

# Semantic Technology for Energy-efficient Building Planning

**SEMERGY**

Gebäudeplanung mit Zukunft



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Funding agency Austrian Research Promotion Agency (FFG)

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# Outline

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Introduction

Motivation and Goals

Design - Barriers and Expectation

SEMERGY: Concept

Objective

Structure

User Interface

Ontology

Baubook

Reasoning Interface

Workflow

Building Data Model

Basic Information

Software overview

Conclusion

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# Introduction

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- ▶ Increasing energy efficiency is one of the most promising strategies for sustainable emission reduction
- ▶ Many potential fields
  - ▶ Mobility
  - ▶ Industry
  - ▶ Energy production
  - ▶ **Building heating and cooling**
  - ▶ etc
- ▶ Minimum Energy Emission
  - ▶ Calculated at early stages of design
  - ▶ Analysing building materials according to weather conditions



# Introduction

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- ▶ **Conventional methods**
  - ▶ Cumbersome, time consuming and error prone
  - ▶ Prevent in-depth design analysis
  - ▶ Ineffective initial decision making
  
- ▶ Proper building products search for effective building design is required
- ▶ Early design alterations in designing building model



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# Motivation and Goals



## Final Goal



- ~~Energy efficient~~ energy
- ~~Not economical~~
- ~~Not driving quality~~ friendly

## Problems

- Sort out various products
- Good quality building structure
- Economical

## BUILDING MATERIALS

- KITCHENS
- FLOORING
- PAINTS & FINISHES
- INSULATION
- CAULKS & ADHESIVES
- PLUMBING
- LUMBER
- WEATHERIZATION
- HEATING & COOLING



## Learn and Observe

Required products and its combination  
Handling local environment  
Terms and condition  
Economical  
and many more



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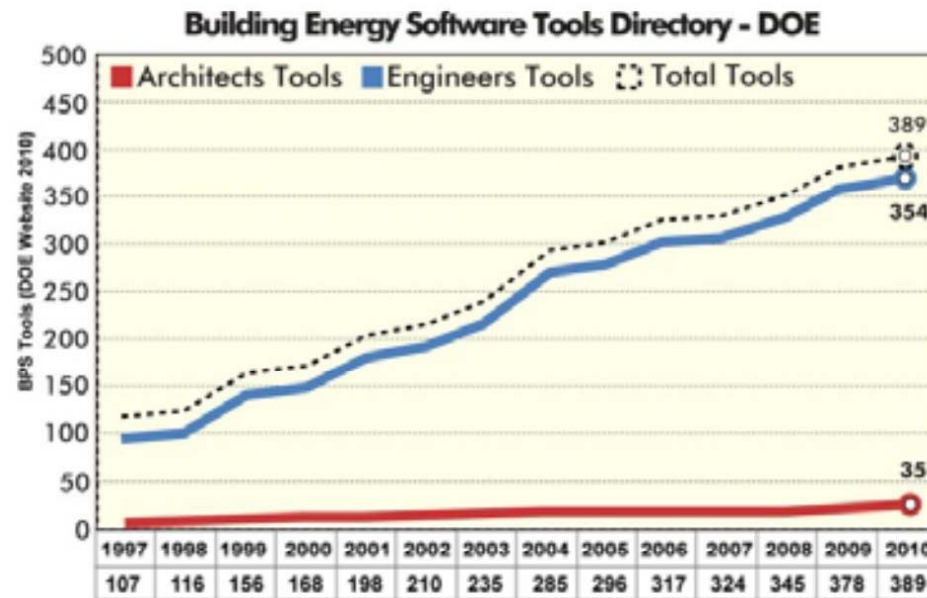
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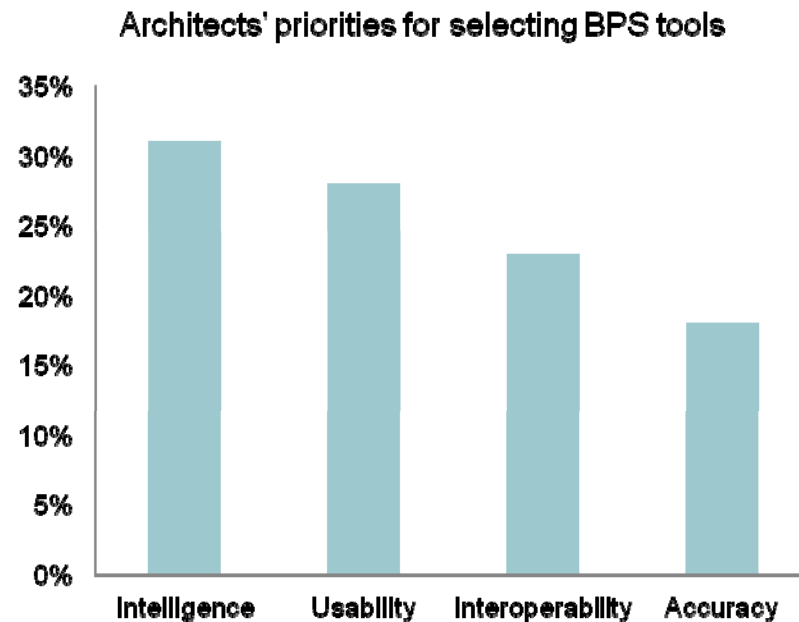
# Design – Barriers and Expectations

- ▶ Early-stage performance assessment can drastically affect final performance of the building
- ▶ Currently assessment tools are used for certification and labeling of the final product rather than to support design decisions
- ▶ Less than 10% of the developed tools are targeted for architects and designers



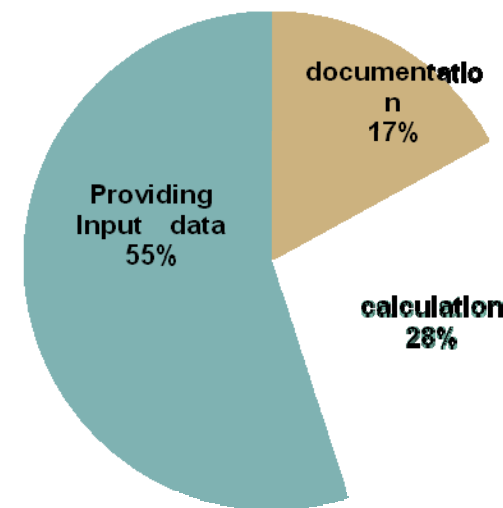
# Design – Barriers and Expectations

- ▶ Intelligence: capability to analyse results, draw meaningful conclusions, and suggest clear guidelines to improve design
- ▶ Usability: Facility of accumulation and entry of input information and performing computations



