Is there an optimal insulation thickness?
An LCA-based study on the environmental performance of insulation materials and natural gas consumption

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Case studies for buildings

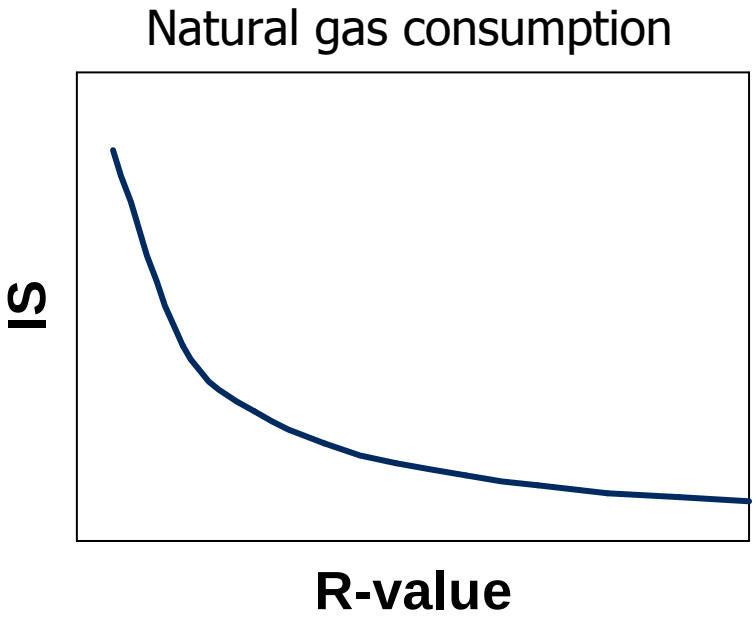
Introduction

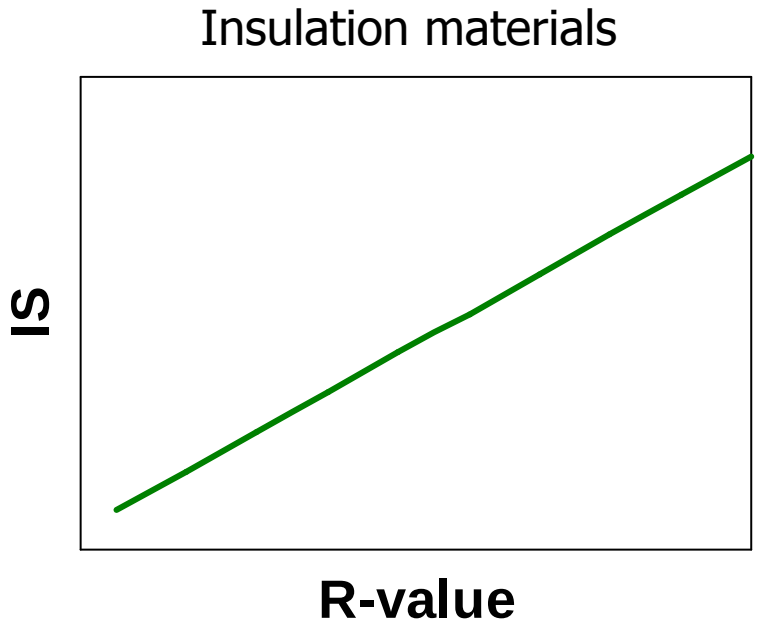
- Building and renovation to low energy (passive house) standard getting more popular
- Passive house: comfortable indoor climate without active heating and cooling systems

Passive house standard

- U-value building envelope < 0.15 W/m²K
- Triple glazing windows with insulated frames
- Efficient HVAC systems
- Thermal bridges to be avoided
- Airflows in building carefully regulated (comfort)

Research question





Is there an optimal insulation thickness?

