Sustainable mobility

Innovation in Electric Vehicle Technologies

International Renewable Agency (Irena)
Irena Innovation Week
Bonn May 12th 2016

Prof. Dr. Guy Fournier
Agenda

- Drivers of the new mobility paradigm
- Innovation in individual mobility: new powertrains
- Innovation in mobility services and value added services:
  - EV as a part of mobility solutions
  - EV as a part of storage solutions
  - Innovation in Autonomous EV: the example of robocabs
- Innovation in Developing Countries: Reverse innovation and frugal economy
- Conclusion

Drivers of the new mobility paradigm

Current Mobility Paradigm
based on cheap fossil fuel energy, high CO2 exhausts, individual mobility (product orientation), linear economy

- Scarcity of resources
- Dependency on Energy
- Growing environmental awareness of the population
- Loss of significance and image of the car as a status symbol
- Legislative measures
- Regulative intervention on local, national, regional or global level
- “Low carbon economy” (similar to EU or in other regions)

New Mobility Paradigm
based on internet, low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)

- New customer requirements (e.g. Kuruma Banare etc.)
- New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
- New mobility business models (e.g. car sharing, car pooling etc.)
- Change of infrastructure (energy, IT & digital economy)
- Change of standardization
- New business opportunities (e.g. integrated services)
Drivers of the new mobility paradigm

**Current Mobility Paradigm**

- Based on cheap fossil fuel energy, high CO₂ exhausts, individual mobility (product orientation), linear economy
- Scarcity of resources
- Dependency on Energy
- Growing environmental awareness of the population
- Loss of significance and image of the car as a status symbol
- New customer requirements (e.g., Kuruma Banare etc.)
- New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
- New mobility business models (e.g., car-sharing, car pooling etc.)
- Legislative measures
- Regulative intervention on local, national, regional or global level
- "Low carbon economy" (similar to EU or in other regions)
- Change of infrastructure (energy, IT & digital economy)
- Change of standardization
- New business opportunities (e.g., integrated services)
- New customer requirements (e.g., Kuruma Banare etc.)
- New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
- New mobility business models (e.g., car-sharing, car pooling etc.)
- New customer requirements (e.g., Kuruma Banare etc.)
- New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
- New mobility business models (e.g., car-sharing, car pooling etc.)

**New Mobility Paradigm**

- Based on internet, low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)
- Growth is an emerging market phenomenon

![Projected total stock of light-duty vehicles by region](image)

- 50 million in the 50s
- 600 million today
- 3 billion by 2050 (IMF)
- Represents an incredible 60-fold increase within a hundred years
- Production in 2011: 75,6 million
- Production in 2012: > 80 million
- Production in 2015: 90 million
Drivers of the new mobility paradigm

**Current Mobility Paradigm**
- Based on cheap fossil fuel energy, high CO₂ exhausts, individual mobility (product orientation), linear economy

- External costs of mobility
  - Rising urbanization (Congestions, Parking Penury, Land use etc.)
  - Pollution Accidents
  - Global Warming

- Social changes (Urbanisation, demography, Kuruma Banare, changes in society)
- Growing environmental awareness of the population
- Scarcity of resources
- Dependency on Energy

- Business model changes
  - Legislative measures
  - Low carbon economy (similar to EU or in other regions)

- New customer requirements
  - (e.g. Kuruma Banare etc.)
  - New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
  - New mobility business models (e.g. car sharing, car pooling etc.)

- Change of infrastructure
  - Change of standardization
  - New business opportunities (e.g. integrated services)

**New Mobility Paradigm**
- Based on internet, low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)

- Technological changes
  - Digitalization
  - Innovation in battery, fuels, power train, lightweight, production and distribution of energy, IT infrastructure etc.

- Business model changes
  - Radical innovation, open-source, niches vs volume strategy, service orientation, cost of usage, mobility on demand etc.

