External Costs of Waste Treatment:
comparison Landfill ↔ Incineration

Ari Rabl

Ecole des Mines de Paris

Methodology

1) Life Cycle Assessment (LCA)

to account for upstream and downstream impacts

2) Site specific impact pathway analysis

(for each pollutant: emission→dispersion→impact→cost)

based on

ExternE = "External Costs of Energy"

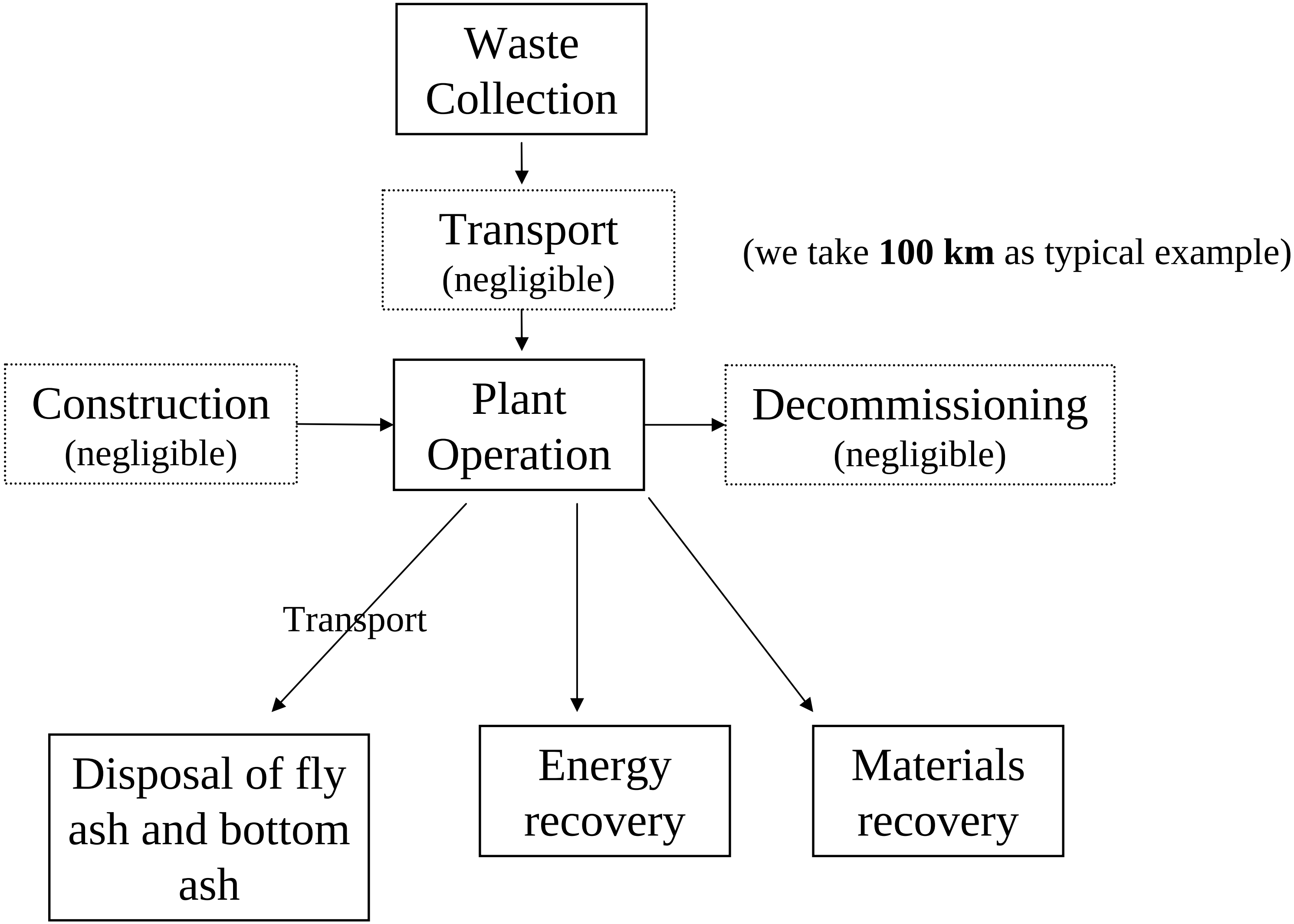
funded by European Commission DG Research, since 1991

