ReCiPe 2008: Mineral resource depletion

An improved method to calculate effects of mineral depletion on midpoint and endpoint level

By An De Schryver, Mark Goedkoop and Arjan Meijer

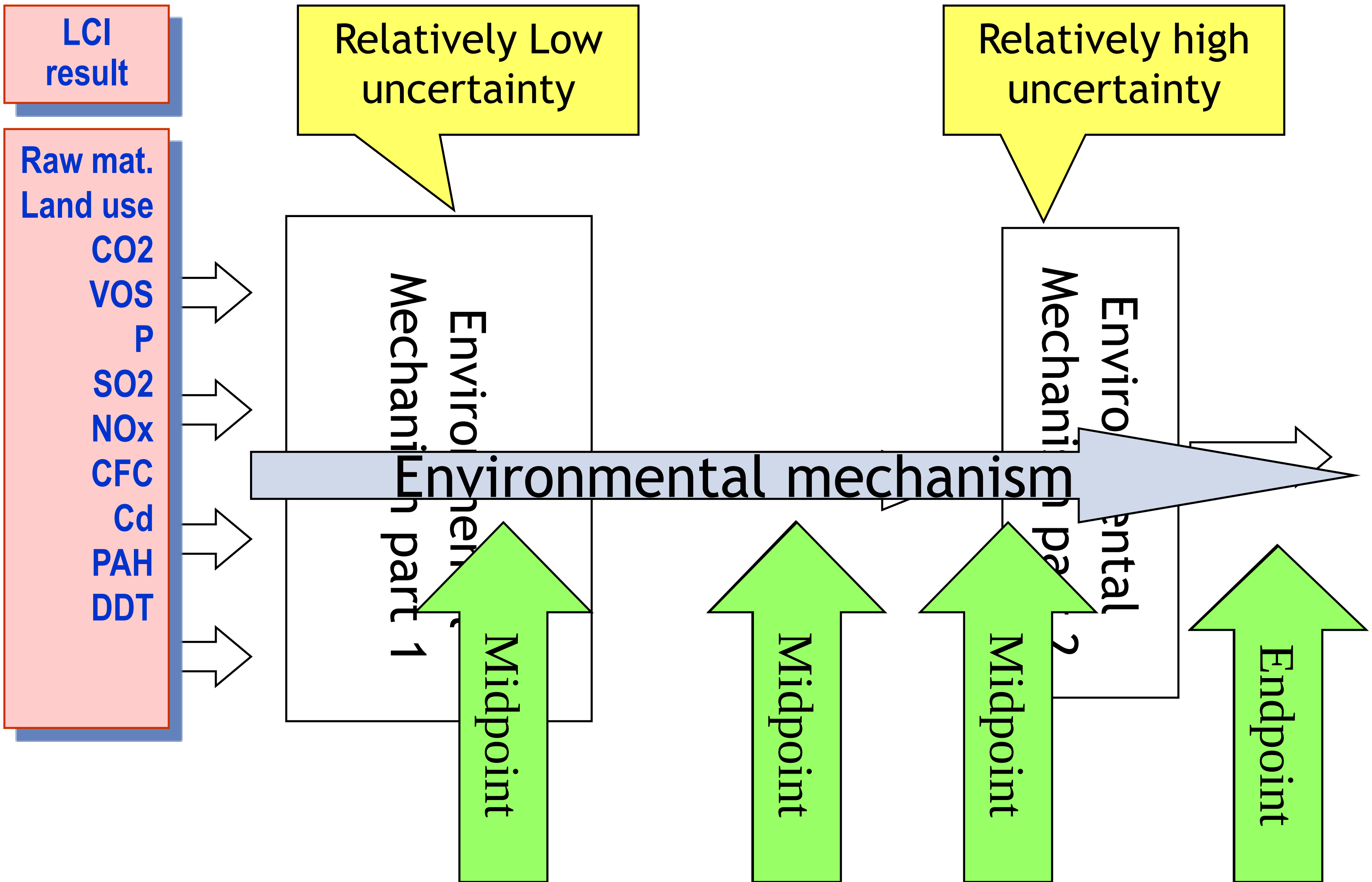
Partners of ReCiPe project

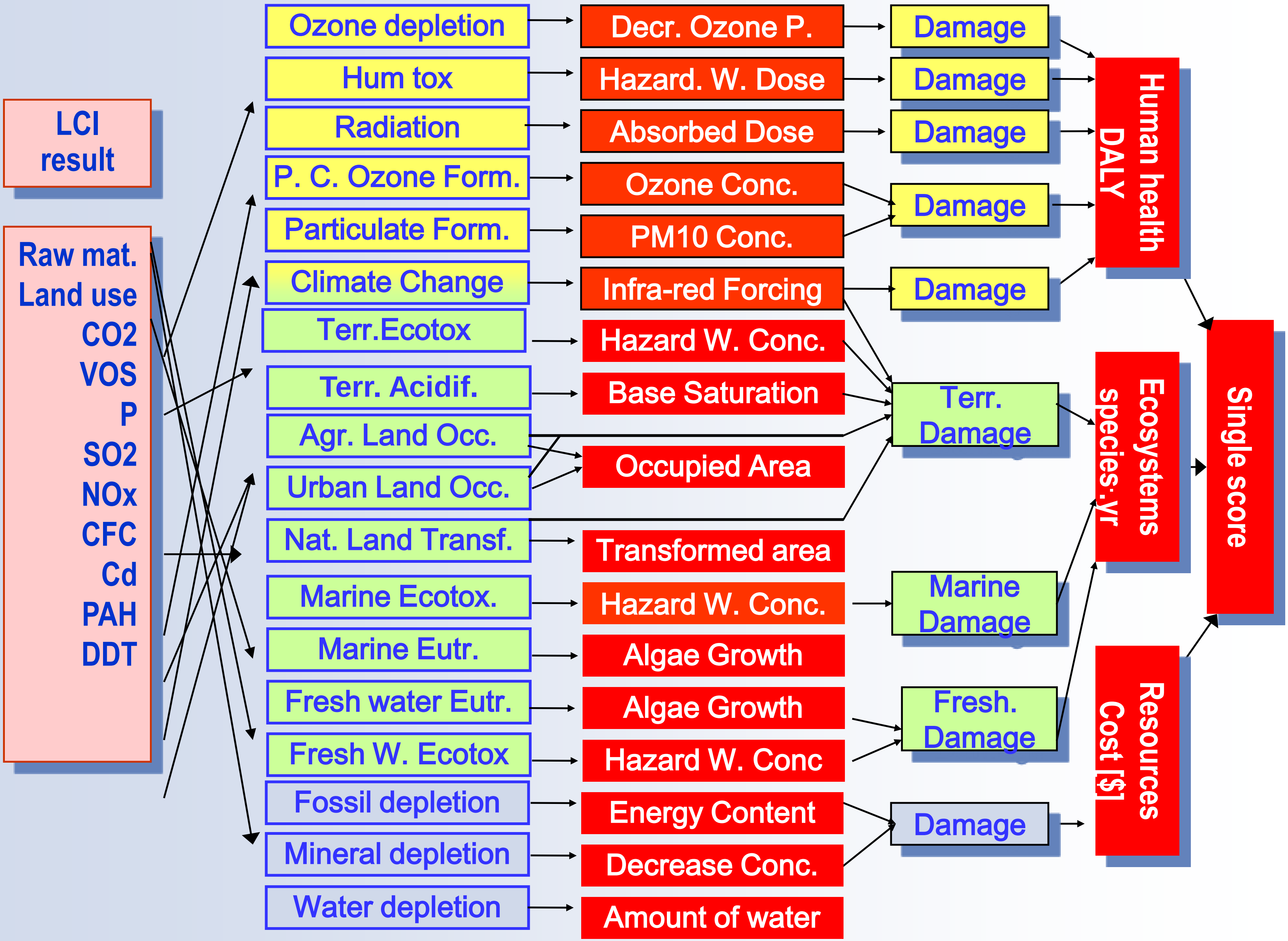
- RIVM
  - modelling expertise in many types of environmental impacts
  - Jaap Struis
- CML
  - developer of midpoint-oriented method in Handbook on LCA
  - Reinout Heijungs
- PRé
  - developer of endpoint-oriented Eco-indicator 99
  - Mark Goedkoop; An de Schryver
- RUN
  - Radboud University Nijmegen
  - Mark Huijbregts, Rosalie van Zelm

