Environmental Assessment of Brownfield Rehabilitation Using Life Cycle Assessment – How Site Reuse Trumps It All

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Green Remediation, Amherst
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INTERNATIONAL INDUSTRIAL CHAIR
IN LIFE CYCLE ASSESSMENT METHODOLOGY

A research unit of the CIRAIG™

ÉCOLE POLYTECHNIQUE MONTRÉAL

Outline

Environmental impacts of brownfields

Life Cycle Assessment (LCA) primer

LCA of brownfield management: A case study

Brownfield potential impacts

	Site physical state (including contamination)	Site economic state (idle)
Economic impacts	-Devaluation of neighbouring sites	-Loss in tax revenues -Lost economic opportunities
Social impacts	-Quality of life of neighbourhood	-deterioration of urban tissue
Environmental impacts	-Impact on life support systems -Human and ecosystem health risks	-Pressure on peripheral land (sprawl)

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Scale : • Local

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Scale:

- Local
- Municipal

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Scale :

- Local
- Municipal
- Regional

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Scale :

- Local
- Municipal
- Regional
- Global

Brownfield management

Evolution of emphasis

Decontamination/
Risk management

	Site physical state	Site economic state
Economic impacts		
Social impacts		
Environmental impacts		

Brownfield management

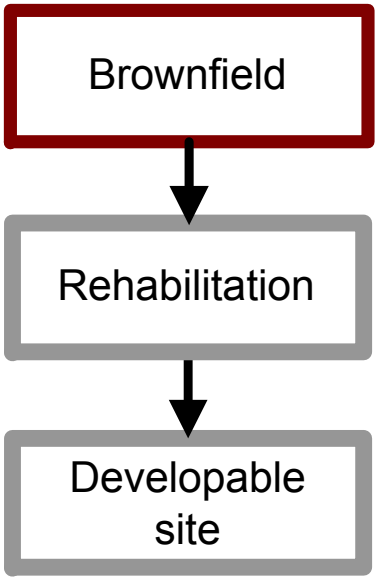
Evolution of emphasis

Decontamination/
Risk management

Rehabilitation-
redevelopment

Function 1: Manage legacy

Function 2: Give site new use



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Brownfield management

Evolution of emphasis

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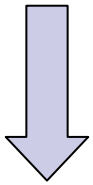


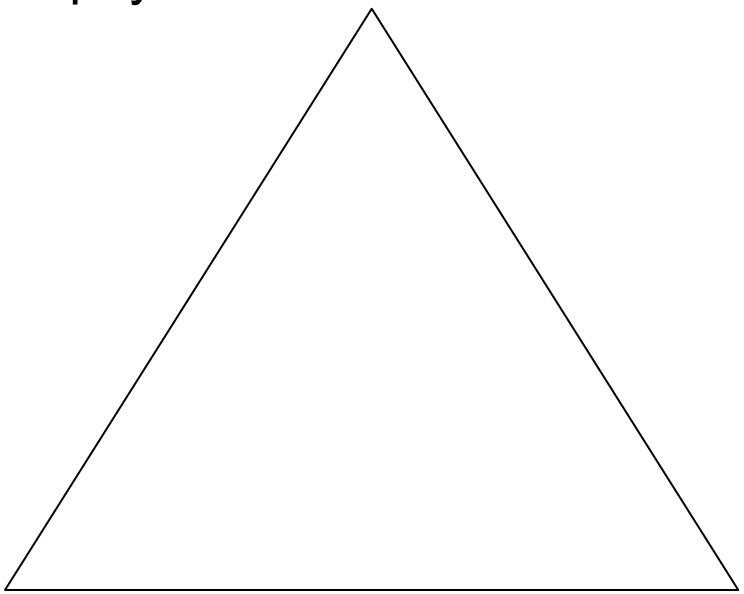
Rehabilitation-
redevelopment

Sustainable
management

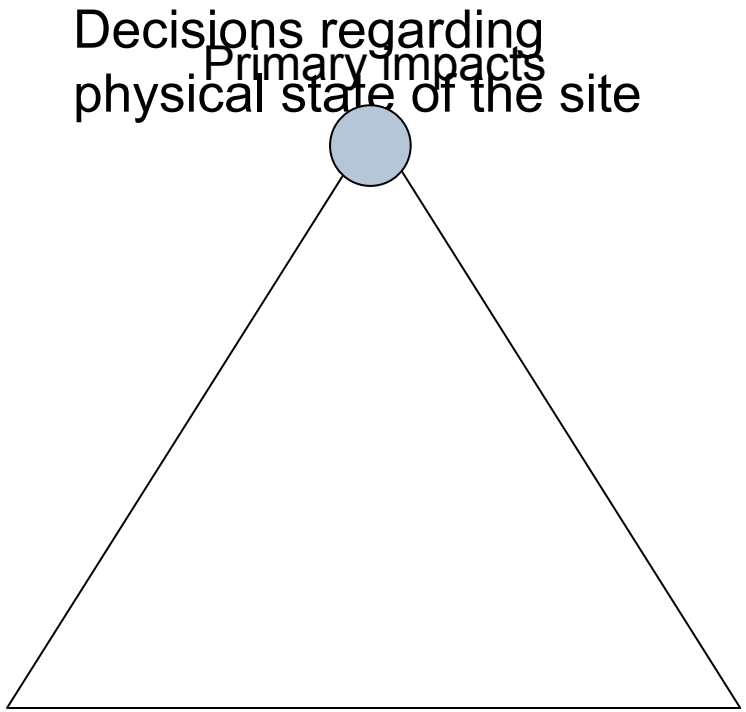
Rehabilitation activities themselves have impacts

To be “sustainable”, these impacts should not surpass the benefits of rehabilitation

Decisions concerning brownfield management



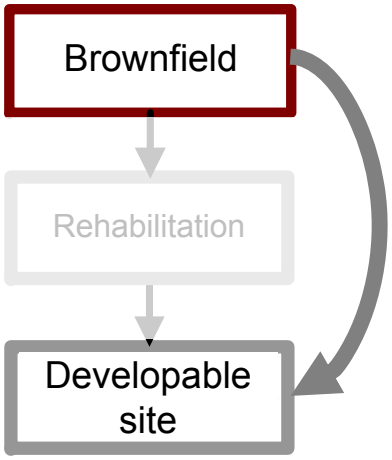
Environmental consequences of bfld mgmt decisions



Primary impacts

Associated with the site itself

- Contamination
  - Toxicity, ecotoxicity
- Physical state
  - Life support functions, biodiversity