Source: Attia 2011

Time spent on different tasks in energy simulation



Source: Mahdavi et al. 2005

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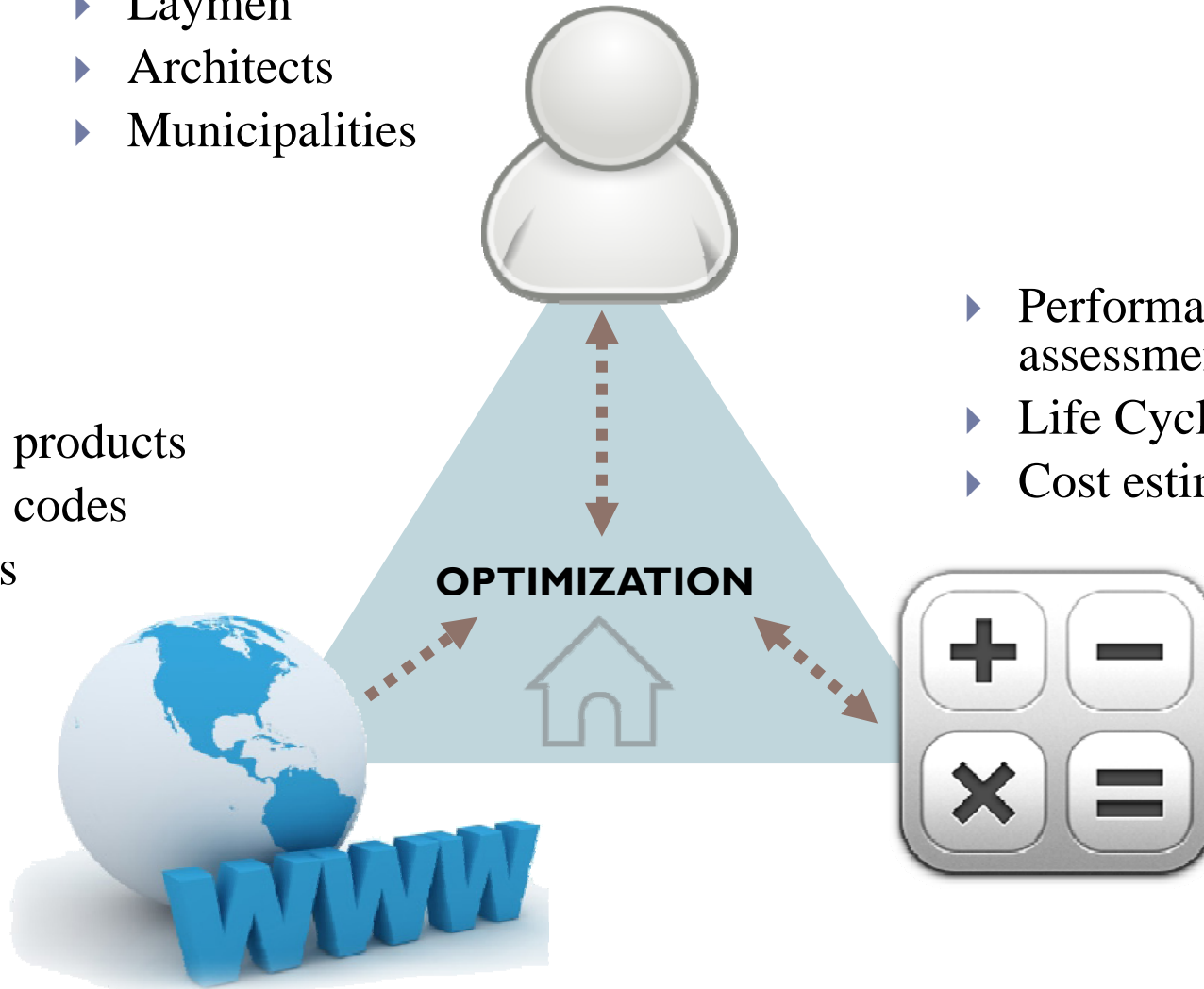
# SEMERY: Concept

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- ▶ Laymen
- ▶ Architects
- ▶ Municipalities

- ▶ Building products
- ▶ Building codes
- ▶ Subsidies

- ▶ Performance assessment
- ▶ Life Cycle Analysis
- ▶ Cost estimation



## SEMERGY: Objective

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- ▶ Effective building design according to provided requirements
- ▶ Evaluating building design
  - ▶ Functional evaluation
  - ▶ Ecological evaluation
  - ▶ Economical
- ▶ Important feature of SEMERGY is
  - ▶ Search building materials using various product libraries
  - ▶ Multi-object decision support, to construct building design