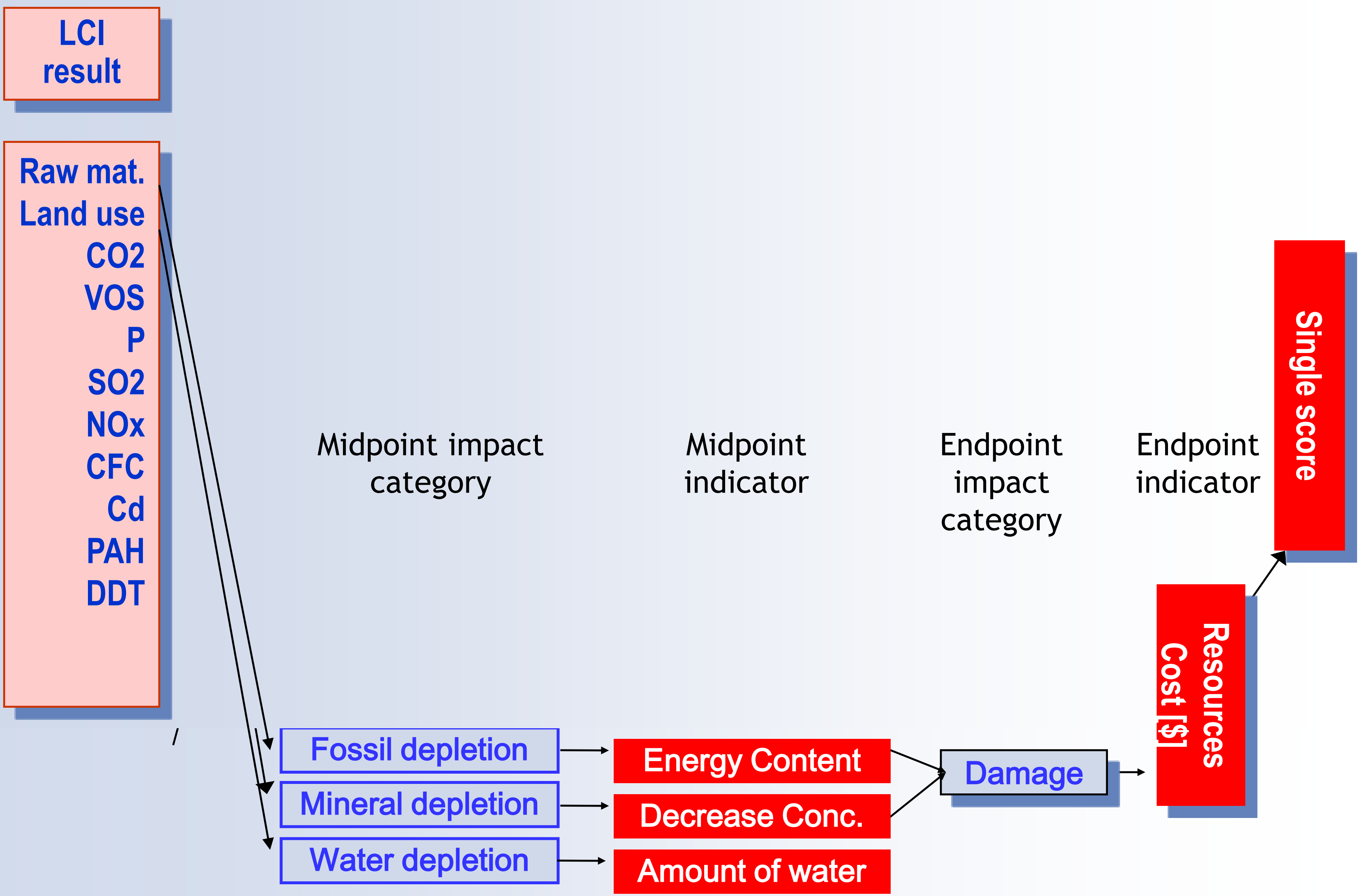
Objective of the project

- Integrate and harmonise two well known Life Cycle Impact Assessment (LCIA) methods, CML and EI 99, into a new method: ReCiPe 2008
- Improve and update the environmental science used.
- Parallel projects:
  - New Updated Normalisation factors
  - Three solutions for the weighting problem

Mid- and endpoints in ReCiPe




LCI result
Raw mat.
Land use
CO2
VOS
P
SO2
NOx
CFC
Cd
PAH
DDT
Ozone depletion
Hum tox
Radiation
P. C. Ozone Form.
Particulate Form.
Climate Change
Terr.Ecotox
Terr. Acidif.
Agr. Land Occ.
Urban Land Occ.
Nat. Land Transf.
Marine Ecotox.
Marine Eutr.
Fresh water Eutr.
Fresh W. Ecotox
Fossil depletion
Mineral depletion
Water depletion
Decr. Ozone P.
Hazard. W. Dose
Absorbed Dose
Ozone Conc.
PM10 Conc.
Infra-red Forcing
Hazard W. Conc.
Base Saturation
Occupied Area
Transformed area
Hazard W. Conc.
Algae Growth
Algae Growth
Hazard W. Conc
Energy Content
Decrease Conc.
Amount of water
Damage
Damage
Damage
Damage
Damage
Terr. Damage
Marine Damage
Fresh. Damage
Damage
Human health DALY
Ecosystems species.yr
Resources Cost [$]
Single score



LCI result
Raw mat.
Land use
CO2
VOS
P
SO2
NOx
CFC
Cd
PAH
DDT
Midpoint impact category
Midpoint indicator
Endpoint impact category
Endpoint indicator
Single score
Fossil depletion
Mineral depletion
Water depletion
Energy Content
Decrease Conc.
Amount of water
Damage
Resources Cost [$]

Introduction:

- Why are these impact categories needed
  - Renewable resources
  - Non-renewable resources: What to preserve?