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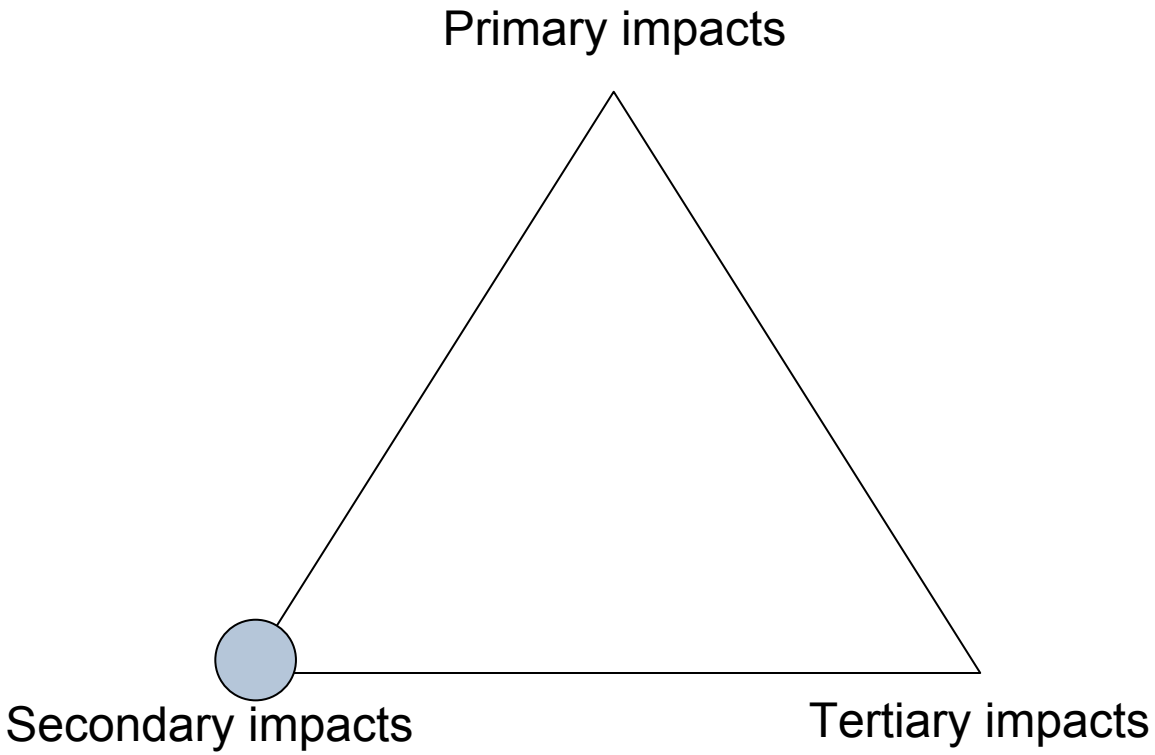
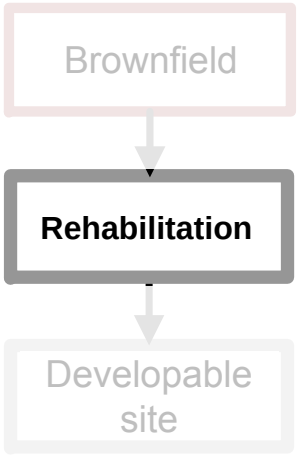


Secondary impacts

Associated with rehabilitation activities

- Sources of potential impacts
  - Onsite operations
  - Offsite operations
  - Fate of contaminants managed offsite
- Evaluation : Life Cycle Assessment
  - Many studies in the late 1990s and 2000's



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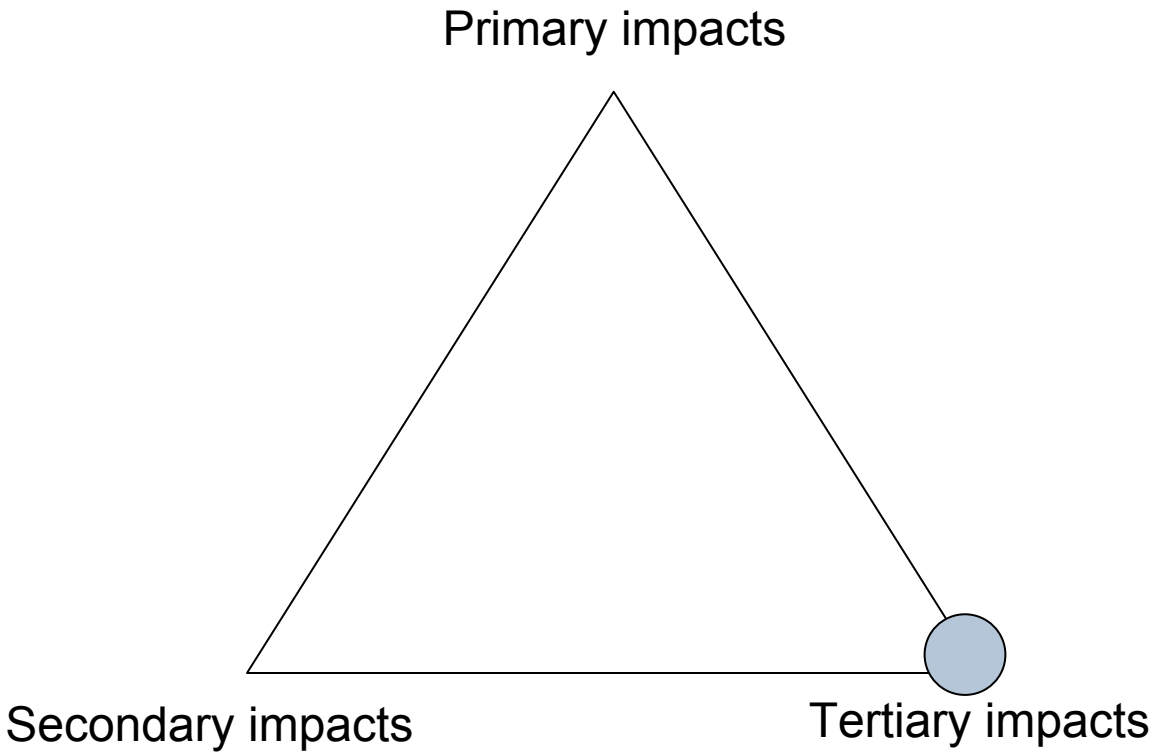
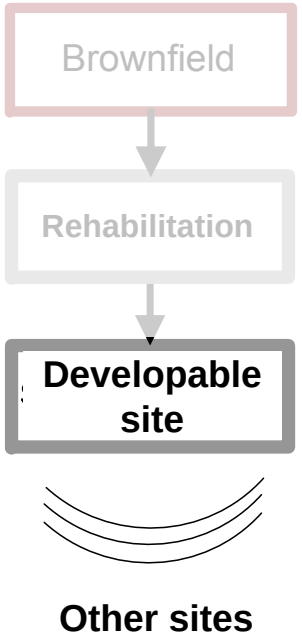


Tertiary impacts

Potential impacts associated with indirect effects on other sites

- Frequent hypothesis: Reuse displaces sprawl
  - Protection of greenfields
  - Reduced transport
  - Energy savings
  - Reduced infrastructure requirements
  - …



