Open your mind. LUT.
Lappeenranta University of Technology
Contents of the presentation

- **Plug-in vehicles**
  - Vehicle fleet and vehicle travel in Finland
  - Penetration scenarios
  - Policies
  - Charging studies
  - Research projects and other activities in R&D

- **Heat pumps**
  - Heating and cooling demands
  - Technologies and penetration
  - Policies
  - Load characteristics and use for DSM
  - Research projects

- **Summary of questionnaire**
Annually sold passenger cars in Finland

Year | Amount of new cars per year
--- | ---
1988 | Gasoline
1990 | Diesel
1992 | Total
1994 | 
1996 | 
1998 | 
2000 | 
2002 | 
2004 | 
2006 | 
2008 | 

The graph shows the annual sales of new passenger cars in Finland from 1988 to 2008, distinguishing between gasoline, diesel, and total sales.
## Annually sold passenger cars in Finland

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline</th>
<th>%</th>
<th>Diesel</th>
<th>%</th>
<th>Others</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>123 020</td>
<td>83,03</td>
<td>25 139</td>
<td>16,97</td>
<td>2</td>
<td>0,00</td>
<td>148 161</td>
</tr>
<tr>
<td>2006</td>
<td>116 128</td>
<td>79,70</td>
<td>29 512</td>
<td>20,26</td>
<td>60</td>
<td>0,04</td>
<td>145 700</td>
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<tr>
<td>2007</td>
<td>89 789</td>
<td>71,48</td>
<td>35 782</td>
<td>28,48</td>
<td>36</td>
<td>0,03</td>
<td>125 608</td>
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<tr>
<td>2008</td>
<td>70 239</td>
<td>50,34</td>
<td>69 247</td>
<td>49,63</td>
<td>49</td>
<td>0,04</td>
<td>139 535</td>
</tr>
<tr>
<td>2009</td>
<td>48 456</td>
<td>53,50</td>
<td>41 904</td>
<td>46,27</td>
<td>75</td>
<td>0,08</td>
<td>90 568</td>
</tr>
<tr>
<td>2010 (1-8)</td>
<td>44 975</td>
<td>57,45</td>
<td>33 067</td>
<td>42,24</td>
<td>238</td>
<td>0,30</td>
<td>78 280</td>
</tr>
</tbody>
</table>
Age of the car fleet

Mäkelä, K., Laurikko, J., and Kanner, H. 2008. Road traffic exhaust gas emissions in Finland. VTT 2008 [In Finnish]
EVs – Population density in Finland

## Penetration scenarios

<table>
<thead>
<tr>
<th></th>
<th>year</th>
<th>Proportion of new cars</th>
<th>Cumulative amount of the sold cars</th>
<th>Proportion of annually driven distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PHEV</td>
<td>EV</td>
<td>PHEV</td>
</tr>
<tr>
<td><strong>Basic scenario</strong></td>
<td>2020</td>
<td>10 %</td>
<td>3 %</td>
<td>66 000</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>50 %</td>
<td>20 %</td>
<td>480 000</td>
</tr>
<tr>
<td><strong>Rapid scenario</strong></td>
<td>2020</td>
<td>40 %</td>
<td>6 %</td>
<td>190 000</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>60 %</td>
<td>40 %</td>
<td>960 000</td>
</tr>
<tr>
<td><strong>Slow scenario</strong></td>
<td>2020</td>
<td>5 %</td>
<td>2 %</td>
<td>38 000</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>20 %</td>
<td>10 %</td>
<td>207 000</td>
</tr>
<tr>
<td><strong>Vision</strong></td>
<td>2020</td>
<td>15 %</td>
<td>10 %</td>
<td></td>
</tr>
</tbody>
</table>

Background report
Vision of the working group

Penetration scenarios – basic scenario

Proportion of new cars

Year

Proportion of annually driven total distance

Year
Profitability of plug-in vehicle for user

- Life-time of the car 10 years, interest rate 5%
- Plug-in hybrid:
  - Full electric range 64 km, Consumption: 20 kWh/100 km (0.1 €/kWh), 4.5 l/100 km (1.3 €/l)
- Gasoline car:
  - Consumption: 6.5 l/100 km (1.3 €/l)
- Diesel car:
  - Consumption 5 l/100 km (1 €/l + fuel based tax 350 €/a)
Daily traveled distance