- Non-renewable resources
  - Based on energy or mass (Ecoscarcity 2006)
  - Based on exergy or entropy (Exergy)
  - Based on use of stock (CML and EDIP)
  - Based on future consequences (Muller-Wenk, Bengt Steen)

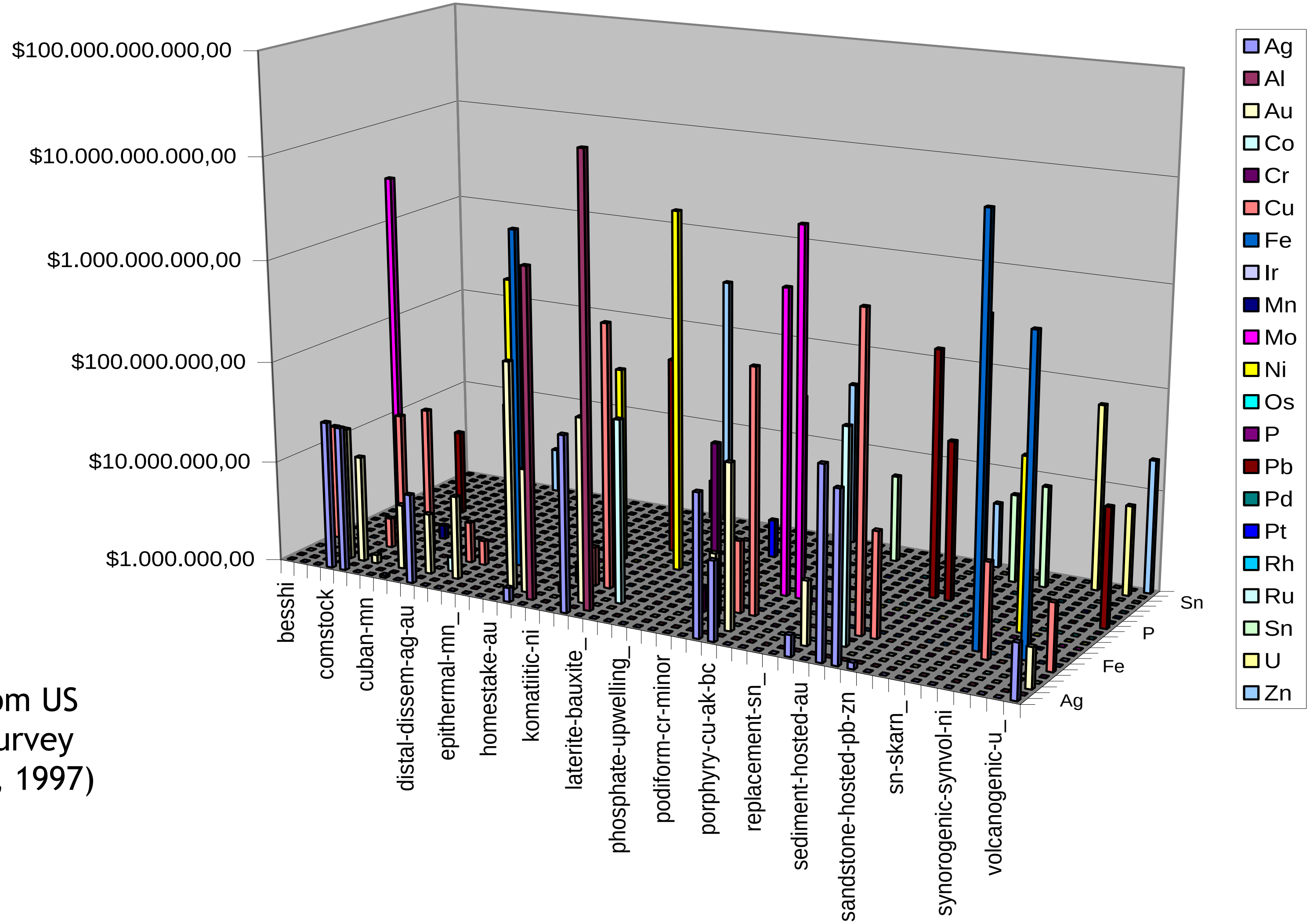
What we did

- We used surplus costs as a basis for fossil fuels and mineral depletion
- Dataset geological survey of Canada (Kirkham and Rafer, 2003).
  - 500 mines
  - 167 deposits of which 50 could be used
  - 17 minerals
- Key problem: one deposit produces multiple materials

