MINES ParisTech

Centre de Gestion Scientifique

GREEN LOGISTICS MANAGEMENT: BALANCING ENVIRONMENTAL AND SHAREHOLDER PRIORITIES

Pr. Eric Ballot

Sept. 2016

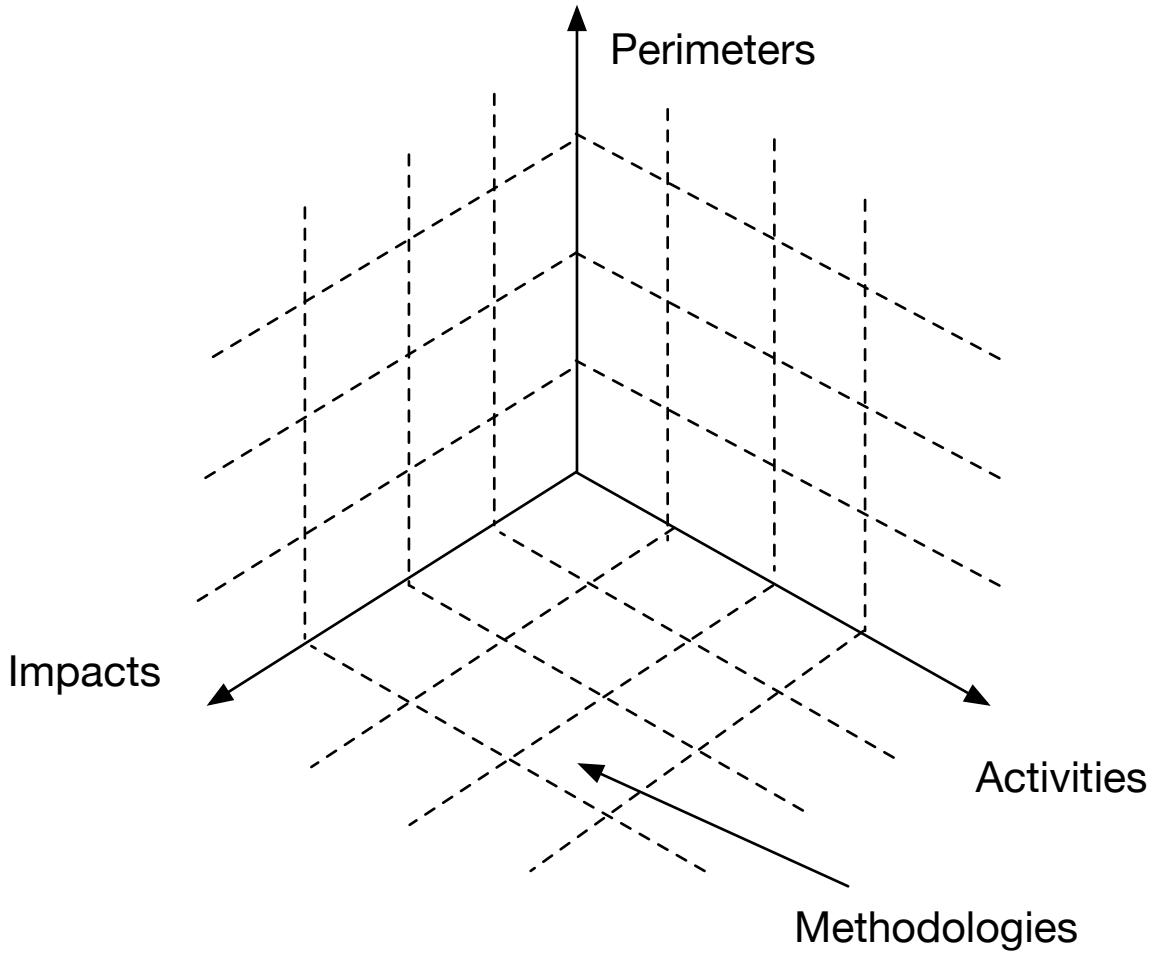
Environmental footprint measurements of supply chain and main influence factors

Historical Complex of Santa Chiara
Via Santa Chiara, 49/C
Naples (Italy)
28th-29th September 2016

Supported by

Agenda

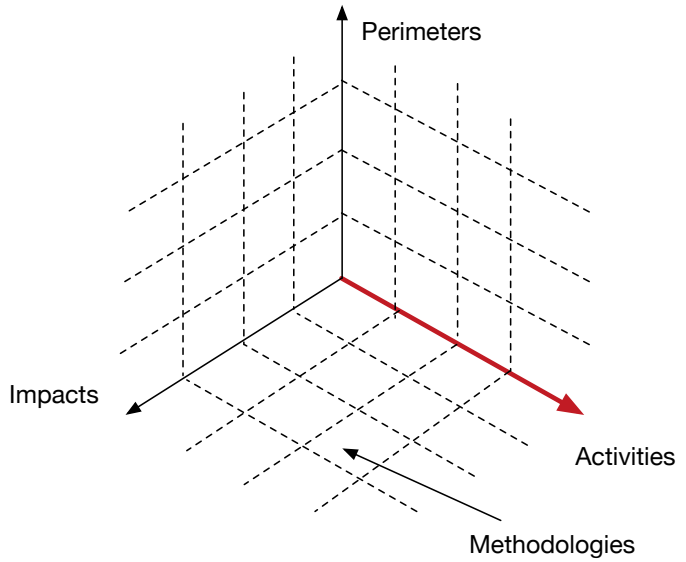
- Environmental footprint measurements of supply chain and main influence factors



Agenda

- 4 main subjects

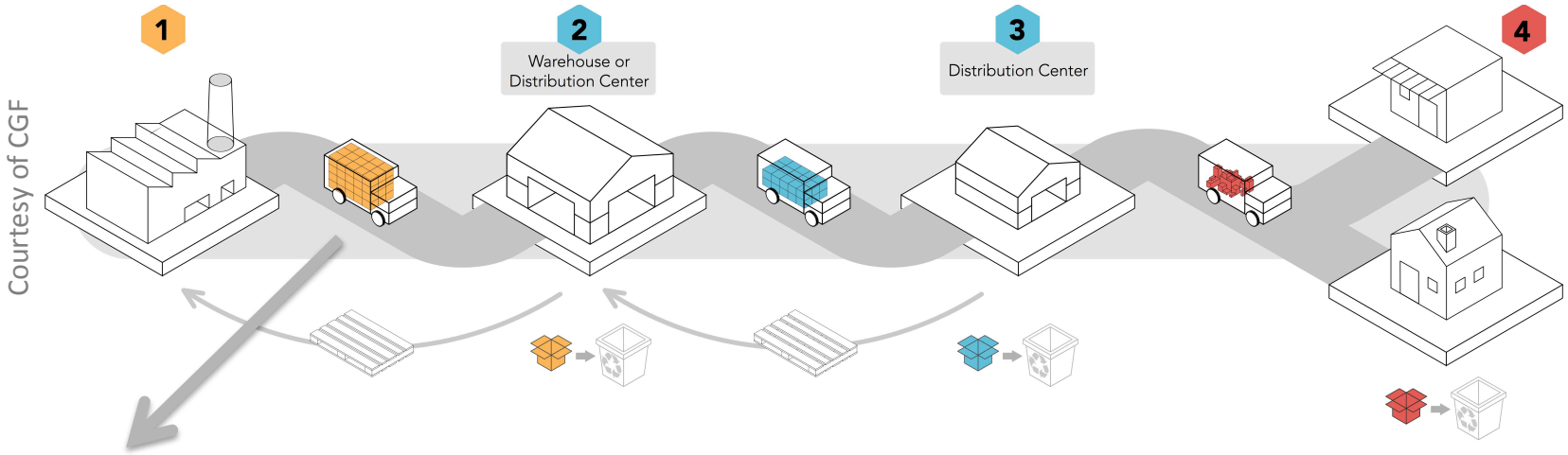
- Activities
  - Transport
  - Warehouse, Distribution centers,…
  - Transport items: containers, pallets, crates, cardboard…
  - Supply chain design
- CO_2 and other impacts
  - Congestion, pollutants
  - Accident, noise
  - Lost of land
- Evaluation methodologies
  - Analytic formula : theory and levers
  - Proxy evaluation : consumption
  - Insight from micro evaluation
- Perimeter
  - Direct: tank to wheel
  - Extended: well to wheel
  - “Embedded emissions”