Vehicle taxation policies in Finland

- **CO₂ based taxation system**
  - Purchase tax 12.2 – 48.8 %, depending on the CO₂ emissions (60…360 g/km)
  - Annual tax 20 – 600 €/a, depending on the CO₂ emissions (66…400 g/km)
  - => incentives for low emission vehicles, including plug-in vehicles (technology neutral)

- **Annual fuel tax for the vehicles using other fuel than gasoline (or natural or bio gas)**
  - Typically 250 – 400 €/year
  - Applied also for electric vehicles => decrease the incentives to purchase electric vehicles
Charging studies

- Grid impacts of the electric vehicles (especially impacts on medium voltage distribution network)
  - Including also possibilities and profitability of V2G function
- Concept of the interface between vehicle and grid
  - Physical interface
  - Interactions between electricity markets and vehicles
Input Parameters on Electric Car Network Simulation

National passenger transport survey
- Spatial and temporal variations in passenger trips
- Length of daily trips
- Annual length of driving (region dependent)
- Length of daily trips according to housing type
- Length of daily trips according to residential area
- Length of daily trips according to the month of year
- Length of trips according to the time of day
- Number of cars in households

Properties of electric cars
- Energy consumption, kWh/km
- Capacity of the batteries, kWh
- Charging power, kW
- Required charging time, h/day (battery properties)

Town planning statistics
- Workplaces according to the area and time of day
- Residential areas (detached houses, terraced houses, apartment houses)

Penetration of electric cars
- Development of electric car markets

Tariffs and supplier
- Distribution fee

Area-specific additional energy
--- kWh/day
(working hours/leisure time)

Network simulations and analysis results
- Load flow and loss calculations
- Estimation of reinforcements required

Electricity distribution network
- Network topology and customer information
- Feeder and hourly-specific actual load curves
- Network volume
- Replacement value
- Parameters: loss costs, load growth, lifetime, unit price of network components

Case Network – Background data

Whole distribution company
- 110/20 kV primary substations: 4
- 20 kV feeders: 22
- Inhabitants/end-customers: 19,470 / 11,000
- Workplaces: 5,333
- Houses: 7,932 (5,992 detached houses, 525 terraced houses, 1,287 apartment houses, 128 others)
- 20/0.4 kV distribution substations: 470
- Peak load: 50 MW
- Annual energy: 200 GWh
- 20 kV lines and cables: 433 km
- 20 kV underground cabling rate: 16%

Feeder 1. (Densely populated area), 20 kV
- Peak load: 8 MW
- Annual energy: 36 GWh
  - Residential 58 %, industry 22 %, public 13 % and service 7 %
- Inhabitants/end-customers: 4,171 / 2,278
- Workplaces: 1,577
- Houses: 1,840 (659 detached houses, 266 terraced houses, 888 apartment houses)
- 20/0.4 kV distribution substations: 39
- 20 kV lines and cables: 21 km
- 20 kV underground cabling rate: 33%

Feeder 2. (Rural area), 20 kV
- Peak load: 2 MW
- Annual energy: 6 GWh
  - Residential 95 %, agriculture 2 %, industry 3 %
- Inhabitants/end-customers: 1,037 / 444
- Workplaces: 84
- Houses: 372 (all detached houses)
- 20/0.4 kV distribution substations: 27
- 20 kV lines and cables: 31 km
- 20 kV underground cabling rate: 6%

Case Network – Electric car charging profiles

Direct night-time charging

Split-level night-time charging

Working-hour and time-off charging

Optimised charging (for Feeder 1)

→ Transmission capacity in the network?
→ Losses and loss costs?

The same amount of charging energy in each profile!

