Possible solutions for a transport system compliant with the energy supply and the environment: measurable analyses

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POSSIBLE SOLUTIONS FOR A TRANSPORT SYSTEM
COMPLIANT WITH THE ENERGY SUPPLY AND THE ENVIRONMENT:
MEASURABLE ANALYSES

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Politecnico di Torino, I – EU

Session «Integrated approach to transport planning»
Sunday, 04.12.2011
New Delhi - India

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1. Aims of society (India, EU) related to transport systems and energy
   ➜ GENERAL TRANSPORT PLANNING

2. Measurable evaluations, well-to-wheel analysis
   ➜ MEASURABLE ANALYSES

3. EU directives, action plans on the promotion of clean and energy-efficient transport systems
   ➜ REGULATIONS

☞ CONCLUSIONS
Some European cities, 1900

A reached **AIM** of the European society

**DIFFUSED MOTORISATION**

Nowadays frequently **REGULATED, CONTROLLED**

Same cities, today

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Vehicles circulating in the WORLD

approximate trend on the basis of few known data and estimates from different sources

~176.5·10^6 vehicles in China (by the resp. Ministry, 2008), ≈21% in the world; 219·10^6 vehicles in 9.2011, cars ≈45.9%, ≈22% in the world; >100 millions of vehicles in India, nearly 12% in the world in 2008 (20.8·10^6 cars in 2011); India and China had in 2008 >1/3 of vehicles in the world with ≈ 37% of global population.
Examples: circulating vehicles (D, I), registrations (I), daily travels (US): features of a saturated market.

USA [Dept. of Transport, 2011] average miles/vehicle per day, 2008-2011
The development of the circulating vehicles, infrastructures and personal mobility, which have significantly marked the second half of the last century in Europe, show today some conditioning factors.

A. saturation of the land
B. limitedness of the energy resource
C. respect of the environment
D. maintenance of all the existing infrastructures
E. safety increase in transport systems, a will
F. relationships among people and families.

India?
new TRANSPORT SYSTEMS

- Travellers
- Vehicles
- Infrastructures
- Energy

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The **urban population** of the **EU-27** amounted to **73%** of the total population in **2008**

[Source: EU energy and transport in figures, Statistical Pocketbook 2010, p. 18]
Transport installations
(trains, metros, APMs)

Public transport

Private transport

Motor cars, ITS

Trains HST

Metros, APMs...

two-wheeled veh., rickshaws

Private cars, ITS

India

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Bicycles, motorcycles, rickshaws and public transport (subways)?

A private motorised mobility? 2-3, 4 wheels?

A balanced scenario? With “ITS” (intelligent transport systems)?

On which basis?
India (2008), CO₂ transport systems: ≈9.2%

Source: IEA, 2010 data 2008
EU (2008), Transport systems: CO$_2$ at 24%, energy use ≈32-33%

Private cars | Emissions
---|---

Unless new engines, hybrid vehicles, electric vehicles (EV) are pursued

City towns: energy solutions | Recharge areas | Private mobility, with more «ITS»
Urban recharging possibilities

Choices by car constructors

ICE - oriented

EV - oriented

Locally unsold vehicles

Home constructors ready

Traditional market, but possibly uncompliant with EU or Indian aims and regulations

The country imports vehicles by foreign constructors

null

Plenty of

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Internal combustion engines (ICEs)
- Diesel,
- Gasoline (fuel),
- CNG

Distance travelled
- Long (>200 km)
- Short (10-100 km)

National production of electric energy from different primary energy sources

Urban recharging possibilities

Point of view of the traveller or driver

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MEASURABLE ANALYSES

On which basis we may prepare a high-level integrated planning?
Fuels

Renewable

Fossil

Crude oil
Natural gas
Coal
Nuclear sources (Uranium, Plutonium)

Primary energy

Energy carrier

Diesel, gasoline, cherosene
Gas
Fuels from synthesis
Hydrogen

Use in transport systems

ICEs for road vehicles
ICEs for locomotives and installations
ICEs for ships
Jet

Internal combustion engines

Power production plants

Electric power

Other uses

Electric motors

Batteries
Fuel cells (electrochemical)

(Source: elaboration from ERTRAC, 2011)
The Well to Tank (WTT) evaluation accounts for the energy expended and the associated GHG emitted in the steps required to deliver the finished fuel into the on-board tank of a vehicle. It also considers the potential availability of the fuels, through their individual pathways and associated costs.