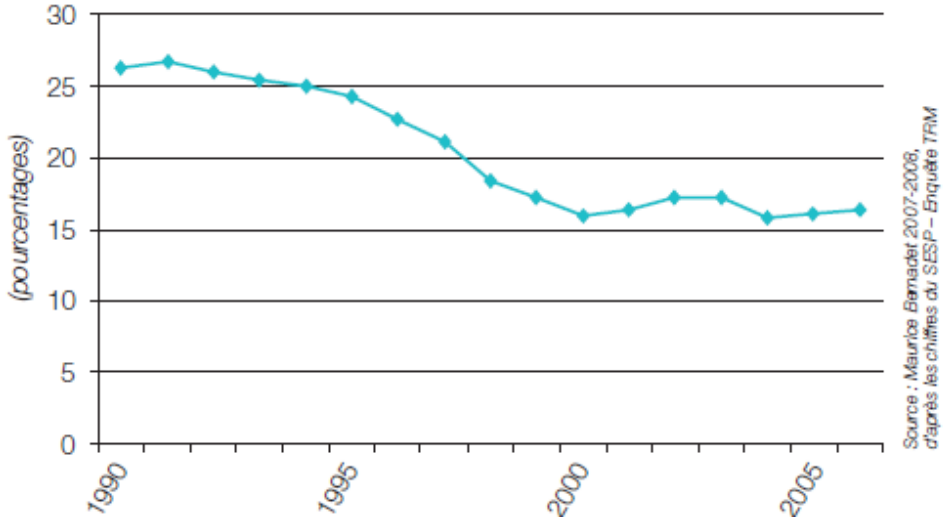
Activities

A major focus on transport

- Many activities to track



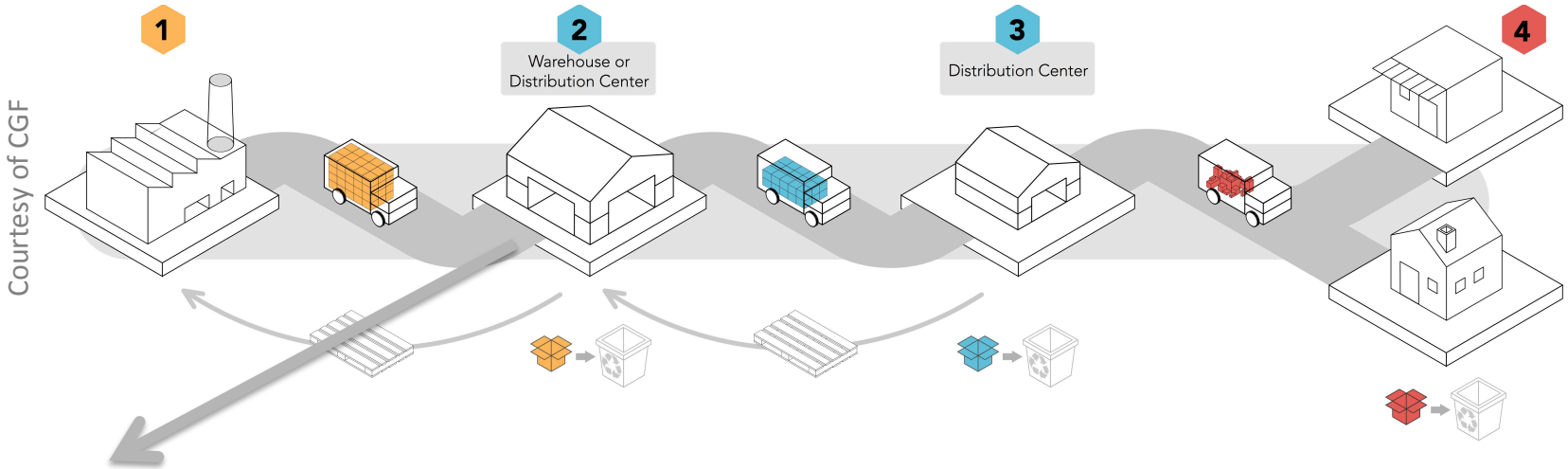
- Transport
  - Less and less easy to track: Now 85% subcontracted
  - Trip before and after?
  - Less than truck load
  - **Impact sharing**



Activities

A major focus on transport

- Many activities to track

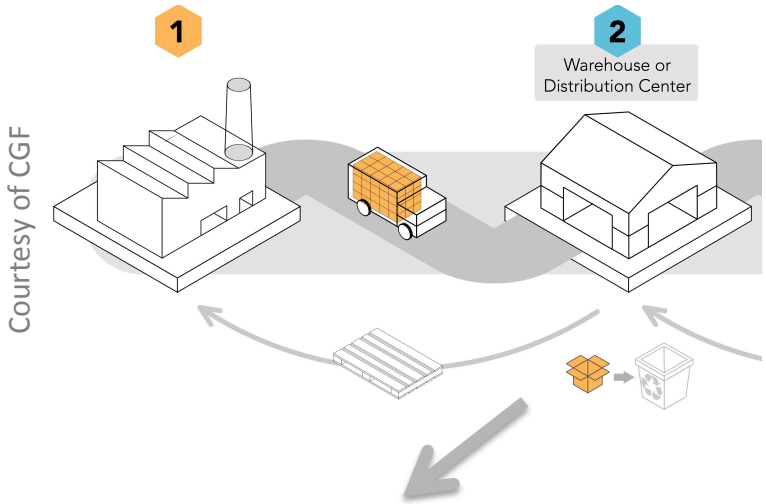


- Warehouse
  - Easier to measure (less subcontracted or few are shared)
  - Main difference between cold chain and ambient chain
  - A major factor is employees' trip up to 1/3 in Cold SC in France (H. Chaari, PhD thesis 2014)
  - Cold chain DC = same order of magnitude as transport but less studied

Activities

A major focus on transport

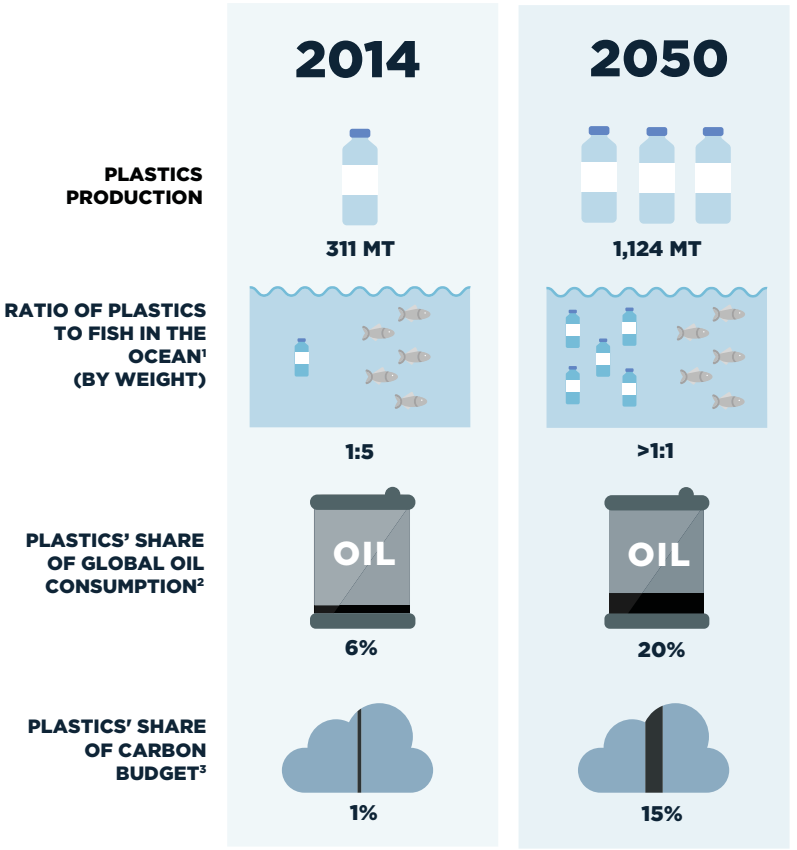
- Many activities to track



- Packaging levels (1/4 of plastic mass)
  - Consumer packaging
  - Cardboard boxes (transport and recycling)
  - Plastic crates (transport and reutilization)
  - Pallets (transport and reutilization)

- Difficult to find independent evaluation
  - Cardboard vs. plastic industries
  - Many parameters to control for comparisons (fill rate, distances, energy sources,…)

Plastic utilization: 32% of packaging leaks in nature

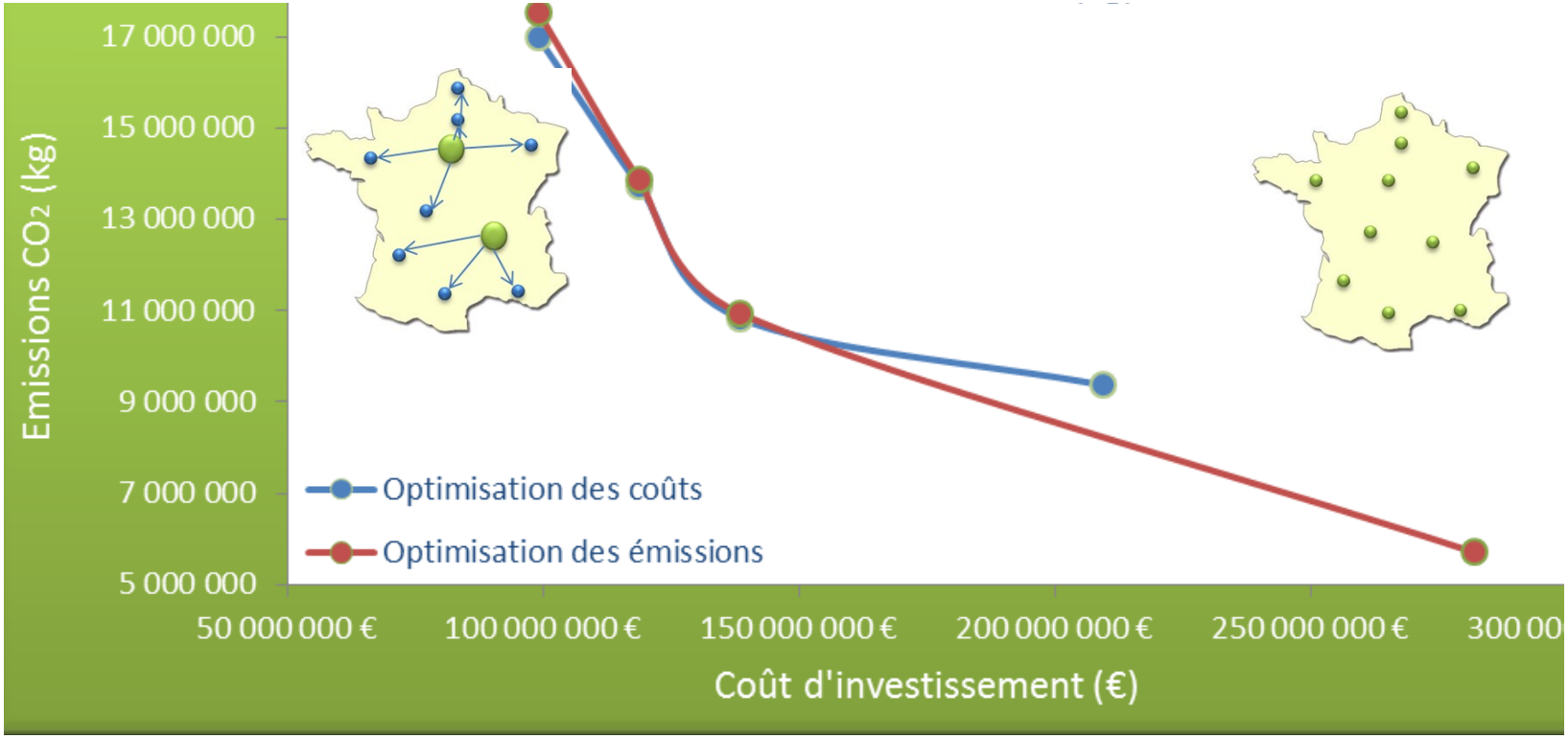


Source: Ellen McArthur foundation

Activities

A major focus on transport

- A major lever: the design of supply chain
  - Short distribution circuit: supply chain to assess
- An example of green supply chain design (fast food sector): trade off between investment and SC footprint