Intelligent EV Charging

- **City area feeder:**
  - Peak load of the day: 6.6 MW
  - Minimum load of the day: 4.0 MW
  - Number of electric cars: 2000
  - Driving distance: 57 km/car/day
  - Energy consumption: 0.2 kWh/km
  - Charging energy: 11.5 kWh/car/day
  - → 22.9 MWh/day for all cars
  - Charging power: 3.6 kW/car
  - **Additional power: 0 – 3.5 MW**
    (depending on charging method)
  - Charging energy (E) is equal in each charging alternative

- **In optimal charging method**
  - Customer interfaces discuss with each other and modern DMS system
  - Interfaces time the charging on the basis of existing network capacity
  - Full exploitation of the network’s transmission capacity, and thus, minimisation of the reinforcement needs due to EV load
  - Network losses per transmitted kWh are minimised

**Case Network – Reinforcement costs**

Network value compared with the peak load in:
- Low-voltage networks: 320 €/kW
- Medium-voltage network: 300 €/kW
- Primary substation level (110/20 kV): 100 €/kW

An example of defining required reinforcement investments on the medium voltage feeder:

- Peak load of the day: 6.6 MW
- Additional power: + 3.0 MW
- Average marginal cost: 300 €/kW

→ Estimated need for reinforcement:

\[ 300 \text{ €/kW} \times 3000 \text{ kW} = 900,000 \text{ €} \]

→ Using intelligent charging system (Optimised charging) charging can be adjusted fully into low-load moments

Case Network – Reinforcement costs

- Replacement value: 50 M€ ( \( \leftarrow 2.9 \text{ M€/a calculated by } p = 5 \% \text{ and } t = 40 \text{ a} \) )

- Annual present delivered energy: 200 GWh/a
  \[ \text{Network value per delivered energy } 1.46 \text{ cnt/kWh} \]

- Estimated additional annual charging energy required by electric cars: + 46 GWh/a ( \( \leftarrow 11 \text{ 000 cars, 20 900 km/car, a and } 0.2 \text{ kWh/km, car} \) )

- Depending on charging method, estimation of the required investments in a new transformer and transmission capacity in the whole distribution network is 0 – 20 M€ (0 – 1 060 k€/a).

\[ \text{New distribution fee: } 1.18 – 1.66 \text{ cnt/kWh after the network reinforcements} \]

EVs as energy storages

How much the peak power could be decreased by utilizing electric vehicles as energy storages on the network?

Annual load curve of the medium-voltage feeder and the question of potential to decrease peak power by energy storages.

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
An optimized charging curve for all electric cars on an example day. The daily need for energy \( E_{\text{cars}} \) for driving is 2.9 MWh/day (250 x 11.5 kWh/car, day).

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
Additional energy ($E_{\text{add}}$) needed to decrease the peak load

$$E = \int P(t)dt$$

$$E_{\text{cars}} = \int \Delta P_{\text{cars}} dt$$

$$E_{\text{peak}} = \int \Delta P_{\text{Peak}} dt$$

$$E_{\text{add}} = E_{\text{peak}}$$

$$E_{\text{cap}} = \sum (E_{\text{battery}})$$

$$\text{Max}(\Delta P_{\text{Peak}}) = \text{Number of EVs} \cdot P_{\text{supply}}$$

$$\text{Max}(E_{\text{add}}) = E_{\text{cap}} - E_{\text{cars}}$$

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
One-year load curve with electric cars but without energy storages (the topmost curve) and in the situation where electric cars and energy storages are included (in the middle). The bottom curve illustrates the minimum powers without cars and storages.

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
EVs as energy storages

One-year duration curves

One-year duration curves of the medium voltage feeder based on load curves

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
If the price of a car battery is 10 000-20 000 € and the lifetime is 2000-4000 cycles, the investment price per discharged energy is 8-33 cent/kWh

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
No remarkable reinforcement network investments needed in 2010-2020, (local investments; parking halls, substations for fast recharging?)

Charging of cars will be mostly slow type charging (1 x 16 A) at home, work places and holiday homes

- In the most cases, households are equipped with car pre-heating poles ← Upgrading requirements, Smartgrids?

- Investments and renovation are needed in work place, apartment house and public parking areas; typically charging power restricted to ~500 W, 2-hour limited use etc.

