LCA of Electric Vehicles Recycling

Comparison of three business lines of dismantling

CHEMICAL ENGINEERING

Processes and Sustainable Development

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LGC CHEMICAL ENGINEERING

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1. Life Cycle Assessment

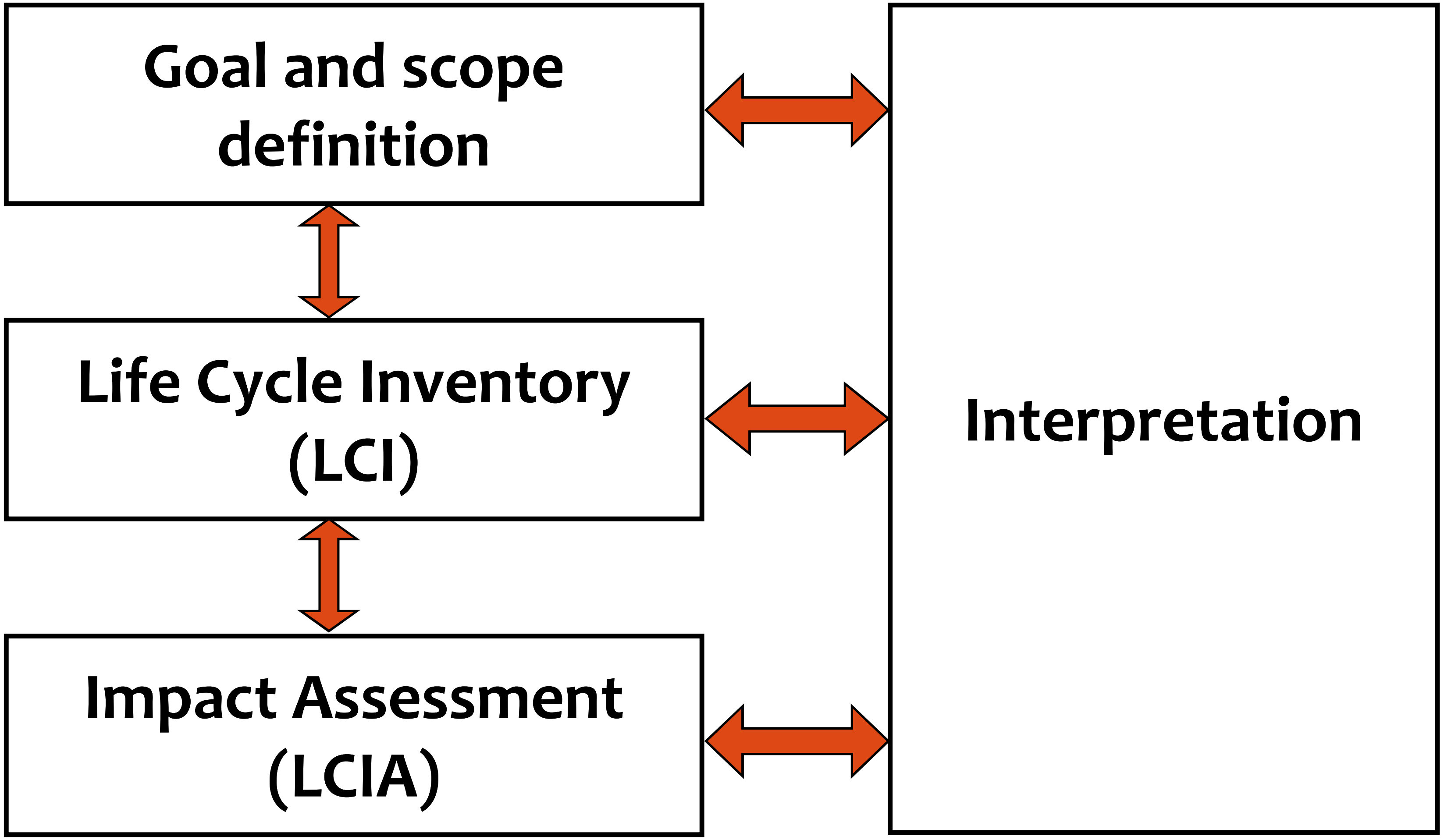
1.1. Methodology

- ISO Standards 14040/44
- Comprises all stages:
  - Extraction
  - Manufacturing
  - Transportation
  - Packaging
  - Distribution
  - Product / Use
  - End-of-Life
- "Craddle to grave"

http://www.coldstreamconsulting.com/life-cycle-analysis

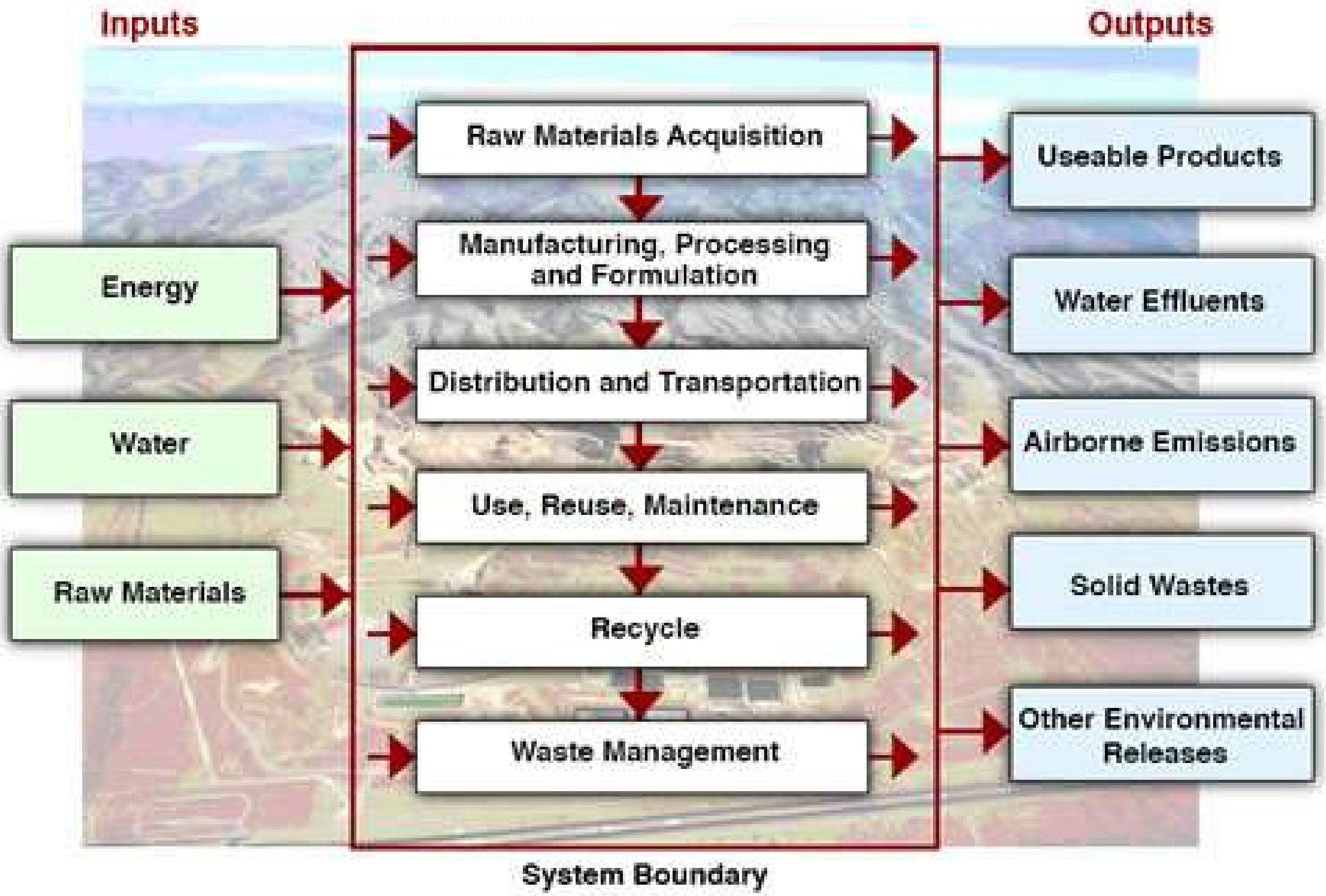
1. Life Cycle Assessment

1.2. Steps



1. Life Cycle Assessment

1.3. Inventory



1. Life Cycle Assessment

1.4. Impact assessment

Impact categories

- Climate change
- Acidification
- Eutrophication
- Non-renewable resources
- Ozone layer depletion
- Photochemical oxidation
- Etc.