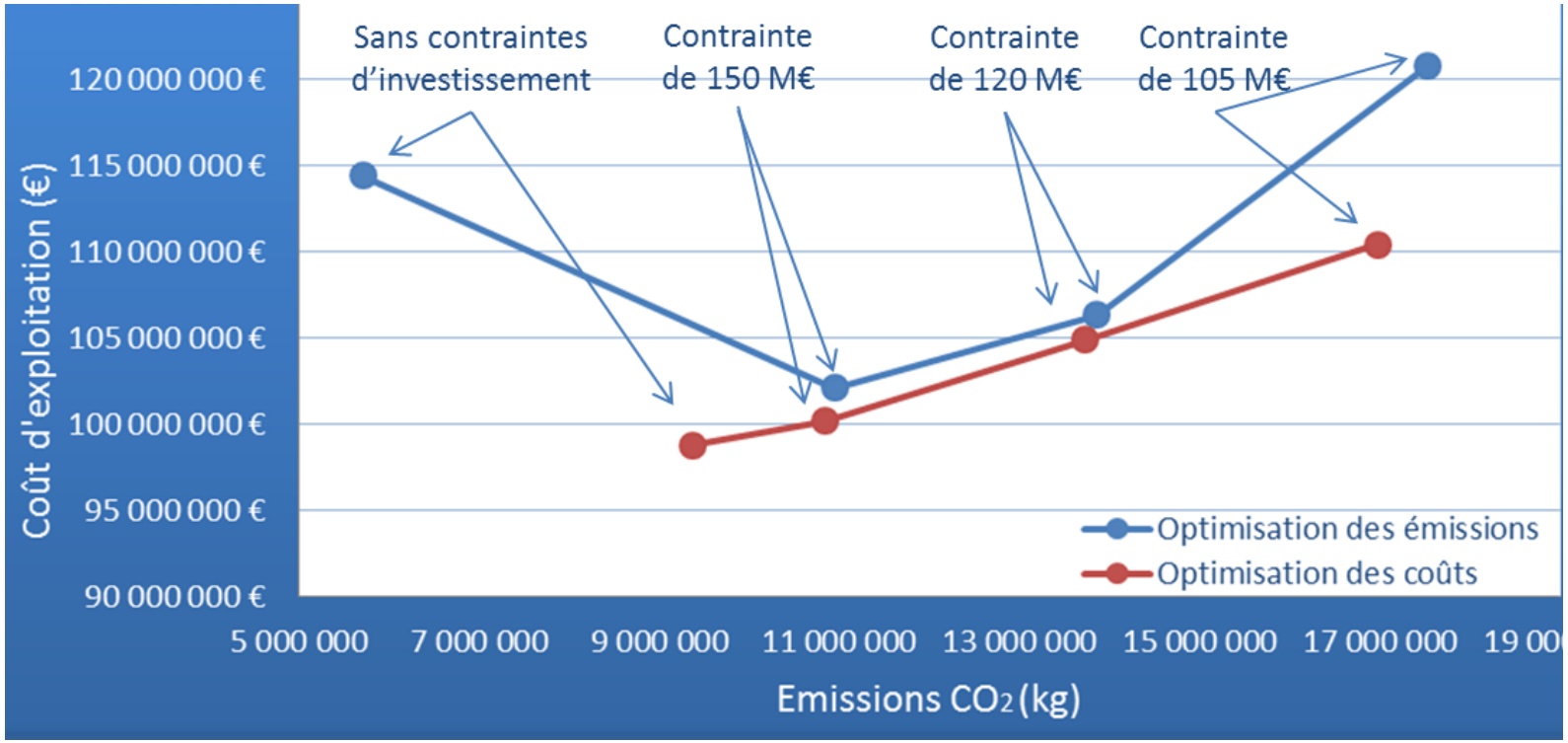


Source: H. Chaari, PhD thesis 2014

Activities

A major focus on transport

- A major lever: the design of supply chain
  - Short distribution circuit: supply chain to assess
- An example of green supply chain design (fast food sector): trade off between investment and SC footprint



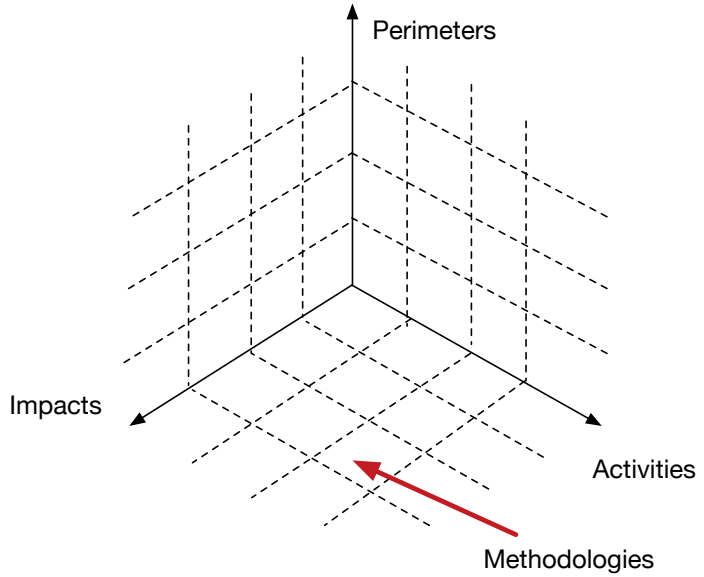
Source: H. Chaari, PhD thesis 2014

Agenda

- 4 main subjects

  - Activities
    - Transport
    - Warehouse, Distribution centers,…
    - Transport items: containers, pallets, crates, cardboard…
    - Supply chain design

  - Evaluation methodologies : CO_2 example
    - Analytic formula : theory and levers
    - Proxy evaluation : consumption
    - Insight from micro evaluation



Measurement methodologies: CO_2

Statistics approach

- Most used approach
- The consumption is transformed in emissions
  - 1kg gasoil generates 2.95 kg CO_2
- Easier to use but a lot of differences between urban an intercity trips
- In France it is in the law to report CO_2 emissions from transport.
  - *L. 1431-3 du code des transports*
- 4 levels of accuracy
  - **Level 1: values by default for a given vehicle class**
    Example: *12T truck – 1.8 of payload 0.240l/km*
  - Level 2: average consumption of the carrier's fleet
  - Level 3: average but by type of service
  - Level 4: actual consumption of a service > Maybe in the furfur but marginal now

Measurement methodologies: CO_2

- Analytic approach

  - Emissions of Trucks,

  - COPERT report, COST and MEET research projects

    – Emissions are split into 3 categories: cold / hot / evaporation

    – If we focus on an empty truck on a flat road with v=speed, an, b, c, d, e, f, K are parameters dependent of type of truck: weight, technology and norm

$$E_{hot} = K + av + bv^2 + cv^3 + \frac{d}{v} + \frac{e}{v^2} + \frac{f}{v^3}$$

    – To take into account load and gradient

$$E_{g/km} = E^{vide}_{g/km}(v) \times C_{charge} \times C_{route}$$

$$C_{charge} = \Phi(\gamma, v) = \kappa + n\gamma + p\gamma^2 + q\gamma^3 + rv + sv^2 + tv^3 + \frac{u}{v}$$

$$C_{route} = \psi(v) = A_6 \cdot v^6 + A_5 \cdot v^5 + A_4 \cdot v^4 + A_3 \cdot v^3 + A_2 \cdot v^2 + A_1 \cdot v^1 + A_0$$

Hickman, J., et al., *Methodology for calculating transport emissions and energy consumption*, in *Deliverable 22 for the project MEET* E.C.D. VII, Editor. 1999, Transportation Research Laboratory: Crowthorne, UK. p. 362.

Measurement methodologies: CO_2

- Analytic approach

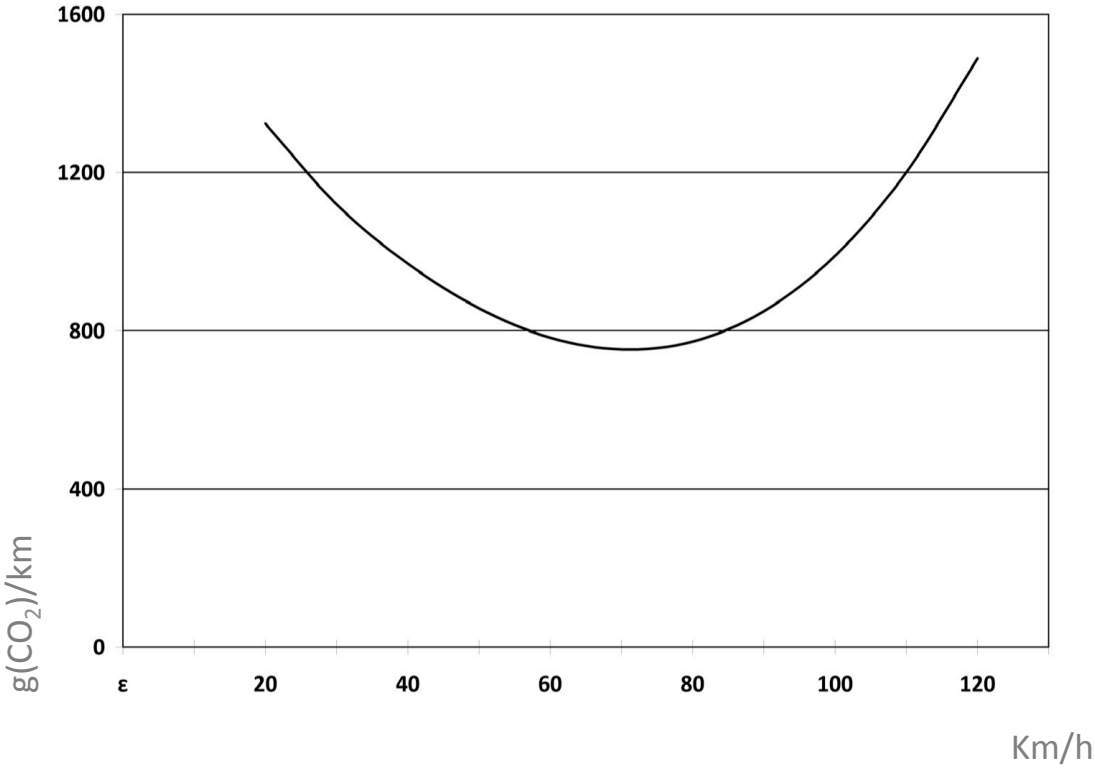
  - Emissions of Trucks…
  - COPERT report, COST and MEET research projects
    - Illustration : speed sensitivity

    - CO_2 emissions could change by:

      50% according to the speed

      42% according to the load

      For HDV [32- 40t]



An average speed is not a good indicator for emissions

Measurement methodologies: CO_2

- Analytic approach

  - Emissions of Trains…
  - COPERT report, COST and MEET research projects
    - Trains are influenced by several factors: speed v, weight T/Tpt and distance between stops x.

