Urban</td>
<td>0.178</td>
<td>0.190</td>
<td>0.212</td>
<td>0.233</td>
<td>0.231</td>
<td>0.235</td>
</tr>
<tr>
<td>Road, FIN</td>
<td>0.193</td>
<td>0.156</td>
<td>0.173</td>
<td>0.199</td>
<td>0.212</td>
<td>0.214</td>
</tr>
<tr>
<td>Artemis Road, EV*</td>
<td>0.157</td>
<td>0.157</td>
<td>0.173</td>
<td>0.199</td>
<td>0.212</td>
<td>0.214</td>
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<tr>
<td>Artemis Motorway, EV*</td>
<td>0.244</td>
<td>0.216</td>
<td>0.216</td>
<td>0.216</td>
<td>0.216</td>
<td>0.216</td>
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<tr>
<td>average, three cycles</td>
<td>0.159</td>
<td>0.156</td>
<td>0.173</td>
<td>0.199</td>
<td>0.212</td>
<td>0.214</td>
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<tr>
<td>average, all cycles</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
</tr>
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</table>

*EV denotes that warm-up part of the cycle is omitted
Energy Consumption (%)  
Ambient Temp & Road Surface

<table>
<thead>
<tr>
<th>cycle</th>
<th>energy use (grid)</th>
<th>asphalt +23 °C %</th>
<th>asphalt 0 °C %</th>
<th>asphalt -20 °C %</th>
<th>old snow -20 °C %</th>
<th>new snow -20 °C %</th>
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</thead>
<tbody>
<tr>
<td>NEDC</td>
<td>100 %</td>
<td>100 %</td>
<td>112 %</td>
<td>135 %</td>
<td>138 %</td>
<td>141 %</td>
</tr>
<tr>
<td>Helsinki City</td>
<td>100 %</td>
<td>100 %</td>
<td>108 %</td>
<td>126 %</td>
<td>154 %</td>
<td>151 %</td>
</tr>
<tr>
<td>Road, FIN</td>
<td>100 %</td>
<td>100 %</td>
<td>112 %</td>
<td>123 %</td>
<td>122 %</td>
<td>124 %</td>
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<tr>
<td>average, three cycles</td>
<td><strong>100 %</strong></td>
<td><strong>100 %</strong></td>
<td><strong>110 %</strong></td>
<td><strong>128 %</strong></td>
<td><strong>138 %</strong></td>
<td><strong>139 %</strong></td>
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</tbody>
</table>
Estimated Range (km)

<table>
<thead>
<tr>
<th>cycle</th>
<th>estimated range</th>
<th>asphalt +23 °C</th>
<th>asphalt ±0 °C</th>
<th>asphalt -20 °C</th>
<th>old snow -20 °C</th>
<th>new snow -20 °C</th>
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<tbody>
<tr>
<td></td>
<td>km</td>
<td>km</td>
<td>km</td>
<td>km</td>
<td>km</td>
<td>km</td>
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<tr>
<td>NEDC</td>
<td>124</td>
<td>124</td>
<td>111</td>
<td>92</td>
<td>90</td>
<td>87</td>
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<td>Helsinki City</td>
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<td>128</td>
<td>119</td>
<td>102</td>
<td>83</td>
<td>85</td>
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<tr>
<td>Artemis Urban</td>
<td>99</td>
<td>128</td>
<td>119</td>
<td>102</td>
<td>83</td>
<td>85</td>
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<tr>
<td>Road, FIN</td>
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<td>93</td>
<td>83</td>
<td>75</td>
<td>76</td>
<td>75</td>
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<td>115</td>
<td>104</td>
<td>90</td>
<td>83</td>
<td>82</td>
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<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
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<tr>
<td>average, three cycles</td>
<td>113</td>
<td>115</td>
<td>104</td>
<td>90</td>
<td>83</td>
<td>82</td>
</tr>
<tr>
<td>average, all cycles</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>104</td>
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</tbody>
</table>
## Estimated Range (±%)

<table>
<thead>
<tr>
<th>cycle</th>
<th>estimated range</th>
<th>asphalt</th>
<th>asphalt</th>
<th>asphalt</th>
<th>old snow</th>
<th>new snow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>+23 °C</td>
<td>±0 °C</td>
<td>-20 °C</td>
<td></td>
<td>-20 °C</td>
</tr>
<tr>
<td>NEDC</td>
<td>100 %</td>
<td>0 %</td>
<td>-10 %</td>
<td>-26 %</td>
<td>-28 %</td>
<td>-30 %</td>
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<tr>
<td>Helsinki City</td>
<td>1 %</td>
<td>4 %</td>
<td>-4 %</td>
<td>-18 %</td>
<td>-33 %</td>
<td>-32 %</td>
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<tr>
<td>Artemis Urban</td>
<td>-20 %</td>
<td>-25 %</td>
<td>-33 %</td>
<td>-39 %</td>
<td>-39 %</td>
<td>-40 %</td>
</tr>
<tr>
<td>Road, FIN</td>
<td>-26 %</td>
<td>-25 %</td>
<td>-33 %</td>
<td>-39 %</td>
<td>-39 %</td>
<td>-40 %</td>
</tr>
<tr>
<td>Artemis Road, EV*</td>
<td>-9 %</td>
<td>-25 %</td>
<td>-33 %</td>
<td>-39 %</td>
<td>-39 %</td>
<td>-40 %</td>
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<tr>
<td>Artemis Motorway, EV*</td>
<td>-42 %</td>
<td>-7 %</td>
<td>-16 %</td>
<td>-28 %</td>
<td>-33 %</td>
<td>-34 %</td>
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<tr>
<td>average, three cycles</td>
<td>-9 %</td>
<td>-7 %</td>
<td>-16 %</td>
<td>-28 %</td>
<td>-33 %</td>
<td>-34 %</td>
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<tr>
<td>average, all cycles</td>
<td>-16 %</td>
<td>-16 %</td>
<td>-33 %</td>
<td>-33 %</td>
<td>-34 %</td>
<td>-34 %</td>
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</tbody>
</table>
The impact of heating and ventilation