CO_2	**10 kg**
CH_4	**12 m^3**
SO_2	**150 g**
As, Cd, HAP	**…**

⇓

CO_2, CH_4, N_2O ⇒ Climate change
SO_2, NOx ⇒ Acidification
As, Cd, HAP ⇒ Carcinogens effects

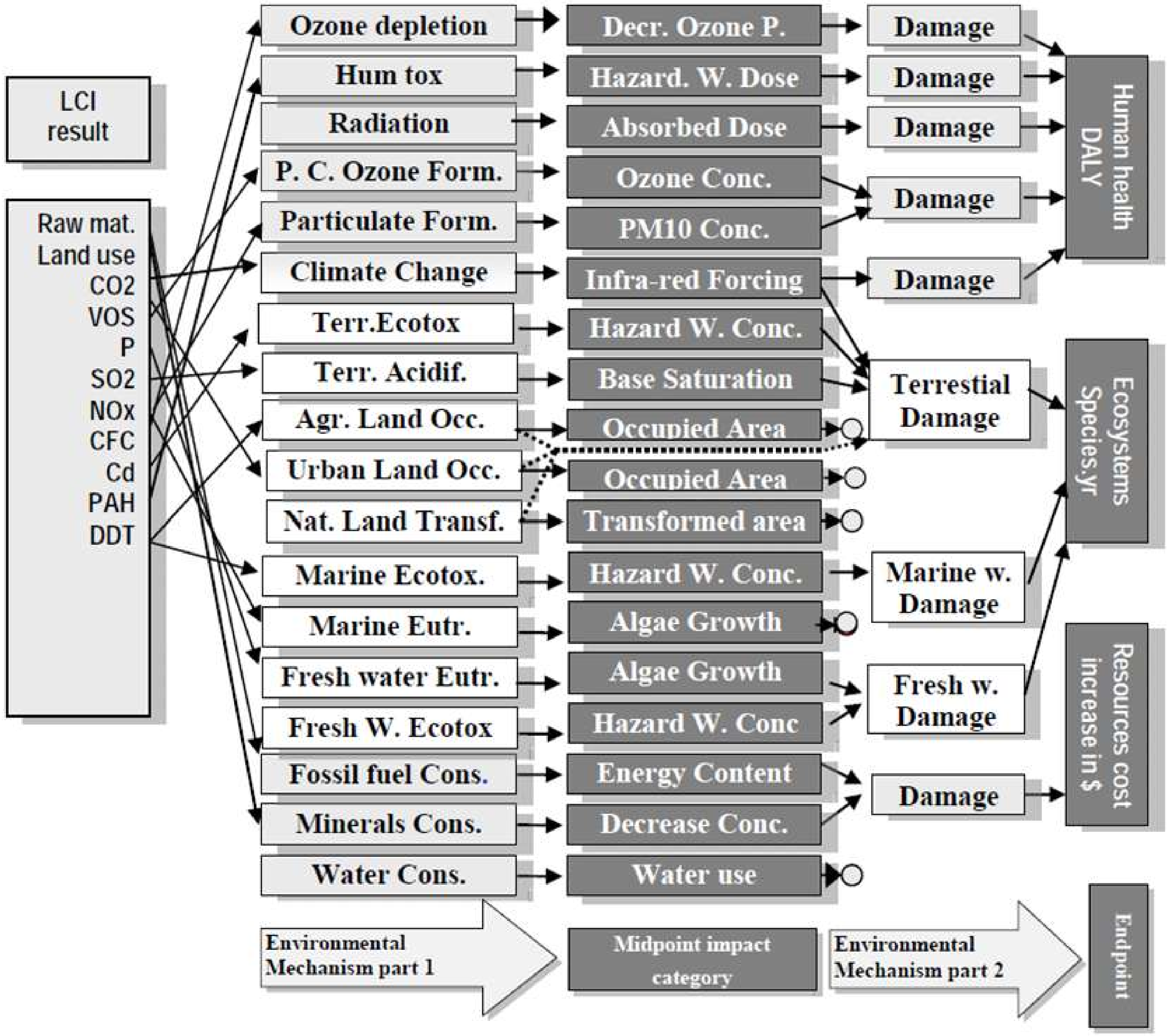
1. Life Cycle Assessment

1.4. Impact assessment

- No universal methodology

- ISO standards refer to international methods
- EC → Joint Research Center (JRC) → International Reference Life Cycle Data System (ILCD) Handbooks

- Examples
  - Eco-Indicator 99
  - CML 2001
  - **ReCiPe 2008**
  - EPD 2008



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 fuel Cons.
Minerals Cons.
Water Cons.
Decr. Ozone P.
Hazard. W. Dose
Absorbed Dose
Ozone Conc.
PM10 Conc.
Infra-red Forcing
Hazard W. Conc.
Base Saturation
Occupied Area
Occupied Area
Transformed area
Hazard W. Conc.
Algae Growth
Algae Growth
Hazard W. Conc
Energy Content
Decrease Conc.
Water use
Damage
Damage
Damage
Damage
Damage
Terrestial Damage
Marine w. Damage
Fresh w. Damage
Damage
Human health DALY
Ecosystems Species.yr
Resources cost increase in $
Environmental Mechanism part 1
Midpoint impact category
Environmental Mechanism part 2
Endpoint

2. Context of the study

European directive : 2000/53/EC

- By 2015: global recovery of End of Live Vehicle (ELV) = 95% wt

- Possibilities :
  - Removal of metal components before shredding (Cu, Al, Mg)
  - Removal of large plastic components (bumpers, dashboards, fluid containers,...)
- BE: no removal of Engine Control Unit (ECU) and plastics → recovering after shredding
- ⇒ selective dismantling

- Life Cycle Assessment of both possibilities to get the environmental performance of these scenarios

3. Goal and Scope

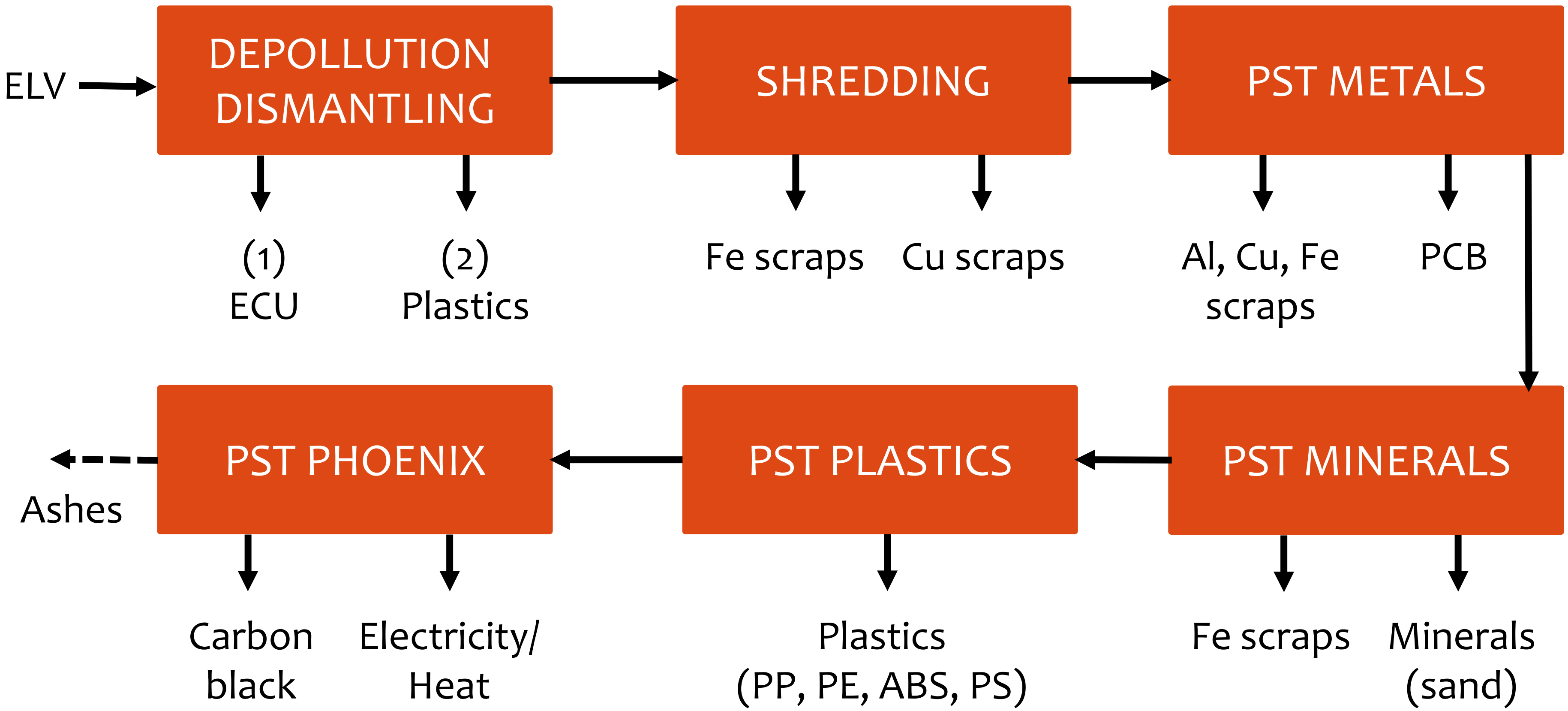
Goal definition

Environmental impact of 2 recycling routes of ELV and comparison with current recycling scenario ("business as usual")

- Dismantling of ECU and recycling before shredding
- Dismantling of large plastics components and recycling before shredding

3. Goal and Scope

Scope: Main stages in scenarios ("gate to grave")



Functional Unit: Treatment and recycling of a depolluted ELV (with or without selective dismantling before shredding)