Top of the deposit list with minerals

Deposit[a]	**Commodities**
Besshi (44)	Ag-Au-Cu-Zn
Carbonatite[b](31)	Nb_2O_5,RE_2O_5[c],P_2O_5
climax-mo_(9)	Mo
Comstock(41)	Ag-Au-Cu-Pb-Zn
Creede(27)	Ag-Au-Cu-Pb-Zn
cu-skarn(64)	Ag-Au-Cu
cuban-mn(93)	Fe-Mn
cyprus-mn (49)	Ag-Au-Cu-Pb-Zn
cyprus-mn-rev (7)	Fe-Mn
distal-dissem-ag-au(10)	Ag-Au
dunitic-ni(22)	Au-Co-Cu-Ir-Ni-Pd
epithermal-qtz-alunite-au(9)	Ag-Au-Cu
epithermal-mn_(59)	Mn
fe-skarn(168)	Cu-Fe
franciscan-mn_(184)	Mn
homestake-au(118)	Ag-Au
hot-spring-au(17)	Ag-Au
karst-bauxite_(41)	Al
komatiitic-ni(31)	Au-Co-Cu-Ir-Ni-Pd-Pt
kuroko-sier(19)	Ag-Au-Cu-Pb-Zn
kuroko-rev(457)	Ag-Au-Cu-Pb-Zn
laterite-bauxite_(122)	Al
lateritic-ni(71)	Co-Ni
olympic-penn-mn(17)	Fe-Mn
phosphate-upwelling_(60)	P_2O_5

Cumulative value of a metal per deposit



Database from US geological survey (Singer et al., 1997)

Dataset of 3310 mines grouped into 50 deposit types, plotted according to there content, in $ (value weighted).

Endpoint in ReCiPe

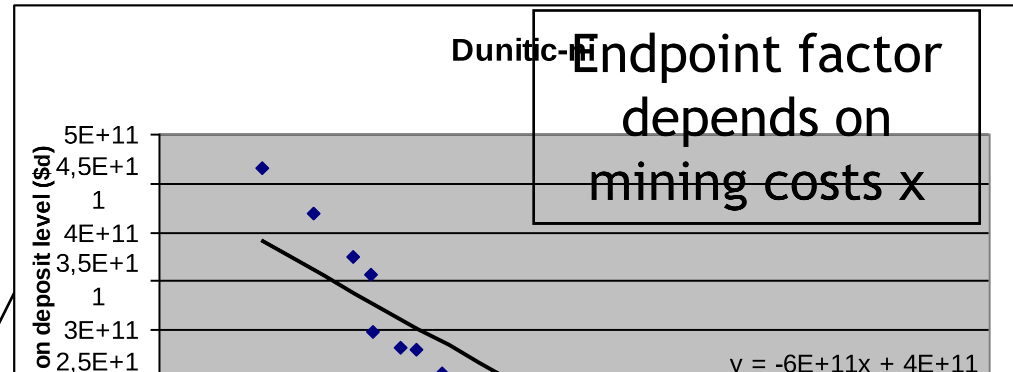
- Unlike eco-indicator 99 we use societal costs as endpoint ($)
- Assumptions:
  - Mankind takes highest grades first
  - Each extraction lowers the grade and this increases the price for *every* future extraction.
  - Marginal cost increase ($/kg) multiplied with production amount
  - In theory this leads to indefinite cost increases
  - We use discount rate of 3%, to take into account inflation.
- Result: each extraction results in a dollar value societal cost

Framework

As a mine usually contains more than one metal, a value weighted yield ($) and value weighted grade ($/kg) for each metal is used.