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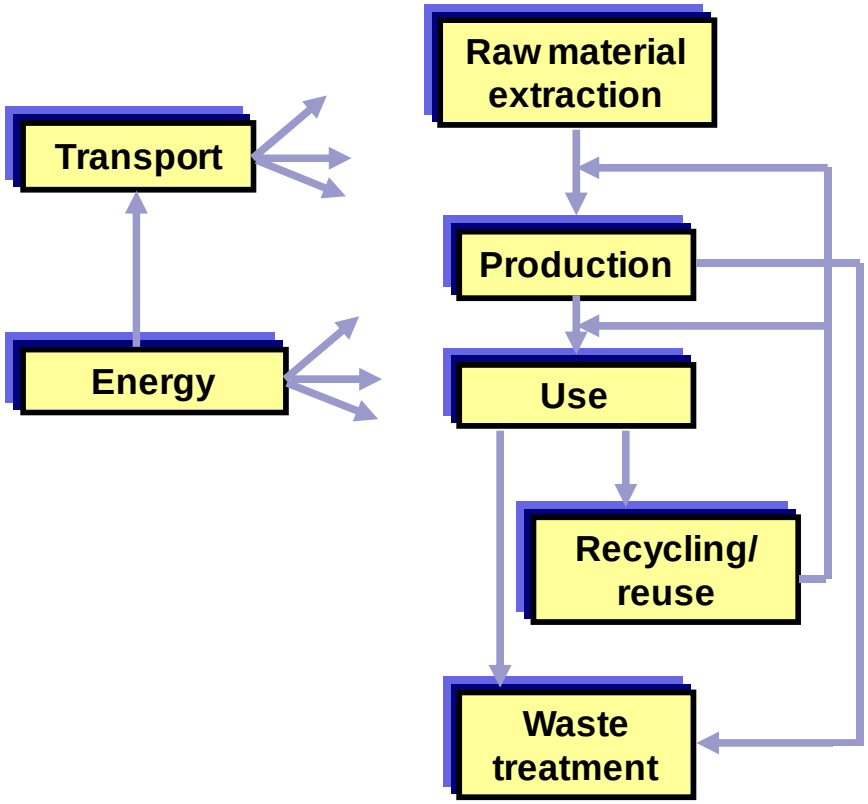
LCA of brownfield management: A case study

Life Cycle Assessment (LCA)

Life cycle of a product

Life cycle *assessment* of a product: evaluation of the potential environmental impacts of a product throughout its life cycle



Example LCA: Transport of soil, truck vs. train

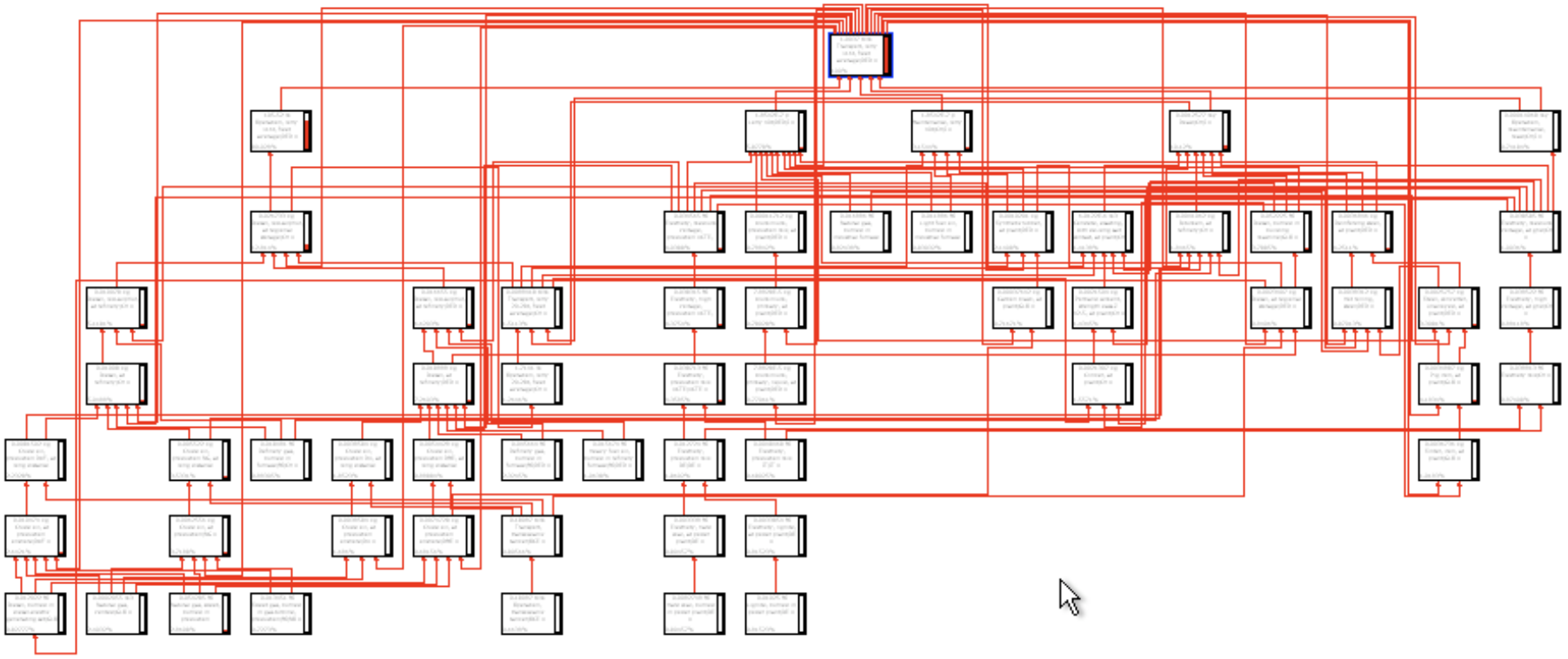
LCA can allow one to compare the potential impacts of different ways of doing something

Example: Hauling 1 tonne of contaminated soil over 100km

2 options: Truck, train

LCA will consider emissions of truck/train, fuel production, truck/train production, maintenance and end-of-life, road/track production, maintenance and end-of-life, etc.

Product system for truck transport



Showing 60 of 1967 nodes…

Life cycle inventory

Compartment: All compartments | Indicator: Inventory | Cut-off: 0% | Per sub-compartment | Skip unused | Default units | Category | Per impact category

No	Substance	Compartment	Sub-compartment	Unit	Paper, woodcontaining,	Paper, woodfree, coated, at
1	Energy, gross calorific value, in biomass	Raw	biotic	MJ	26	26
2	Energy, gross calorific value, in biomass, primary forest	Raw	biotic	MJ	3.03E-5	0.0216
3	Peat, in ground	Raw	biotic	kg	0.0123	2.75E-6
4	Wood, hard, standing	Raw	biotic	m3	0.000362	0.000848
5	Wood, primary forest, standing	Raw	biotic	m3	2.81E-9	2.01E-6
6	Wood, soft, standing	Raw	biotic	m3	0.0023	0.00156
7	Wood, unspecified, standing/m3					
8	Carbon					
9	Ener					
10	Ene					
11	Alu					
12	Anh					
13	Bar					
14	Bas					
15	Bor					
16	Cad					
17	Cal					
18	Car					
19	Cer					
20	Chr					
21	Chr					
22	Cin					
23	Cla					
24	Cla					
25	Coa					
26	Coa					
27	Col					
28	Col					
29	Cop					
30	Cop					
31	Cop					
32	Cop					
33	Dia					
34	Dol					