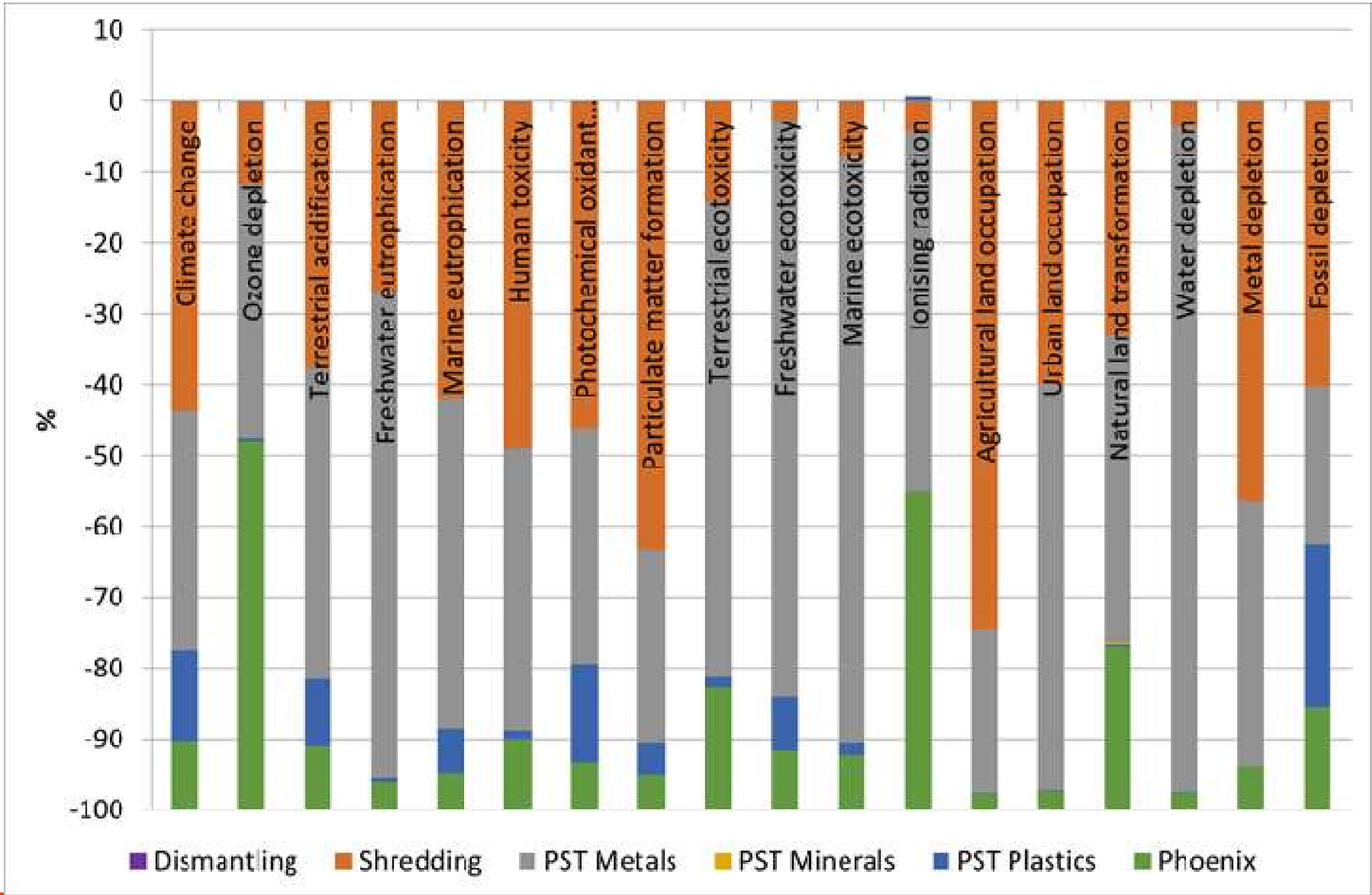
4. Main assumptions and results

Belgian electricity mix:

Fuel	Belgium
Coal	6.0%
Natural gas	28.2%
Hydroelectricity	1.6%
Nuclear energy	53.5%
Wind	2.6%
Waste	2.2%
Biomass	4.3%
Solar PV	1.3%
Oil	0.3%