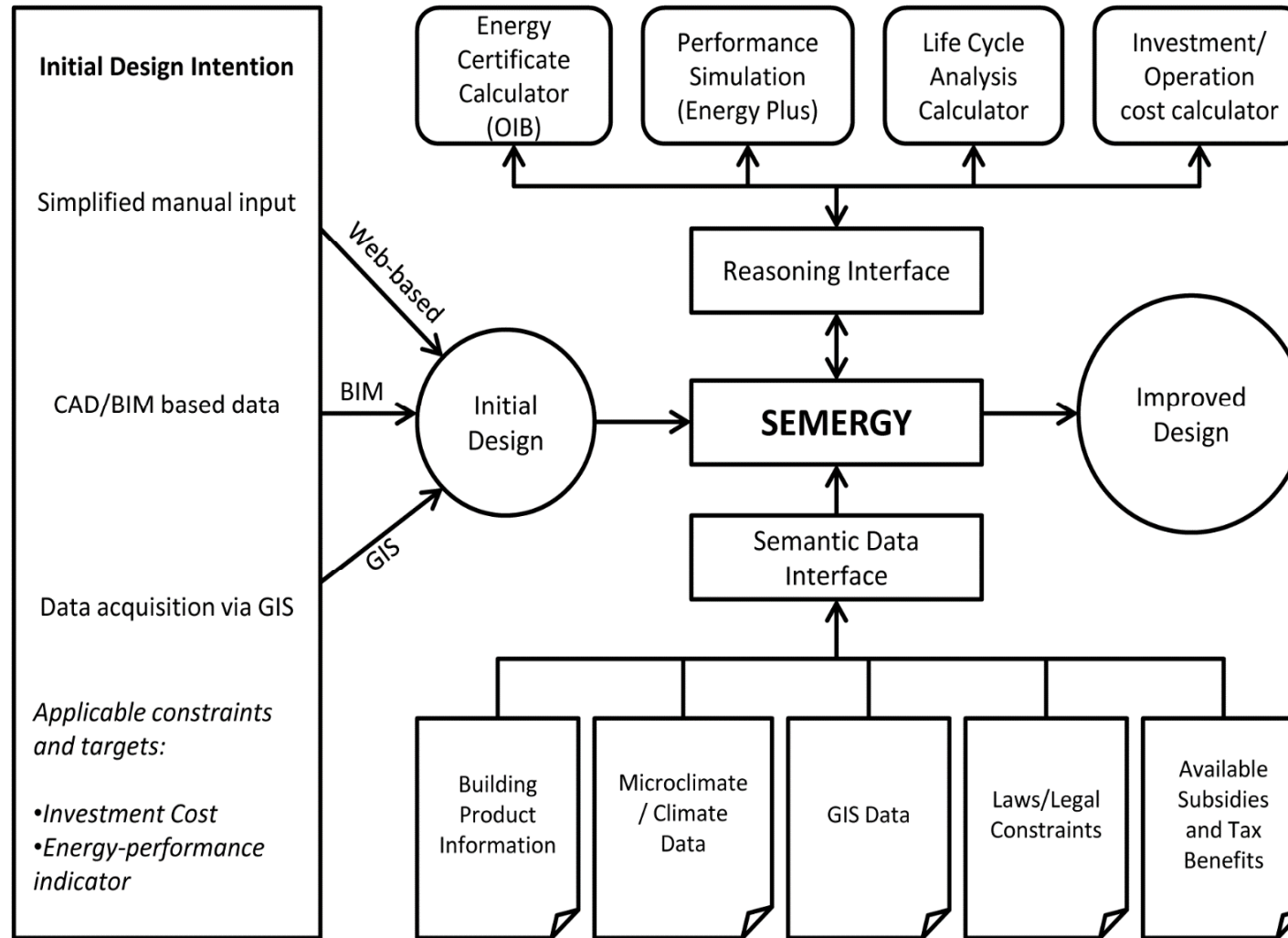
# SEMERGY: Focus

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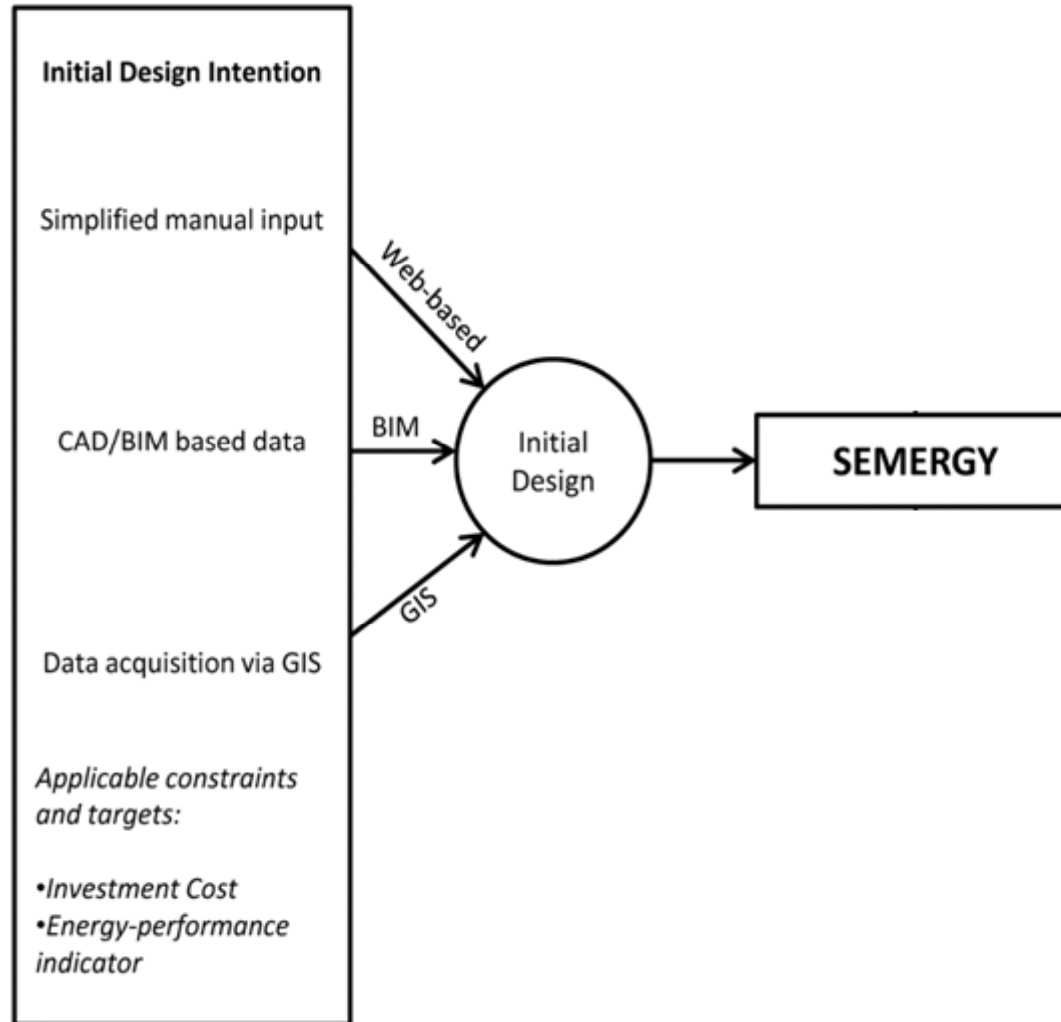
- ▶ SEMERGY bridge the gap between
  - ▶ Complex Real world products
  - ▶ User's requirements
- ▶ SEMERGY focus on
  - ▶ Investment and operation costs
  - ▶ Energy performance and environmental impact
- ▶ SEMERGY has information that includes
  - ▶ Building material
  - ▶ Building products
  - ▶ Building components
  - ▶ Climate information in region
  - ▶ Financial information