>100 scientists in all countries of EU

Major publications **1995**, **1998**, **2000, 2004**

www.externe.info

System boundary - LCA approach



Results extremely dependent on assumptions on energy recovery

⇒ Consider several scenarios

Impact Pathway Analysis

to calculate damage of a pollutant emitted by a source

Impacts are summed over entire region that is affected (Europe) and all damage types that can be quantified:
- health
- loss of agricultural production
- damage to buildings and materials

Result:
€/kg of pollutant

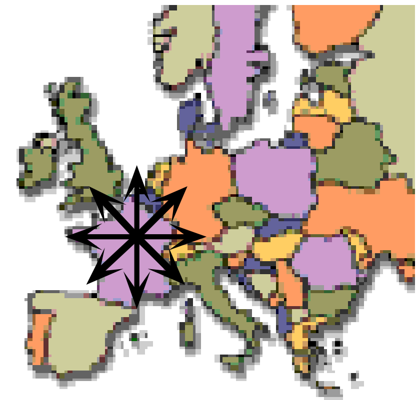
Multiply by kg/t_{waste} to get $€/t_{waste}$

SOURCE
(site, stack height and technology)

⇒ **emission**
(e.g., kg/yr of PM_{10})

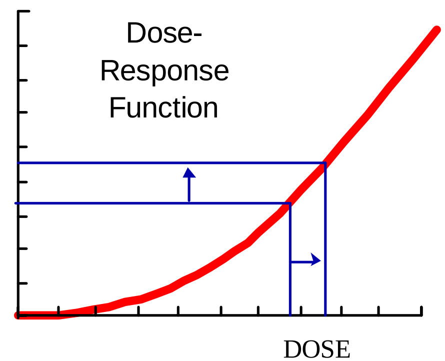
DISPERSION
(atmospheric dispersion & chemistry)

⇒ **increase in concentration at receptor sites**
(e.g., $\mu g/m^3$ of PM_{10} in all affected regions)



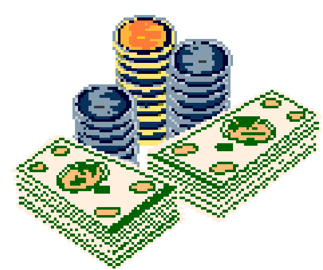
DOSE-RESPONSE FUNCTION

⇒ **impact**
(e.g., hospital admissions due to PM_{10})



MONETARY VALUATION

⇒ **cost**
(e.g., cost of hospital admission, includ. WTP to avoid suffering)



Methods and Priority Impacts

1) CO_2 and CH_4

assume **19 Euro/tCO_2**

2) Air pollutants:

Assume emissions = limit values of EC Directive

real emissions probably lower (but difficult to get data)

NO_x, SO_2, PM_{10}, VOC (O_3 from VOC and NO_x) *“classic air pollutants”*

impacts on **health**, buildings, crops

Dioxins and toxic metals (As, Cd, Cr, Hg, Ni, Pb) *“trace pollutants”*

3) Leachates from landfill, residues from incineration

4) Amenity impacts

meta-analysis of literature (loss of property values)

Key Assumptions

Local + regional dispersion models

Linear dose-response functions for health (no threshold):

Mostly $PM_{2.5}$, PM_{10}, O_3

A few for SO_2 and CO

None for NO_2

Sulfates are treated like PM_{10}, Nitrates like $0.5 \times PM_{10}$

also As, Cd, Cr, Hg, Ni and Pb

Mortality in terms of LLE (loss of life expectancy) rather than number of deaths

Monetary valuation based on Willingness-to-pay (**WTP**) to avoid a loss:

Value of a Life Year (VOLY) due to air pollution = **50,000 €**

Cancers 2M€/cancer, based on VSL = 1 M€

(VSL = "Value of Statistical Life" = WTP to avoid risk of an anonymous premature death; *typical values used in EU and USA* ***1-5 M€)***

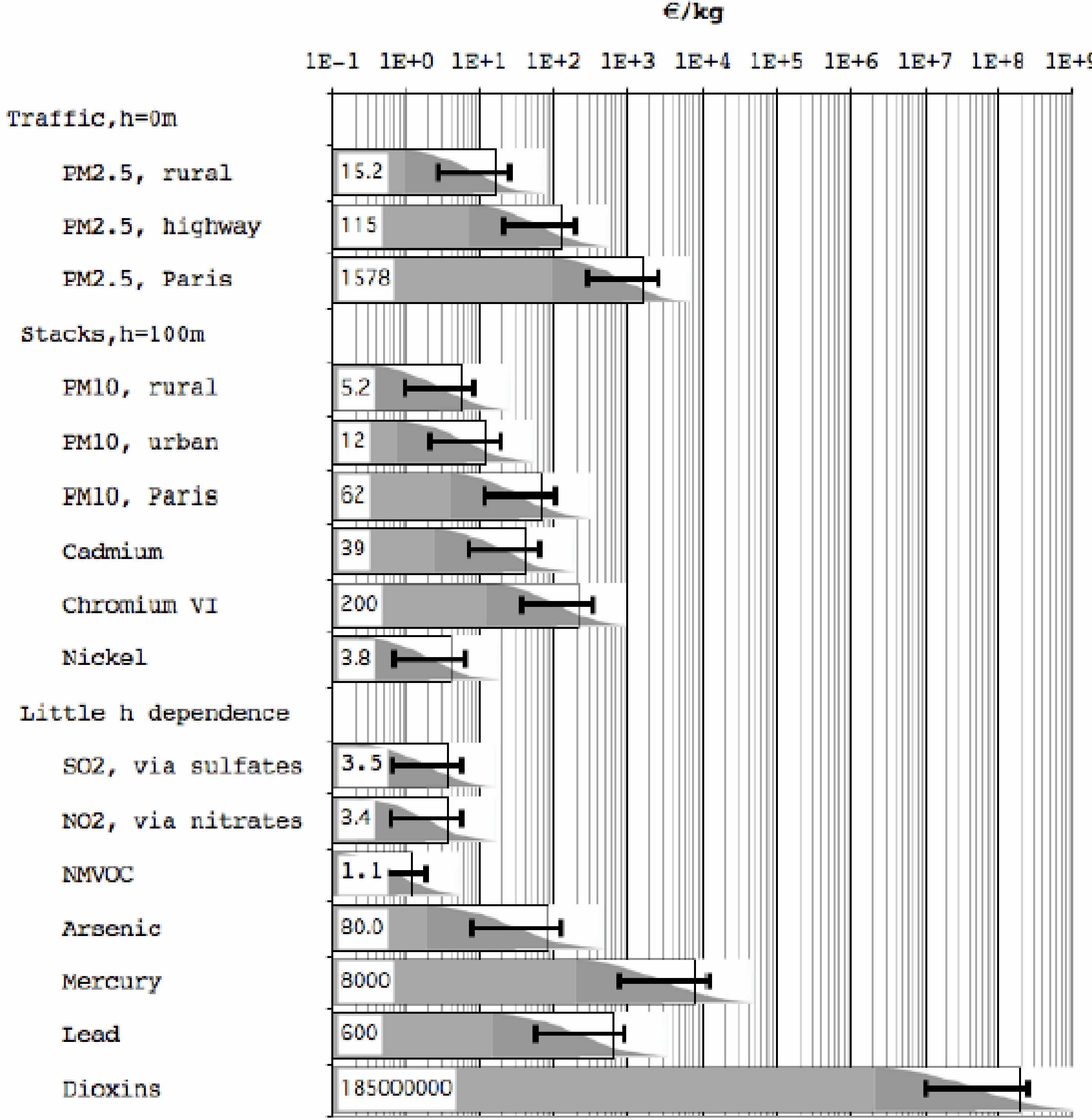
Damage Cost per kg of Pollutant,

and uncertainty (error bars and probability distribution)

h = stack height

These are values for France, but they are fairly typical for central Europe.

For greenhouse gases 0.019 €/kg$_{CO2eq}$



Impact of Leachates

Difficulties of quantification:

Long life time of pollutants in soil (unlimited for toxic metals)
Very **complex pathways** (diffusion and chemistry in soil)