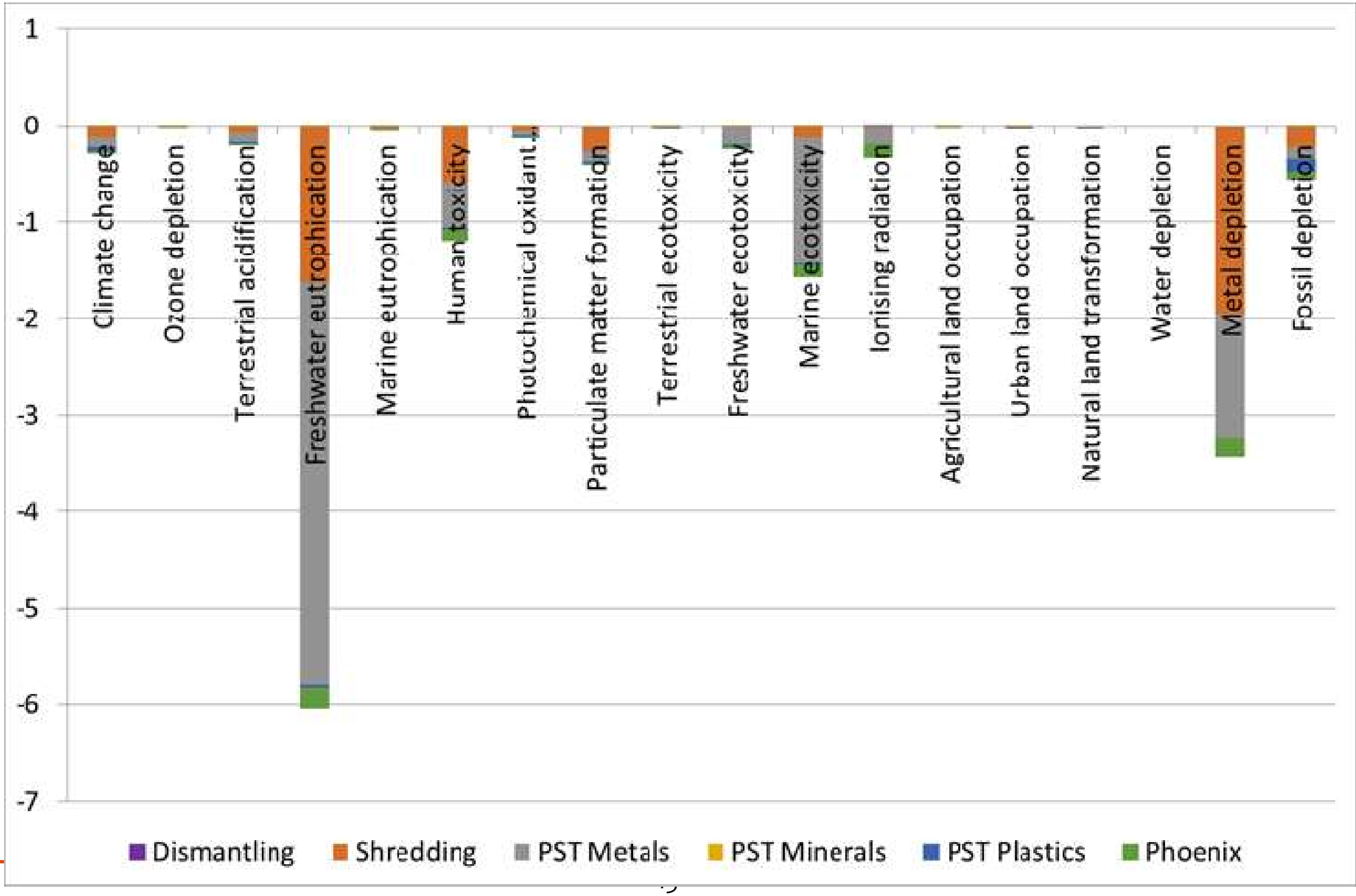
4. Main assumptions and results

First route: classical vehicles



4. Main assumptions and results

First route: classical vehicles



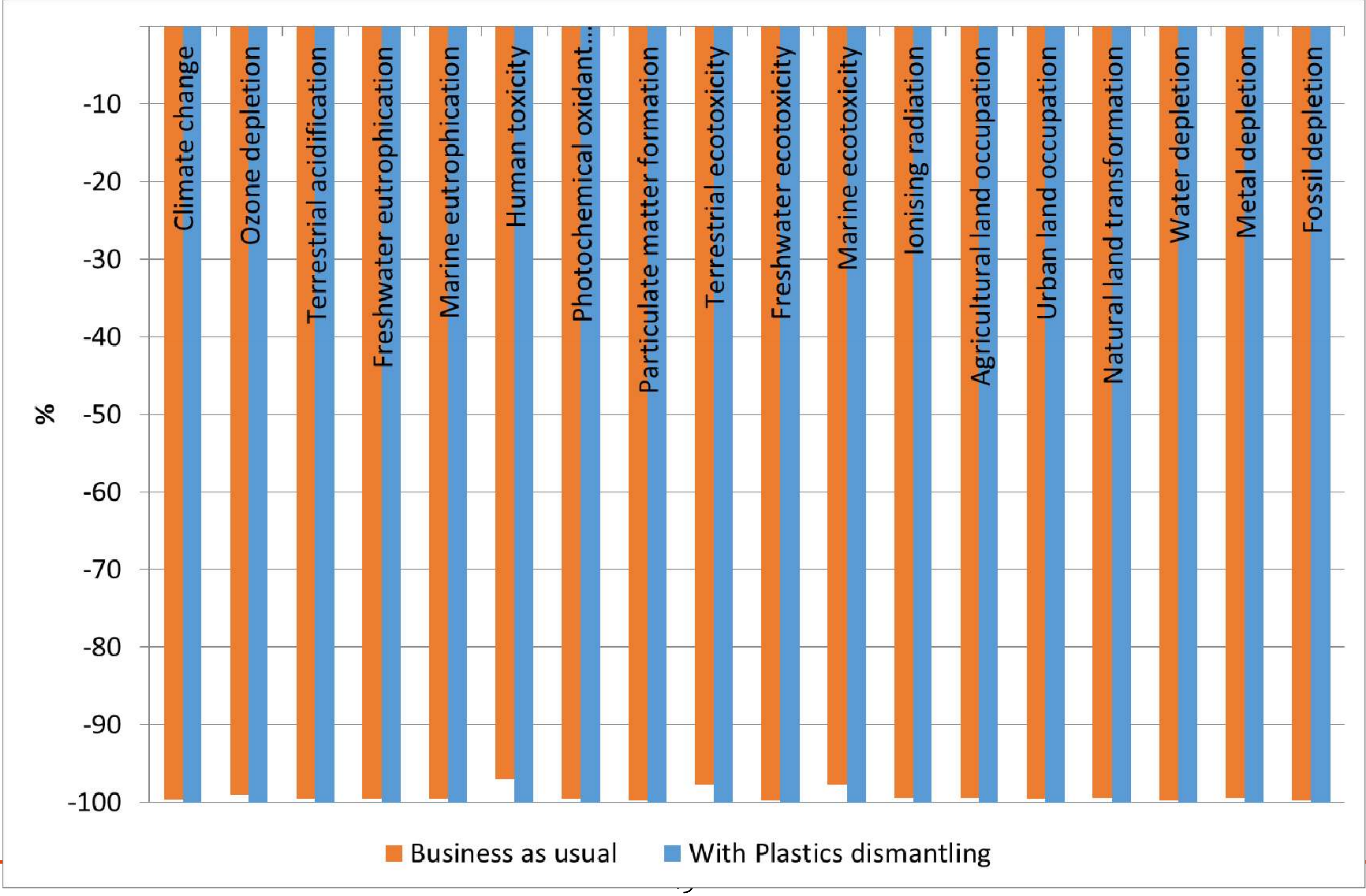
5. Second route

Dismantling of plastics

- *Same steps than before*
  - *Dismantling*
  - *Shredding*
  - *PST Metals*
  - *PST Minerals*
  - *PST Plastics*
  - *PST Phoenix*
- *Recovery of plastics during the dismantling phase*
- *Main assumption : yield of valorisation for plastic before or after shredding is the same = 97%* $\Rightarrow$ *sensitivity analysis*

5. Second route

Dismantling of plastics



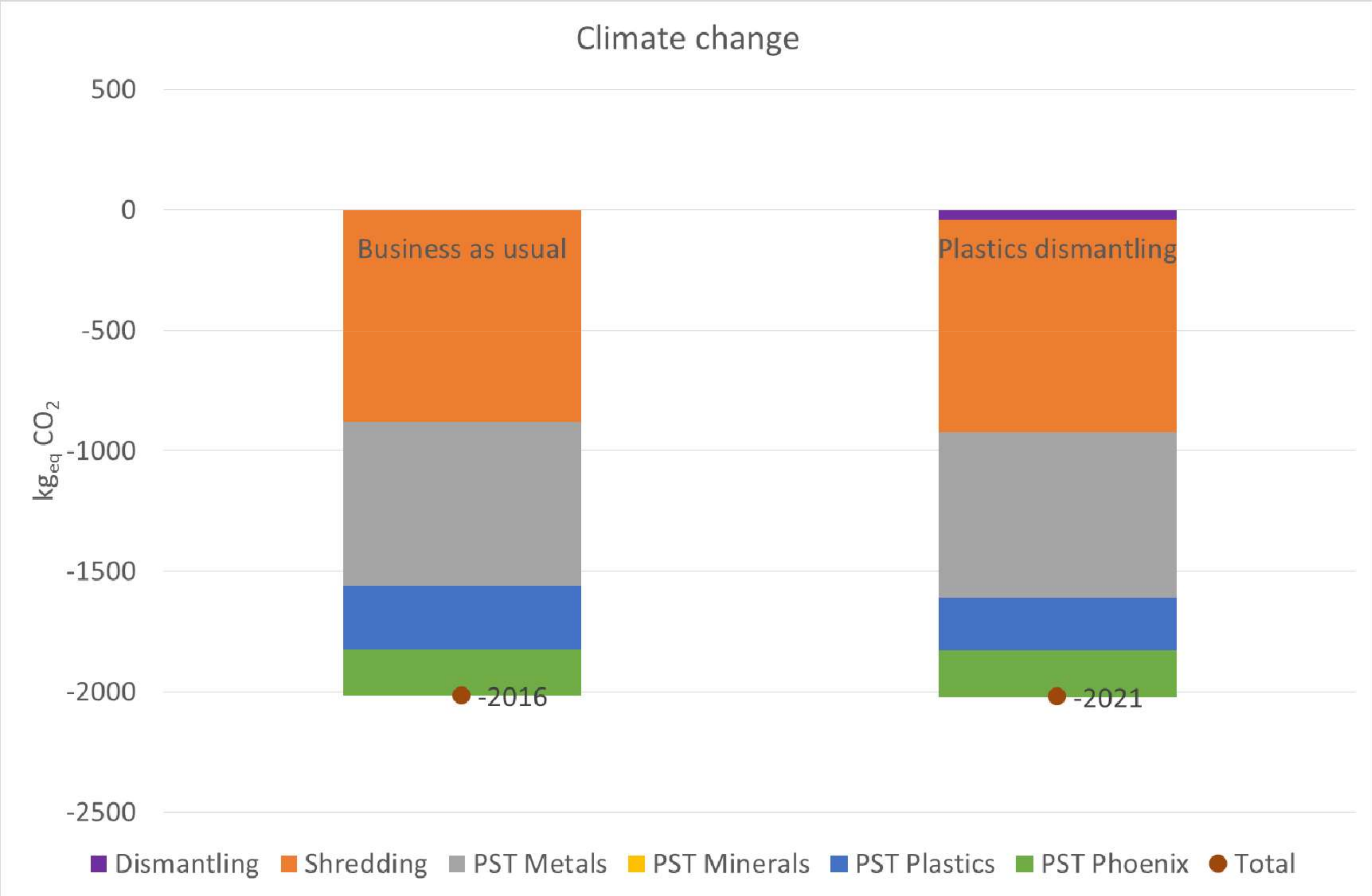
5. Second route

Dismantling of plastics

Impact category	Unit	Classical route	Dismantling of plastics	Gain
Climate change	kg $CO_{2\ eq}$	-2015.50	-2021.07	0.3%
Terrestrial acidification	kg $SO_{2\ eq}$	-7.99	-8.03	0.5%
Freshwater eutrophication	kg P $_{eq}$	-1.75	-1.76	0.6%
Human toxicity	kg 1.4-DB $_{eq}$	-140.06	-144.32	3.0%
Particulate matter formation	kg $PM_{10\ eq}$	-5.78	-5.80	0.3%
Metal depletion	kg Fe $_{eq}$	-1527.12	-1534.52	0.5%
Fossil depletion	kg oil $_{eq}$	-721.04	-722.73	0.2%