# SEMERGY: Structure



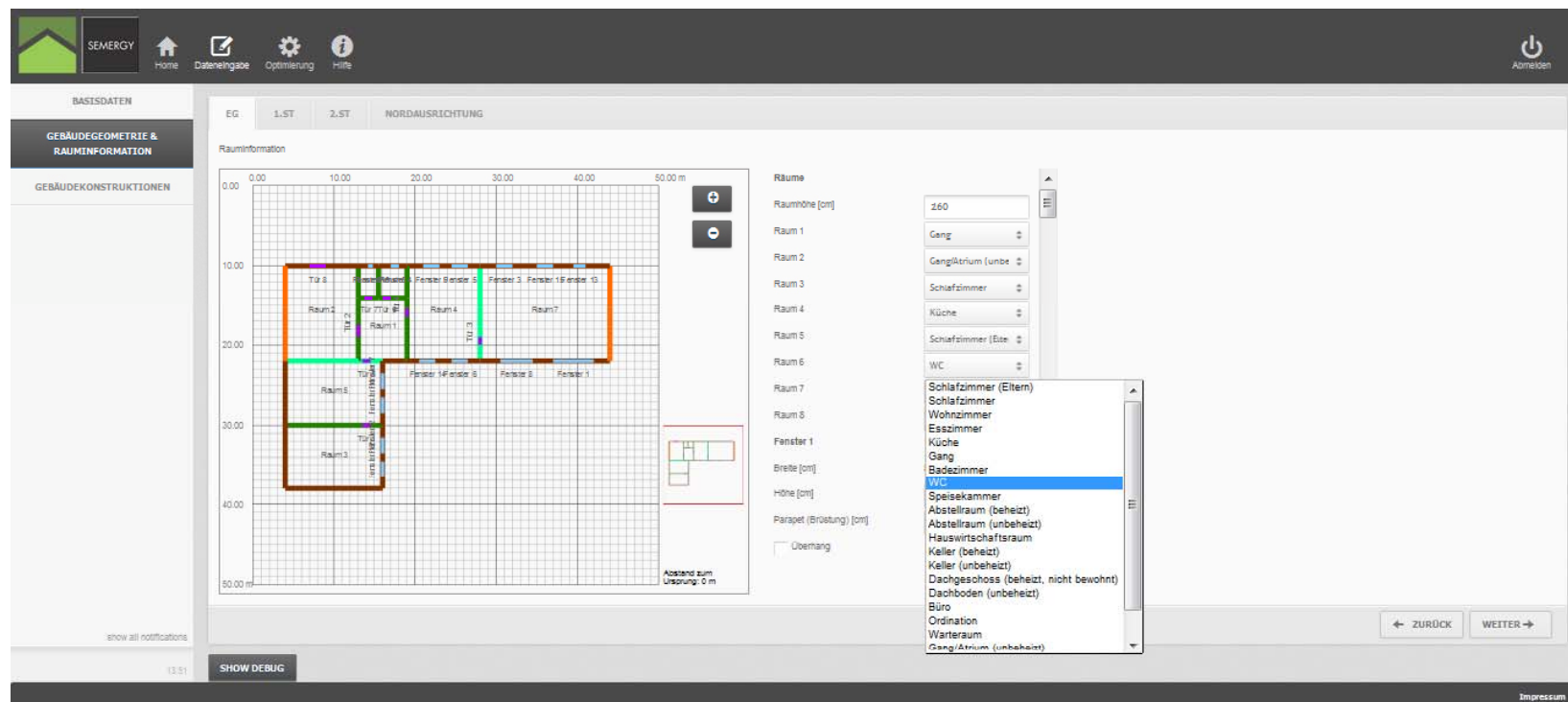
# SEMERY: Structure





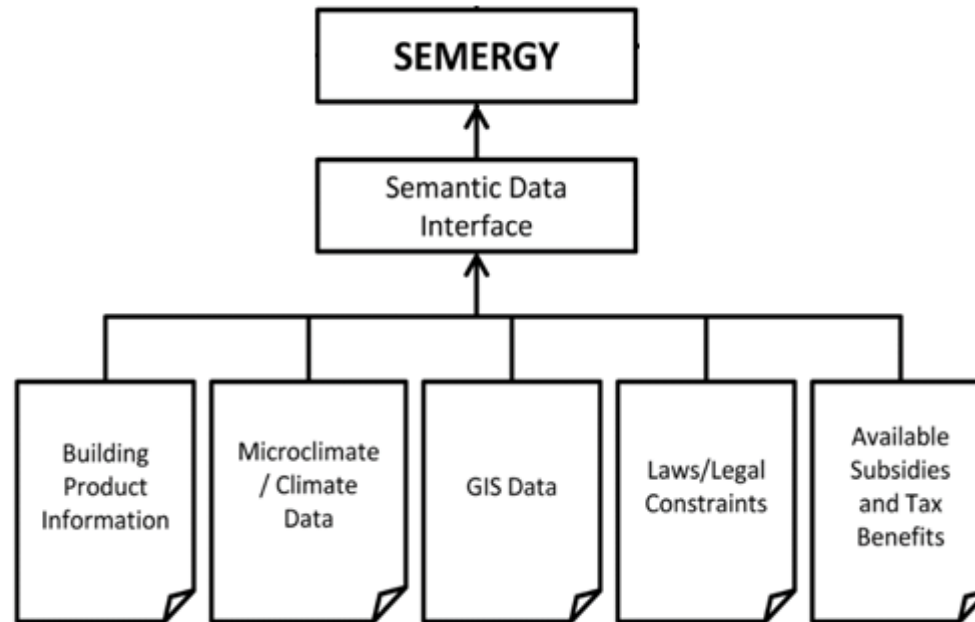
# SEMERGY: GUI

- ▶ Novice users: SEMERGY Graphical Web-Based User Interface
- ▶ Experienced professionals (architects): Extended SEMERGY Graphical Web-Based User Interface, with import possibility from BIM and CAD
- ▶ Area municipalities or other local authorities: Import from GIS data



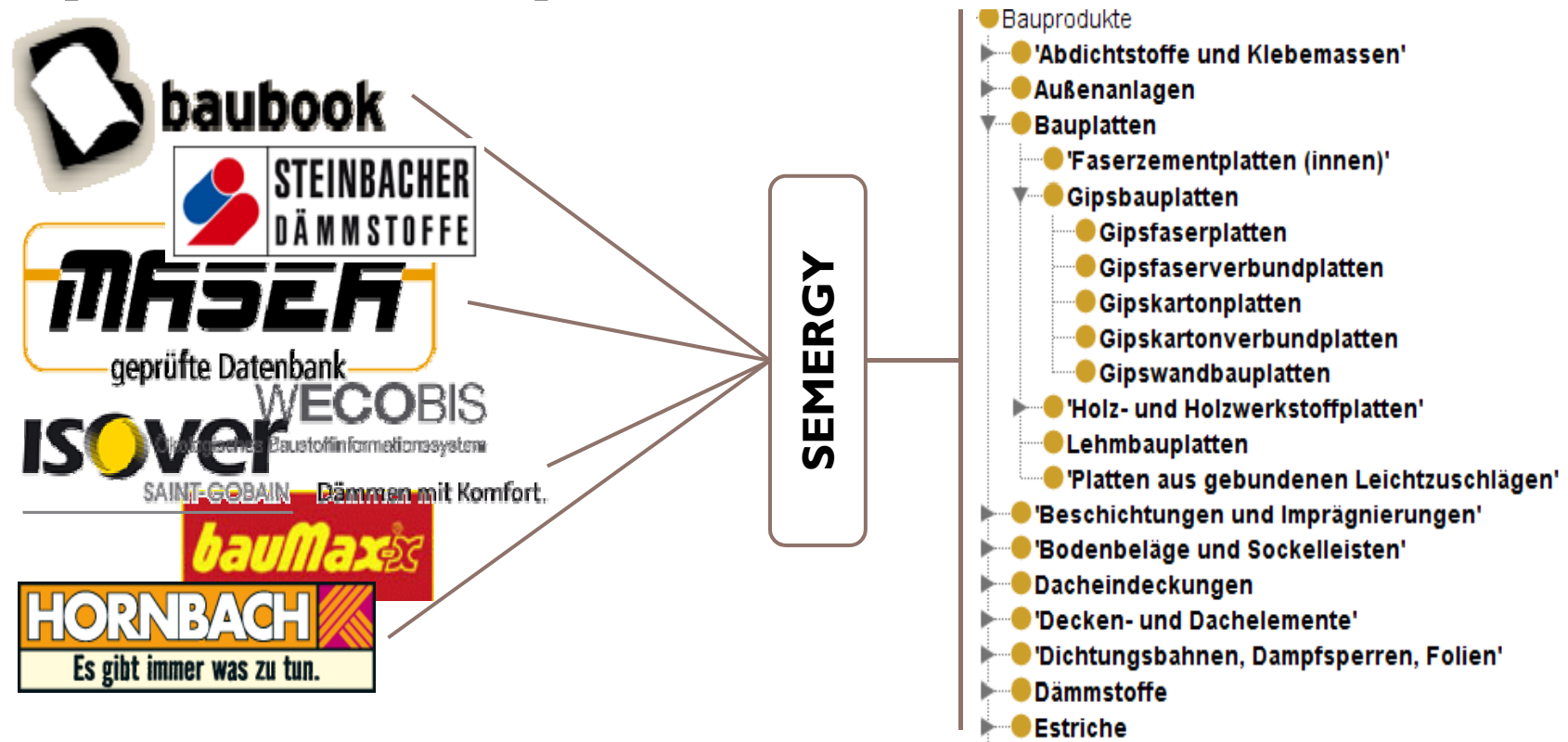
# SEMERGY: Structure

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# SEMERY: Ontology

- ▶ Acquisition of data from different sources
- ▶ Restructuring of the acquired data to enable specific queries
- ▶ Extension of restructured data with additional information to allow precise search and implementation of rules