1165	Thiram	Soil	agricultural	kg	1.12E-12	7.99E-10
199						19E-10
200						47E-9
201						42E-10
202						89E-6
203						48E-5
204						000301
205						78E-6
206						11E-9
207						39E-6
208						78E-8
209						11E-5
210						35E-6
211						74E-6
212						39E-8
213						05E-8
214						39E-7
215						75E-8
216	Butadiene					
217	Butane					
218	Cadmium					
219	Carbon dioxide, biogenic					
220	Carbon dioxide, fossil					
221	Carbon disulfide					
222	Carbon monoxide, biogenic					
1183	Heat, waste	Soil	industrial	MJ	0.00311	0.0121
1184	Iron	Soil	industrial	kg	6.22E-6	5.57E-6
1185	Magnesium	Soil	industrial	kg	2.49E-6	2.23E-6
1186	Manganese	Soil	industrial	kg	1.24E-7	1.11E-7
1187	Oils, unspecified	Soil	industrial	kg	1.64E-6	5.84E-6
1188	Phosphorus	Soil	industrial	kg	1.55E-7	1.39E-7
1189	Potassium	Soil	industrial	kg	1.09E-6	9.74E-7
1190	Silicon	Soil	industrial	kg	3.11E-7	2.78E-7
1191	Sodium	Soil	industrial	kg	6.22E-6	5.57E-6
1192	Strontium	Soil	industrial	kg	3.11E-8	2.78E-8
1193	Sulfur	Soil	industrial	kg	1.87E-6	1.67E-6
1194	Zinc	Soil	industrial	kg	4.66E-8	4.18E-8

TOTAL: 1193 types of emissions and extractions from 1967 processes:
Too much information

Life Cycle Impact Assessment

Concept: Calculate how each of these emissions and extractions contribute to specific environmental impact categories

Procedure: Multiply elementary flow by « characterisation factor », which represents how much 1kg of the elementary flow contributes to an impact category, usually compared to a reference substance

Example: Climate change

- **Many emissions contribute to climate change**
- **1 kg of each of these substance has a different impact on climate change, in relation to CO2:**
  - 1 kg of CO2 = 1 kg CO2 eq
  - 1 kg of CH4 = 25 kg CO2 eq
  - 1 kg of N2O = 298 kg CO2 eq

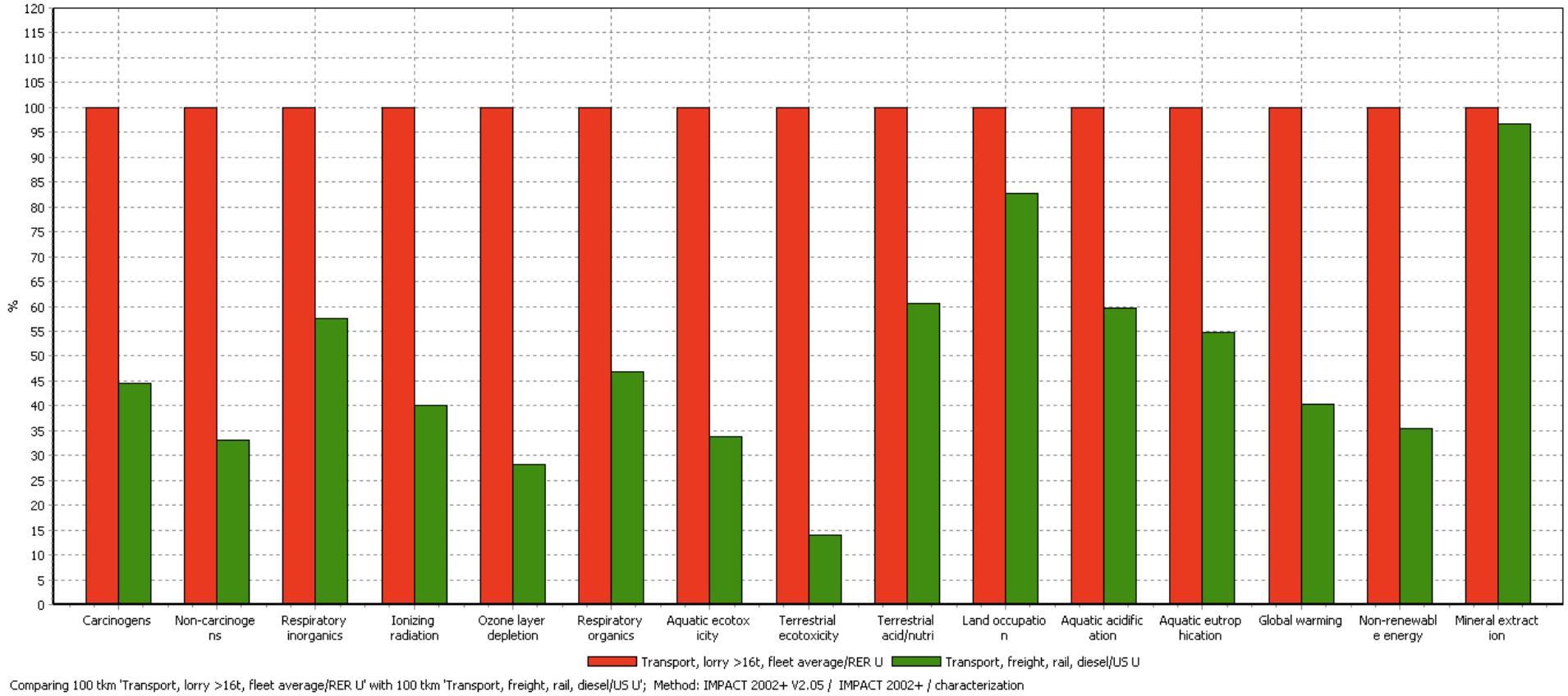
Life Cycle Impact Assessment

Different research institutes have developped collections of characterization factors for different impact categories such as:

- **Global warming**
- **Ozone depletion**
- **Smog**
- **Human toxicity**
- **Ecotoxicity (land, water)**
- **Acidification (land, water)**
- **Eutrophication**
- **Biotic resource depletion**
- **Abiotic resource depletion**
- **Land use**