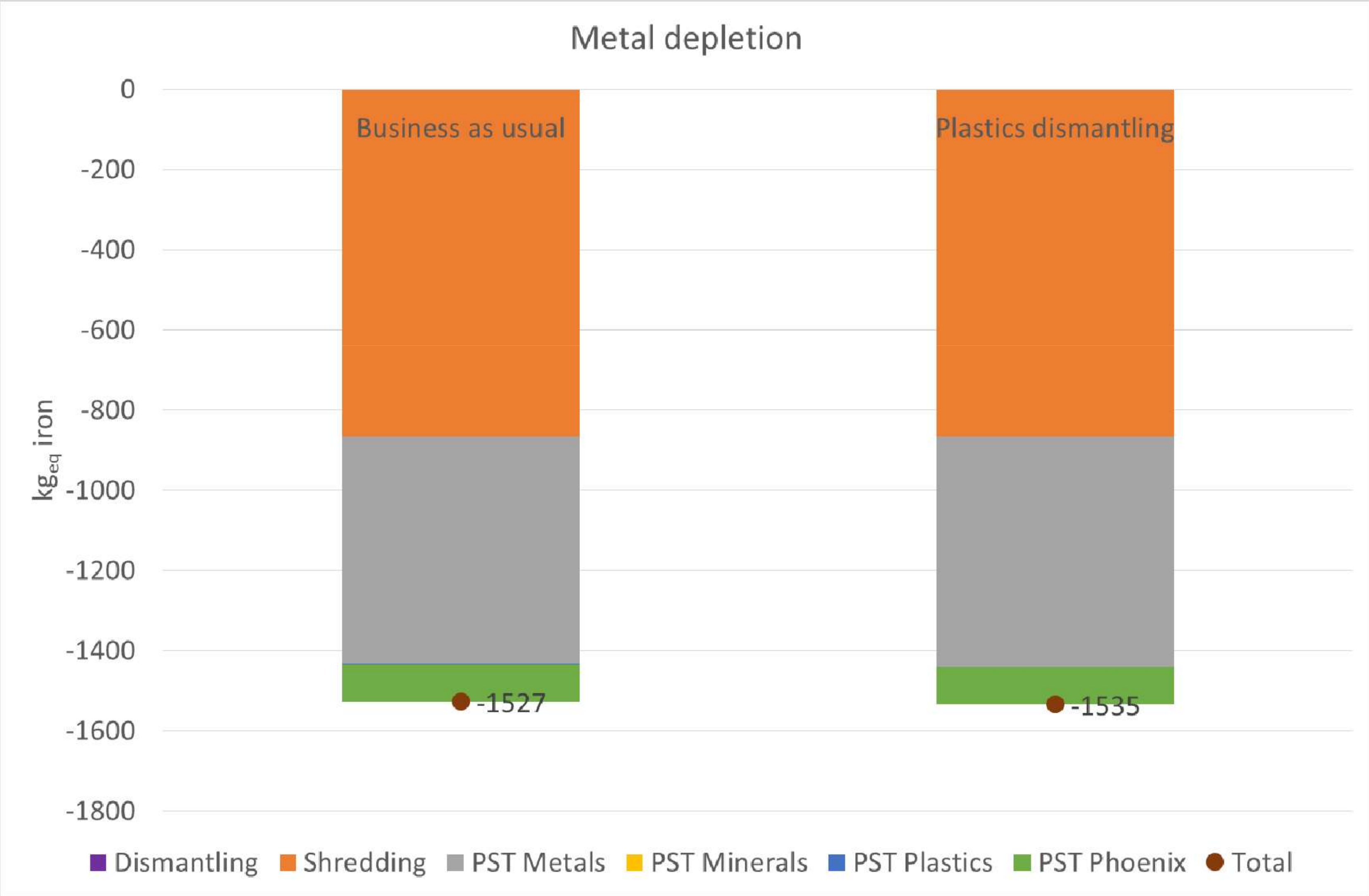
5. Second route

Dismantling of plastics – climate change



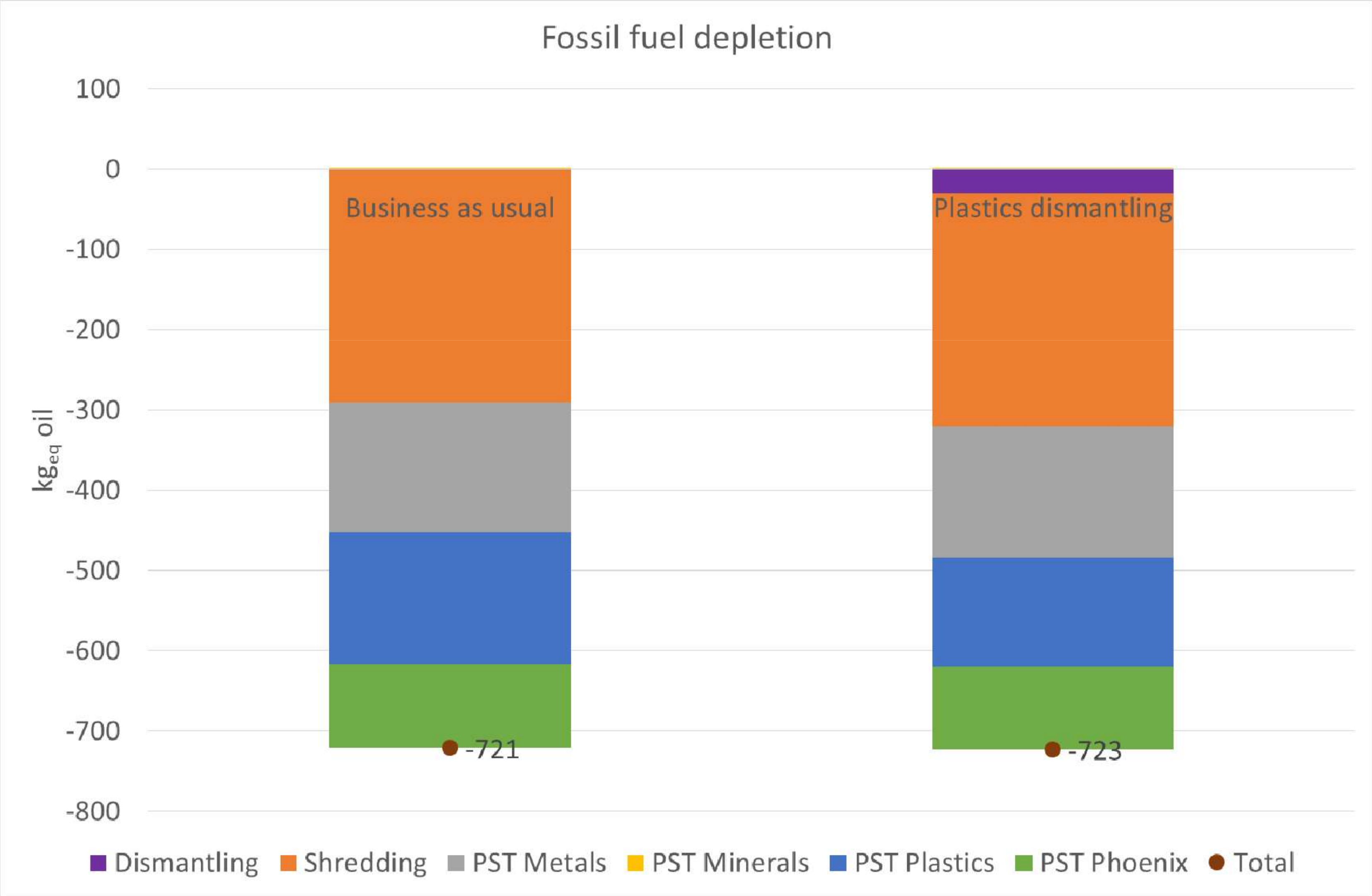
5. Second route

Dismantling of plastics – metal depletion



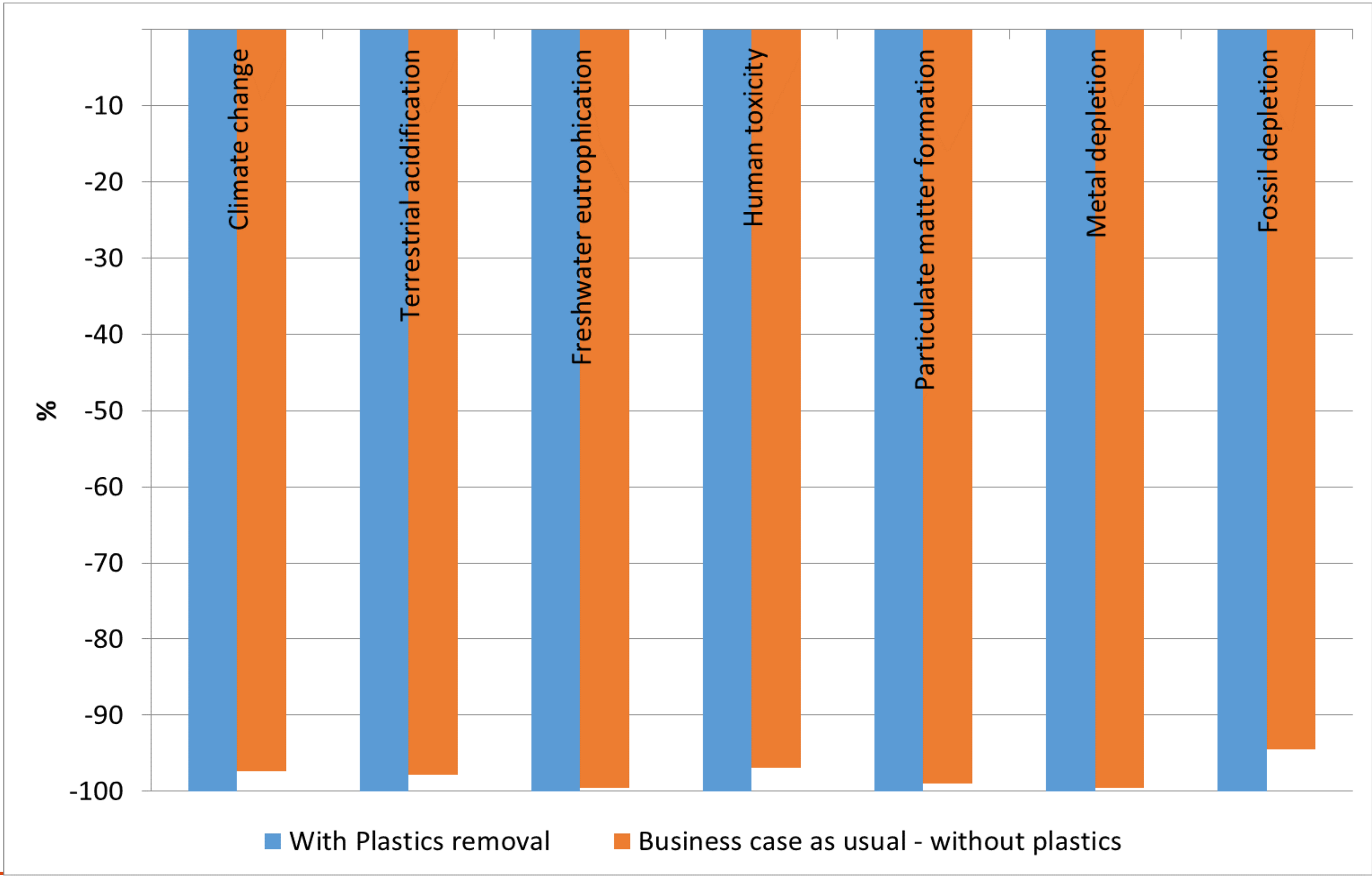
5. Second route

Dismantling of plastics – fossil fuel depletion



5. Second route – Sensitivity analysis

Yield of Plastics recovery and valorisation



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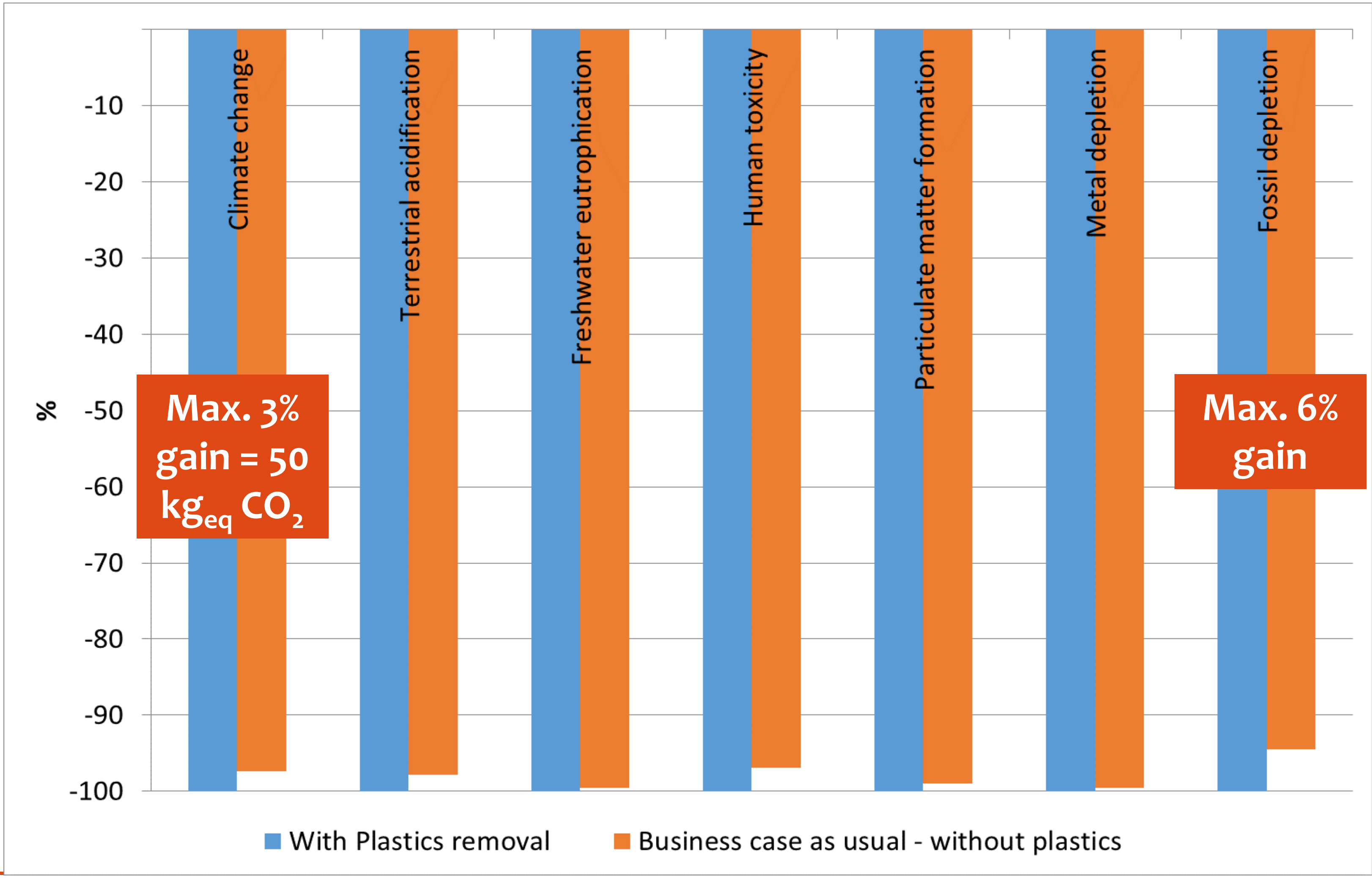