**External costs of passenger transport in 2000**
(excluding costs of traffic congestion)

- Car: € 71.0
- Bus: € 37.7
- Train: € 22.9
- Plane: € 62.5

Drivers of the new mobility paradigm

- Growing environmental awareness of the population
- Scarcity of resources
- Dependency on Energy

- Business model changes
  - Legislative measures
  - Low carbon economy (similar to EU or in other regions)

- New customer requirements
  - (e.g. Kuruma Banare etc.)
  - New offerings (OEM, supplier, raw materials, third parties, new parties, customer)
  - New mobility business models (e.g. car sharing, car pooling etc.)

- Change of infrastructure
  - Change of standardization
  - New business opportunities (e.g. integrated services)
Drivers of the new mobility paradigm

Transportation as a driver of external costs

- Target for the EU to reduce its CO₂ emissions by 20% until 2020, or 30% if a broader international agreement is reached

- Cost estimation in Europe:
  - Global warming
  - Noise
  - Air pollution
  - Traffic Congestion 1.1% GDP

- The aim of the EU is to internalise the external costs of transportation

- "Greening Transport Package"

Comparison of the Daily Sea Ice

Temperature Anomalies in Europe

The hottest summer since 1500:
- 2010
- 2013
- 2002
- 2006

2015 will probably be the hottest summer since 1500

Barriopedro et al., 2010

Climate Change

Greenhouse gases (in gigatons CO₂ equivalent)

Pledges or promises that governments have made, including in submitted INDCs (Intended Nationally Determined Contributions):
- Pledges end of 2014: + 3°
- Pledges end of 2015: + 2.7°

IPCC is working on a special 1.5° report

© Guy Fournier - Pforzheim University of Applied Sciences
Drivers of the new mobility paradigm

Current Mobility Paradigm
based on cheap fossil fuel energy, high CO₂ exhausts, individual mobility (product orientation), linear economy

- External costs of mobility
  - Rising urbanization (Congestions, Parking Penury, Land use etc.)
  - Pollution
  - Accidents
  - Global Warming

- Scarcity of resources
- Dependency on Energy

- Growing environmental awareness of the population
- Loss of significance and image of the car as a status symbol

- New customer requirements (e.g. Kuruma Banare etc.)
- New offerings (OEM, supplier, raw materials, third parties, new parts, customer)
- New mobility business models (e.g. car sharing, car pooling etc.)

- Change of infrastructure (energy, IT & digital economy)
- Change of standardization
- New business opportunities (e.g. integrated services)

- New customer requirements
- New offerings (OEM, supplier, raw materials, third parties, new parts, customer)
- New mobility business models (e.g. car sharing, car pooling etc.)

- New customer requirements
- New offerings (OEM, supplier, raw materials, third parties, new parts, customer)
- New mobility business models (e.g. car sharing, car pooling etc.)

New Mobility Paradigm
based on internet, low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)

Comparison of global CO₂ regulations for new passenger cars

ICE powertrain optimization is unlikely to be enough to meet European CO₂ emission limits of 95 g/km by 2020

By 2017 the new world standard WLTP (Worldwide harmonized Light vehicles Test Procedures) will take the place of the updated NEDC
Drivers of the new mobility paradigm

Current Mobility Paradigm
based on cheap fossil fuel energy, high CO₂ exhausts, individual mobility (product orientation), linear economy

- Scarcity of resources
- Dependency on Energy
- Rising urbanization (Congestions, Parking Penury, Land use etc.)
- Pollution
- Accidents
- Global Warming

External costs of mobility
- Scarcity of resources
- Dependency on Energy
- Rising urbanization (Congestions, Parking Penury, Land use etc.)
- Legislation (product orientation)
- “Low carbon economy” (similar to EU or in other regions)

New Mobility Paradigm
based on internet, low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)

- Growing environmental awareness of the population
- Loss of significance and image of the car as a status symbol
- Legislative measures
- Regulative intervention on local, national, regional or global level

Drivers of the new mobility paradigm:
Kuruma Banare (車離れ)

- Japan:
  - Between 2001 and 2005 the Japanese population not possessing vehicles raised from 21.3 to 32.1 %
  - From 20 to 60y., more important than a car:
    - Internet (74 %)
    - Mobile (56 %)
  - Other reasons (Jama):
    - Growing urbanisation (congestion)
    - Local public transportation
    - Regulation & taxes