Comparison of papers at midpoint

Impact2002+, ecoinvent 2.2 data



Endpoint impact categories

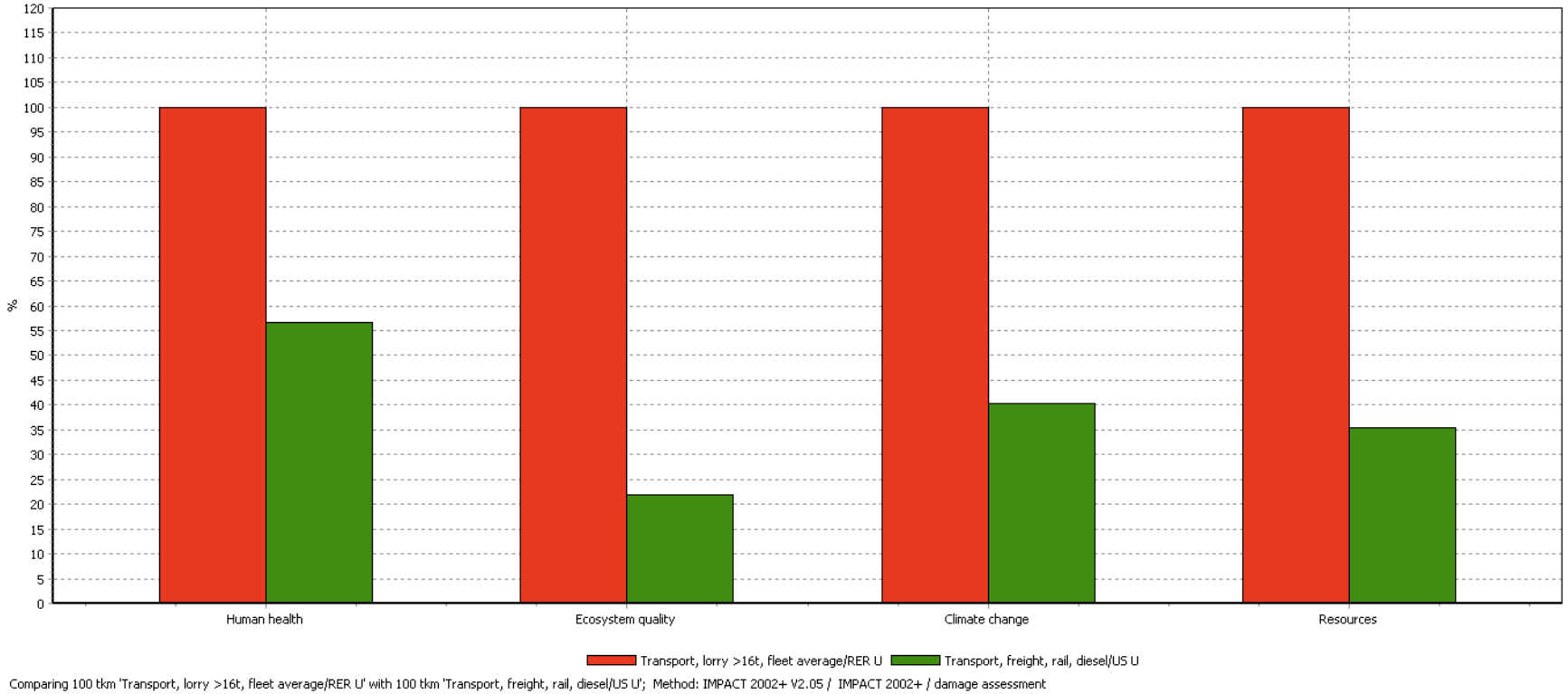
It is (sometimes) possible to group different mid-point impact categories in endpoint categories, representing a common problem or area of concern

Typical endpoints:

- **Human Health**
- **Ecosystem Quality**
- **Resources**
- **Climate Change**

Comparison of transport at endpoint

Impact2002+, ecoinvent 2.2 data



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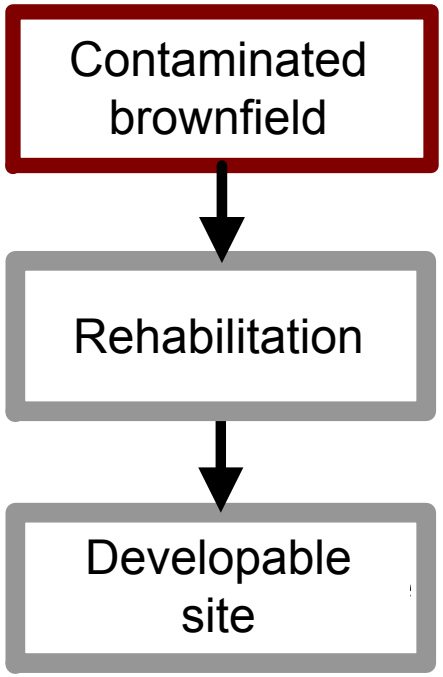
Angus site case study

50 ha contaminated brownfield in Montreal

- **Heavy industrial past**
- **Mixed and persistent contamination mixte (metals, PAH, petroleum hydrocarbons, sulfurs) clinker**
- **Represented an unnacceptable human health risk**

Angus site case study: Compared options

Decisions	**Option 1** **Rehabilitation-reuse**



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Decisions	**Option 1** **Rehabilitation-reuse**
Site physical state	Decontaminate to generic criteria for residential reuse Backfill for redevelopment

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Means	*Risk management*: Dig and haul *Infrastructure management*: Demolition and recycling

Angus site case study: Compared options

Decisions	Option 1 Rehabilitation-reuse	Option 2 Exposure minimisation
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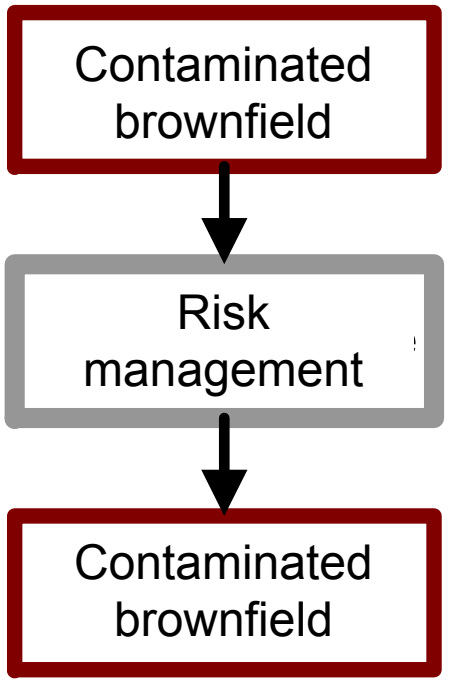
Means	*Risk management*: Dig and haul *Infrastructure management*: Demolition and recycling	



Angus site case study: Compared options

Decisions	Option 1 Rehabilitation-reuse	Option 2 Exposure minimisation
Site physical state	Decontaminate to generic criteria for residential reuse Backfill for redevelopment	Leave contaminants in place Reduce exposure to acceptable amount
Ulterior use	Residential development	
Means	*Risk management*: Dig and haul *Infrastructure management*: Demolition and recycling	

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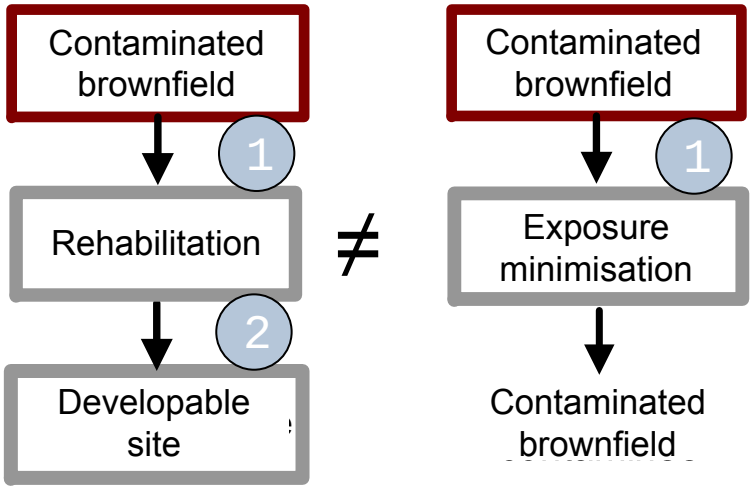
Ulterior use	Residential development	None
Means	*Risk management*: Dig and haul *Infrastructure management*: Demolition and recycling	Clean soil cover (15cm)