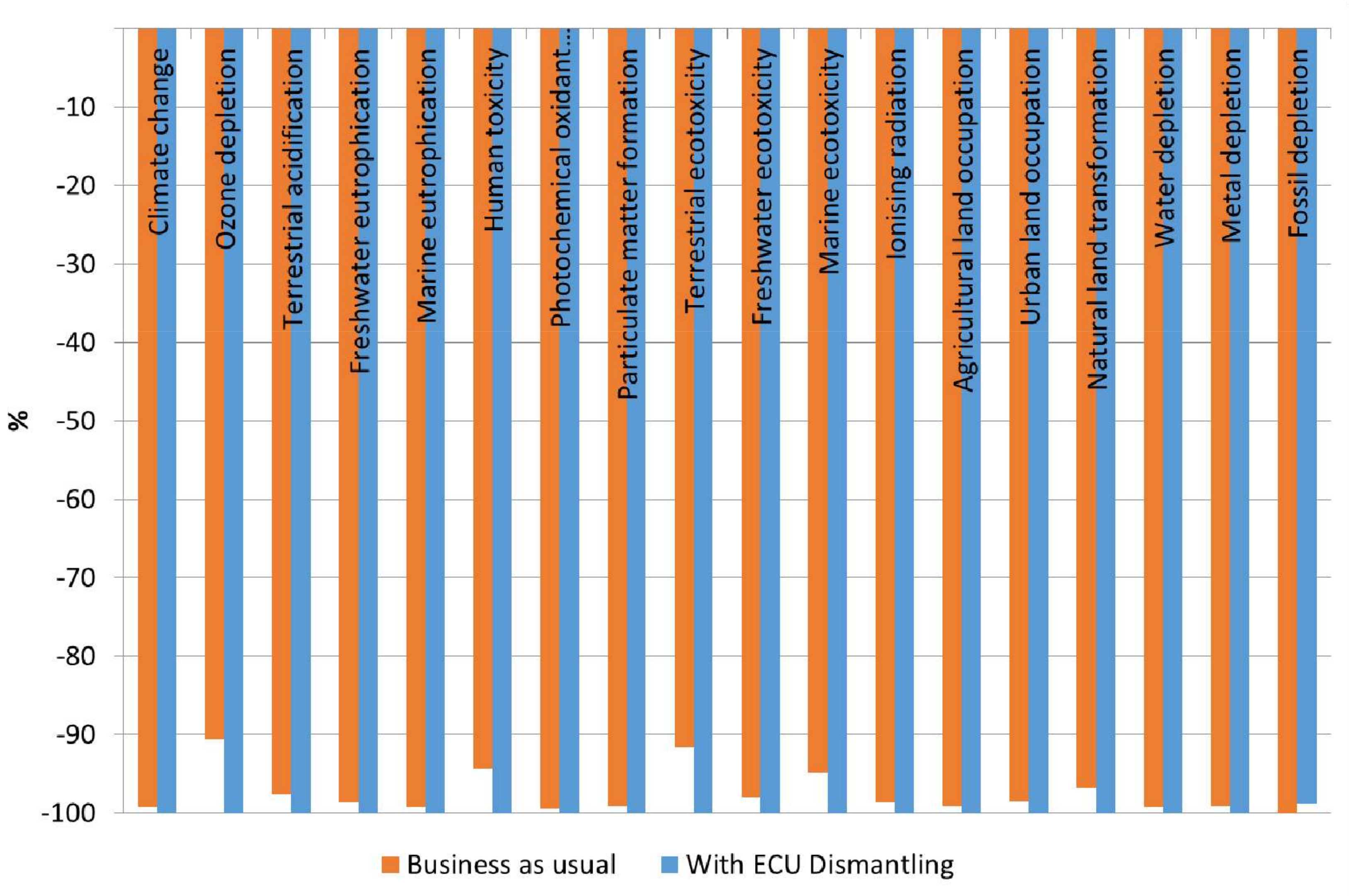
6. Third route

Dismantling of ECU

- *PCB and Aluminium (+ plastics: incinerated → heat)*
- *Same steps than before*
    - *Dismantling*
    - *Shredding*
    - *PST Metals*
    - *PST Minerals*
    - *PST Plastics*
    - *PST Phoenix*
- *Recovery of ECU during the dismantling phase*
- *Main assumption: 1 kg of PCB scrap replaces 1 kg of primary PCB ⇒ sensitivity*

