Shift from Oil Fuelled Cars
for a Sustainable Mobility in France

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Mobility Issues

Mobility is an essential element of modern societies

- *an important input to economic growth*
- *a core societal aspiration*
- *an enabler of well being or personal development*

Mobility is the key end-use sector for the battle against climate change:

- “we won’t be able to satisfy growing demands for transportation services with current solutions without seriously harming the environment.”

Transport became one of the main activities of human beings
Externals Drivers of Mobility

Five main drivers develop outside the transport system and have a direct impact on it:

- energy
- economy
- population
- technological change (diffusion of ICT technologies)
- social change
Social Change

the increased purchasing power (income growth)
le travail des femmes
les logements en peri-urbain
Internal Drivers of Mobility

Drivers that develop within the transport sector itself and contribute to shape transport demand patterns:

- the continuous development of new transport infrastructure
- vehicle and fuels technologies which make transport easier and faster

Drivers where the transport system produces an impact on the environment and society contexts:

- the contribution to climate change
- environment degradation
- safety concerns
Policy Drivers of Mobility

- Promouvoir ou dissuader – fiscalité
- Inciter – bonus/malus
- Imposer – réglementation
The developments of transport networks were driven:

- by the emergence of cheap and abundant fossil fuels
- By the development of high-quality distribution medium of fuels

Travelling and transporting goods, has become faster, cheaper, more comfortable and reliable.

This allowed for the impressive mobility growth we have experienced.

The development of mobility was also for the take off of economic
French Mobility

French mobility steadily increased

- + 40% from 1988 to 1998 for personal vehicles
- while travel time remains constant (1 hour per day)
  - and has not changed over the last 40 years
- increasing vehicle speed
  - Only 12% vehicle have a maximal speed less than 160km/h
The French GHG Emissions Specificity

The transport part in the French GHG total emissions is more important than in United States or all the European countries.

However CO2 emissions per capita for transport are the same 2.2 t.

France is one of the industrial nations which emits least carbon dioxide per capita.

- French energy sector emits 58 MtCO2e against 345 for Germany or 178 for Poland.
- France emits 386 MtCO2e a year against 846 in Germany or 307 in Poland.
The French Energy Specificity

20% increase in overall primary energy consumption from 1990 to 2004 … but the energy situation in France has improved

Thanks to

- the rapid growth of nuclear power production (2WW rank)
- Importance of hydraulics in its energy balance

However France is still very dependent on oil and gas, particularly for transport (98% dependency on oil)
Focus on Road Transport Sector in France

Clearly a dominant sector with a consumption of 88% of the French domestic passengers transportation sector in 2005

- *It contributes for more than 18% to the GHG Emissions*

Private cars account for 55.9% of the total energy consumed in road transport in 2005 ... but this share was 60.6% in 1990

between 1990 and 2005, road transport activity has improved

- *its energy efficiency increased* by 20%
- *its activity* by 61%
- *its energy consumption* by 29%
- *its related GHG emissions following a corresponding decreasing trend*
The other Sectors have reduced or stabilized theirs emissions

**Industry:**
- The '90s restructuring has driven a considerable reduction of energy intensity of industrial value added
- 2.74 % per year during 1990-2000 and 1.13 % after

**Agriculture:**
- Energy intensity of has decreased substantially between 1990 and 2005 (1.5% per year)

**Residential sector**
- Its consumption (26 % of total final energy consumption in 2005) is slightly up from 25 % in 1990
Because the answer is less straightforward, there is a need for scientific forecast based on modeling approach.

- They are inadequate to predict exactly the long-range future.
- But they are able to highlight:
  - links between issues
  - relationships between global and local activities
  - actions such as energy or mobility saving
  - policies such as taxes or emission constraints
Transport Sector Issues

The transport sector will have to

- satisfy a greater demand for Mobility

- find solutions to address its negative externalities which affect
  - the environment (pollution, CO2 emissions, and noise)
  - the economy (congestion)
  - the society (health, safety and security).

- Be the end-use sector for the battle against climate change
The French Markal/Times Reference Energy System

- we define the contribution to mitigation from the transport sector
- which depends on efforts in other sectors
- “we run different scenarios on the French Markal / TIMES Reference Energy System designed by Edi Assoumou”
- Markal / TIMES is a bottom-up approach
- based on an explicit description of the technologies used
- Where the input-output relationships is explicitly formulated for each technology
- investments levels, activities levels and total installed capacities are the main decision variables
The French Markal/Times RES

- optimises energy systems in the long-term (2000-2050)
- minimises the total discounted cost
  - over the chosen time horizon and for given final services demands
- required demands for energy services
- Mobility demands
  - are differentiated in short and long distance travels
  - have to be satisfied with strong constraints on CO2 emission levels (three scenarios will be studied)
- The systemic approach used ensures consistency of the results across all end-use sectors
- This paper propose a focus on road sector more precisely on personal vehicles
CO2 emissions of the French Transport Sector

Emissions de CO2 du secteur des transports

MtCO2

0 20 40 60 80 100 120 140 160


Route  Fer  Fluvial  Maritime*  Aérien*

Emissions de CO2 du secteur des transports

CO2 emissions of the French Transport Sector
Passengers Transport by Mode: A Major Contribution of Personal Vehicles