Options not equivalent

In LCA, compared options need to be functionally equivalent



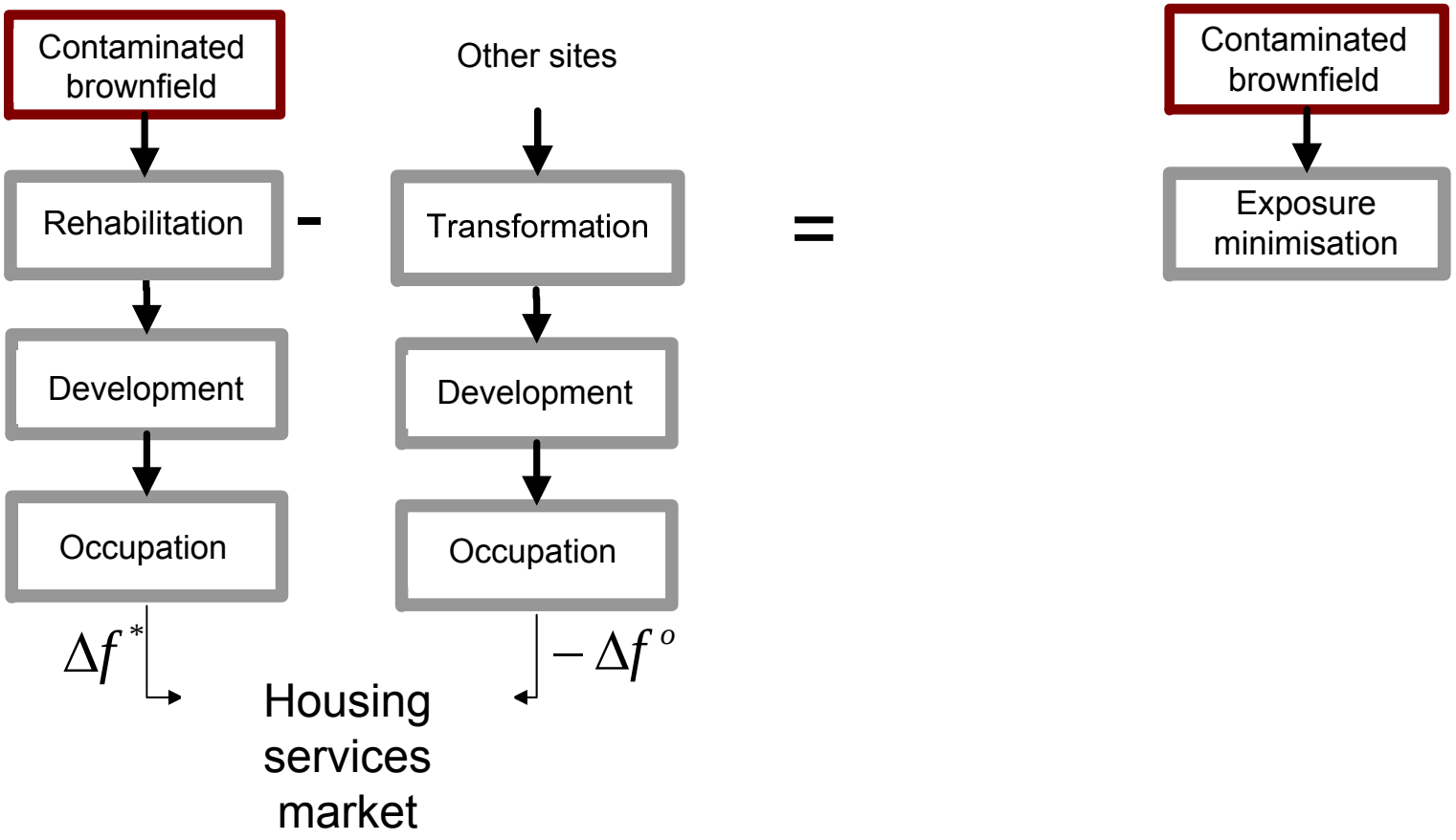
Common function: Legacy management

Function only associated with rehabilitation: redevelopable site production

Solved by “system expansion”

Brownfield redevelopment avoids new developments

This avoided development is substracted from the rehabilitation product system



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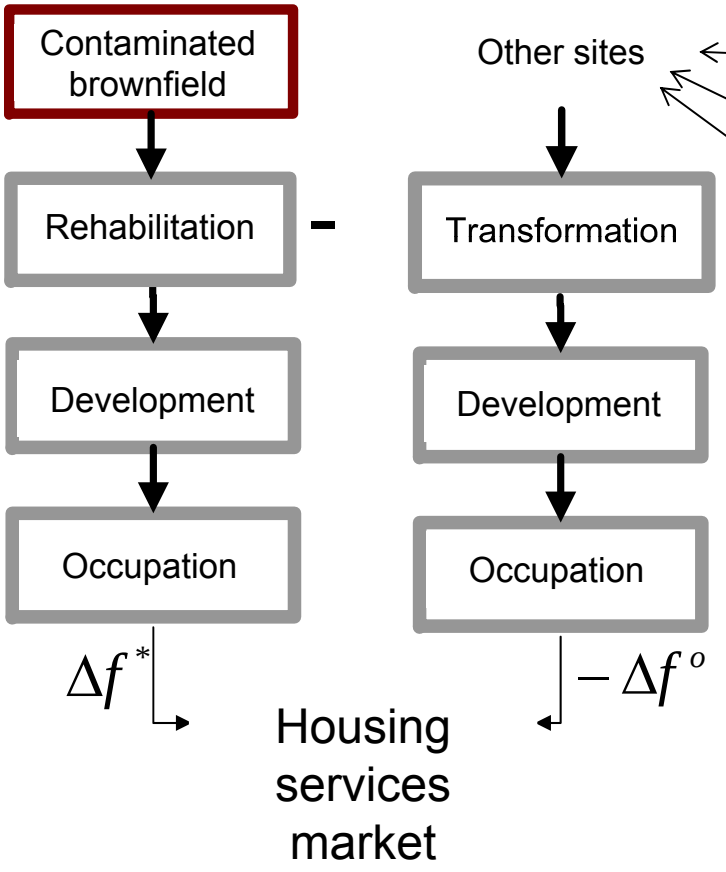