Goal of study

LCA-based comparison of environmental performance of scenarios with different insulation performance of building envelope

- Insulation materials
- Natural gas consumption for heating

Methodology

Methodology

Assessed building: Gallery flat built in 1960s

- 5 levels with 7 dwellings of 34 m² each
- Unheated ground floor for storage
- Roof area is 300 m²
- Brick masonry, little insulation, double glazing

Representative for concerning house types in these periods in Netherlands (8% of housing stock in Netherlands)

Insulation

Heat resistance:

$R = d / \lambda$ [m²K/W]

Heat transmission coefficient:

$U = 1 / R$ [W/m²K]

Scenarios

R-Value roof, walls and first floor	Window glazing	U-value window glazing	U-value window frame	U-value door	U-value basement floor	Annual gas consumption (GJ)
0	Single	5.80	2.20	2.09	3.20	1290
1	Single	5.80	2.20	1.00	3.20	658
2	Double	2.70	0.72	0.50	3.20	257
3	Double	2.70	0.72	0.33	3.20	193
4	Double	1.20	0.72	0.25	3.20	95
5	Double	1.20	0.72	0.20	3.20	77
6	Triple	0.74	0.72	0.17	3.20	65
7	Triple	0.74	0.72	0.14	3.20	38
8	Triple	0.74	0.72	0.13	3.20	33
9	Triple	0.74	0.72	0.10	3.20	29
10	Triple	0.74	0.72	0.10	3.20	26
11	Triple	0.74	0.72	0.09	3.20	24
12	Triple	0.74	0.72	0.08	3.20	22
13	Triple	0.74	0.72	0.08	3.20	20

Materials

- Insulation between basement and first floor, walls and roof: cellulose (λ = 0.035 W/mK)
- Window glazing single, double or triple glazing
- Window and door frames: hardwood
- Doors: hardwood with cellulose insulation

Life cycle assessment

Functional unit:
Renovation and maintenance of insulation materials in windows, doors, roofs and basement floor

Time period: 100 years

Background data: Ecoinvent 2.2
Including waste processes, transport and capital goods

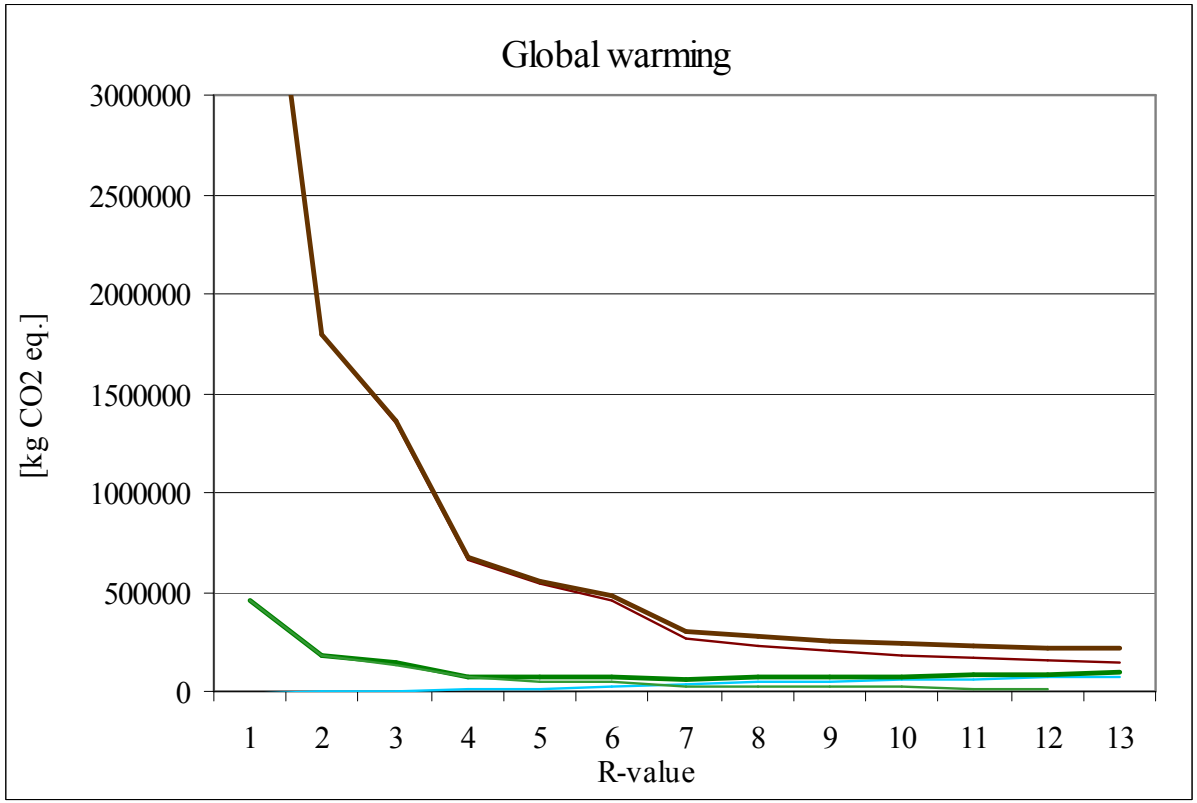
Impact assessment: CML2000
Normalisation: Netherlands 1997

