Wuppertal Institute
for Climate, Environment
and Energy

*51st LCA Discussion Forum*

# Modelling the Impacts of Climate Protection Strategies on Resource Consumption and Emissions – a Dynamic LCA for the HEAT Sector in Germany

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# Content



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Material Efficiency & Resource Conservation

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# Content

Aim of the Study

# Basic Idea and Case Study

Background

- Current system of production and consumption is based on a non-sustainable and non-future oriented resource depletion.
- Resource issues are national and international strongly discussed.

Main research questions

- How can resource efficiency be modelled?
- Which are the effects of resource efficiency measures with regard to both the total resource consumption and other socio-political targets (especially climate protection)?

Performing a case study

- ... using the example of “warm living area” as part of the field of needs “building & living”
- … analysing the impacts of individual resource policy instruments in Germany
- ... doing a long-term analysis by 2050
- … developing a bottom-up impact analysis model by coupling a technology assessment model with a material flow analysis model

## Aim of the Study
# Methodological Approach and Scenario Analysis

Methodological approach

- Using the knowledge of energy scenario analysis
- Extending the impact assessment to resource consumption and interaction with environmental impact indicators (life cycle approach)
- Starting with energy resource targets due to easier approach

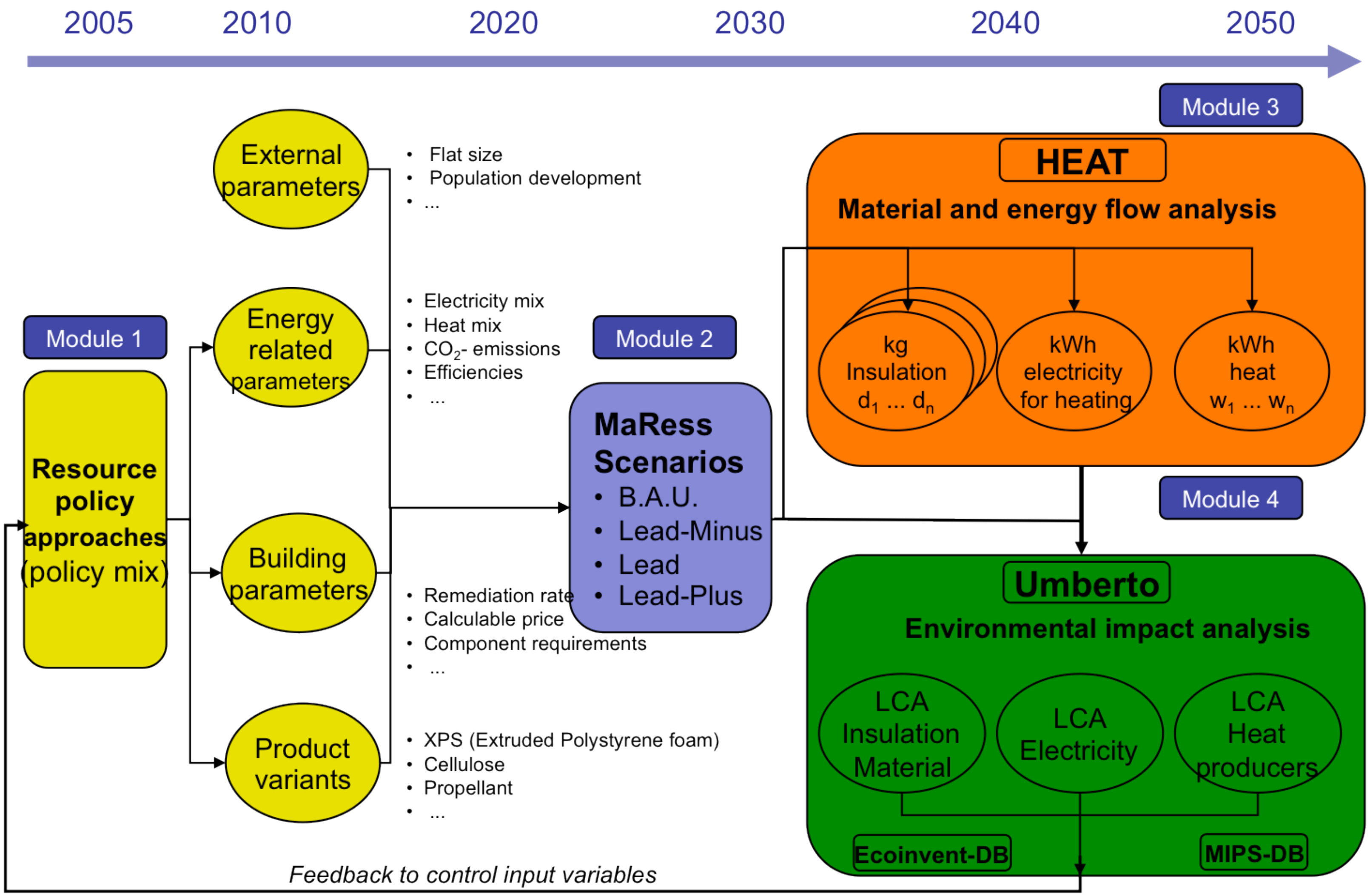
Development of four MaRess-Scenarios with different level of intervention