$$E_i = WSEC \cdot \frac{Tkm}{Tpt} \cdot BSEF_i \cdot \frac{1}{3.6 \cdot 10^6}$$

    - With

$$WSEC = \frac{kJ}{tonne \times km} = 0.019 \frac{v^2}{\ln x} + 63$$

We usually don't know the distance between two stops [Δ=±30%] in [50, 250] km
If the speed varies from 80 to 100 [Δ=+56%]

    - BESF = emission factor for a given source of energy g/kWh

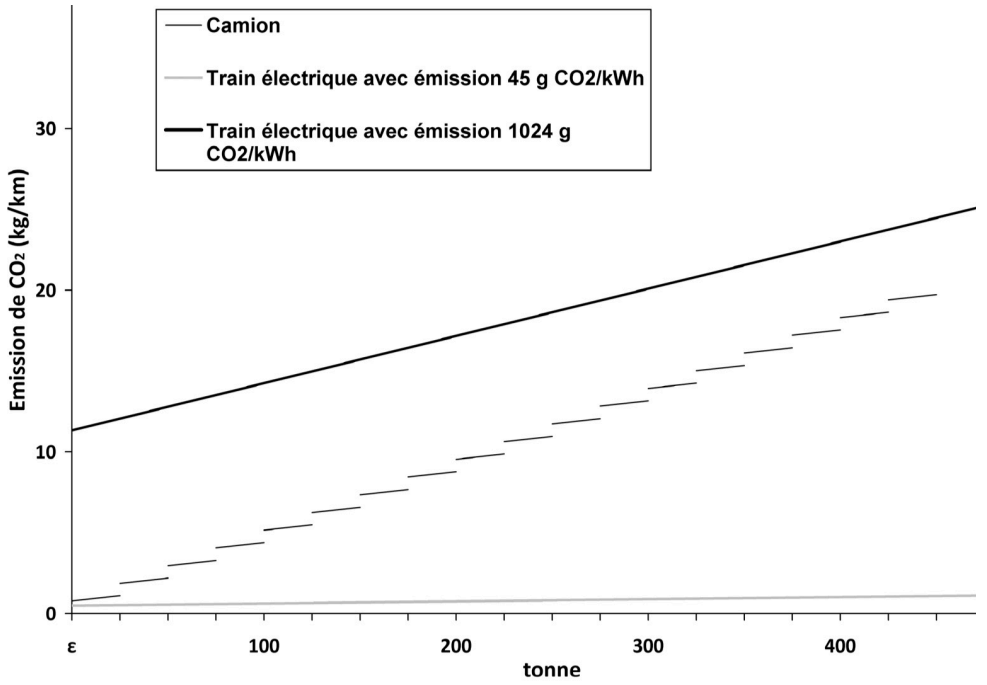
Jørgensen, M.W. and S.C. Sorenson, *Estimating Emissions from Railway Traffic*, in *Deliverable No 17*, R.f.t.P. MEET, Editor. 1997, Technical University of Denmark: Lyngby. p. 136.

Measurement methodologies: CO_2

- Analytic approach

  - Emissions of Trains…
  - COPERT report, COST and MEET research project

    - Truck tank to wheel
    - Train well to wheel



V=100km/h and x=100km

  - Production of energy is a major factor of differentiation Germany / France = 20

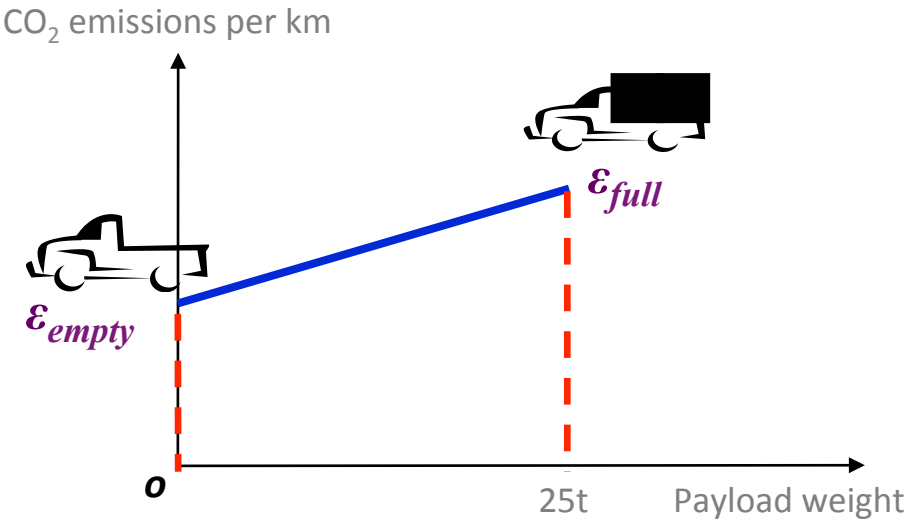
A tool for optimization

- Very sensitive choice

- Fill rate impact
  - Hypothesis
    - Payload 25t
    - 80km/h flat road

ε_{empty} = 0.772 kg/km

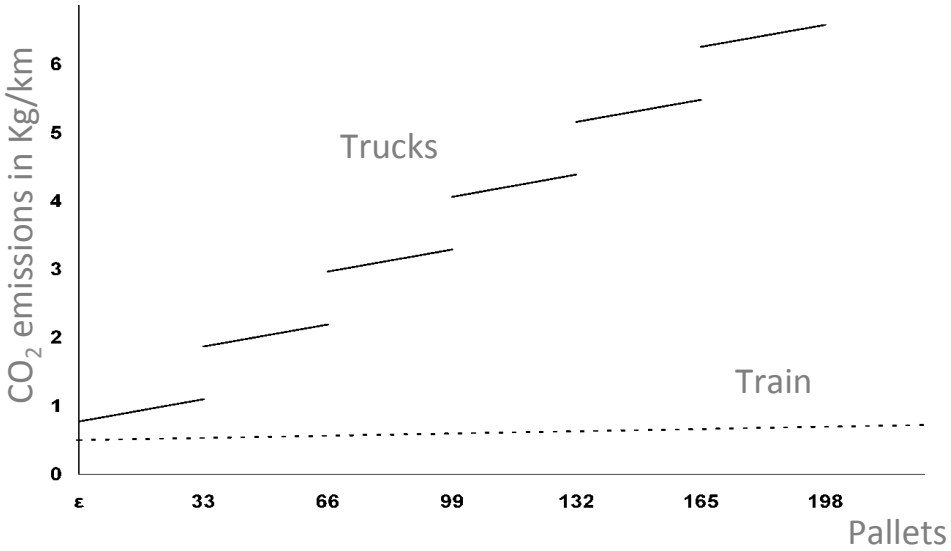
ε_{full}= 1.096 kg/km



- 2 half full trucks vs. 1 full

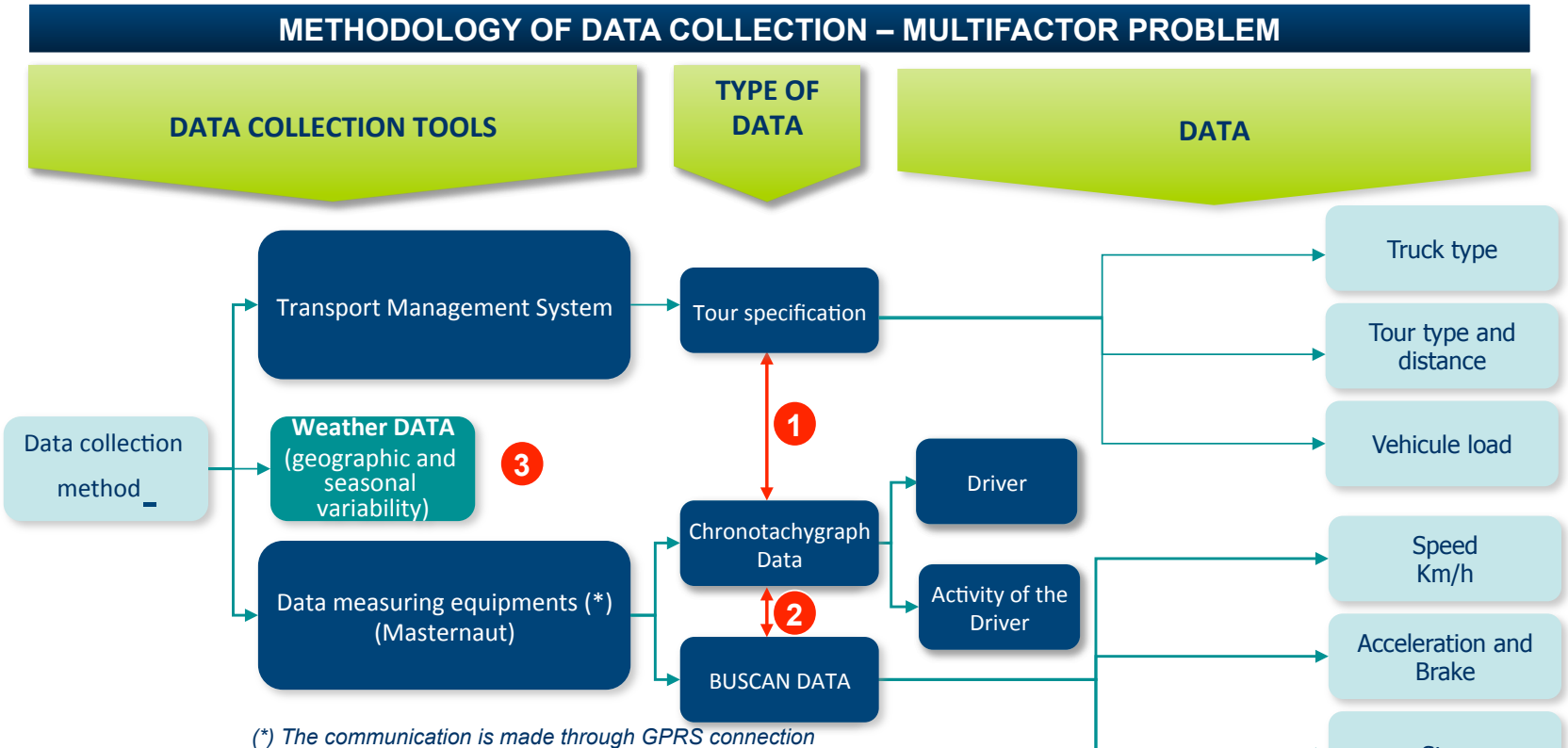
  2x0.93=1.86 > 1.09 / -41% of reduction!