Voitures particulières
Bus&Cars
Ferroviaire hors métro
Métro
Transports aériens
Energy Consumption for the transport sector from 1990 to 2004 [DGEMP] in ktoe

![Energy Consumption Graph]

- Modes and Resources
- Ktep
- Essence VP
- Essence Util.
- Essence Air
- Diesel VP
- Diesel Util.
- Diesel Car&bus
- Diesel Fer
- Fioul Nav.
- Kérozène Air
- Electricité Fer
Focus on French Transport Sector

Passengers Mobility in giga of passengers kilometres (Gvoy.km)
Goods Mobility in giga of metric tons kilometres (Gt.km)
CO2 emissions from energy consumption in kilo metric tons (Kt)
Euro actualisation rate is 5% for all sectors
### Characteristics of the Personal Vehicle

<table>
<thead>
<tr>
<th>Global Description</th>
<th>Performances, class, …</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of kilometres travelled per year</td>
<td></td>
</tr>
<tr>
<td>Average rate of occupancy</td>
<td></td>
</tr>
<tr>
<td>Energy source (commodity on)</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency per mobility type</td>
<td>Short distance mobility</td>
</tr>
<tr>
<td>Long distance mobility</td>
<td></td>
</tr>
<tr>
<td>Minimal part of each mobility type (%)</td>
<td>Short distance mobility</td>
</tr>
<tr>
<td>Long distance mobility</td>
<td></td>
</tr>
<tr>
<td>costs</td>
<td>investement</td>
</tr>
<tr>
<td>Opération et maintenance</td>
<td></td>
</tr>
<tr>
<td>Actualisation rate</td>
<td></td>
</tr>
<tr>
<td>CODE</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>E1_2002</td>
<td>Gasole Indirecte injection Ignition spark</td>
</tr>
<tr>
<td>E2_2002</td>
<td>Gasole Directe injection Ignition spark</td>
</tr>
<tr>
<td>E1_2010</td>
<td>Gasole Indirecte injection Ignition spark</td>
</tr>
<tr>
<td>E2_2010</td>
<td>Gasole Directe injection Ignition spark</td>
</tr>
<tr>
<td>D_2002</td>
<td>Diesel Directe injection Ignition by compression</td>
</tr>
<tr>
<td>D_2010</td>
<td>Diesel Directe injection Ignition by compression</td>
</tr>
<tr>
<td>G_2002</td>
<td>Gas naturel Indirecte injection Ignition spark</td>
</tr>
<tr>
<td>G_2010</td>
<td>Gas naturel Indirecte injection Ignition spark</td>
</tr>
<tr>
<td>H_2010</td>
<td>Hydrogen Indirecte injection Ignition spark</td>
</tr>
<tr>
<td>E1_Hyb</td>
<td>Gasole Indirecte injection Ignition spark Hybrid</td>
</tr>
<tr>
<td>E2_Hyb</td>
<td>Gasole Directe injection Ignition spark Hybrid</td>
</tr>
<tr>
<td>D_Hyb</td>
<td>Diesel Directe injection Ignition by compression Hybrid</td>
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<td>G_Hyb</td>
<td>Diesel Indirecte injection Ignition spark Hybrid</td>
</tr>
<tr>
<td>H_Hyb</td>
<td>Hydrogen Indirecte injection Ignition spark Hybrid</td>
</tr>
<tr>
<td>E1_PHEV96</td>
<td>Gasole Indirecte injection Ignition spark Hybrid Rec.60 miles - 96Km</td>
</tr>
<tr>
<td>E2_PHEV96</td>
<td>Gasole Directe injection Ignition spark Hybrid Rec.60 miles</td>
</tr>
<tr>
<td>D_PHEV96</td>
<td>Diesel Directe injection Ignition by compression Hybrid Rec.60 miles</td>
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<tr>
<td>G_PHEV96</td>
<td>Gas naturel Indirecte injection Ignition spark Hybrid Rec.60 miles</td>
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</table>
Vehicle Additional Cost/ MCI Essence 2002

Surcoûts véhicules MCI divers vs MCI Essence 2002

€

E1  _2002  E2  _2002  E1  _2010  E2  _2010  D_  _2002  D_  _2010  G_  _2002  G_  _2010  H_  _2010  E1  _Hyb  E2  _Hyb  G_  _Hyb  D_  _Hyb  H_  _Hyb  E1  _PHEV 96 km  E2  _PHEV 96 km  D_  _PHEV 96 km  G_  _PHEV 96 km  H_  _PHEV 96 km

E1  _2002  E2  _2002  E1  _2010  E2  _2010  D_  _2002  D_  _2010  G_  _2002  G_  _2010  H_  _2010  E1  _Hyb  E2  _Hyb  G_  _Hyb  D_  _Hyb  H_  _Hyb  E1  _PHEV 96 km  E2  _PHEV 96 km  D_  _PHEV 96 km  G_  _PHEV 96 km  H_  _PHEV 96 km
Influence of Short/Long Distances (freeway/city) on Personal Vehicles CO2 Emissions
Demand Projection for Domestic Passengers Transportation
Hypothesis for Demands Projection
For Domestic Passengers-Mobility
Voluntarist Scenario