The Tank to Wheels (TTW) evaluation accounts for the energy expended and the associated GHG emitted by the vehicle/fuel combinations. It also includes an assessment of the expected relative retail prices of the various vehicle configurations.

We refer to the Well to Wheels (WTW) integration, giving a global assessment of the energy required and the GHG emitted per km driven on the fuel/vehicle combinations considered.

\[
WTW \begin{bmatrix} \frac{MJ_t}{km} \end{bmatrix} = WTT \begin{bmatrix} \frac{MJ_t}{MJ_f} \end{bmatrix} \cdot TTW \begin{bmatrix} \frac{MJ_f}{km} \end{bmatrix}
\]
# WTT of most common and promising fuels (EU)

*in collaboration with Dept. of Energy (prof. Santarelli), Politecnico di Torino - I*

<table>
<thead>
<tr>
<th>FUEL</th>
<th>WTT [MJ\textsubscript{i}/MJ\textsubscript{f}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel-gasoline (petrol)</td>
<td>1.14</td>
</tr>
<tr>
<td>Gasoil-diesel</td>
<td>1.16(^1)</td>
</tr>
<tr>
<td>CNG</td>
<td>1.19</td>
</tr>
<tr>
<td>Hydrogen from NG</td>
<td>1.82</td>
</tr>
<tr>
<td>Hydrogen from electrolysis (from wind power)</td>
<td>1.74</td>
</tr>
<tr>
<td>Hydrogen from electrolysis (European mix)</td>
<td>4.58</td>
</tr>
<tr>
<td>Electricity (European mix)</td>
<td>2.86</td>
</tr>
<tr>
<td>Electricity (European mix based on carbon)</td>
<td>2.59</td>
</tr>
<tr>
<td>Electricity from wind power</td>
<td>0.04</td>
</tr>
<tr>
<td>Electricity from nuclear energy</td>
<td>3.73</td>
</tr>
</tbody>
</table>

\(^1\) Nearly 1 *barrel each 6* cannot be benefited in its final use.

## TTW, motor-cars (EU)

<table>
<thead>
<tr>
<th>PROPULSIVE TECHNOLOGY</th>
<th>TTW [MJ\textsubscript{f}/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE, fuel/gasoline/petrol*</td>
<td>1.91</td>
</tr>
<tr>
<td>ICE – gasoil/diesel*</td>
<td>1.72</td>
</tr>
<tr>
<td>ICE – CNG</td>
<td>1.9</td>
</tr>
<tr>
<td>ICE – Hydrogen</td>
<td>1.67</td>
</tr>
<tr>
<td>ICE, hybrid - fuel/gasoline</td>
<td>1.62</td>
</tr>
<tr>
<td>ICE- hybrid – gasoil/diesel</td>
<td>1.41</td>
</tr>
<tr>
<td>Electric car with, batteries</td>
<td>1.1</td>
</tr>
<tr>
<td>FC – Hydrogen</td>
<td>0.91</td>
</tr>
</tbody>
</table>

### TTW of main propulsive technologies in the motor-car field in 2010

* In 2002, the TTW of ICEs (*internal combustion engines*) – fuel/petrol and gasoil were respectively 2.25 and 2.09 MJ\textsubscript{f}/km
TTW, trains (EU)

<table>
<thead>
<tr>
<th>TRAIN</th>
<th>TTW $[MJ/(t\cdot km)]$</th>
<th>[t/place]*</th>
<th>[t/place]$_{FL}$</th>
<th>Use level</th>
<th>TTW$^*$ $[MJ/(p\cdot km)]$</th>
<th>TTW$_{FL}$ $[MJ/(p\cdot km)]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGV (F)</td>
<td>0.148</td>
<td>0.914</td>
<td>0.966</td>
<td>65%</td>
<td>0.209</td>
<td>0.143</td>
</tr>
<tr>
<td>ICE (D)</td>
<td>0.104</td>
<td>1.294</td>
<td>1.336</td>
<td>51%</td>
<td>0.263</td>
<td>0.138</td>
</tr>
<tr>
<td>AVE (SP)</td>
<td>0.136</td>
<td>1.305</td>
<td>1.346</td>
<td>66%</td>
<td>0.268</td>
<td>0.183</td>
</tr>
</tbody>
</table>