- Modal shift impact
  - Hypothesis
    - French CO_2 emission factor
    - Up to 20 times less



Measurement methodologies: CO_2

- Experimental approach
  - A complex approach



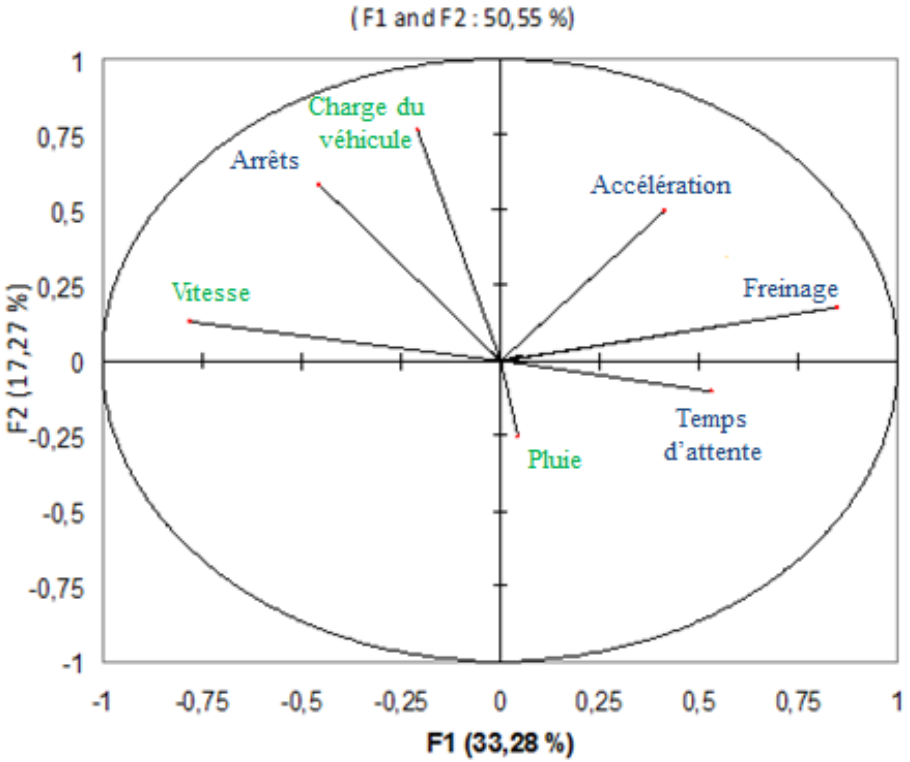
H. Chaari ILS conference 2012

Measurement methodologies: CO_2

- Experimental approach

  - Example of principal component analysis

    - Speed
      Consumption diminishes with speed !
    - Load
    - Rain
    - Driver behavior
    - Not controlled factors:
      - Tire pressure,
      - …

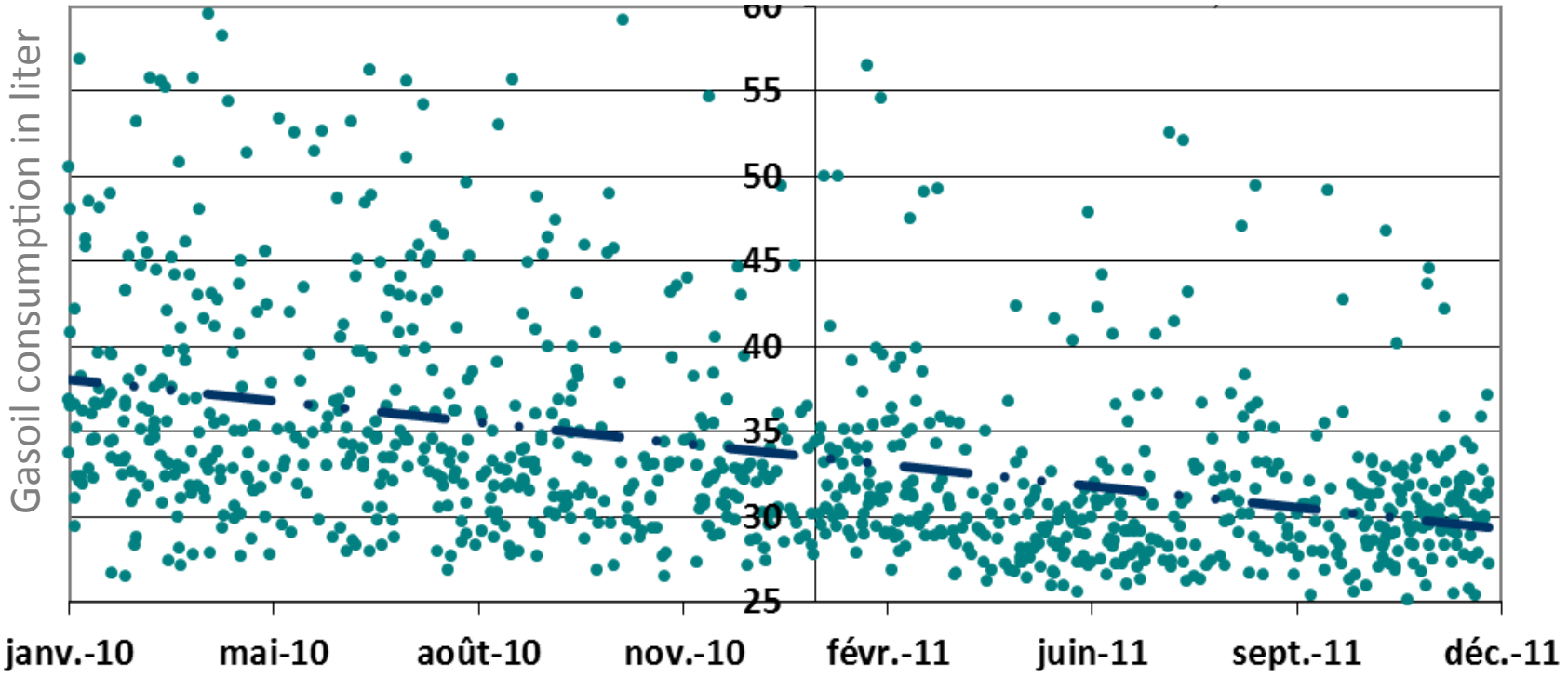


Measurement methodologies: CO_2

- Experimental approach

- Actual consumption of a set of vehicle tours in the South-East of France.
  - Delivery of food in urban areas, mid towns and rural areas.
  - Trend is the monitoring of an eco driving experimentation during operations
  - **A huge variance!**

How to separate a great driver from a fuel efficient tour?