Extremely site dependent (how to obtain typical damage costs for policy applications?)
Depends on future management of site

Alternative approach:

Look at measured data for concentration of pollutants in leachate,
Estimate maximal leachate production rate,
Consider an **extreme scenario** where **all the leachate goes into the water supply**,
Compare pollutant concentration in water with limit values of Water Quality Directive,

Result: concentrations below limit values

$\Rightarrow$ **Not a significant problem**

if EC Directives are respected

(attack other sources of these pollutants before worrying about leachates!)

comparison Incineration ↔ Landfill

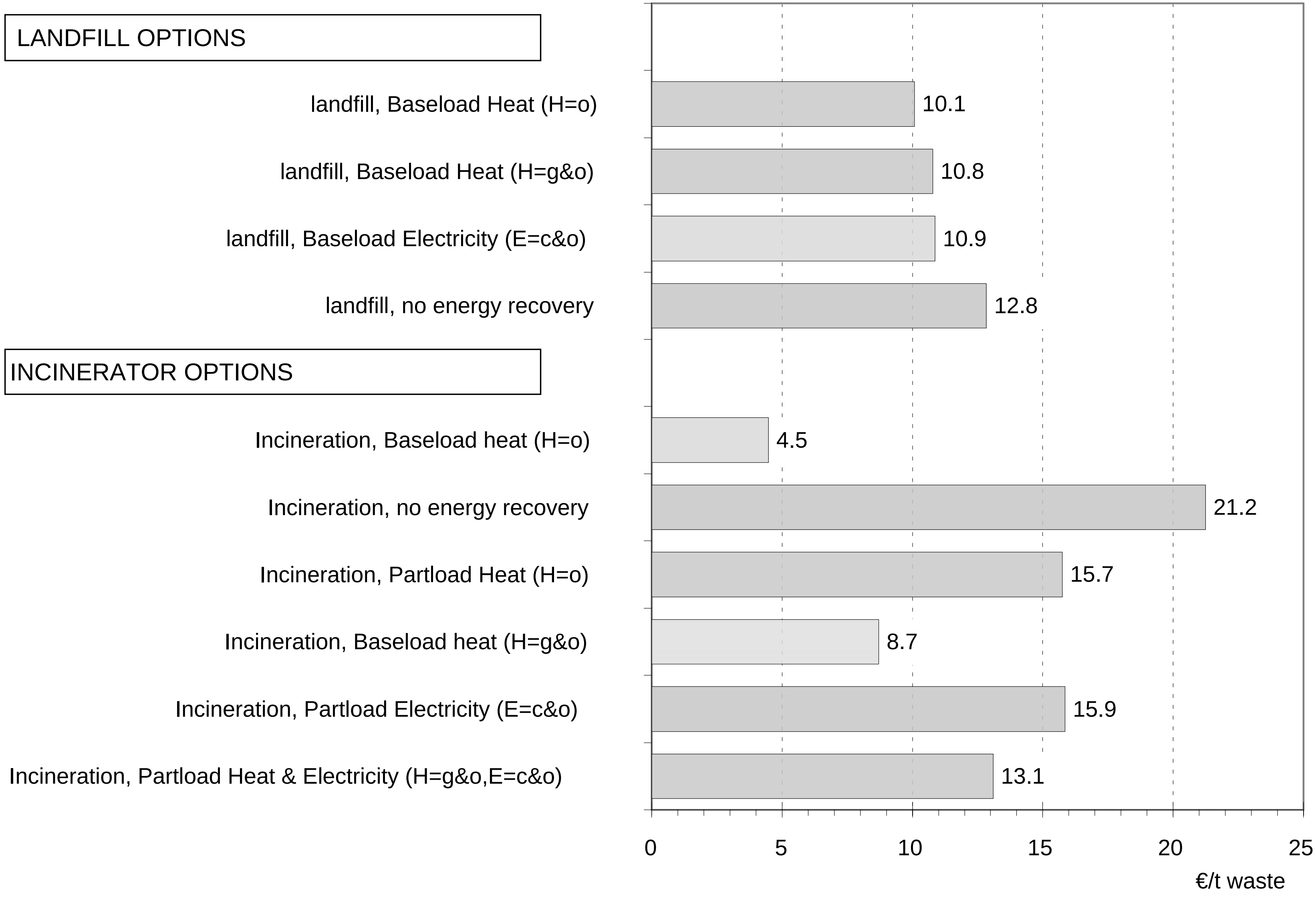
Variation with energy recovery assumptions