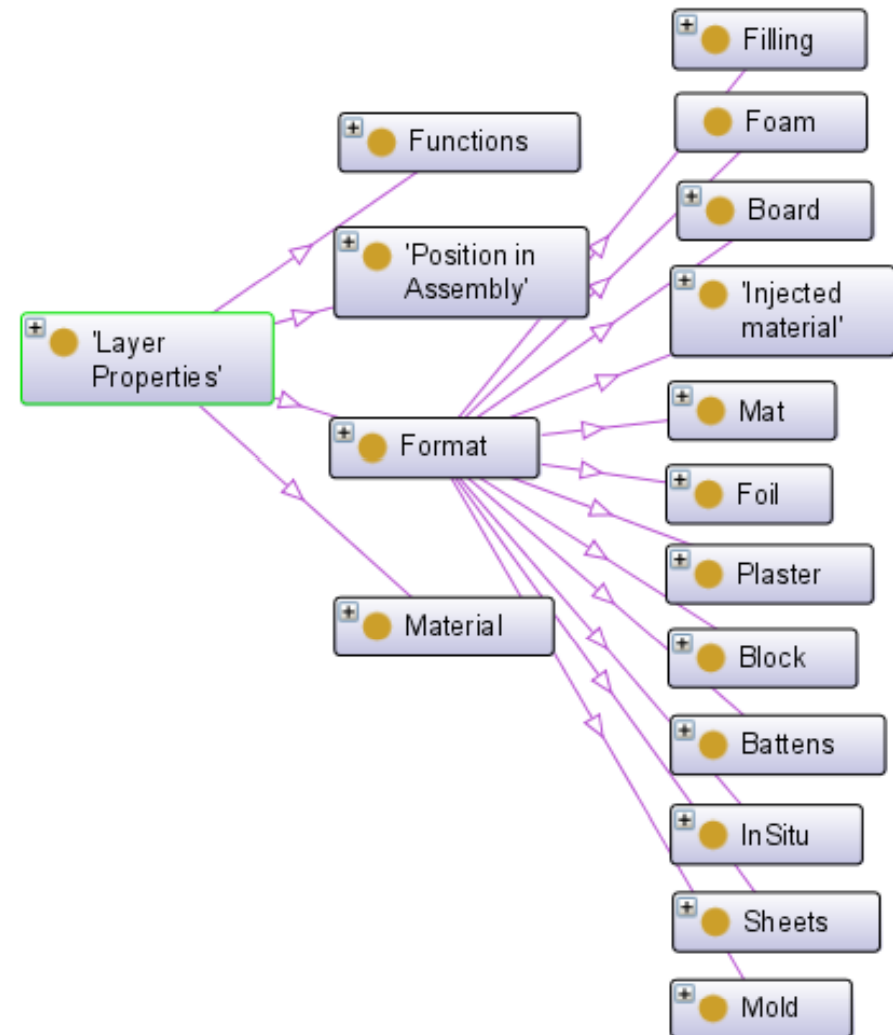
# SEMERGY: Ontology, Product Hierarchy

- ▶ Baubook platform is used for building design
  - ▶ Ecological
  - ▶ PhysicalProperties of building products.
- ▶ Baubook is categorized as the main hierarchy of SEMERGY ontology.
- ▶ Baubook products are extracted and then converted to RDF format.
- ▶ An example of such derived property is thermal resistance
  - ▶ R-Value
    - ▶ Calculated on the base of thickness and thermal conductivity of products



# SEMERGY: Ontology, Sub-Product Properties

- ▶ Details of products are required, for rule based reasoning
  - ▶ Gypsum board, is a moisture-sensitive, and not appropriate for exterior usage
- ▶ Properties in SEMERGY ontology are categorized as
  - ▶ Functional aspects of building
    - ▶ Wall, Ceiling or Roof components
  - ▶ Position in Assembly
    - ▶ Includes model specific aspects of building that are used in different parts of building construction
  - ▶ Format
    - ▶ Physical properties and Shape of products
  - ▶ Material of a product
    - ▶ Wood, Concrete, Glass, Metal



# SEMERGY: Ontology, Enriching Hierarchy

- ▶ Descriptions of products cannot provide complete information for reasoning
  - ▶ Baubook hierarchy should be enriched
- ▶ Established connection between Baubook classes and extended properties
  - ▶ Wall is a subclass of SEMERGY ontology
    - ▶ Load Bearing
    - ▶ Heavy
    - ▶ Solid
- ▶ Enriching Baubook hierarchy helps
  - ▶ Calculation and simulation purpose
- ▶ Each product is categorized in two default products
  - ▶ Non-expert users
  - ▶ Expert users

Annotations: 'Wall element with synthetic material'

Annotations +

**hasExpertDefaultProduct**  
◆ 3i-Leichtbauwand

**hasNoviceDefaultProduct**  
◆ 'MABA LIAPOR'

**label**  
"Wall element with synthetic material"@en

Description: 'Wall element with synthetic material'

Equivalent classes +

Superclasses +

- 'Load Bearing'
- 'Moisture resistant'
- 'Wall Suitable'
- 'Wandelemente aus Leichtbeton'
- Closed
- Heavy
- Non-deformable
- Prefabricated
- Solid

# Baubook Interface

The screenshot shows a web browser window with the address bar displaying `www.baubook.at/zentrale/`. The page features the Baubook logo and a navigation menu with items like 'Kriterien', 'Produkte', 'Firmen', 'Richtwerte', 'Archiv', 'Home', 'Kontakt', 'Info/FAQ', 'Favoriten', and 'Anmelden'. A search bar is located in the top right corner.