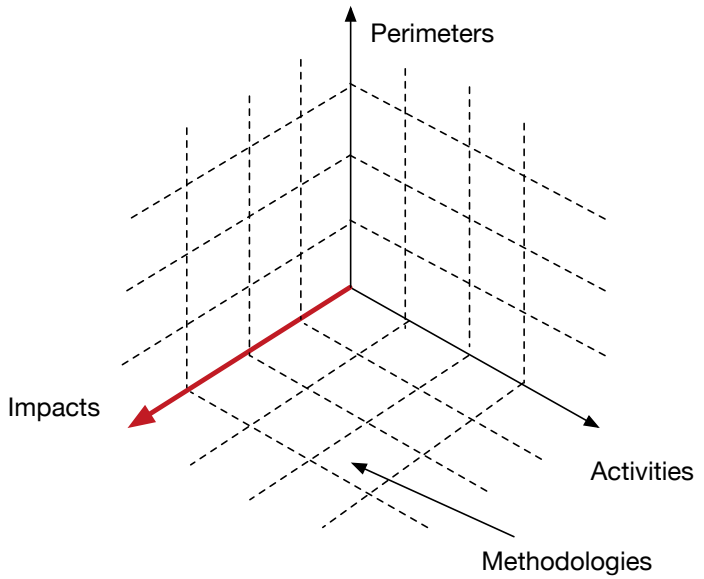


H. Chaari ILS conference 2012

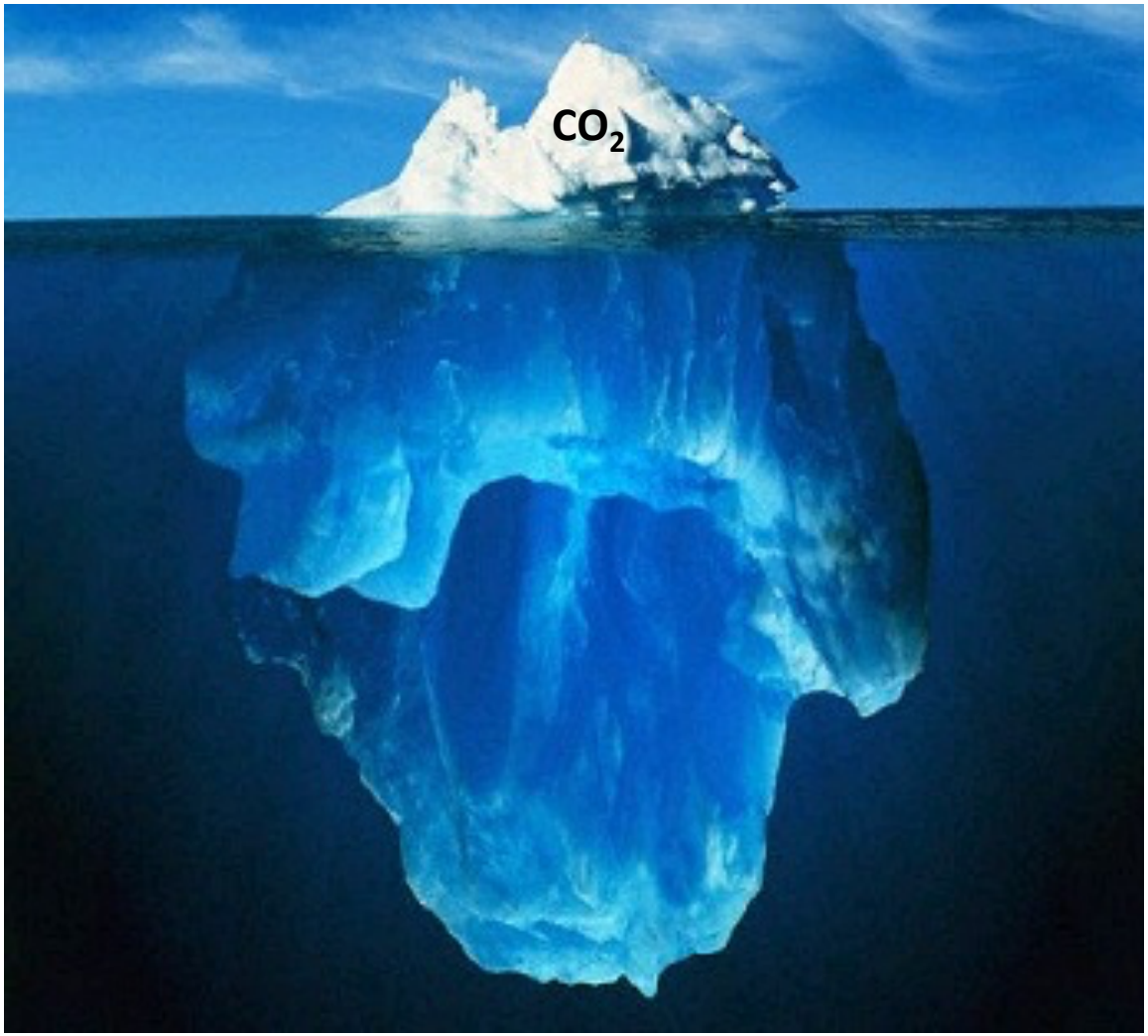
Agenda

- 4 main subjects

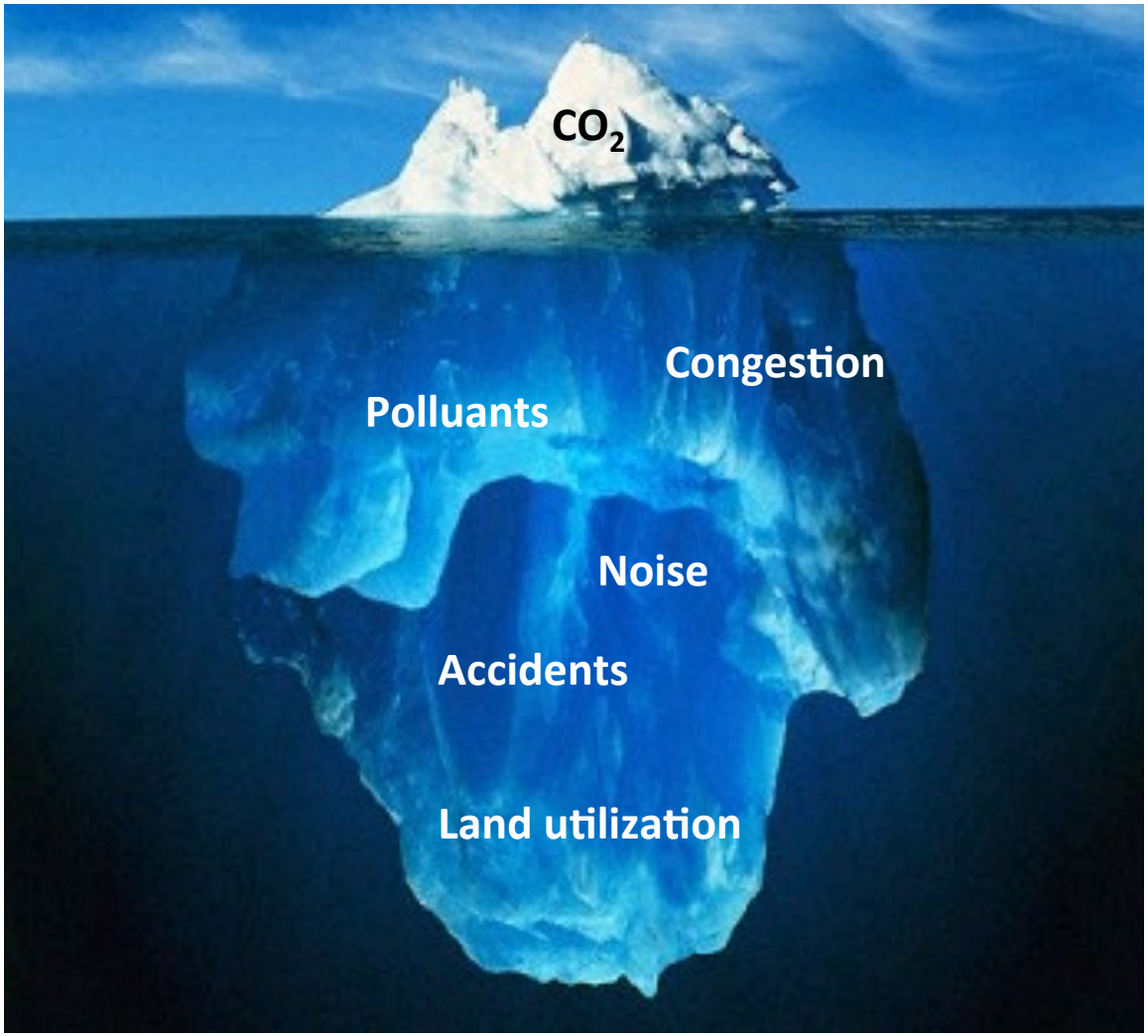
  - Activities
    - Transport
    - Warehouse, Distribution centers,…
    - Transport items: containers, pallets, crates, cardboard…
    - Supply chain design
  - Evaluation methodologies
    - Analytic formula : theory and levers
    - Proxy evaluation : consumption
    - Insight from micro evaluation
  - CO_2 and other impacts
    - Congestion, pollutants
    - Accident, noise
    - Lost of land



Impacts



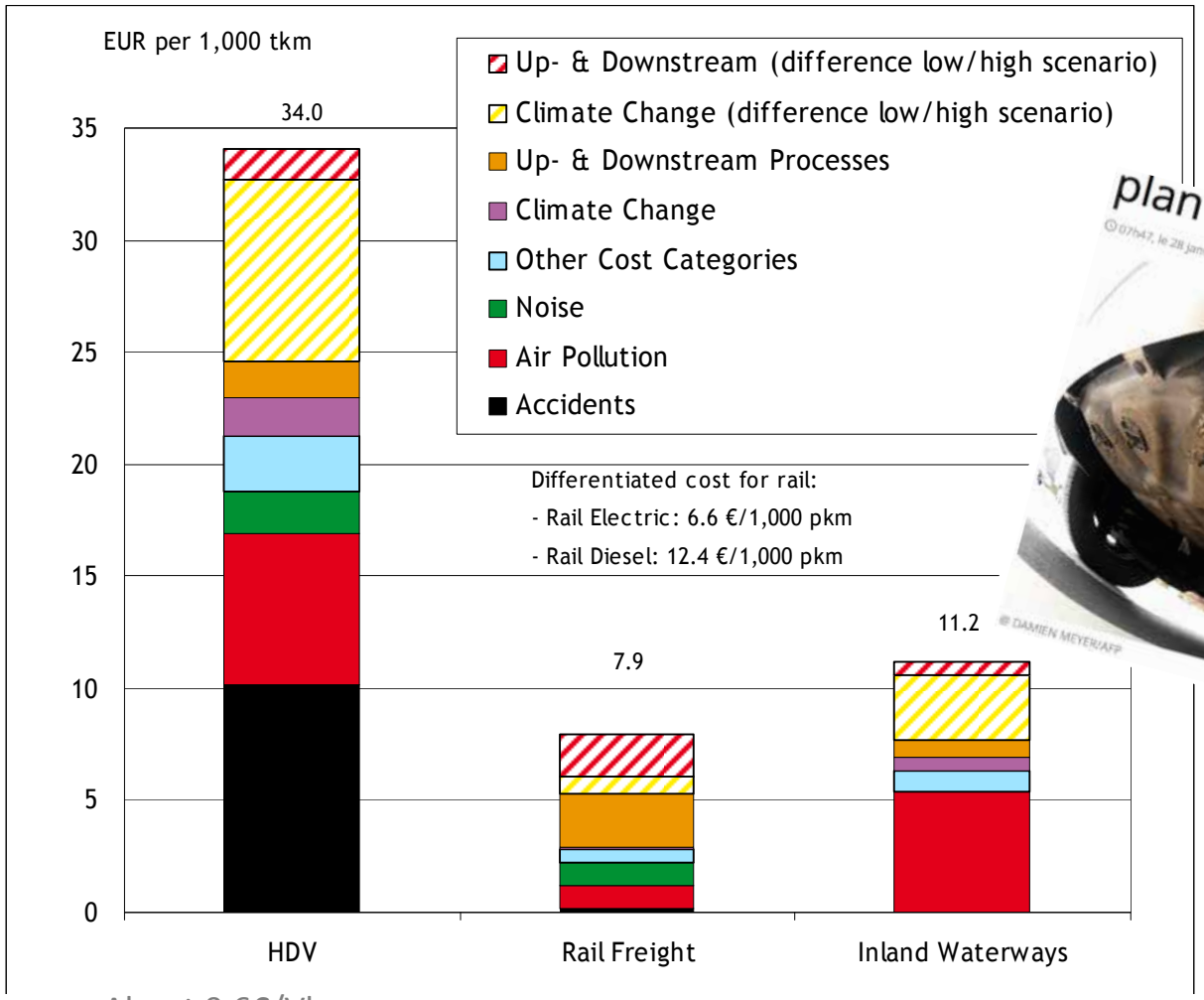
Impacts


CO_2
Congestion
Polluants
Noise
Accidents
Land utilization

Transport impacts… (without congestion)

- A value on all negative externalities - Delft report

Average external costs 2008 for EU-27*: freight transport (heavy freight transport; excluding congestion)



About 0.6€/Vkm

Transport impact… (congestion)

- The impact on other users of road, rail, port, air…

Recommended maximum congestion charges by road type (€$_{2008}$ per VKM)

Area and road type	Passenger cars			Goods vehicles			HDV
	Min.	Centr.	Max	Min.	Centr.	Max.	PCU
Large urban areas (> 2,000,000)							
Urban motorways	0.33	0.56	1.00	1.17	1.94	3.50	3.89
Urban collectors	0.22	0.56	1.33	0.56	1.39	3.33	2.78
Local streets centre	1.67	2.22	3.33	3.33	4.44	6.67	2.22
Local streets cordon	0.56	0.83	1.11	1.11	1.67	2.22	2.22
Small and medium urban areas (< 2,000,000)							
Urban motorways	0.11	0.28	0.44	0.39	0.98	1.56	3.89
Urban collectors	0.06	0.33	0.56	0.14	0.83	1.39	2.78
Local streets cordon	0.11	0.33	0.56	0.22	0.67	1.11	2.22
Rural areas							
Motorways*	0.00	0.11	0.22	0.00	0.39	0.78	3.89
Trunk roads*	0.00	0.06	0.17	0.00	0.14	0.26	2.78

Source: Updated from CE/INFRAS/ISI, 2008a.