For energy recovery: E=electricity, H=heat, g=gas, o=oil, c=coal

Private cost
Landfill
~50€/t_{waste}

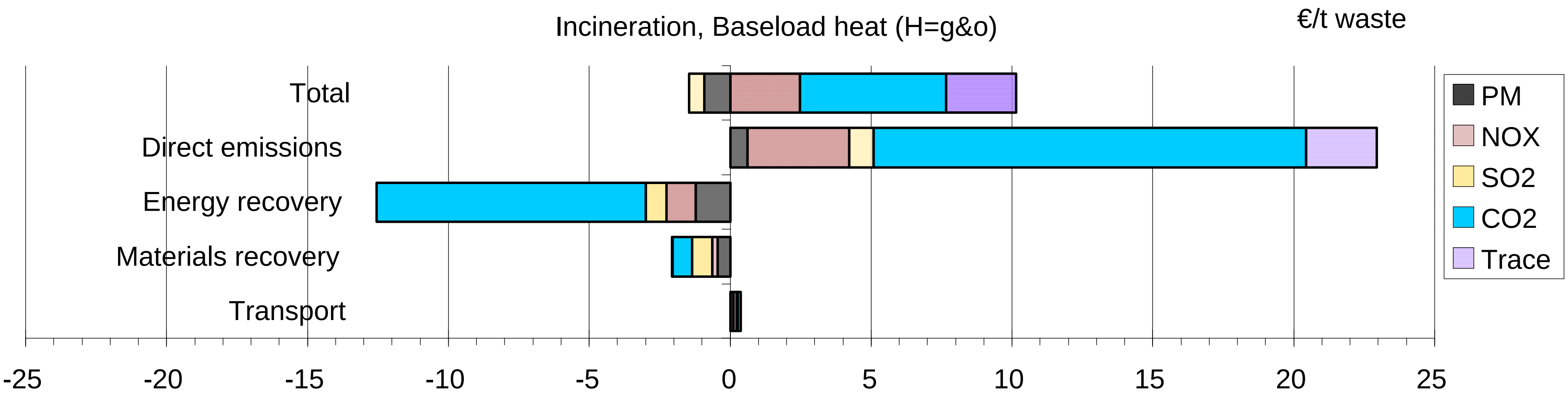
Private cost
incinerator
~100€/t_{waste}