$TTW^* e TTW_{PC}$ for some European trains

$$TTW^* \left[ \frac{MJ}{pkm} \right] = TTW \left[ \frac{MJ}{tkm} \right] \cdot \left[ \frac{t}{place} \right] \cdot \left[ \frac{p}{place} \right]^{-1}$$
Empirical methods for calculating the TTW in railways

\[
\left[ \frac{MJ}{tkm} \right]_{\text{average}} = \frac{1}{N} \sum_{i=1}^{N} \left[ \frac{MJ}{tkm} (v_{\text{aver.}} ; d) \right]_i
\]

\[
\left[ \frac{MJ}{tkm} \right] = A \cdot \frac{v_{\text{average}}^2}{\ln(x)} + B
\]

<table>
<thead>
<tr>
<th>TRAIN</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE, Germany</td>
<td>0.007</td>
<td>74</td>
</tr>
<tr>
<td>TGV, France</td>
<td>0.0097</td>
<td>70</td>
</tr>
<tr>
<td>APT, Great Britain</td>
<td>0.012</td>
<td>70</td>
</tr>
<tr>
<td>Heavy freight trains (more than 600 tons unloaded)</td>
<td>0.019</td>
<td>63</td>
</tr>
<tr>
<td>RC, Sweden</td>
<td>0.015</td>
<td>81</td>
</tr>
</tbody>
</table>
Empirical methods for calculating the TTW in railways

\[ F = A_0 + A_1 v + A_2 v^2 + mg \sin \alpha \]

\[ F' = B_0 + B_1 v + B_2 v^2 + g \sin \alpha \]

<table>
<thead>
<tr>
<th>TRAIN</th>
<th>B_0</th>
<th>B_1</th>
<th>B_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>APT, GB</td>
<td>16.6</td>
<td>36.6 \times 10^{-2}</td>
<td>26 \times 10^{-3}</td>
</tr>
<tr>
<td>Oldest UK trains</td>
<td>15.5</td>
<td>29.2 \times 10^{-2}</td>
<td>57.4 \times 10^{-3}</td>
</tr>
<tr>
<td>Freight trains</td>
<td>24.7</td>
<td>0</td>
<td>84.5 \times 10^{-3}</td>
</tr>
<tr>
<td>IC3, Denmark– single unit</td>
<td>19.7</td>
<td>0</td>
<td>42.5 \times 10^{-3}</td>
</tr>
<tr>
<td>IC3, Denmark – multiple units</td>
<td>19.7</td>
<td>0</td>
<td>24 \times 10^{-3}</td>
</tr>
<tr>
<td>ICE, Denmark – Loco BR103</td>
<td>16</td>
<td>0</td>
<td>22.5 \times 10^{-3}</td>
</tr>
</tbody>
</table>

\[ E' = \frac{1}{L} \int_0^L \left( a + B_0 + B_1 v + B_2 v^2 \right) dl + g \frac{\Delta h}{L} \]

\[ E' \approx \frac{N_{fer} + 1}{L} \cdot \frac{v_{\text{max}}^2}{2} + B_0 + B_1 \cdot v_{\text{med}} + B_2 \cdot v_{\text{med}}^2 + g \cdot \Delta h \]
### WTW for car and WTW\textsubscript{FL} of trains and cars