Best case: 100% peripheral greenfields

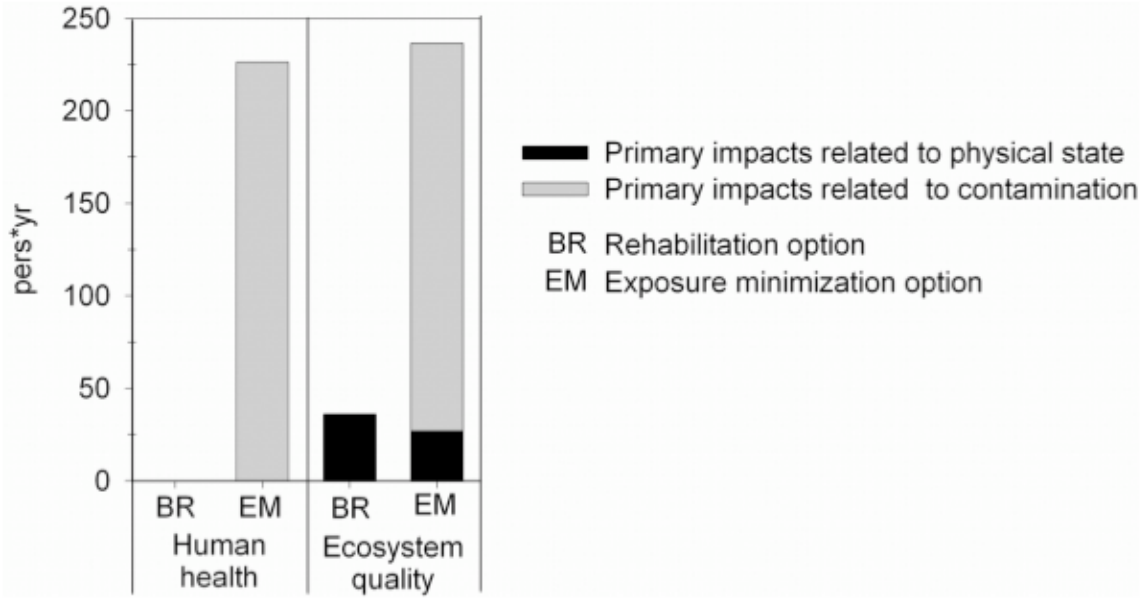
Worst case: 100% urban sites

Partial equilibrium: 82% urban sites, 18% peripheral sites

Considered aspects

Primary impacts

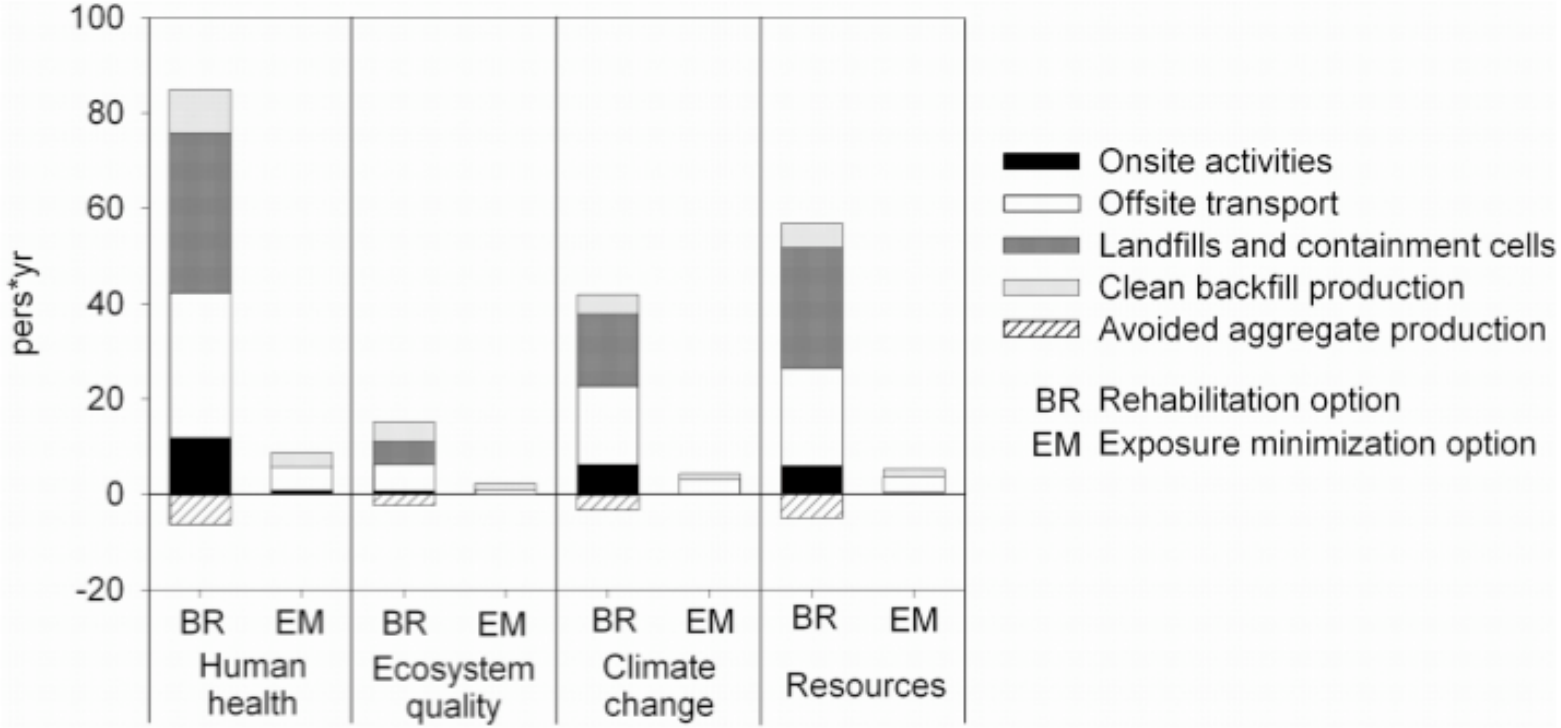
- Difference in contamination levels left onsite
  - Coarse models
- Biodiversity impacts
  - Coarse models