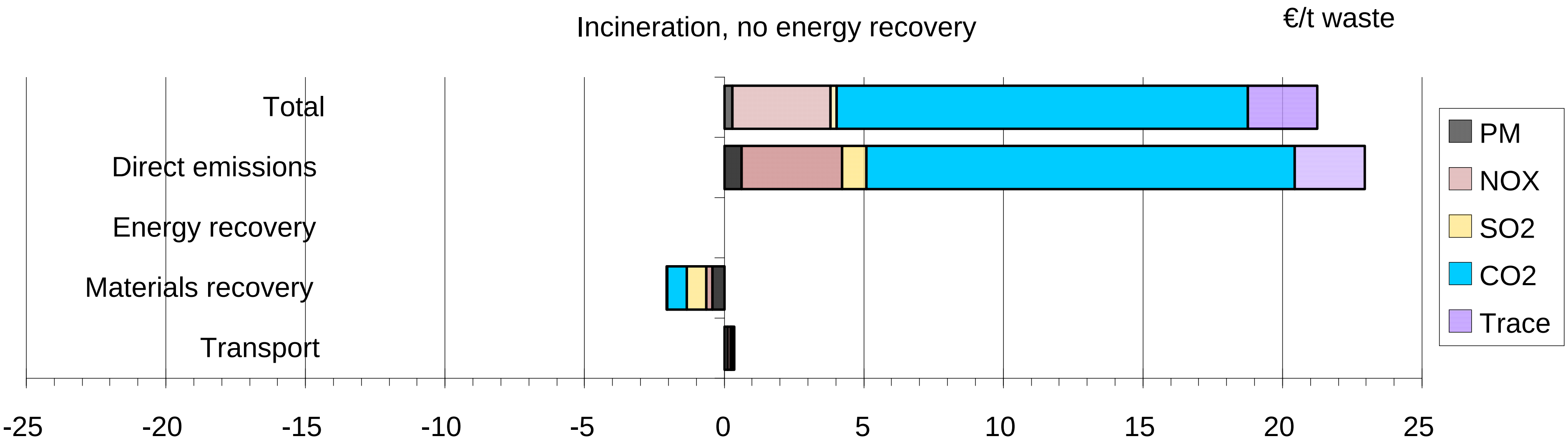
But costs are not the only criterion!



Incineration, some detailed results

- If electricity displaces nuclear (France), like no energy recovery.
- Transport based on hypothetical 100 km.





Landfill, some detailed results

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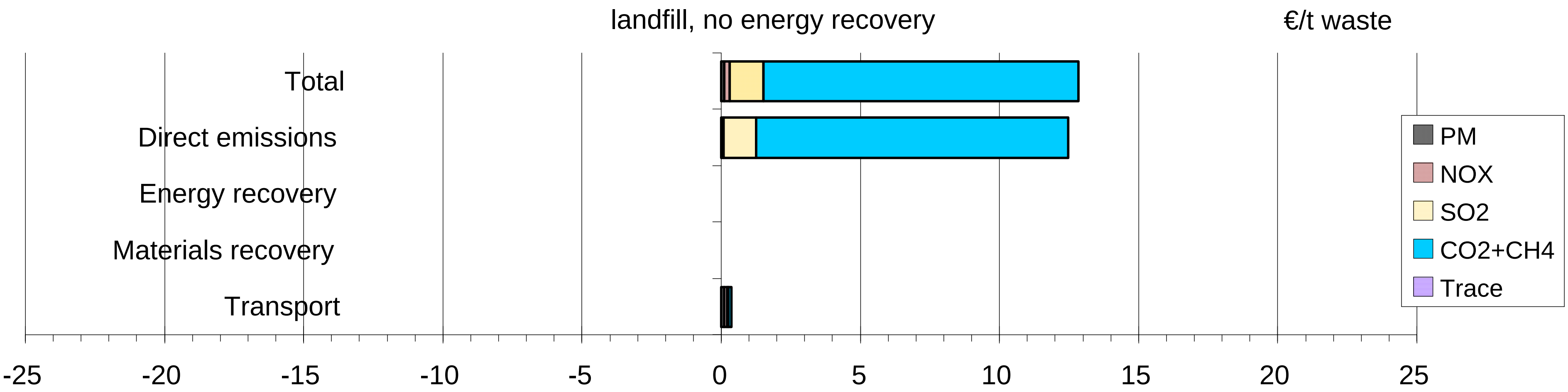