6. Third route

Dismantling of ECU



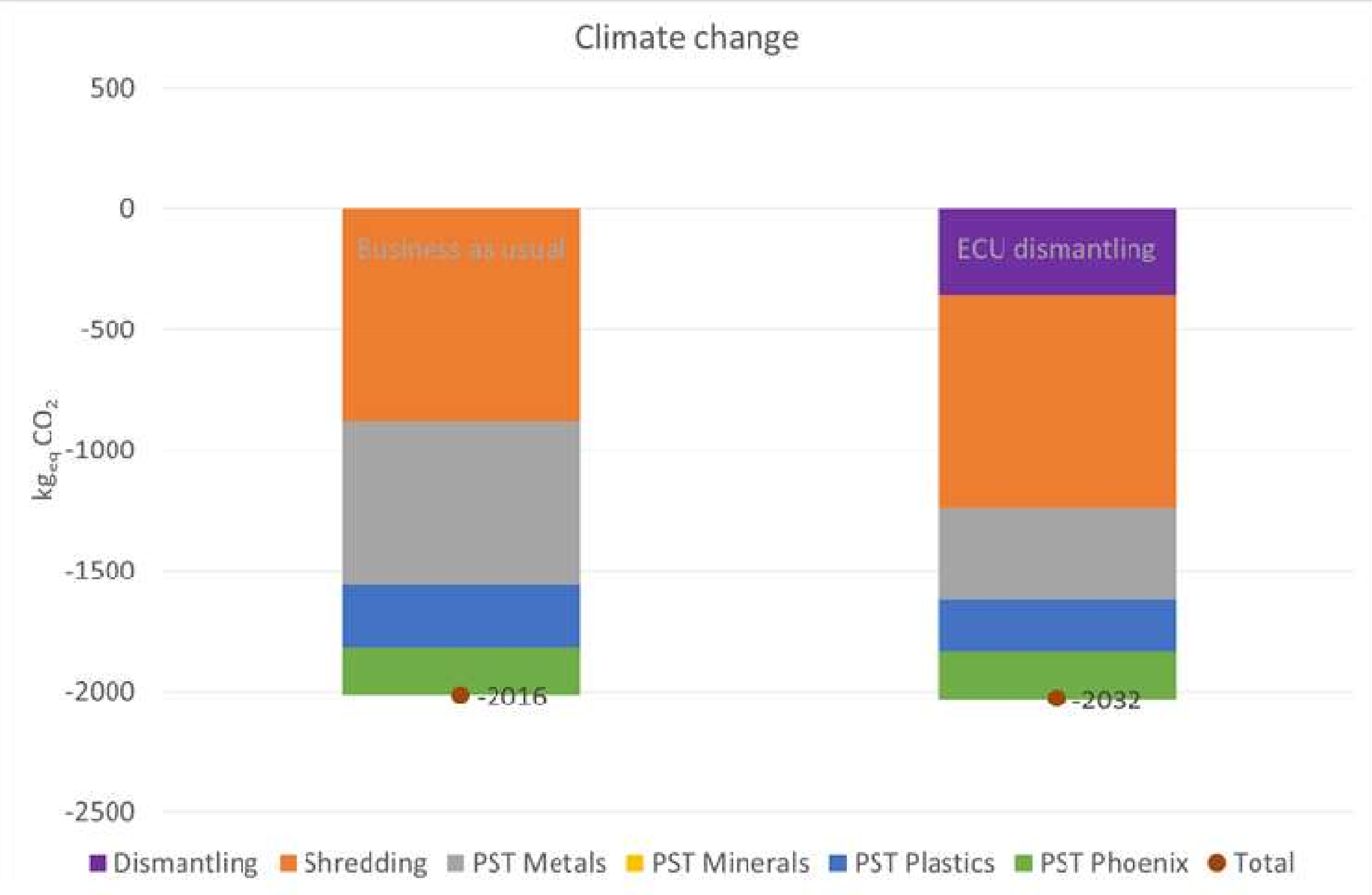
6. Third route

Dismantling of ECU

Impact category	Unit	Classical route	Dismantling of ECU	Gain
Climate change	kg $CO_{2\ eq}$	-2015.50	-2031.89	0.8%
Terrestrial acidification	kg $SO_{2\ eq}$	-7.99	-8.18	2.4%
Freshwater eutrophication	kg P_{eq}	-1.75	-1.78	1.7%
Human toxicity	kg 1.4-DB_{eq}	-140.06	-148.46	6.0%
Particulate matter formation	kg $PM_{10\ eq}$	-5.78	-5.83	0.9%
Metal depletion	kg Fe_{eq}	-1527.12	-1539.93	0.8%
Fossil depletion	kg oil_{eq}	-721.04	-712.05	-1.2%