Fast charging option to ”gasoline” stations

- Fast charging (~80 kW) in low-voltage network is too much

- Super fast charging (~250 kW) will be located in primary substations (for instance 20 cars → several MW)

Jukka Lassila, Juha Haakana, Nadezda Belonogova and Jarmo Partanen. 2010. Methodology to Analyze the Effects of Electric Cars on the Electricity Distribution Networks. Accepted to be published in IEEE Transactions on Smart Grids.
Active customer gateway

Information systems

Energy storage

Grid

Business players; TSO, DSO, supplier, aggregator

Generation
Solar, wind, fuel cell, biogas

Loads
Charging infrastructure

Henri Makkonen, Jarmo Partanen, Pertti Silventoinen. 2010. Concept of battery charging and discharging in automotive applications. SPEEDAM 2010
Charging infrastructure

R&D activities concerning plug-in vehicles in Finland

- Research projects
  - Issues related to electricity networks and energy markets mostly in SGEM project
- Development and manufacturing of the vehicles and batteries
  - Valmet Automotive
  - European Batteries
  - ERA electric racecar
- Research and development in hybridization of the working machines
  - Forklifts, cranes, forestry machines, mine machinery
E-RA – Electric-RaceAbout

Finnish engineers at Helsinki Metropolia University of Applied Sciences and designers at Lahti University of Applied Sciences are developing superefficient and clean car as a solution to environmental concerns regarding individual mobility.

The break-through technology never sells cheap. This is why a sports car, - first for those who can afford it, and then when the time is right, put the new concept on market

The Automotive X-PRIZE competition is a perfect forum to demonstrate the performance.

Source: Nils-Olof Nylund, VTT 19.8.2010
Official Finals Results

Last Updated August 10, 2010

Finals: Results

7 teams representing 9 vehicles will advance to the Validation Stage. The status by prize category is as follows:

- Mainstream Class – Edison2 (Virginia - vehicles 97 and 98)
- Alternative Class (Tandem) – X-Tracer (Switzerland - vehicles 72 and 79)
- Alternative Class (Side-by-Side) – 5 teams (5 vehicles)
  - Lithium Ion Motors (North Carolina)
  - RaceAbout Association (Finland)
  - TW4XP (Germany)
  - 2AP (California)
  - Aptera (California)

Finals: Combined Performance and Efficiency Test

This is a timed race designed to serve as the "tie-breaker" should two or more vehicles in a class achieve all competition requirements coming out of Validation testing next month. As the Alternative Side-by-Side class was the only class with multiple teams in contention, it was the only class required to participate in the event.

Placement results for the final Combined Performance and Efficiency Test tie-breaker for the Alternative (Side-by-Side) Class

1st Place Team Lithium Ion Motors of North Carolina (125 MPGe average fuel economy for the event)
2nd Place RaceAbout Association of Finland (0.179 seconds behind the leader and 100 MPGe average fuel economy for the event)
3rd Place TW4XP of Germany (11 minutes, 36.9 seconds behind the leader and 139 MPGe average fuel economy for the event)
4th Place 2AP of California (DNF – 48 laps completed)
5th Place Aptera of California (DNF – 18 laps completed)

There were a few penalties assessed for speed violations
- Team Liv-ion received 1 penalty for driving under 45 mph
- RaceAbout received 2 penalties for exceeding 70 mph
- TW4XP had 4 penalties for being under 45 mph

You can get more detailed information on this event on our blog [here](http://www.progressiveautomotive.com/blog)

Finals: Full Results

Download Results [PDF]

Finals: Week 2 Results

Download Results [PDF]
Electric vehicles – manufacturing industry in Finland

Source: Markus Hirvonen, Valmet Automotive Inc.
"Eva" electric vehicle concept 2010

Source: Markus Hirvonen, Valmet Automotive Inc.
European batteries

- Manufacturing plant in Varkaus, Finland will begin its operations in spring of 2010
  - inauguration June 8th 2010
- First independent large battery manufacturer in Europe
- 100 MWh annual production capacity, which equals the need of 3,000 full-electric cars
- Capacity expansion to 300 MWh is scheduled to be ready in 2012.

Source: Martti Alatalo, European Batteries
Infrastructure demos in Espoo and Helsinki
Paying by parking ticket or by mobile phone

Source: Matti Rae, ENSTO