The main content area is divided into several sections:

- Navigation:** '← Vorheriges Produkt' and '↑ zurück zur Produktliste' on the left, and 'Nächstes Produkt →' on the right.
- Product Title:** 'Fassadentafeln Textura / Natura'.
- Allgemein:** 'Gelistet seit: 29. 10. 2010' and 'Produktindex: 8698 ac'.
- Einsatzbereich:** 'Faserzementtafeln zur Bekleidung der Fassade und im Innenraum'.
- Erfüllung der Kriterien:**
  - 8. Materialwahl, Baustoffe
    - ✗ Zertifizierte ökologische Produkte
    - 8. 1. PVC-Vermeidung
      - ✗ PVC-freie Verpackungen
  - 11. Lebensdauer und Wartung
    - ✓ Witterungsbeständigkeit von Fassade und Fenster
- Summary: '✓ Das Produkt erfüllt das Kriterium' and '✗ Das Produkt erfüllt das Kriterium nicht oder es liegen keine entsprechenden Nachweise vor'.
- Produktbeschreibung:**
  - Produktgruppe: Faserzementplatten (Fassaden), Faserzementplatten (innen)
  - Hersteller-Beschreibung: Material: Faserzement (DIN 12467); Beschichtung: verschiedenen Varianten zur Auswahl: deckend beschichtet, mit Farblasur, mit Graffiti-Schutz (PRO-Oberflächenbeschichtung); Oberfläche: verschiedene Varianten zur Auswahl: glatt, körnig oder mit Graffiti-Schutz; Dicken: 8 und 12 mm

ditor SVN286

# SEMERGY: Data Source

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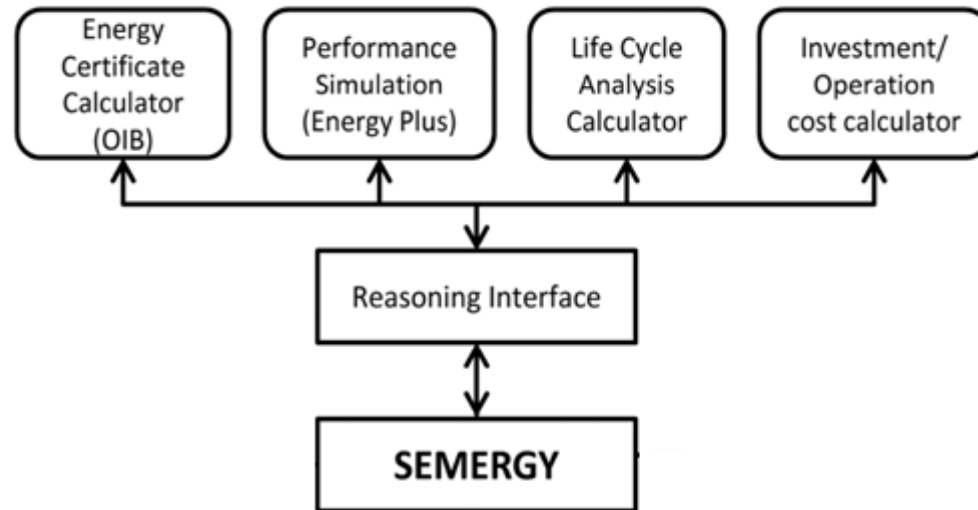
```
<owl:NamedIndividual rdf:about="#solidwood_2142705277">
  <rdf:type rdf:resource="#SolidWood"/>
  <rdfs:label l:lang="de">Brettsperrholzplatte</rdfs:label>
  <rdfs:comment xml:lang="de,,> Großformatige Massivholzpaneele aus
    Kreuzweiseverleimten Brettlagen ...
</rdfs:comment>
<semergy:heatTransferCoefficient>0.12</semergy:heatTransferCoefficient>
<semergy:acidificationPotential>0.0034</semergy:acidificationPotential>
<semergy:notRenewablePEI>8.04</semergy:notRenewablePEI>
<semergy:globalWarmingPotential>-
  11.26</semergy:globalWarmingPotential>
</owl:NamedIndividual>
```





# SEMERGY: Structure

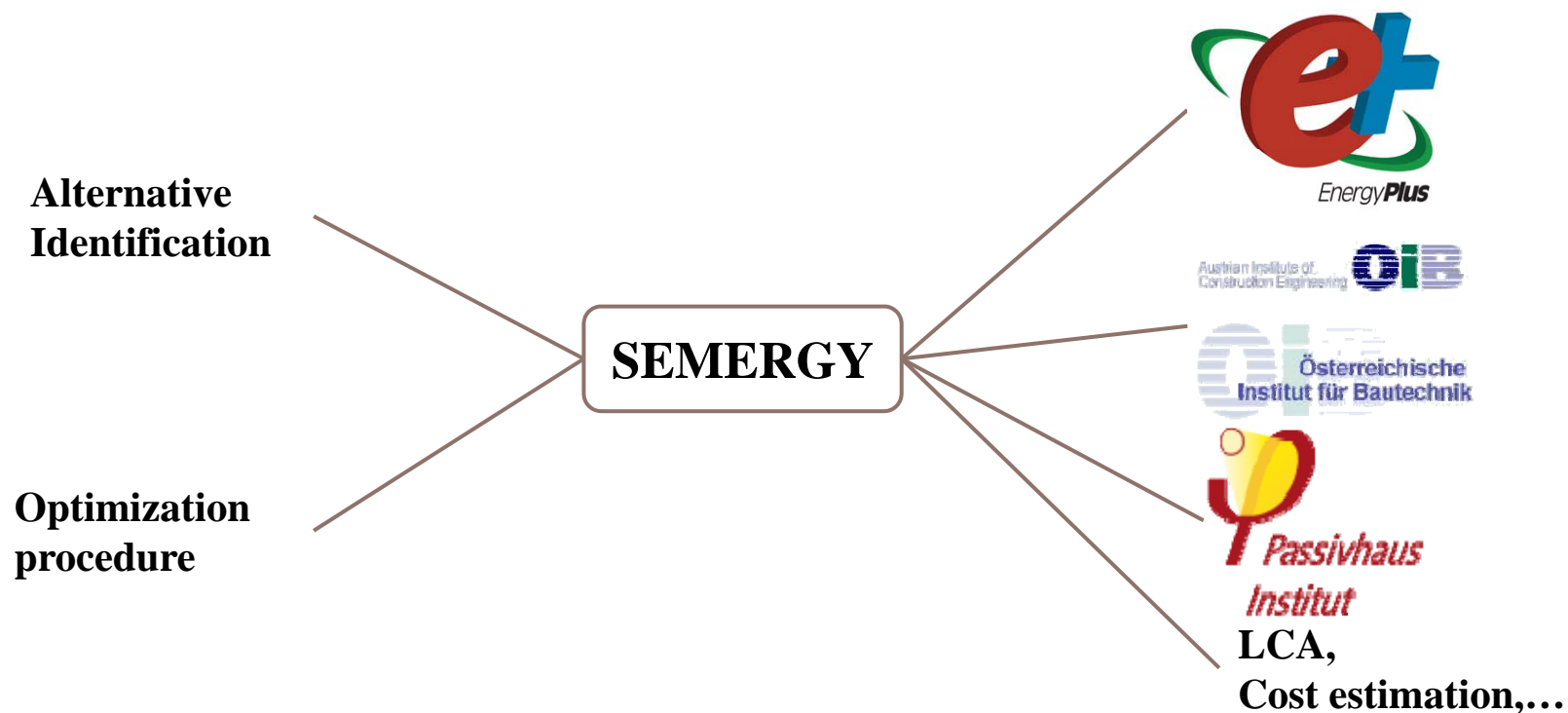
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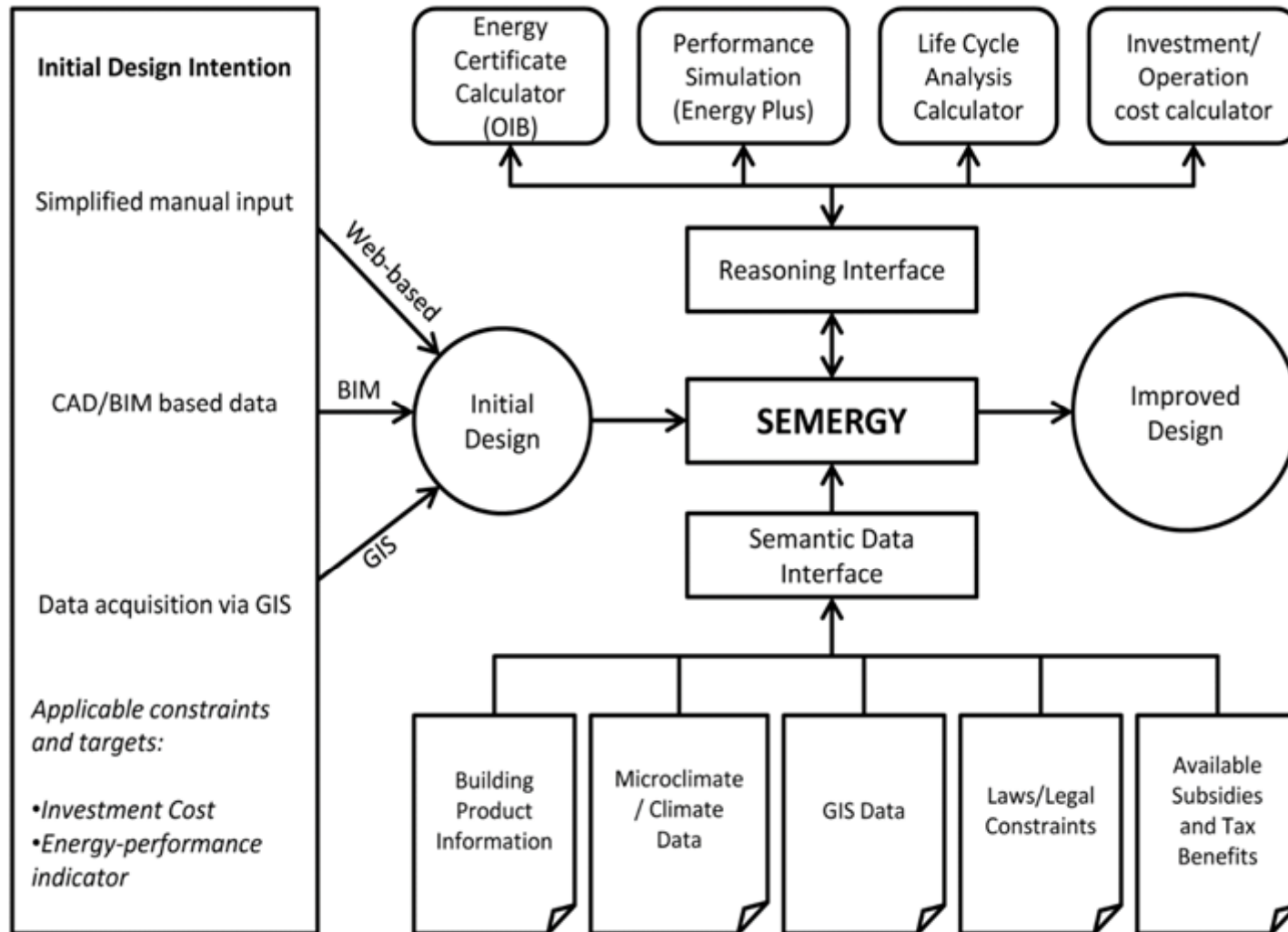
# SEMERGY: Reasoning Interface