![Graph showing demands projection for different transportation modes from 2002 to 2050. The graph includes categories for Voluntary Road Proximity (VP routier proximité), Voluntary Road Long Distance (VP routier longue distance), Collective Proximity (T collectif proximité), Collective Inter-Urban (T collectif interurbain), and Domestic Aviation (Aviation intérieur).]
Hypothesis

Economic growth

| Croissance annuelle moyenne (monde) | ➢ 3% par an |
| Croissance annuelle moyenne (France) | ➢ 2,5% par an jusqu'en 2015 1,8% au-delà |

Demography growth

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Population en milliers</td>
<td>58 796</td>
<td>60 702</td>
<td>62 302</td>
<td>63 728</td>
<td>64 984</td>
<td>66 123</td>
<td>67 204</td>
<td>68 214</td>
<td>69 019</td>
<td>69 563</td>
<td>69 961</td>
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</table>
### Hypothesis of Energy Price

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>gazole ($/baril)</td>
<td>54</td>
<td>67</td>
<td><strong>80</strong></td>
<td>103</td>
<td>126</td>
<td><strong>150</strong></td>
<td>137,5</td>
<td>125</td>
<td>112,5</td>
<td><strong>100,0</strong></td>
</tr>
<tr>
<td>gas ($/MBTU)</td>
<td>6,4</td>
<td>7,7</td>
<td>9</td>
<td>11,3</td>
<td>13,7</td>
<td>16</td>
<td>15,75</td>
<td>15,5</td>
<td>15,25</td>
<td><strong>15,0</strong></td>
</tr>
<tr>
<td>coal ($/tonne)</td>
<td><strong>60,0</strong></td>
<td>68,0</td>
<td>76,0</td>
<td>84,0</td>
<td>92,0</td>
<td><strong>100,0</strong></td>
<td>105,0</td>
<td>110,0</td>
<td>115,0</td>
<td><strong>120,0</strong></td>
</tr>
</tbody>
</table>
# Hypothesis of Mobility

<table>
<thead>
<tr>
<th>G.VOY.Km Millions de passagers</th>
<th>Base 2002</th>
<th>Volontariste 2004</th>
<th>Volontariste 2025</th>
<th>Volontariste 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>VP routier proximité</td>
<td>463</td>
<td>530</td>
<td>560</td>
<td></td>
</tr>
<tr>
<td>VP routier longue distance</td>
<td>205</td>
<td>315</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>T collectif proximité</td>
<td>48</td>
<td>70</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>T collectif longue distance</td>
<td>93</td>
<td>170</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>Aviation : intérieur.</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Aviation : international</td>
<td>76</td>
<td>132</td>
<td>213</td>
<td></td>
</tr>
</tbody>
</table>
Scenarios with Environmental Constraints

CMP1_FR_EVOLn_CCx_SC
CMP1_FR_EVOLn_CCx_SC_TnoG

- CMP = Chaire de Modélisation Prospective
- FR = France
- EVOLn = Demandes VOLontaristes
- SC = scenarios Sans Crise (without crisis)
- TnoG = No gas for transport
- CCx = Contrainte carbone de x \( \text{(from 0 to 50)} \)
  - from 2010 to 2020, the CO2 emissions must decrease by \( x\% / 1990 \)
  - After they’ll decrease by 47 \%
Comparison of CMP1_FEEVOLn_CC10_SC and CMP1_FEEVOLn_CC10_SC_TnoG

In 2050 an important level of electricity appeared.

2040 gas becomes predominant.

2050 gas is replaced by electricity, diesel and gasoline.
CO2 emissions reduction

- C10_SC
- C10_SC_TnoG
- C20_SC
- C20_SC_TnoG
- C30_SC
- C30_SC_TnoG
Evolution of Private Vehicles fleet with/without gas propulsion over the modeling horizon

until 2020, conventional injection motorisation technologies are the preferred technologies; between 2020 and 2030 the tighter carbon constraints induces a shift to gas powered vehicles to conventional hybrid;

from 2030 on, the trend confirms previous technological choices; from gas to hybrid gas, and from hybrids to plug-in hybrids;

pure biofuel vehicles remain marginal (they appear and disappear over a vehicle life time); without support, pure electric vehicles are not selected.
in order to achieve sustainable mobility, our quantitative results highlighted:

- appropriate substitutions between energy sources (and sectors)

- the quick apparition of pure Biofuel (or non hybrid natural gas vehicle) only used as a transition in the French market, may reflect either a world-wide diffusion of the technologies with regard to local conditions, or the high pressure of the environmental constraint and the lack of mature alternative carbon-free technologies at that period. Selected road-maps through enforced R&D and investments could also enable a direct shift from conventional vehicles towards the more promising ones.

The history of innovations of course reminds us that good strategies, diffusion channels and distribution infrastructures are equally important for a commercial success. Yet technical-economic assessments as proposed here provide a valuable first step in order to validate technological landscapes in a prospective vision.