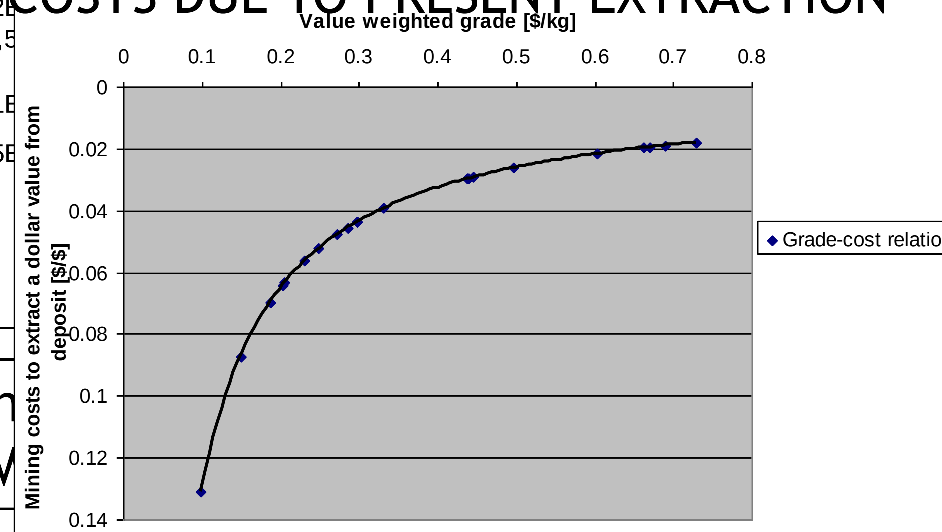
Deposit level

Marginal increase in yield ($d)



Endpoint factor depends on mining costs x

HOW TO CALCULATE THE FUTUR COSTS DUE TO PRESENT EXTRACTION



Marginal decrease in grade ($/kgd)

Midpoint factor depen
the slope factor M

Framework

As a mine usually contains more than one metal, a value weighted yield ($) and value weighted grade ($/kg) for each metal is used.

Deposit level

Endpoint and midpoint CF on deposit level per $ extracted ($\$/\$_{d}^{2}$)

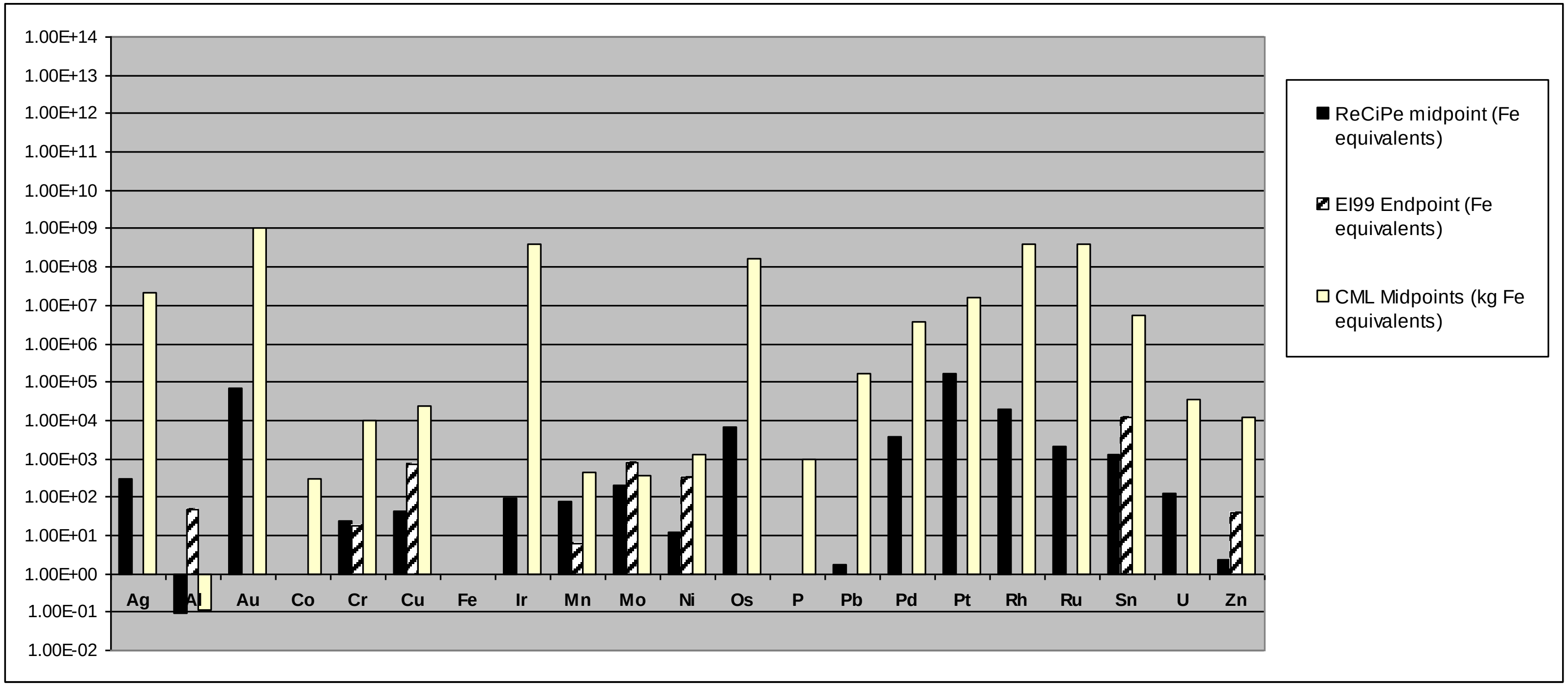
Not applicable: Inventory based on kg metal extracted