Energy calculations

- Natural gas for heating: Passive House Planning Package 2007 (PHPP)
- Infiltration rates: Large Building Air Leakage Test Calculator
- Building standards for air infiltration: taken from UK
- Thermal bridges: EuroKOBRA

Results

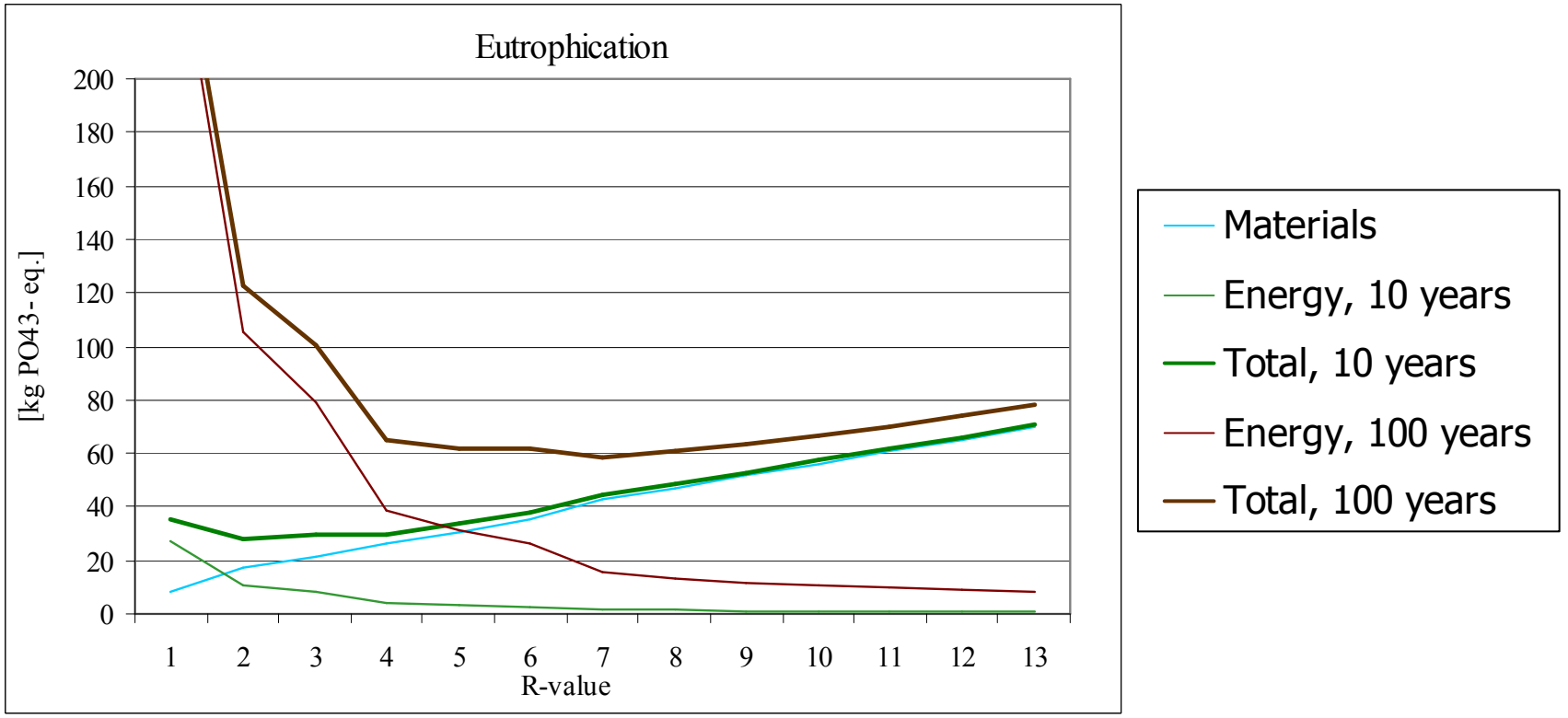
Group 1: IS building materials < IS natural gas