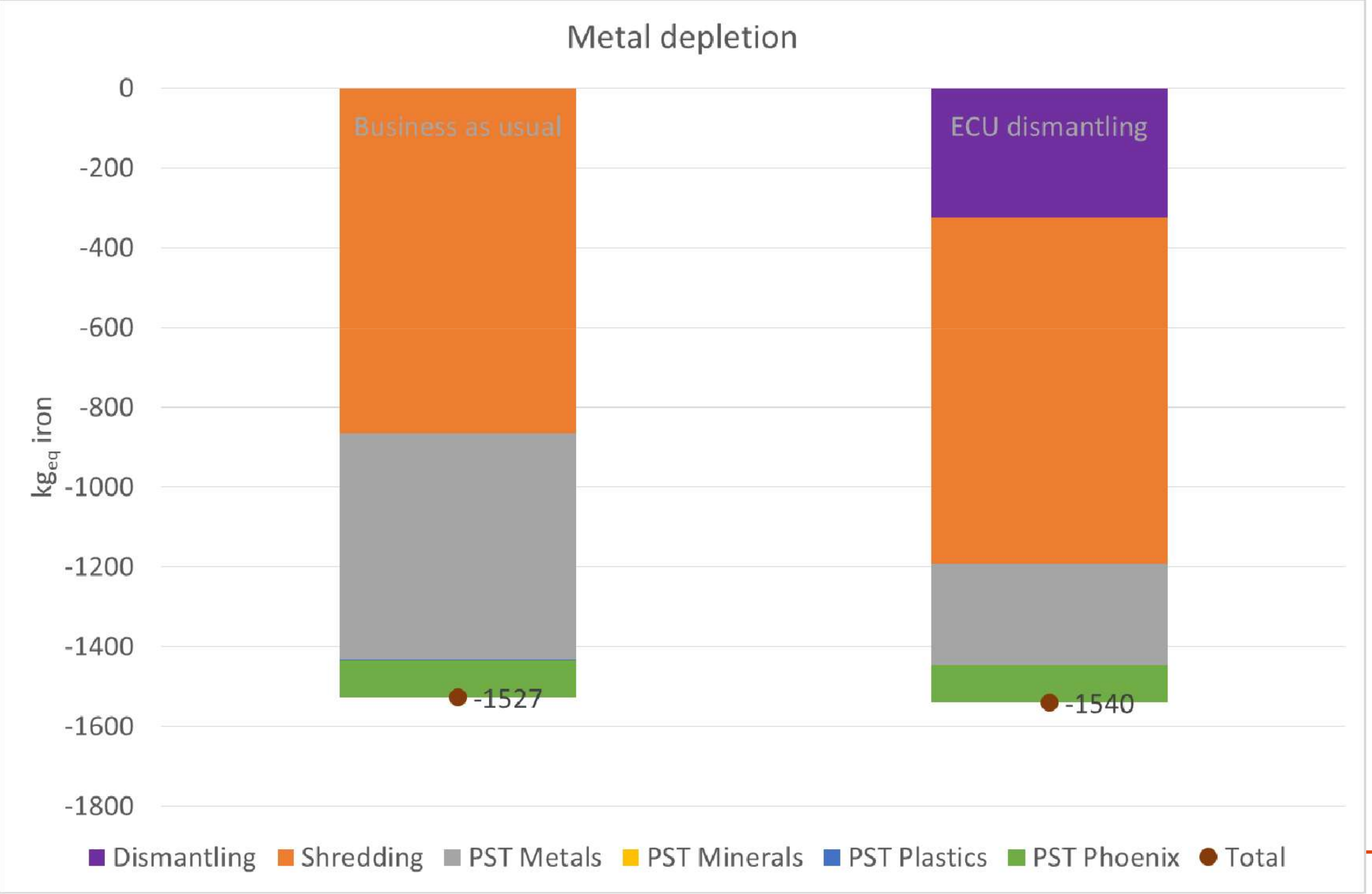
6. Third route

Dismantling of ECU – climate change



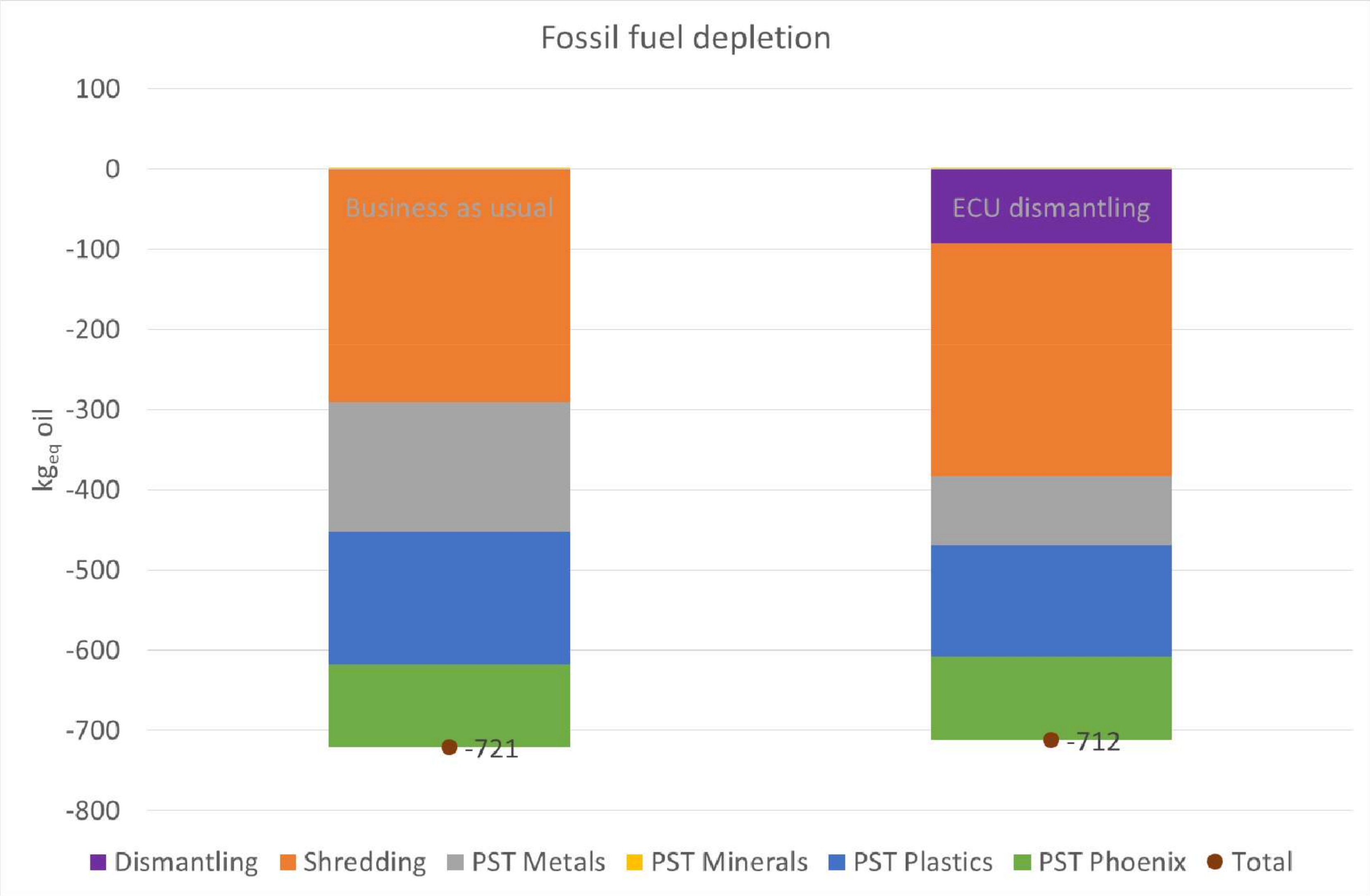
6. Third route

Dismantling of ECU – metal depletion



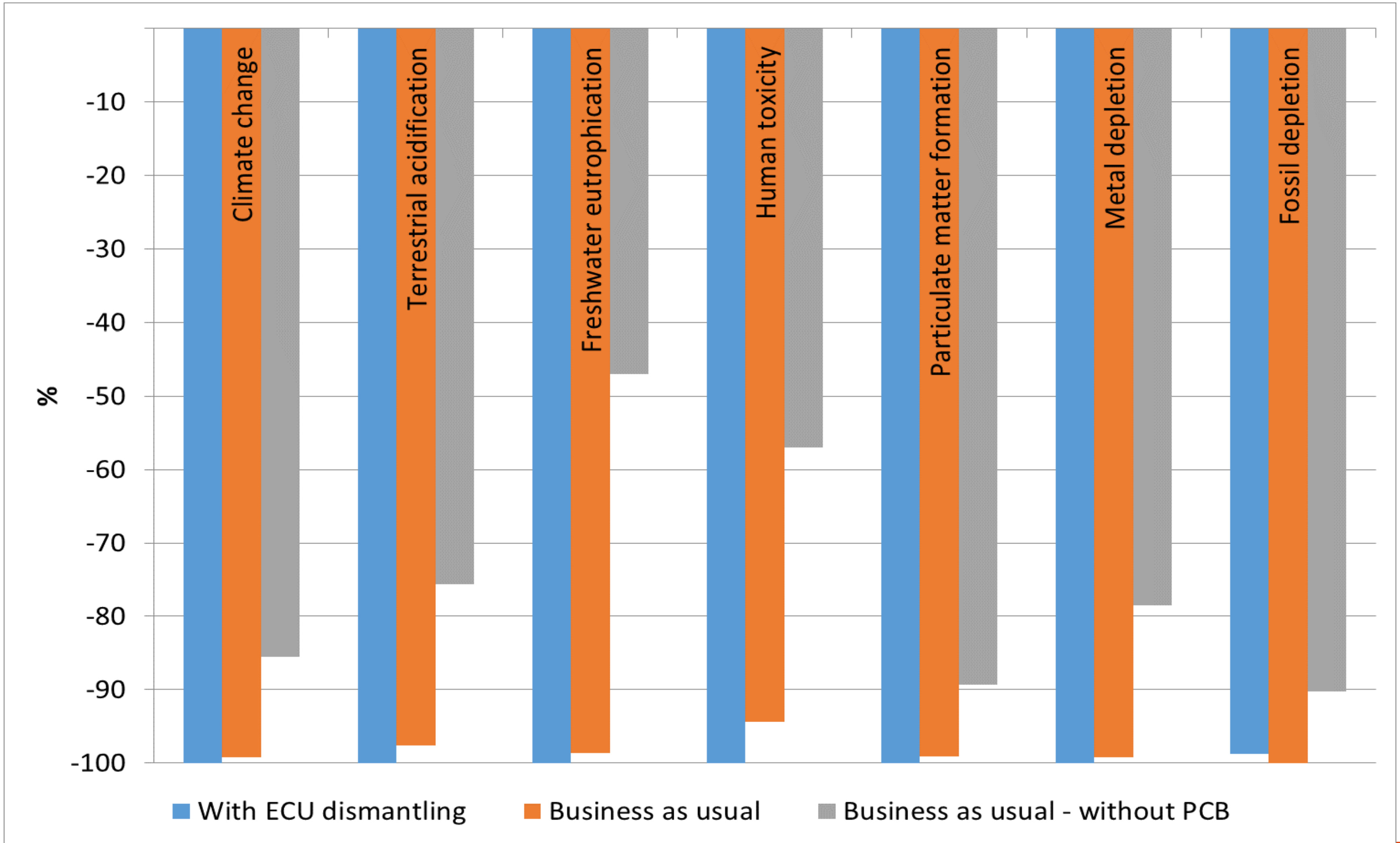
6. Third route

Dismantling of ECU – fossil fuel depletion



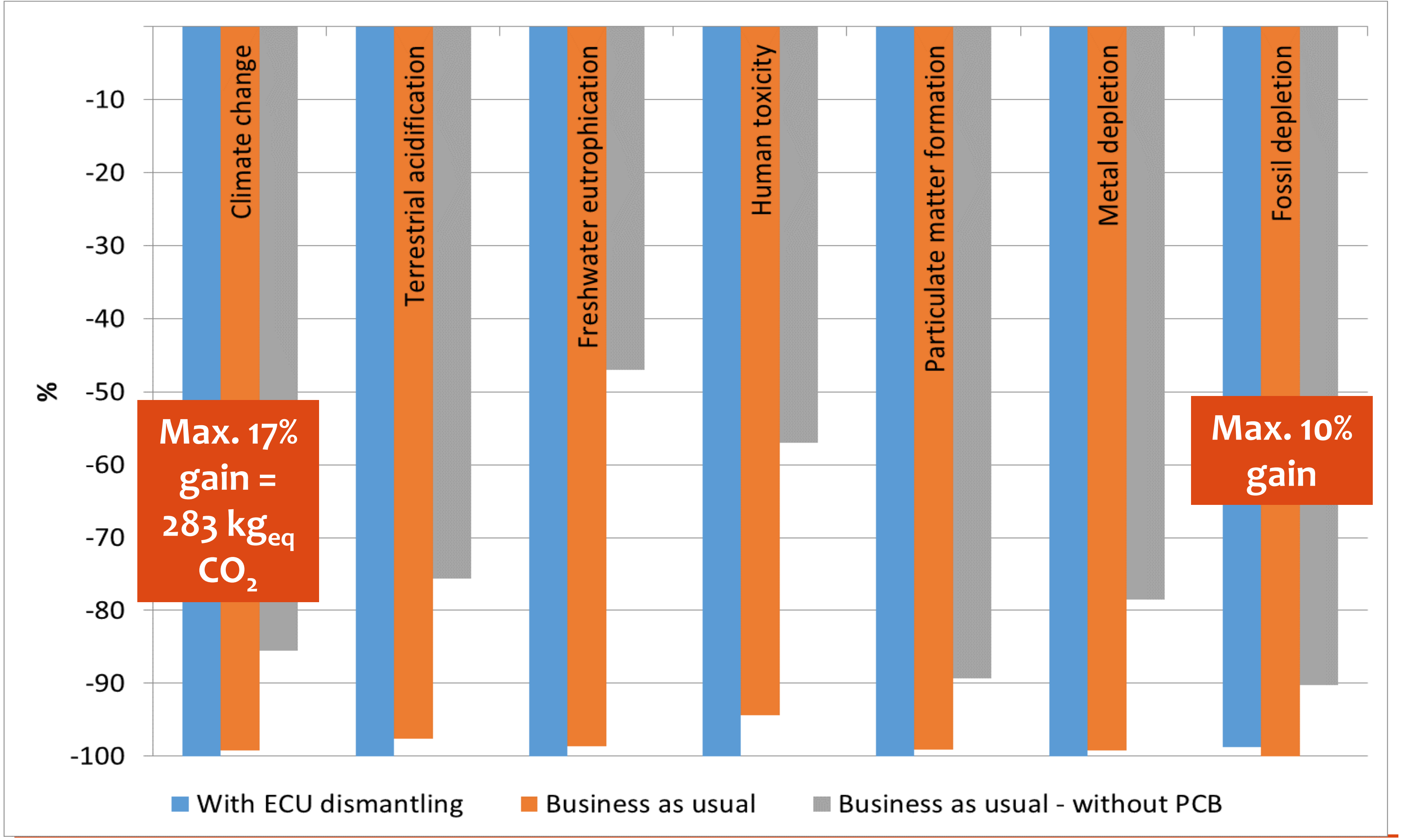
6. Third route - Sensitivity analysis

Yield of PCB recovery and valorisation



6. Third route - Sensitivity analysis

Yield of PCB recovery and valorisation



7. Conclusions

Classical route

- Shredding step is the most important
- All processes obtain a negative score $\Rightarrow$ positive environmental impacts
- All results are dependent to the market

Dismantling of plastics

- Small gain relative to the classical route
- Depends on the plastics valorisation
- In the worst case for the classical scenario :
  - Climate change gain = 3%
  - Fossil fuel depletion gain = 6%

7. Conclusions

Dismantling of ECU

- Small gain relative to the classical route
- Few changes in all valorisation units
- In the worst case for the classical scenario :
  - Climate change gain = 17%
  - Fossil fuel depletion gain = 10%

ECU and Plastics recovery before shredding is not significant in an environmental point of view.

THANKS!

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