- Following existing energy scenarios based on the BMU “Lead Study 2008”
- Deriving specific resource efficiency requirements in the “warm living area”
- Modelling these requirements and the resulting needs of insulation material and energy with the technology model HEAT
- Assessing the environmental impacts (resources and emissions) by performing an LCA based on a material flow network
(functional unit = stock of heatable dwelling houses in Germany)
- Including MIPS analysis for an extended resource assessment

# Content

## Model Development

# The Bottom-up Impact Analysis Model




*HEAT = Household Energy and Appliances Tool; Umberto = LCA tool; Ecoinvent: Database of LCA datasets; MIPS: Database of MIPS-modules*

Material Efficiency & Resource Conservation

Model Development

# Characteristics of the MaRess Scenarios

| MaRess Scenario | Level of intervention | | Requirements in the field of needs “building & living” |
|---|---|---|---|
| *MaRess B.A.U.* | *Low* | Reference development by 2050 | • Rate of long-term remediation<br>• Calculable prices<br>• Amortisation expectation<br>• Component requirements for old and new buildings |
| *MaRess Lead-Minus* | *Middle* | Weakened BMU-„Lead scenario 2008“ (diminished application of energy efficiency measures) | |
| *MaRess Lead* | *High* | BMU-„Lead scenario 2008“ (energy productivity, deployment of renewable energies, $CO_2$ reduction of 80% by 2050 compared to 1990) | |
| *MaRess Lead-Plus* | *High* | Further reduction of heat energy demand, resulting in higher energy efficiency than in BMU-„Lead scenario 2008“ | |
| *Scenario independent:*<br>*Demographic development, living size development, component standardisation etc.* | | | |

## Model Development

# Some Details of Performing the LCA

- Dynamic LCA (2010 – 2050)
- Consequential LCA to identify the resource consequences of future-oriented energy scenarios
- Most datasets taken from ecoinvent 2.0 and 2.1 (usually result processes)
- Use of unit processes in case of parameter variations (e.g. different electricity mix as input in production processes and heating systems)
- CML as LCIA method
- Additionally use of MIPS as further resource indicator
- Use of Microsoft COM interface to couple Umberto with HEAT and databases via Python script
- Environmental burdens of insulation materials allocated to the year of production