Abiotic depletion, global warming, ozone layer depletion, photochemical oxidation

Results

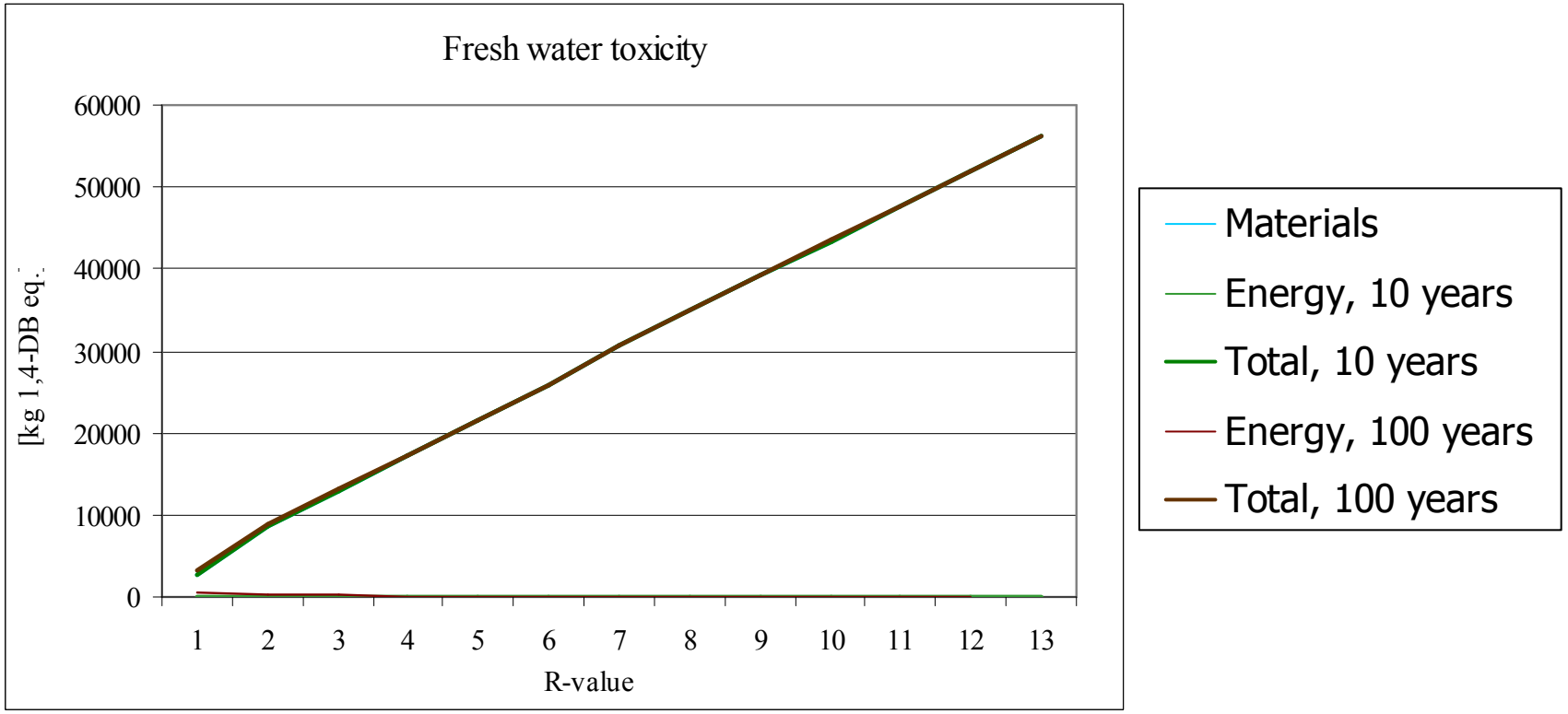
Group 2: IS building materials ≈ IS natural gas