<table>
<thead>
<tr>
<th>Transport means</th>
<th>WTW [MJ/km]</th>
<th>Case 1 (driver)</th>
<th>Case 2 (average)</th>
<th>Case 3 (5 pass.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE Train – wind power</td>
<td>-</td>
<td></td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>TGV Train – wind power</td>
<td>-</td>
<td></td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>AVE Train – wind power</td>
<td>-</td>
<td></td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Electric car – wind power</td>
<td>0.044</td>
<td>0.011</td>
<td>0.012</td>
<td>0.013</td>
</tr>
<tr>
<td>ICE Train – carbon mix</td>
<td>-</td>
<td></td>
<td>0.333</td>
<td></td>
</tr>
<tr>
<td>ICE Train – EU mix</td>
<td>-</td>
<td></td>
<td>0.368</td>
<td></td>
</tr>
<tr>
<td>TGV Train – carbon mix</td>
<td>-</td>
<td></td>
<td>0.371</td>
<td>0.410</td>
</tr>
<tr>
<td>TGV Train – EU mix</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Car FC – H\textsubscript{2} from electrol. from wind power</strong></td>
<td>1.583</td>
<td>0.396</td>
<td>0.440</td>
<td>0.485</td>
</tr>
<tr>
<td><strong>Hybrid car – electricity and gasoil</strong></td>
<td>1.636</td>
<td>0.409</td>
<td>0.455</td>
<td>0.501</td>
</tr>
<tr>
<td><strong>Car FC – H\textsubscript{2} from Natural gas</strong></td>
<td>1.656</td>
<td>0.414</td>
<td>0.461</td>
<td>0.507</td>
</tr>
<tr>
<td><strong>AVE Train – carbon mix</strong></td>
<td>-</td>
<td></td>
<td>0.473</td>
<td></td>
</tr>
<tr>
<td><strong>ICE Train – nuclear energy</strong></td>
<td>-</td>
<td></td>
<td>0.479</td>
<td></td>
</tr>
<tr>
<td><strong>Hybrid car – electricity and gasoline/oil</strong></td>
<td>1.847</td>
<td>0.462</td>
<td>0.514</td>
<td>0.565</td>
</tr>
<tr>
<td><strong>AVE Train – EU mix</strong></td>
<td>-</td>
<td></td>
<td>0.522</td>
<td></td>
</tr>
<tr>
<td><strong>TGV Train – nuclear energy</strong></td>
<td>-</td>
<td></td>
<td>0.534</td>
<td></td>
</tr>
<tr>
<td><strong>Internal combustion car – gasoli/diesel</strong></td>
<td>1.995</td>
<td>0.499</td>
<td>0.555</td>
<td>0.611</td>
</tr>
<tr>
<td><strong>Internal combustion car – oil/gasoline</strong></td>
<td>2.177</td>
<td>0.544</td>
<td>0.605</td>
<td>0.667</td>
</tr>
<tr>
<td><strong>Internal combustion car – natural gas</strong></td>
<td>2.261</td>
<td>0.565</td>
<td>0.629</td>
<td>0.692</td>
</tr>
<tr>
<td><strong>AVE Train – nuclear energy</strong></td>
<td>-</td>
<td></td>
<td>0.681</td>
<td></td>
</tr>
<tr>
<td><strong>Electric car – carbon mix</strong></td>
<td>2.849</td>
<td>0.712</td>
<td>0.792</td>
<td>0.872</td>
</tr>
<tr>
<td><strong>Internal combustion car – H\textsubscript{2} from electrolysis from wind energy</strong></td>
<td>2.906</td>
<td>0.726</td>
<td>0.808</td>
<td>0.889</td>
</tr>
<tr>
<td><strong>Internal combustion car – H\textsubscript{2} from natural gas</strong></td>
<td>3.039</td>
<td>0.760</td>
<td>0.845</td>
<td>0.930</td>
</tr>
<tr>
<td><strong>Electric car – EU mix</strong></td>
<td>3.146</td>
<td>0.787</td>
<td>0.875</td>
<td>0.963</td>
</tr>
<tr>
<td><strong>Electric car – Nuclear energy</strong></td>
<td>4.103</td>
<td>1.026</td>
<td>1.141</td>
<td>1.256</td>
</tr>
</tbody>
</table>
**TTW, WTW* e WTW_{FL} for some Italian trains**