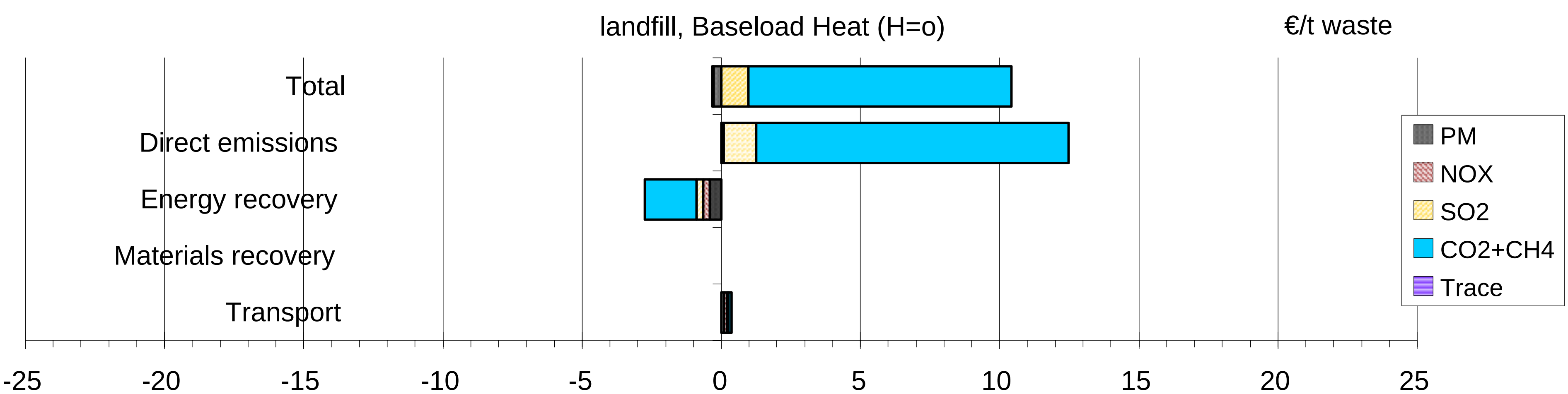

Methodological issues

•How large is **cost of global warming**?
(we have assumed 19 €/t_{CO2eq}, but uncertain and controversial)

main impact of landfill

•**Biomass CO_2** – include or exclude in the calculation?
One should count each source and sink when and where it occurs!

•How large are the **CH_4 emissions** (taking into account oxidation)?

•What fraction of landfill CH_4 can be captured?

•Transferability of **incineration amenity** – very site-specific

Conclusions

- **Environmental costs are significant** - dominated by CO_2 and CH_4, then air pollution, then amenity
- **Trace air pollutants**: low for toxic metals, negligible for dioxins
- Strong **variation across countries and sites** – differences in damage cost per kg of pollutant, differences in amenity cost, (differences in emissions?)
- **Strong variation with energy recovery** – especially with incinerators (can potentially change the attractiveness over landfill). Benefit greatest if constant heat load.
- **Assumed value for CO_2 and CH_4 can change the overall comparison** incinerators over landfill (value is **controversial and uncertain**)
- Impact of **leachates** from landfill or from incineration residues negligible (if EC Directives are respected)
- Impacts due to **transport** (if < 100 km) very small
- **CH_4 collection and energy recovery** can significantly reduce environmental costs of landfill