Acidification, eutrophication, human toxicity, terrestrial ecotoxicity

Results

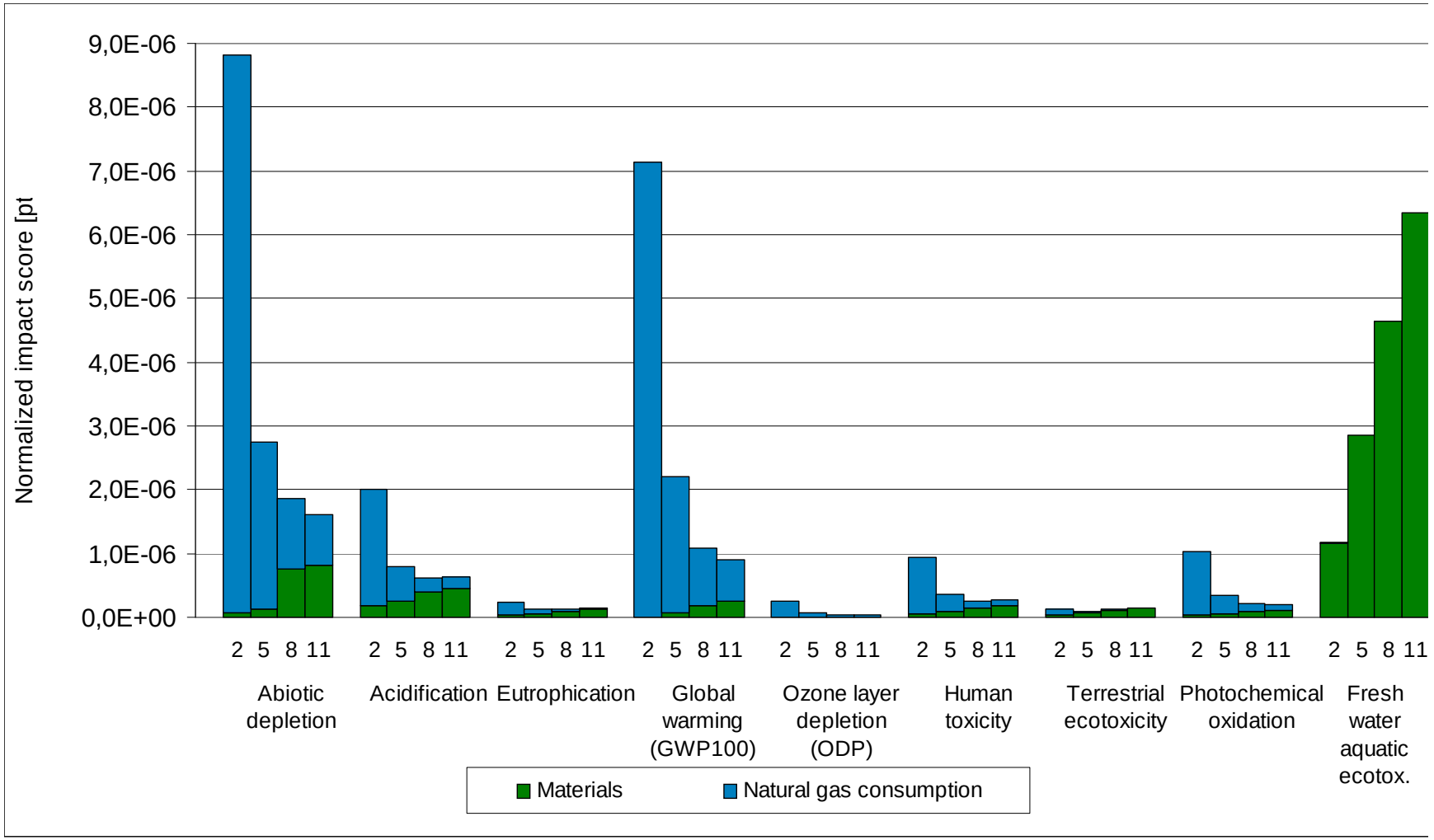
Group 3: IS building materials >> IS natural gas