Considered aspects

Secondary impacts

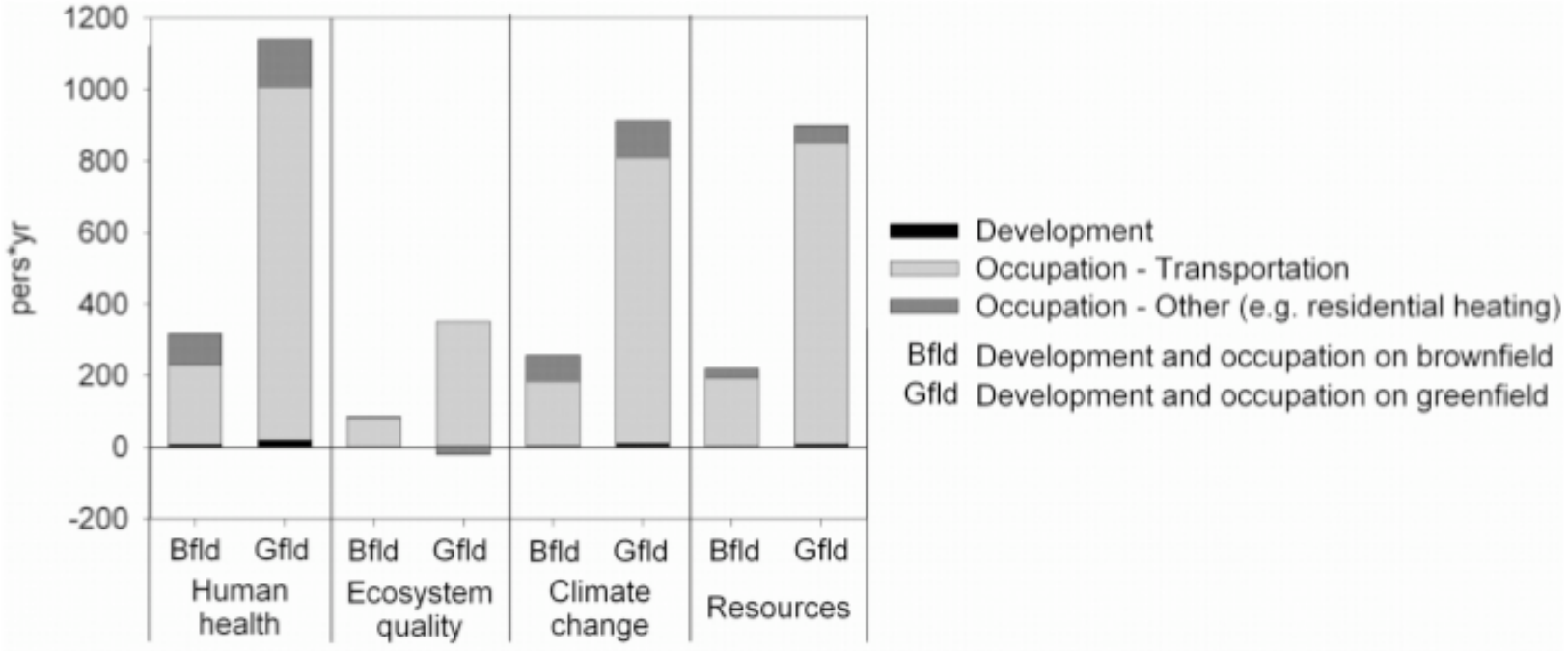
- Onsite operations
- Life cycle impacts of these operations



Considered aspects

Tertiary impacts

- Development (infrastructure, residences)
- Occupation (Transport, energy consumption, infrastructure maintenance)



Bringing it all together

Primary, secondary and tertiary impacts expressed in the same units

One could assume that they can be summed

Potential impacts of rehabilitation

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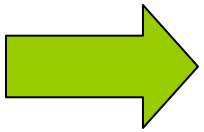
Potential impacts of exposure minimisation

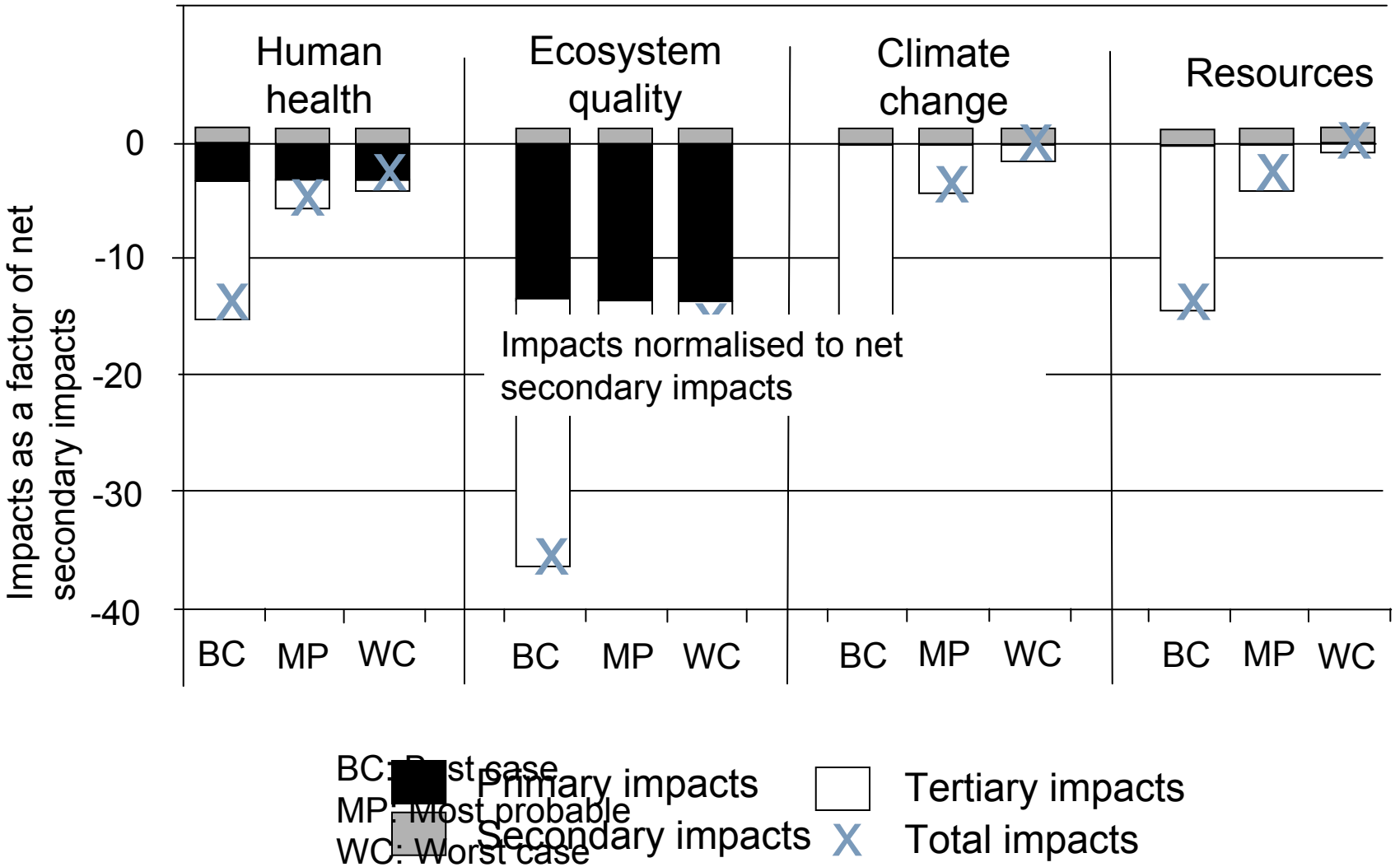


<0 ; Rehabilitation preferable

=0 ; Options environmentally equivalent

>0 ; Exposure minimisation preferable

Bringing it all together



Conclusions

LCA allowed a holistic view of environemntal consequences fo brownfield management decisions

When assuming redevelopment avoids sprawl, the benefits of reoccupation (especially reduced transport requirements) dominate secondary impacts

Even when assuming only a portion of development (12%) is avoided on peripheral greenfields, gains in terms of tertiary impacts are larger than the investement (secondary impacts)

Primary impacts are ill-assessed with generic LCA models, but in this particular case they simply reinforce the conclusions

Thank you for your attention