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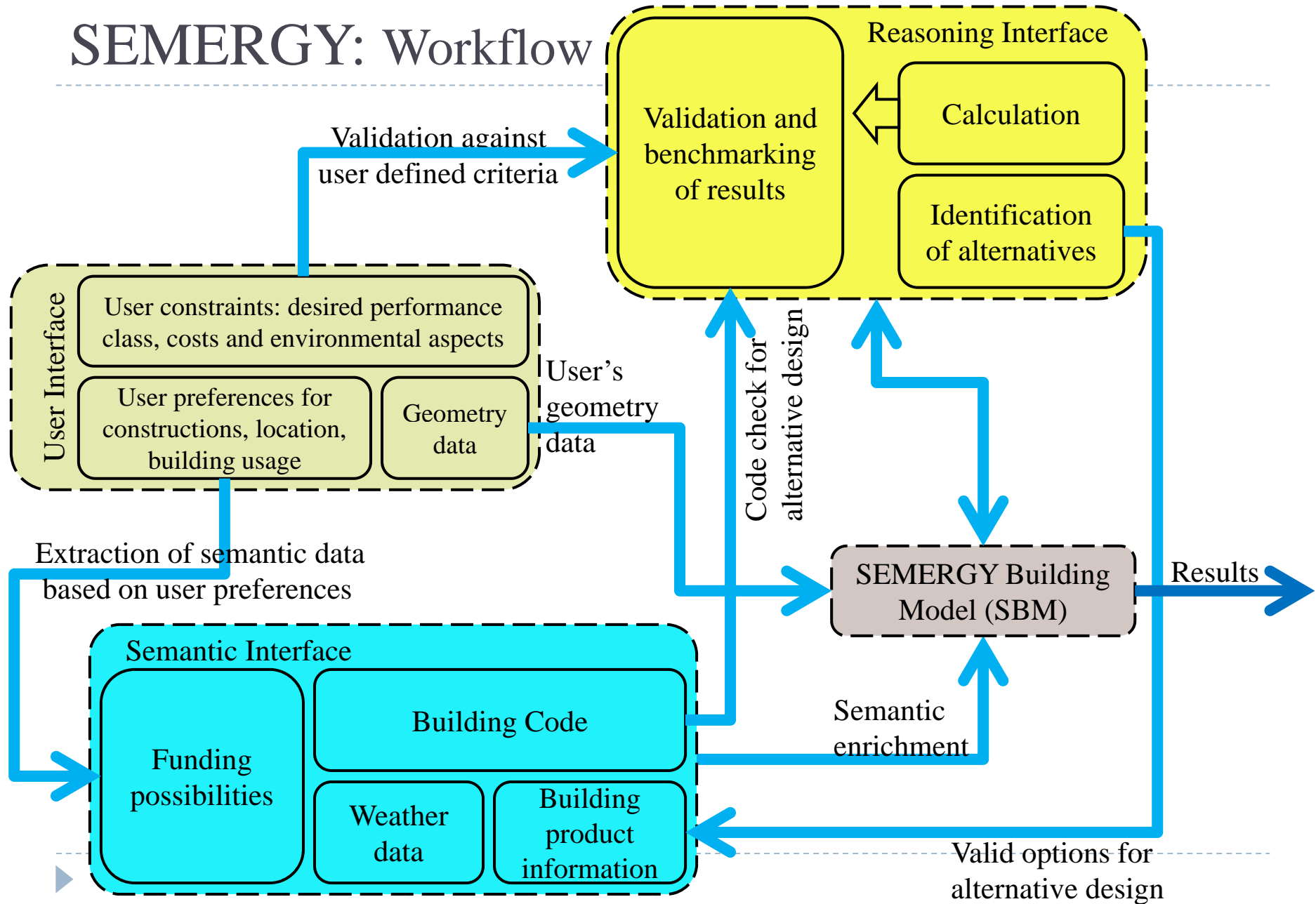
- ▶ Incorporation of computational engines (performance simulation, normative assessment tools)
- ▶ Identification of design alternatives
- ▶ Optimization of the initial design towards better performance within the limits of the user defined constraints



# SEMERGY: Structure



# SEMERGY: Workflow



# SEMERGY: Basic Building Information

- ▶ Input data: Geographic Location (Address), Year of Construction, Cardinal directions, Type of building, Number of Floors, Room Type, etc.