<table>
<thead>
<tr>
<th>TRENO</th>
<th>Primary energy source</th>
<th>Occupancy</th>
<th>TTW [kJ/(t⋅km)]</th>
<th>TTW* [MJ/(p⋅km)]</th>
<th>TTW_{FL} [MJ/(p⋅km)]</th>
<th>WTW* [MJ/(p⋅km)]</th>
<th>WTW_{FL} [MJ/(p⋅km)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
<td>EU Mix carbon. Eur. Mix</td>
<td>&gt; 50%</td>
<td>70.49</td>
<td>0.118</td>
<td>0.062</td>
<td>0.336</td>
<td>0.176</td>
</tr>
<tr>
<td></td>
<td>Wind energy</td>
<td></td>
<td></td>
<td>0.005</td>
<td>0.002</td>
<td>0.304</td>
<td>0.159</td>
</tr>
<tr>
<td>IR</td>
<td>EU Mix carbon. Eur. Mix</td>
<td>&gt; 50%</td>
<td>109.4</td>
<td>0.187</td>
<td>0.098</td>
<td>0.476</td>
<td>0.280</td>
</tr>
<tr>
<td></td>
<td>Wind energy</td>
<td></td>
<td></td>
<td>0.007</td>
<td>0.004</td>
<td>0.431</td>
<td>0.254</td>
</tr>
<tr>
<td>ETR 500</td>
<td>EU Mix carbon. Eur. Mix</td>
<td>54.8%</td>
<td>74.35</td>
<td>0.136</td>
<td>0.077</td>
<td>0.352</td>
<td>0.200</td>
</tr>
<tr>
<td></td>
<td>Wind energy</td>
<td></td>
<td></td>
<td>0.005</td>
<td>0.003</td>
<td>0.388</td>
<td>0.220</td>
</tr>
</tbody>
</table>

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Example:
Absolute energy consumption on the Turin – Milan link
(by rail, road by private car or PT)

<table>
<thead>
<tr>
<th>Transport system</th>
<th>Absolute energy consumption [GJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train ETR 500</td>
<td>48.54</td>
</tr>
<tr>
<td>Train Intercity</td>
<td>51.44</td>
</tr>
<tr>
<td>Bus, in line</td>
<td>65.05</td>
</tr>
<tr>
<td>Inter-regional Train</td>
<td>72.85</td>
</tr>
<tr>
<td>Private car 2010</td>
<td>169.80</td>
</tr>
<tr>
<td>Private car 2002</td>
<td>297.31</td>
</tr>
</tbody>
</table>

HST (high speed train): minor length and absence of stops
The EU Parliament has launched extensive measures to enhance energy efficiency and energy saving and for the integration of climate change objectives into transport and energy policies as well as the need for specific measures in the transport sector to address energy use and greenhouse gas emissions.

In order to introduce a new culture for urban mobility, the community approved also the support for stakeholders in promoting more efficient vehicles.

The approach is based on the internalisation of external costs by means of lifetime costs of fuel, CO₂ emissions and pollutant emissions of the vehicles.

According to requirements of Directive 33/2009, it is possible to obtain details of the various vehicle categories and sub-categories.

Results for passenger cars only on the base of a TTW analysis, in I semester 2011 (costs of NG and Diesel/Fuel vary)

Source: Santarelli, De Oliveira – Politecnico di Torino, I Semester, 2011

• Particulate matter
• Non methane hydrocarbures
• Nitrogen oxides
<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description of SCENARIOS for TTW and WTW</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCN1</td>
<td>Cost based on the internalization of external costs by means of lifetime costs of fuel, CO\textsubscript{2} emissions and pollutant emissions of the vehicles (TTW) → previous graph</td>
</tr>
<tr>
<td>SCN2</td>
<td>It considers the well to wheel analysis of the electricity and also of all others energy carriers or vectors (WTW)</td>
</tr>
<tr>
<td>SCN3</td>
<td>Inclusion of analysis of a short term forecast, in which new technologies under development are taken into account and compared with previous scenarios (WTW)</td>
</tr>
<tr>
<td>SCN4</td>
<td>Inclusion of analysis of a long term forecast, in which new technologies and fuels will become affordable and applicable in large scale (WTW)</td>
</tr>
</tbody>
</table>
Cost based on the internalization of external costs by means of lifetime costs of fuel, CO2 emissions and pollutant emissions of the vehicles (T2W)

It considers the well to wheel (W2W) analysis of the electricity and also of all others energy vectors.
Inclusion of analysis of a short term forecast, in which new technologies (turbocharging/downsizing, variable valve actuation) under development are taken into account and compared with previous scenarios (W2W+new technologies); estimations!
Inclusion of analysis of a long term forecast (nearly 2030), in which new technologies would become affordable and applicable in large scale (W2W)