From physics to economy

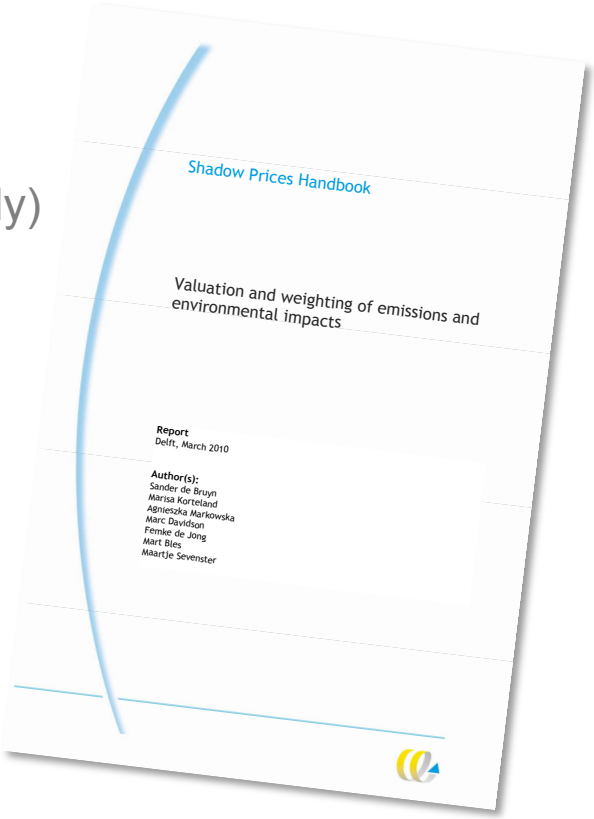
A value on all negative externalities

- 1kg gasoil generates 2.95 kg of CO_2 and the value of CO_2 is 90€ /t Source Delft report 2014
  Or 0€/t or 200€/t ???????

- € are useful to rank and sum externalities

- However there is no consensus on values even (especially) on CO_2

- What is the value of congestion?
  - External impact on others?
  - In urban delivery it is a function of:
    - Size
    - Time
    - Stop duration
    - Width of street / width of the vehicle
    - Parking availability
    - …



A practical consequence

- Is it a good idea to switch from heavy duty vehicles to light electric duty vehicles?

  - In a major the city the major could think about removing trucks and other commercial vehicles …

  - We consider here a 500tkm delivery:
    - GHG emissions cost:

Urban delivery	LDV Elec. 80% 1t	HDV 26T Euro VI 80% 10t
GHG	0 €	4,24 €
Total	(10x) 0 €	4,24 €

Source: Tk'Blue

A practical consequence

- Is it a good idea to switch from heavy duty vehicles to light electric duty vehicles?

  - In a major the city the major could think about removing trucks and other commercial vehicles and switch to electric light duty vehicles

  - We consider here a 500tkm delivery:
    - GHG emissions cost:

Urban delivery	LDV Elec. 80% 1t	HDV 26T Euro VI 80% 10t
GHG	0 €	4,24 €
Congestion	8 €	20,09 €
Pollution	0,21 €	1,03 €
Accident	0,55 €	0,55 €
Noise	0,14 €	3,89 €
Total	93 €	30 €

Source: Tk'Blue

A practical consequence

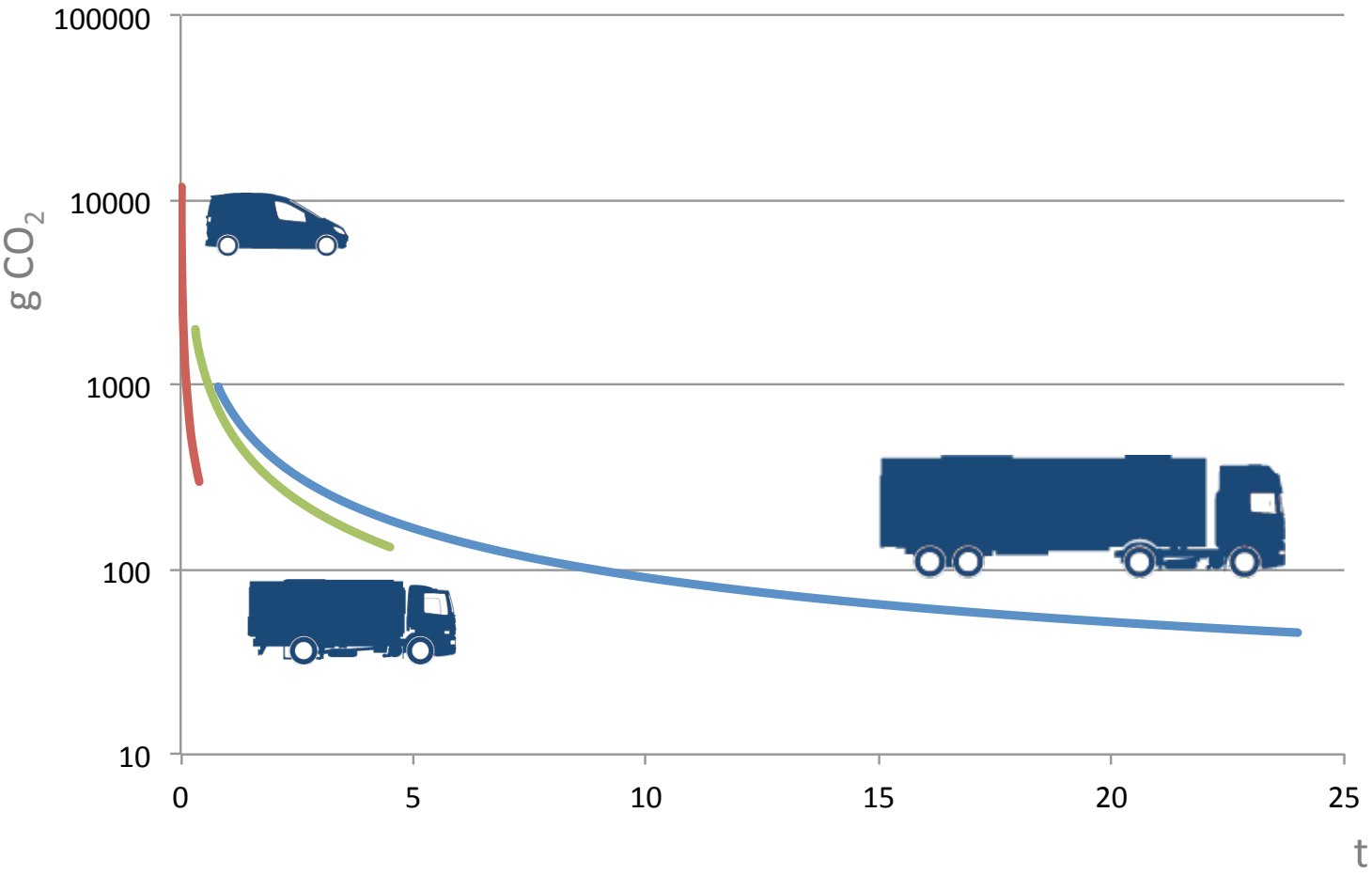
- Is it a good idea to switch from light duty vehicles to drones

Vs.

As you like! From an environmental footprint point of view if you are able to reasonably fill the LDV

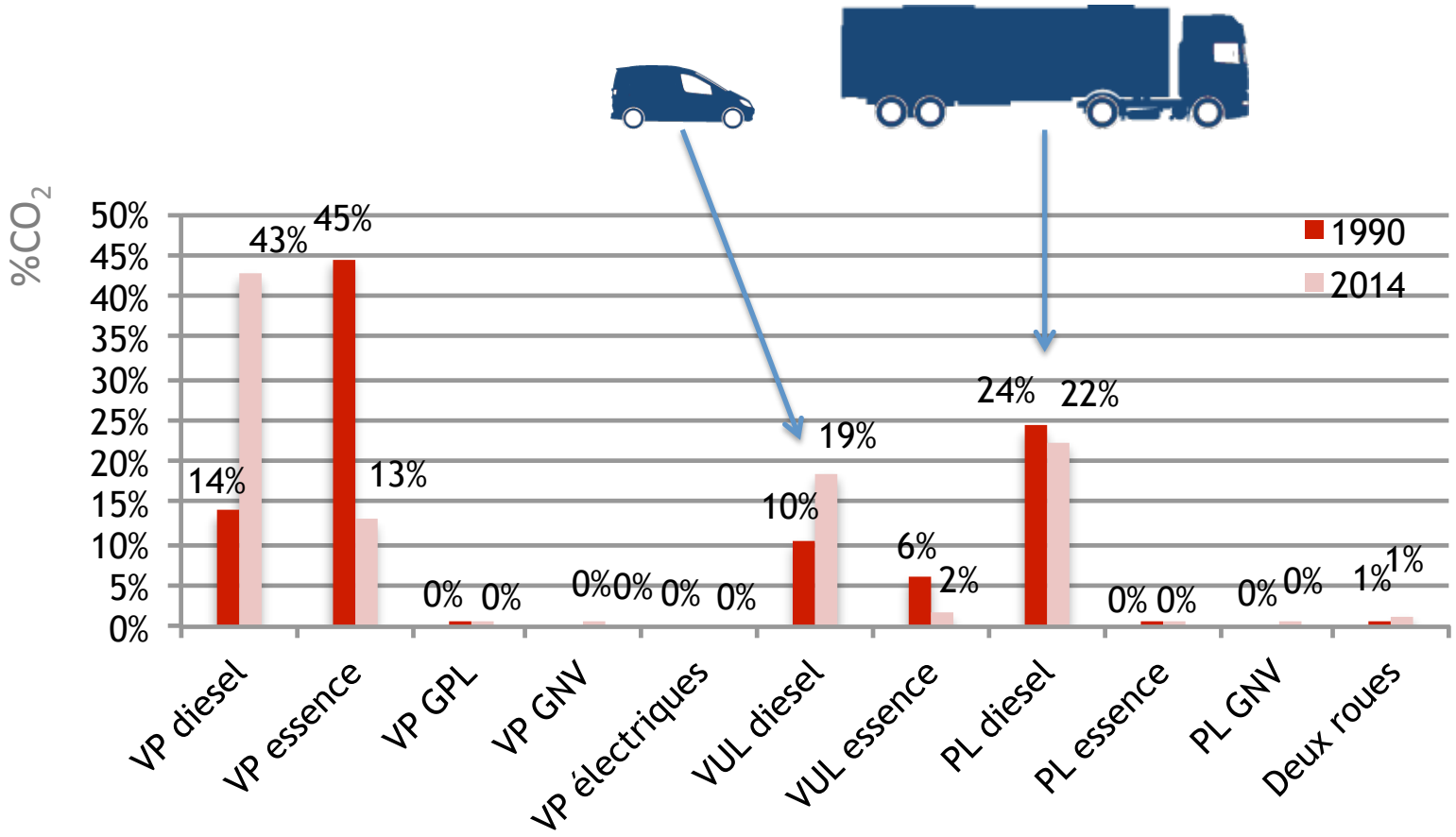
Another practical consequence

- Fill rate and vehicle size adjustment is really important!