- A similar development can be observed in Germany and France
Drivers of the new mobility paradigm

Current Mobility Paradigm
based on cheap fossil fuel energy, high CO₂ exhausts, individual mobility (product orientation), linear economy

New Mobility Paradigm
low carbon oriented (low carbon economy), new mobility services (customer oriented, intermodality), energy and resource efficient (circular economy)

The Internet of Things and Services – Networking people, objects and systems

Customer centricity and customer contact become easier through the digitalisation of the economy
Agenda

- Drivers of the new mobility paradigm
- Innovation in individual mobility: new powertrains
- Innovation in mobility services and value added services:
  - EV as a part of mobility solutions
  - EV as a part of storage solutions
  - Innovation in Autonomous EV: the example of robocabs
- Innovation in Developing Countries: Reverse innovation and frugal economy
- Conclusion

Range with one hectare (10,000 m²) cultivated area

Solar Energy: 330-fold range compared to Rape Oil or Biodiesel, 115-fold to BtL

Rape Oil
Bioethanol
Biodiesel
Biomethane
BtL (Biomass-to-Liquid)
Biomethane of byproducts (colza cake, draff, straw)

Electric Vehicle

Solar Energy

ICE 1. Gen Biofuel

ICE 2. Gen Biofuel

Algae Fuel
3. Gen Biofuel

- huge amount of oil
- 100x oil / ha / p.a. than soya bean
- but not until 2020

Car fuel consumption: Petrol 7.4 l/100 km, Diesel 6.1 l/100 km

** 1 280 000 kWh per hectare (Central Germany, 2008), 15 kWh / 100 km per vehicle

Source: Fachagentur Nachwachsende Rohstoffe e.V. 2008 ; Fournier 2009

7 800 000 km**
Biodiesel: cure worse than the disease: Fossil diesel emissions vs first-generation biodiesel

Drivers for the future mobility
CO₂ and energy efficiency of power trains (Well-to-Wheel)

Source: based on data from Concawe, Euca, JCR 2007, Daimler Optiresource tool

- China is in 2015 the biggest (38% of Global market sales) and fastest growing market (+ 245% between 2014 and 2015)
- Western Europe is the second biggest market with 33% of Global market sales
- US market represents 20% of global sales
- But: Global automobile production is 90,68 Million

Obstacles to the diffusion of EV's are range, costs and availability of charging stations.

Battery: key success factor for EV and Hybrid

- Limit of weight and range (Li-ion batteries): energy density of gasoline or diesel is 100 times higher in comparison to a Li-ion battery
- Limit of price (Li-ion)
- Limit of Lithium Carbonate and Cobalt
Battery: key success factor for EV and Hybrid

Figure 1: Cost of Li-ion battery pack in $/kWh. Data are from multiple types of sources and these both reported cost for the industry and costs for market-ready manufacturing. As costs such costs per kWh this is commonly considered as the point of commercialization of these.

Nykvist and Nilsson (2015)

Goal of Tesla

Tesla is now leader with the model S in USA and Germany in comparison with class S from Daimler

Expected Rise of Electric Vehicles

By 2022 electric vehicles will cost the same as their internal-combustion counterparts. That’s the point of lift off for sales.
Agenda

- Drivers of the new mobility paradigm
- Innovation in individual mobility: new powertrains
- Innovation in mobility services and value added services:
  - EV as a part of mobility solutions
  - EV as a part of storage solutions
  - Innovation in Autonomous EV: the example of robocabs
- Innovation in Developing Countries: Reverse innovation and frugal economy
- Conclusion

Multimodal Mobility in La Rochelle: customer centric mobility services

http://www.yelo-larochelle.fr/
Multimodal Mobility: customer centric, cost and resource efficient mobility services; storage services

Multimodal and intermodal mobility (e.g. Moovel, Multicity, Captain train etc.)