Source: Dalla Chiara, Pinna, Navarro Herdy – Politecnico di Torino, November 2011
Established and emerging battery technologies
(Source: ABB Batteries & Electric Vehicles, elab. 2010-2011)

- Lead-acid
- Ni-MH
- Ni-Cd
- Li-ion
- Li-polymer
- Li-metal
- Al/Air
- Li/Air
- New systems

Ref: 18650s; 2.6Ah
Ref: AA alkaline
5 mm prismatic cells <1300 mAh

Wh/kg vs Wh/l

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Comparison of energy storage technologies suitable for HEVs
(Source: Mi, Marsur and Wenzhong- HEV, elab. 2011)
• **Wired recharging**
• **Wireless recharging, contactless, inductive**
• **Wireless recharging with contact, conductive**
• **Battery substitution**
Most important European Communications, Action Plans and legislation concerning urban ITS deployment and Energy issues include:

- **The ITS Directive** *(2010/40/EU)*

  concerned with the coordinated and coherent deployment of ITS within the Union including the development of specifications and standards.

- **Action Plan on Urban Mobility** *(COM (2009) 490)*

  on sustainable urban mobility and concerned with ITS deployment in urban areas in regard to “Action 20: ITS for urban mobility” (e.g., electronic ticketing and payment, traffic management, travel information, access regulation and demand management and opportunities via Galileo).


  adopted to accelerate and coordinate the deployment of ITS is especially concerned with urban ITS in regard to “Action 6.4: Set up of a European Urban ITS collaboration platform on urban mobility”. As a result of this action the “Urban ITS Expert Group” has been established by the European Commission with key stakeholders and organisations.

[Source: elaboration from ERTICO thematic paper: “ITS for Urban Mobility”, Nov 2011]
Published in 2011, concerned with competitive and resource efficient European transport systems which includes inter alia “clean urban transport and commuting”. Use of “conventionally fuelled” cars in urban transport should be halved by 2030 and they should be phased out in 2050. Furthermore, major urban logistics should be CO2 free by 2030. In addition goals 8 (the establishment of the framework for European multimodal transport information, management and payment system by 2020) and 9 (close to zero road fatalities on road transport by 2050) are concerned with urban mobility.

In the Green Paper on urban mobility the deployment of ITS in urban areas is clearly emphasised in section 2.3 “Towards smarter urban transport”.

Digital Agenda for Europe


A European strategy on clean and energy efficient vehicles (COM (2010) 186):
According to this communication fully electric vehicles (FEV) are said to be most promising especially in urban use.

[Source: elaboration from ERTICO thematic paper: “ITS for Urban Mobility”, Nov 2011]

- Aims to stimulate the market for clean and energy-efficient road transport, and especially – since this would have a substantial environmental impact – to influence the market for standardized vehicles produced in larger quantities: passenger cars, buses, coaches and trucks;
- the aim is to ensure a level of demand for clean and energy-efficient road transport vehicles which is sufficiently substantial to encourage manufacturers and the industry to invest in and further develop vehicles with low energy consumption, CO₂ emissions, and pollutant emissions.

2 December 2011

“Intelligent Transport Systems in the field of road transport and interfaces with other transport modes”
Towards:

**OIL-INDEPENDENT ROAD TRANSPORT**

**ITS**

**RAILWAYS, APMs, METROS, systems in fixed guideways, including rope traction**
Some EU cities, today

FUTURE AIMS OF SOCIETY
QUALITY, SAFETY, SECURITY, EFFICENCY

Technological solutions

Automated People movers and Metros

Intelligent transport systems

More oil-independent vehicles and green motor vehicles

including bike sharing
Some EU trends in cities

Transport systems in guided ways

Intelligent transport systems

Oil-independent road transport

B. Dalla Chiara, Politecnico di Torino - IT, EBTC, New Delhi 4th of December 2011

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Motorised road transport

ENERGY: COUNTRY

Research and industrial capabilities

Electricity producer

Oil importer

Natural gas

multifuel

LONG HAULAGE, LONG TRAVELS

SHORT TRAVELS

Battery intensive

Urban recharging possibilities

Role of the city

B. Dalla Chiara, Politecnico di Torino - IT, EBTC, New Delhi 4th of December 2011
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References