Another practical consequence

- Fill rate and vehicle size adjustment is really important!



Source CITEPA / format SECTEN - avril 2016 / Secten_90-xx-d.xlsx

Supply chain impacts

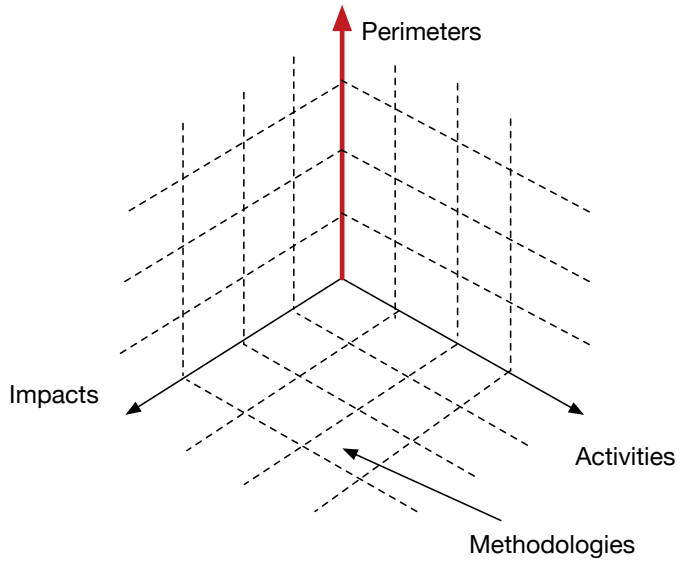
- Major shadow costs!

- Freight transport and goods to man only
  (without man going to a shopping mall by car)
  - **Externalities around the order of magnitude as transport itself!**
- **Major difference between modes in cost and externalities…**
- **Change not really taken into account**
  - Platforms, infrastructure…
  - Impact embedded
- Land footprint: **-26m^2/sec**. for agriculture - France

Agenda

- 4 main subjects

  - Activities
    - Transport
    - Warehouse, Distribution centers,…
    - Transport items: containers, pallets, crates, cardboard…
    - Supply chain design
  - CO_2 and other impacts
    - Congestion, pollutants
    - Accident, noise
    - Lost of land
  - Evaluation methodologies
    - Analytic formula : theory and levers
    - Proxy evaluation : consumption
    - Insight from micro evaluation
  - Perimeter
    - Direct: tank to wheel
    - Extended: well to wheel
    - Under looked impact



Perimeter

- Well to wheel vs. tank to wheel

  - A main difference and essential for electricity and bio fuels

  - We consider here a 500tkm delivery:
    - GHG emissions cost (**battery included**)

Urban delivery	LDV Elec. 80% 1t	HDV 26T Euro VI 80% 10t
GHG	0 €	4,24 €
Upstream & Downstream	1 €	2,31 €
Total	11,27 €	6,55 €

Source: Tk'Blue

Recall: it comes for free for the time being

Perimeter

- Well to wheel vs. tank to wheel

  - A main difference and essential for **electricity and bio fuels energy production**
  - If we take into account the origin of the energy: 2 order of magnitude of difference!

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	62.9	14.5	92.7	16.0	74.2	80.3	6.9
Belgium	94.3	16.7	289.4	12.2	533.5	240.3	27.2
Denmark	257.3	43.0	811.6	24.7	912.9	902.7	62.7
Finland	155.1	38.6	307.3	15.6	198.0	310.9	23.4
France	17.6	3.2	61.0	3.2	183.9	36.1	7.9
Germany	189.7	27.3	306.3	9.4	931.5	465.1	56.2
Greece	296.4	38.7	393.6	38.9	979.2	604.0	62.4
Ireland	212.9	33.8	672.0	44.6	1639.5	466.7	74.3
Italy	162.5	33.4	551.7	105.3	977.2	111.8	41.1
Luxembourg	101.9	16.2	90.1	16.9	71.1	27.3	3.7
Netherlands	175.7	31.6	281.8	32.0	185.2	392.5	19.0
Norway	1.7	0.6	2.8	0.2	3.7	0.6	0.2
Portugal	170.4	34.0	507.1	53.7	1260.7	359.0	59.4
Spain	126.8	19.4	414.2	16.0	1235.8	306.8	57.8
Sweden	20.6	6.0	42.2	6.6	34.7	22.2	3.1
Switzerland	6.6	2.5	12.9	1.4	21.5	0.7	1.1
UK	167.8	27.4	631.8	20.2	1445.8	458.9	69.9
European Average	127.4	21.3	325.9	22.6	744.9	282.6	39.1

  - **No Nuclear waste!**

Perimeter

- A huge focus on one side of the supply chain

Goods to man

Man to goods

Perimeter

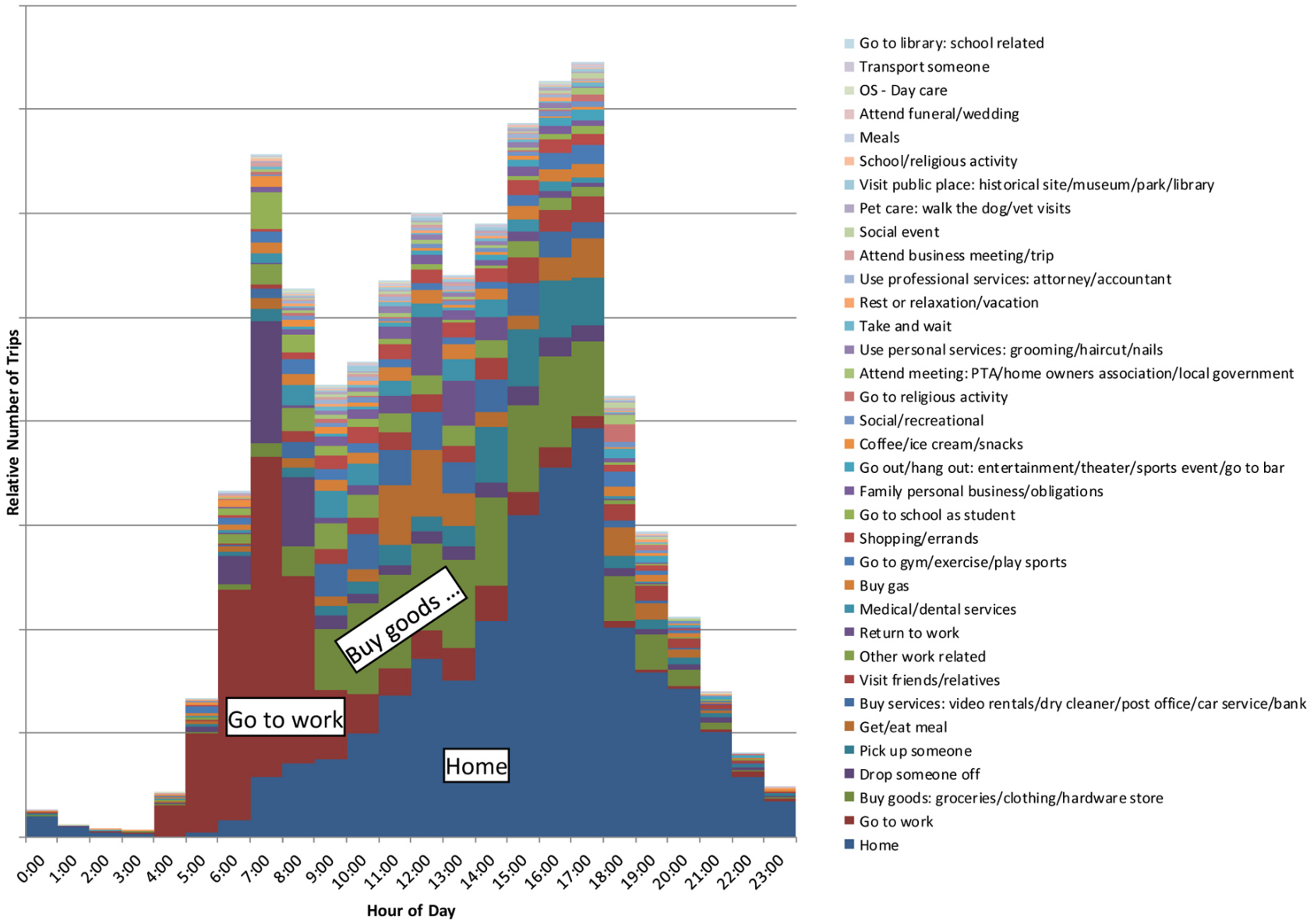
- A huge focus on one side of the supply chain

Goods to man

Man to goods

We must also consider how consumers reach the shops…

Car utilization… in the US



Krumm, J., "How People Use Their Vehicles: Statistics from the 2009 National Household Travel Survey," SAE Technical Paper 2012-01-0489, 2012, doi:10.4271/2012-01-0489.

Wrap-up

- Huge challenges and extremely hard problems
  - **Still a lack of data**
  - **Many activities to track and measure : a lot of open question (rail road congestion…)**
  - **Really hard to accurately measure all aspects**
  - **Allocation of impacts to stakeholders**
  - **Most traps are on the perimeter and the fill rate**
  - **Apparently we have some technologies (modal-shift) to reach some targets but they hard to use!!!**
  - **What happens if we go shopping by foot?**
  - **What happens if we buy from nearby?**
  - **What happens if we accept to share logistics means?**

…

Thank you

Hitching a ride through the physical internet by Daimler-Benz

Pr. Eric Ballot
Mines ParisTech
60, boulevard Saint-Michel
75006 Paris – France
Tel: +33 1 40 51 90 97
Email: eric.ballot@mines-paristech.fr