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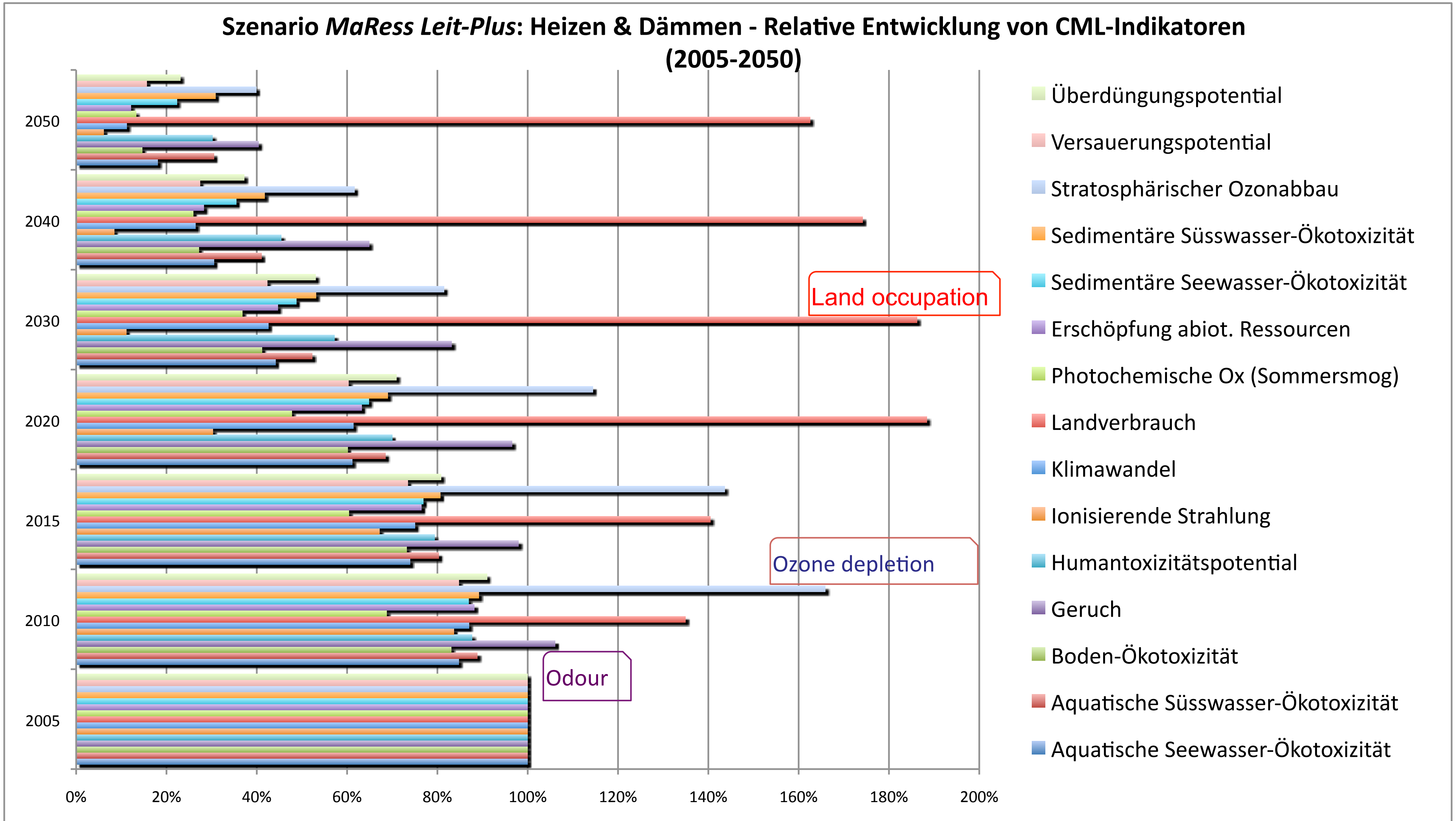
Results and Conclusions

# Environmental Impact Categories by the Example of *MaRess Leit-plus*



Model Development

## Including the Material Footprint Indicator Additionally to the LCA

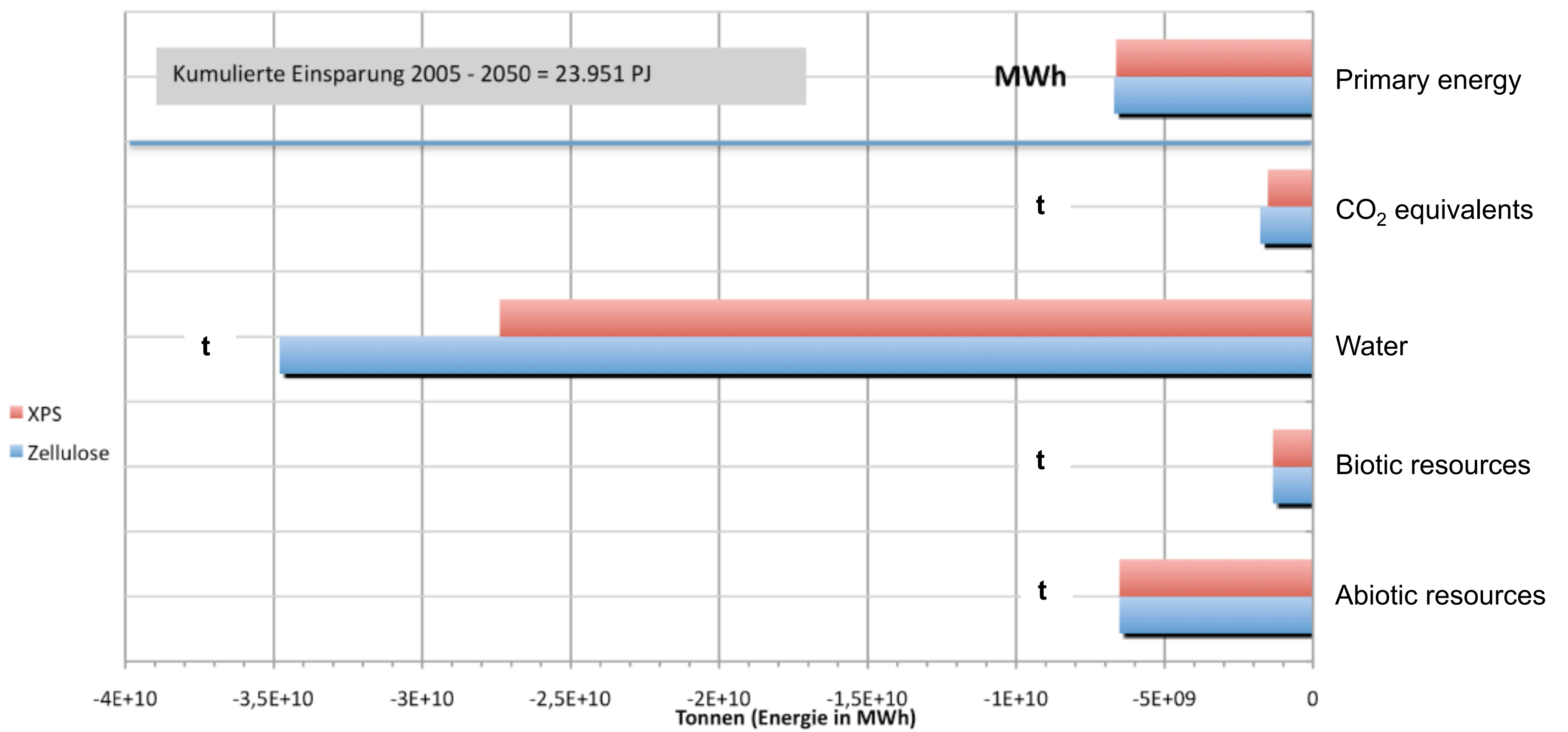
- The material footprint (also known as *Material Input per Service Unit, MIPS*) quantifies the life cycle wide *amount of natural resources* (material input) which is necessary to provide a specific service:

$$MIPS = \frac{MI}{S} = \frac{Material\ Input}{Service\ Unit}$$

- In contrast to other life cycle wide approaches, the Material Footprint considers not only the economically used, but *also the not economically used abiotic and biotic resource flows* (*unused extraction*) as they also implicate environmental impacts.
- The unused extraction can have a *high share in the overall amount of resources*, especially regarding the overburden from mining activities.
- Resources are classified in 5 resource categories measured in mass units
  - Abiotic resources
  - Biotic resources
  - Water, Air
  - Earth movements in agriculture and silviculture

Results and Conclusions

## MIPS Indicator Set Results for XPS vs. Cellulose (*MaRess Leit-plus)*




| | Nicht nachwachsende Rohstoffe | Nachwachsende Rohstoffe | Wasser | CO2-Äqu. | Primärenergieaufwand |
|---|---|---|---|---|---|
| XPS | -6522521333 | -1350429185 | -27389684153 | -1521791597 | -6.637.855.394 |
| Zellulose | -6524117169 | -1350429185 | -34803888107 | -1782416129 | -6.704.123.783 |

Results and Conclusions

## Conclusions

- For the first time dynamic modelling of additional expenses caused by insulation materials and comparison with reduced expensed from primary energy
  - including the life cycle of products
  - regarding impacts of both resource use and emissions
- The additional resource and emissions flows caused by insulation materials are overcompensated by considerable reductions caused by avoided heat production →in general, no negative trade-offs visible
- The higher the level of intervention, the stronger the results.
- The share of insulation materials in environmental impact categories is low compared to that of the fossil fuels.
- Use of FHC-propellants (fluorinated hydrocarbons, instead of $CO_2$) causes strong net *increase* of the indicator Ozone Depletion (originally caused by the production process of the FHC).
- Despite the higher density of cellulose, the material requirements do not differ significantly.

## Content

Outlook and Open Questions

## Material Flow Model

Material Flow Model

- MIPS: Currently no harmonisation of LCA method and MIPS indicators in existing LCA software
- Coupling of LCA and further resource indicators necessary
  - Further development of resource indicators
  - Integration of such indicators in LCA (WI currently develops LCIA method based on MIPS and the Ecospold format and tests it in current projects)
- MIPS analysis currently static since no update (and review) available
- Some issues regarding ecoinvent
  - Updated and dynamic data sets necessary
  - Parametrisation by applying unit processes costs lots of calculation time
  - Not all of the considered processes were available in sufficient details (e.g. fossil fired large-scale CHP plants, district heating from renewables, long-distance heating, geothermal power plants)
  - Applying MIPS would require 140 resource flows in ecoinvent to be analysed regarding MI factors

Outlook and Open Questions

## Technology Modell and Bottom-up Modelling

Technology model

- By now only modelling of the current stock which should be extended by demolition, new buildings and recycling.
- Extension of the HEAT model by types of settlements useful to model demand of renewable energies.