Fresh water ecotoxicity

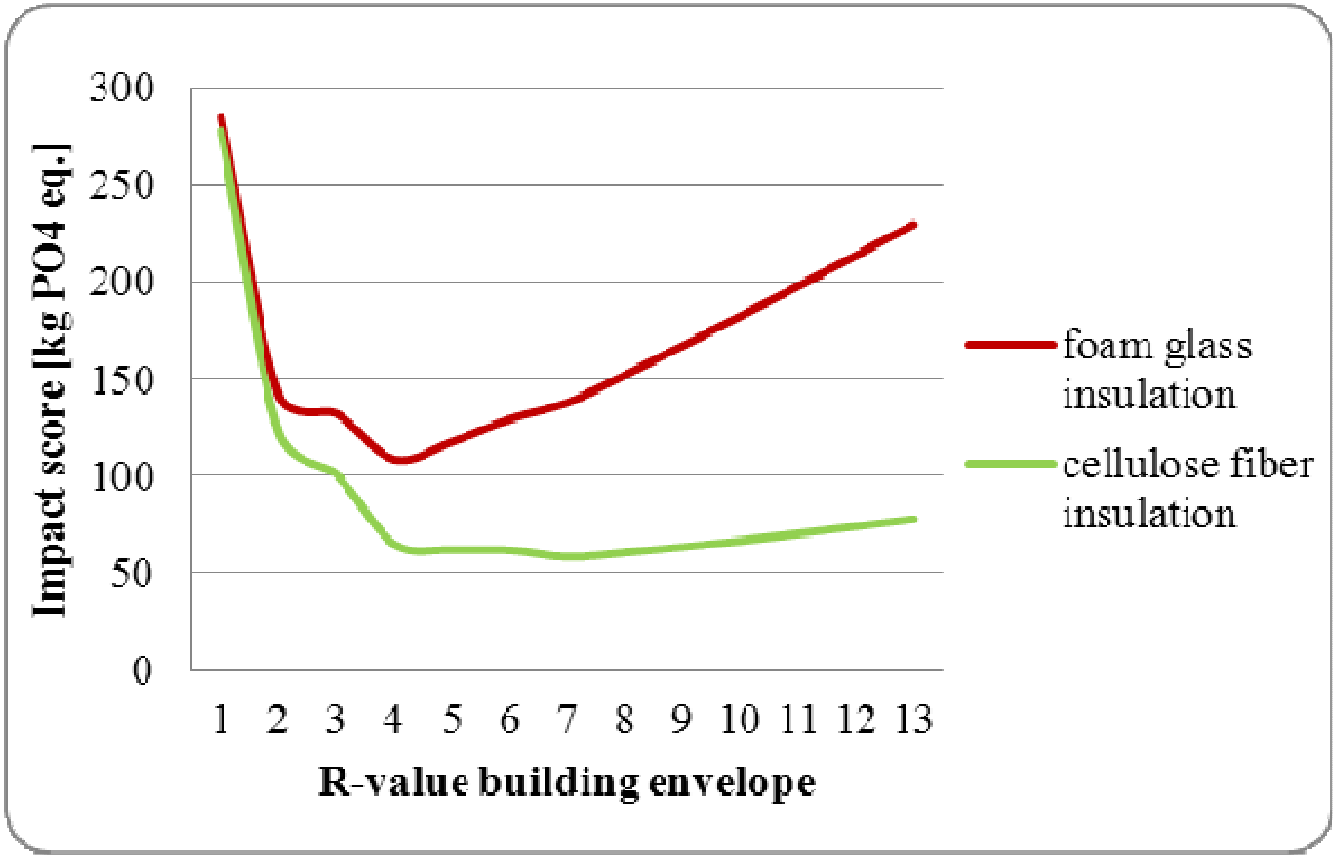
Results

Normalized impact scores



Results

Eutrophication, normalized impact score



Conclusions

- Increased R-value →
  - IS natural gas consumption ↓
  - IS insulation materials ↑

- R-value 0→(4-7): Total IS ↓
- R-value (4-7)→13: small decrease or increase of total IS

- Optimal R-value: 7 m^2K/W

- Optimal R-value lower for shorter time period
- Optimal R-value different for other materials