Endpoint and midpoint CF on deposit level per kg extracted ($\$/kg_{d}^{2}$)

Commodity level

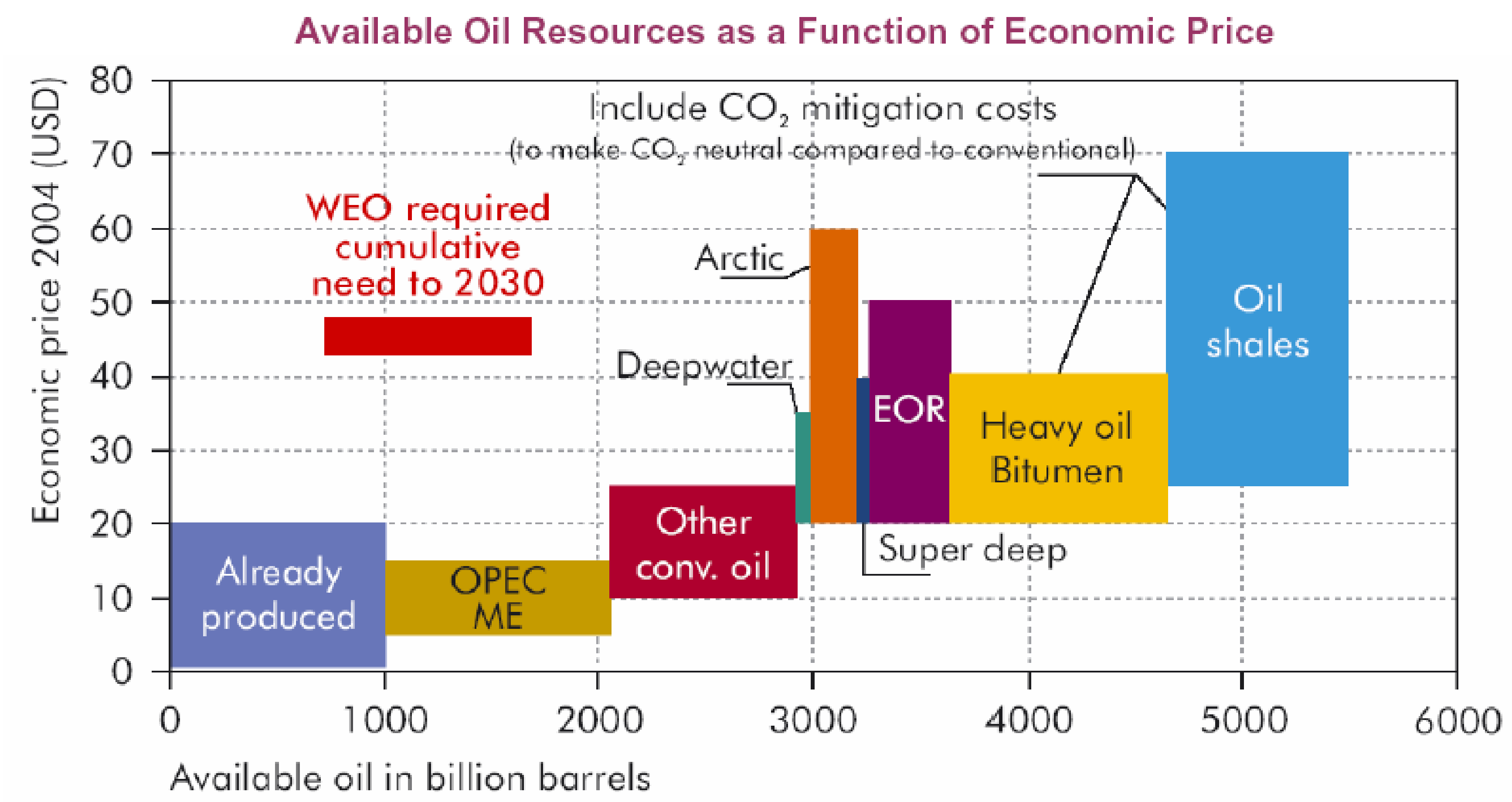
Endpoint and midpoint CF on commodity level ($\$/kg^{2}$)