Bottom-up Modelling

- Energy models and scenarios are currently mainly focusing on emissions and should be extended by resource efficiency analyses
- Trade-off analysis needed between resource efficiency and
  - Renewable energies (see WI project KRESSE)
  - Mobility (see WI/DLR project STROM)
  - Electrical components
- However, quantification of resource policy instruments currently not available

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# Wärmedämmungs-Strategien im Haushaltssektor und ihr Beitrag zu Materialeffizienz und Emissionsminderung – eine Langfristanalyse bis zum Jahr 2050

**Ole Soukup · Thomas Hanke · Peter Viebahn**

Online publiziert: 29. November 2011


**Zusammenfassung** Eine oft kontrovers diskutierte Frage ist, ob eine massive Dämmung von Häusern in der Gesamtbilanz nicht mehr Ressourcenverbrauch und Emissionen verursacht, als sie im Endeffekt einspart. Zur Untersuchung dieser Frage wurde nun erstmals eine trade-off Analyse durchgeführt. Hierzu wurde ein bottom-up Wirkungsanalyse-Modell entwickelt, dessen Kern ein Emissions- und Energiemodell für den Haushaltssektor bildet, gekoppelt mit einem Ökobilanzierungs-Tool. Den Rahmen für beide Modelle bilden Energieszenarien bis 2050, die für jede Dekade Sanierungsraten und Energiemixe vorgeben. Damit können „reine" Energieszenarien um ressourcenpolitische Analysen erweitert und die Auswirkungen verschiedener Dämmstrategien ermittelt werden.

Das zentrale Ergebnis der Modellierung ist, dass zusätzliche Aufwendungen für Dämmstoffe (untersucht wurden extrudierter Polystyrolhartschaum XPS und Zellulose) sowohl ressourcen- als auch emissionsseitig in fast allen Umweltwirkungskategorien durch erhebliche Einsparungen bei der Gebäudebeheizung überkompensiert werden. Im Wesentlichen sind keine Trade-offs erkennbar und der prozentuale Beitrag der Dämmstoffe an den Umweltwirkungsindikatoren ist gering. Relevant ist dagegen die Wahl des Treibmittels bei den aufgeschäumten XPS-Dämmstoffen: Gegenüber dem in Deutschland verwendeten XPS, das weitgehend mit $CO_2$ aufgeschäumt wird, führt ein Dämmstoff, der hohe Anteile an Fluorkohlenwasserstoffen aufweist, zu einem hohen Trade-off bezüglich der Wirkungskategorie „stratosphärischer Ozonabbau" und zu einer erkennbaren, jedoch nicht so deutlichen Wirkung auf das Treibhaus-Potenzial.

Eine Sensitivitätsanalyse mit dem alternativen Dämmmaterial Zellulose zeigt, dass sich die an sich schon geringen Anteile der Dämmstoffe an den Umweltwirkungsindikatoren weiter verringern. Hinsichtlich der Materialintensität sind XPS- und Zellulose-Dämmung jedoch mit vergleichbaren Auswirkungen verbunden.

Zusammenfassend lässt sich festhalten, dass für beide Materialien ambitionierte Dämmstoffstrategien im Hinblick auf alle in dieser Studie analysierten Faktoren einen wesentlichen Beitrag sowohl zu Materialeffizienz- als auch zu Emissionsminderungszielen leisten können.

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**Schlüsselwörter** HEAT-Modell · Bedarfsfeld warmer Wohnraum · Umberto · Bottom-up modell · MaRess · Wärmedämmung

**Thermal Insulation Strategies in the Household Sector and Its Contribution to Material Efficiency and Reducing Emissions—A Long-Term Analysis up to 2050**

**Abstract** An often controversial question is whether a massive insulation of houses in the overall balance does not cause more resource consumption and emissions than it saves in the end. To investigate this question, for the first time a trade-off analysis has been performed. For this, a bottom-up impact analysis model was developed, whose core forms an emissions- and energy model for the household sector which is coupled with a life cycle assessment tool. Both models provide the framework for energy scenarios to 2050, claiming for each decade refurbishment rates and energy mixes. Thus, "pure" energy scenarios can be extended by resource policy analyses and the effects of various insulation strategies might be determined.

The central result of modeling is that additional costs are compensated for insulating (extruded polystyrene foam XPS

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# Thank you very much!


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