Direct Electric Heating Imposed on Critical Components

Electric (PTC) Heater of Coolant for Cabin Heating

Both Systems Use Primary Energy from the Battery, as no Waste Heat is Available!
The impact of heating and ventilation

**Citroën C-Zero - Simulated Heater Effect**

<table>
<thead>
<tr>
<th>Cycle</th>
<th>+23 °C</th>
<th></th>
<th>-20 °C w/o and with PTC heater (4.5 kW)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>driving energy* kWh/km</td>
<td>est. range km</td>
<td>driving energy* kWh/km</td>
<td>est. range km</td>
</tr>
<tr>
<td>NEDC</td>
<td>0.121</td>
<td>124</td>
<td>0.129</td>
<td>88</td>
</tr>
<tr>
<td>Helsinki City</td>
<td>0.116</td>
<td>130</td>
<td>0.118</td>
<td>96</td>
</tr>
<tr>
<td>Artemis Urban</td>
<td>0.143</td>
<td>105</td>
<td>0.145</td>
<td>78</td>
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<td>Road, FIN</td>
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<td>89</td>
<td>0.184</td>
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</tr>
<tr>
<td>Artemis Road</td>
<td>0.129</td>
<td>117</td>
<td>0.137</td>
<td>83</td>
</tr>
<tr>
<td>Artemis Motorway</td>
<td>0.205</td>
<td>73</td>
<td>0.224</td>
<td>51</td>
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</tbody>
</table>

*theoretical road load +10% **calculated
Cold temperature range shortening depends on the cabin heating.
Fuel fired heating adds the range

Nissan Leaf 2012 range with electric cabin heater and fuel-fired heater

<table>
<thead>
<tr>
<th>ambient</th>
<th>-20 °C</th>
<th>heater</th>
<th>gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>cycle</td>
<td>electric</td>
<td>fuel-fired</td>
<td>km</td>
</tr>
<tr>
<td>NEDC</td>
<td>58</td>
<td>98</td>
<td>40</td>
</tr>
<tr>
<td>Helsinki City</td>
<td>48</td>
<td>113</td>
<td>65</td>
</tr>
<tr>
<td>Road, FIN</td>
<td>74</td>
<td>85</td>
<td>10</td>
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</tbody>
</table>
Field Testing Activities by TSS
Test Site Sweden

Photo: Erika Brokvist, Gröna Bilister, SWE
RekkEVidde Field Test Codes

Two test codes:
Basic Field Test (BFT)
Advanced Field Test (AFT)
Field-Testing of EVs

3.14 km Running Length

Large oval track used to run NEDC cycle

- Reduced EUDC max speed from 120 km/h to 100 km/h due to safety
- Gives about 2% lower total-NEDC workload
Basic Field Test (BFT)
3 x NEDC on track (or road)
Vbox to verify speed & distance
Re-charging with ChargeAlyzer
Test time max 24 hours
Heating & ventilation not tested
RekkEVidde Field Test Codes - AFT

Advanced Field Test (AFT)
3 x NEDC on track (or road)
Vbox to verify speed & distance
Kvaser CAN-logger (for power & SOC)
Re-charging with ChargeAlyzer
Test time 2 x 24 hours for heater tests

Photo: Erika Brokvist, Gröna Bilister, SWE
AFT: 3xNEDC Run on a Track

EV: Citroën C-Zero

<table>
<thead>
<tr>
<th></th>
<th>NEDC1</th>
<th>NEDC2</th>
<th>NEDC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed km/h</td>
<td>35.20</td>
<td>35.66</td>
<td>35.57</td>
</tr>
<tr>
<td>SOC %</td>
<td>11.49</td>
<td>11.42</td>
<td>11.48</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>2.699</td>
<td>2.699</td>
<td>2.669</td>
</tr>
</tbody>
</table>

Photo: Erika Brokvist, Gröna Bilister, SWE

Vbox GPS & data logger

Kvaser CAN data logger

Power

SOC

Speed
Test Fleet - January 2013
Range estimate based on CAN-info (SOC) and nominal battery capacity

Example of Advanced Field Test Results
Energy Labelling

ACS Zed EV

- **A/C**: yes
- **heater**: yes/electric

**urban driving**

- **summer** +23 °C on 63 km
  - with A/C on
- **winter** -20 °C on 57 km
  - with heater full on

**countryside driving**

- **summer** +23 °C on 78 km
- **winter** -20 °C on 43 km

**Manufacturer's reference**

- 150 kWh/100 km
- 110 Manufacturer's reference

**average driving cost**

- 3.4 EUR/100 km

**full charge / charge time**

- 16.5 kWh / 6.5 h

**Charge mode and temp limit**

**NEDC or ext-NEDC?**

**Testing or Calculations?**

**Tesla S as the norm?**

**With/without pre-heating**

**Charge mode dependent**

**Cabin temperature**

**More than one speed?**

**www.energyandtransport.net**

**www.rekkevidde.no**
Summary & Conclusions

Cold weather and adverse road conditions increase driving resistances >> range becomes shorter
Electric heating consume high amounts of prime battery energy >> range is adversely affected especially if average speed is low
Cabin preheating before driving and use of a fuel heater and permission to use bus lanes increases the range

The RekkEVidde project has produced
Methodology for the EV cold temperature testing
Proposal for the EV Energy label
Contact Information

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