- Lowering transaction costs, customer orientation, customer choosing different transport modes (multimodal) and combining transport modes (intermodal)
- Increasing the productive use of assets
- Growing asset value, lowering vehicle ownership
- EV as a storage solution: V2G

- Meet the individual needs to ensure mobility
- Can be used as quasi-stationary energy storage devices
- Electric vehicles can also be used for intelligent load and power management

EV as a storage solution: V2G

- Profits / Losses can vary from -350 to +570 €/a/vehicle and more depending on the market in Germany
## EV as a storage solution: V2G

**Evaluation of the V2G potential in Germany (Energy Market and Capacity Market)**

<table>
<thead>
<tr>
<th></th>
<th>Spot market</th>
<th>Capacity market</th>
<th>Primary Control</th>
<th>+ Secondary Control</th>
<th>- Secondary Control</th>
<th>+ Tertiary Control</th>
<th>- Tertiary Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>No market</td>
<td>No analysis</td>
<td>Will influence</td>
<td>the other markets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profits/Losses (€/a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Whole sale market
- Energy price [€/kWh]
- Power price [€/kW]
- Battery size: 20 kWh
- Battery size: 30 kWh
- Cost of Batteries: 250 €/kWh (Basis 2020); costs of inverter, telematics etc.: 425 €/vehicle
- Capital costs: 7%, 10 years

### Control reserve market
- Daimler autonomous vehicle
- Google autonomous vehicle

---

## Autonomous EV: the example of robocabs (autonomous taxis) in New York

- **Reducing greenhouse Gas (GHG) emissions by 87-94%** (in comparison with conventionally driven vehicles in 2014) is possible by 2030
- Replacement of New York’s 13,000 yellow cabs with 9,000 self-driving ones could **lower costs per mile by 87% and reduce the waiting time by 15%** due to:
  - fewer taxis,
  - less empty miles
  - reduced labor costs of the driver
- Google, Uber, Daimler, Navya etc. are working on autonomous vehicles
Agenda

- Drivers of the new mobility paradigm
- Innovation in individual mobility: new powertrains
- Innovation in mobility services and value added services:
  - EV as a part of mobility solutions
  - EV as a part of storage solutions
  - Innovation in Autonomous EV: the example of robocabs
- Innovation in Developing Countries: Reverse innovation and frugal economy
- Conclusion

Saving resources and energy: Frugal economy and Reverse Innovation

What is jugaad innovation?
Jugaad is a Hindi word that roughly translates as “overcoming harsh constraints by improvising an effective solution using limited resources”. A such jugaad innovation is a frugal and flexible approach to innovation that is dominant in India. In the West it’s often called “Do It Yourself” (D-I-Y) innovation.

“Think Frugal, Be Flexible, Generate Breakthrough Growth.”

Indian Frugal Engineering with experience from Renault and Nissan:
- 97% localized
- most fuel-efficient petrol car in India: 25,17 kmpl (international business times sept. 29th 2015)
- Price: 4200 - 5500 Euro
Agenda

- Drivers of the new mobility paradigm
- Innovation in individual mobility: new powertrains
- Innovation in mobility services and value added services:  
  - Using surpluses of renewables for storage and mobility  
  - Autonomous EV: Robocabs
- Innovation in Developing Countries: Reverse innovation and frugal economy
- Conclusion

Conclusion:

The current mobility paradigm based on cheap fossil fuel energy, high CO₂ emissions and individual mobility brings our economical, social and environmental systems on their limits

Innovation in:

- New powertrains (EV) will improve their range and be cheaper in the future than ICE vehicles to satisfy individual mobility
- Added value services can satisfy customer centric multimodal mobility, integrate renewables and bring huge opportunities to save resources and energy
- Developing countries, so called Jugaad or reverse innovation, can help to satisfy mobility needs in a frugal economy

To conclude: Innovation can save energy and resources, limit pollution and satisfy mobility needs in a more sustainable world
Conclusion:

“The best way to predict the future is to create it“
Peter F. Drucker

Thank you for your attention!

Prof. Dr. Guy Fournier
Pforzheim University, Germany
guy.fournier@hs-pforzheim.de