Comparison with other methods



- Significant differences with older methods
- Weak points:
  - Data only spans the concentrations found in mines
  - Dataset from 1993
  - Market values, as basis for weighting, fluctuates significantly

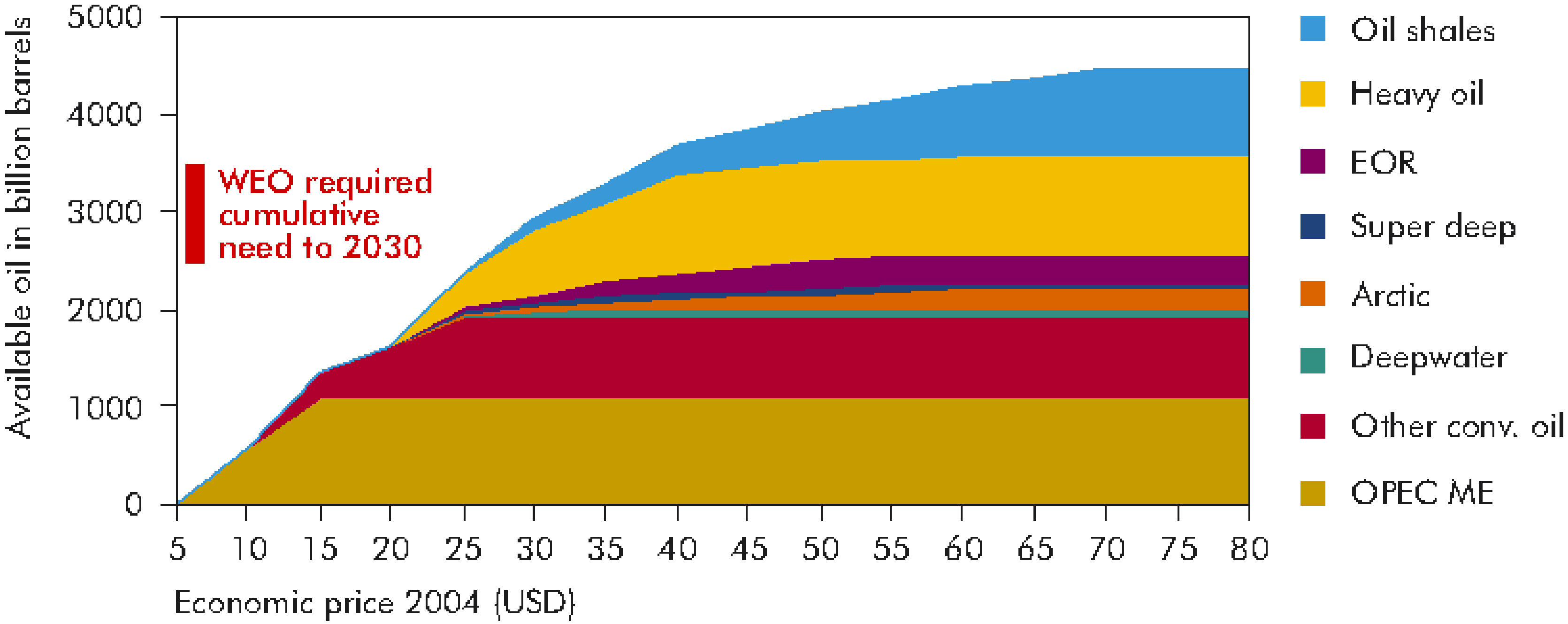
How much oil is there, and what would it cost to get it



Source: *Resources to Reserves - Oil and Gas Technologies for the Energy Markets of the Future*, IEA, 2005

Depletion fossil fuels (oil)

- We are shifting from conventional to non conventional oils
- Production cost will go up with increasing demand
- Slope is used to express price increase



Source: IEA.

Results

- Starting basis: deposit depletion, resulting in higher costs
- Characterisation factors for 20 metals
- Characterisation factor for oil only, other fossils included based on energy content

- Follow up work starting

PRé

Characterisation factors

- Midpoint characterization factor (1/kg)

$$CF_{c.kg.mid} = V_c^2 * \frac{\overline{M}_c}{(\overline{c}_c)^2} * P_c$$

On deposit level

- Endpoint characterization factor ($/kg²)

$$CF_{c.kg.end} = V_c^2 * \frac{\overline{M}_c}{(\overline{c}_c)^2} * 4x * P_c$$

On deposit level

V_c= value of commodity/metal
M_c= slope grade-yield relationship
c_c= constant
x= mining costs per kg ore extracted (0.013$/kg ore mined)
P_c= Production per year