The screenshot displays the SEMERGY web application interface. The top navigation bar includes the SEMERGY logo, a Home icon, and menu items for 'Dateneingabe', 'Optimierung', and 'Hilfe'. A power icon labeled 'Abmelden' is in the top right corner. The left sidebar contains a 'BASISDATEN' section with sub-sections for 'GEBÄUDEGEOMETRIE & RAUMINFORMATION' and 'GEBÄUDEKONSTRUKTIONEN'. The main content area features a map of 'Favoritenstrasse 9, 1040 Wien' with a red location pin. To the right of the map is a form for entering building information:

- Neubau** (selected) / **Sanierung**
- Baujahr**: 2012
- Nordausrichtung**: 12
- Bauweisen**: Massivbau
- Verwendungszweck**: Einfamilienhaus
- Anzahl KG Geschosse**: 1
- Anzahl OG Geschosse**: 1
- Dachform**: Walmdach
- Dachgeschosstyp**:
  - Dachgeschoss (bewohnt)
  - Dachboden (Abstellraum)
  - Offen (kombiniert mit oberstem Geschoss ohne Zwischendecke)
- Dachneigung**: 22

The bottom left corner of the interface shows the URL 'www.wired.com'.

# SEMERGY: Building Geometry

- ▶ Web-based drawing tool for simple specification of Outer walls, Inner walls, Windows, and Doors for each floor of the building.

The screenshot displays the SEMERGY web-based drawing tool interface. The top navigation bar includes the SEMERGY logo, a Home icon, and menu items for 'Dateneingabe', 'Optimierung', and 'Hilfe'. A 'Abmelden' (Logout) button is located in the top right corner. The left sidebar contains a 'BASISDATEN' section with a sub-section 'GEBÄUDEGEOMETRIE & RAUMINFORMATION' and a 'GEBÄUDEKONSTRUKTIONEN' section. The main workspace features a grid with axes ranging from 0 to 50 meters. A blue arrow icon is positioned at the top left of the grid. A brown rectangular outline represents the outer wall, and two vertical green lines represent inner walls. A red box highlights a zoomed-in view of the inner walls. To the right of the grid are three navigation buttons: a plus sign for zooming in, a minus sign for zooming out, and a cross for resetting the view. Below the grid, the coordinates 'X:2300, Y:5000' and 'MX:0 ; MY:0' are displayed. The 'Werkzeuge:' (Tools) panel on the right shows a 'Wand' (Wall) tool with a dropdown menu currently set to 'Innere nichttragende Wand' (Inner non-load-bearing wall). A 'RÜCKGÄNGIG' (Undo) button is also present. At the bottom of the interface, there are '← ZURÜCK' (Back) and 'WEITER →' (Next) buttons. The footer includes the website 'www.wired.com' and a 'show all notifications' link.

# SEMERGY: Room Information

- ▶ Input data based on Floor Plan: Room height, Room type (Office, Living room, etc.), Window and Door Heights.

The screenshot displays the SEMERGY software interface for room information input. The interface is divided into several sections:

- Navigation Bar:** Includes the SEMERGY logo, Home, Dateneingabe, Optimierung, Hilfe, and Abmelden (Logout) buttons.
- Left Sidebar:** Contains navigation options: BASISDATEN, GEBÄUDEGEOMETRIE & RAUMINFORMATION (selected), and GEBÄUDEKONSTRUKTIONEN.
- Main Area:**
  - KG EG:** Project identifiers.
  - Rauminformation:** A grid-based floor plan showing four rooms (Raum 1, Raum 2, Raum 3, Raum 4) and various windows (Fenster 1-7) and a door (Tür 1). The grid ranges from 0 to 50 meters on both axes.
  - Räume (Rooms):** A list of rooms with input fields for their properties:
    - Raumhöhe [cm]: 260
    - Raum 1: Büro (Office)
    - Raum 2: Wohnzimmer (Living Room)
    - Raum 3: Gang (Corridor)
    - Raum 4: Büro (Office)
  - Fenster 1 (Window 1):**
    - Breite [cm]: 400
    - Höhe [cm]: 150
    - Parapet [cm]: 50
  - Fenster 2 (Window 2):**
    - Breite [cm]: 400
    - Höhe [cm]: 150
    - Parapet [cm]: 50
  - Fenster 3 (Window 3):** (Properties are not visible)
- Bottom Right:** Navigation buttons: ← ZURÜCK and WEITER →.

www.wired.com show all notifications

# SEMERGY: Building Construction

- ▶ Predefined set of building constructions (Like: Walls, Floors, Ceilings, Doors, and Windows) allows the user to choose the type for each of these constructions (e.g., Wall construction with layers Plaster (1), Brick (2), Insulation (3))

The screenshot displays the SEMERGY software interface. At the top, there is a navigation bar with icons for Home, Dateneingabe, Optimierung, Hilfe, and Abmelden. The main content area is divided into sections for selecting building components. On the left, a sidebar lists 'BASISDATEN', 'GEBÄUDEGEOMETRIE & RAUMINFORMATION', and 'GEBÄUDEKONSTRUKTIONEN'. The main area shows three selection panels:

- Innere nichttragende Wand:** A dropdown menu is set to 'Lehmziegel-Scheidewand, Hochlochziegel-Scheidewand,'. Below it, the layers are listed as:
  - Lehmziegel-Scheidewand, Hochlochziegel-Scheidewand, nichttragend
  - Schichten:
    - 1. Lehmputz; Kalkzementputz
    - 2. Lehmziegel; Hochlochziegel porösisiert
    - 3. Lehmputz; Kalkzementputz
- Äußere tragende Wand:** A dropdown menu is set to 'Einschaliges Mauerwerk mit Wärmedämmverbundsystem'. Below it, the layers are listed as:
  - Einschaliges Mauerwerk mit Wärmedämmverbundsystem
  - Schichten:
    - 1. Innenputz
    - 2. Mauerwerk
    - 3. Dämmanteil des WDVS
    - 4. Putzanteil des WDVS
- Äußere Fenster:** A dropdown menu is set to 'Allgemeines Fenster'.
- Äußere Tür:** A dropdown menu is set to 'Allgemeine Tür'.

At the bottom right of the main area, there are navigation buttons: '← ZURÜCK' and 'WEITER →'. The footer of the interface contains the text 'Impressum'.



# SEMERGY: Building Construction

- ▶ Comprehensive building material catalog allows to specify proper materials for each layer.

The screenshot displays the SEMERGY software interface for building construction. The top navigation bar includes the SEMERGY logo, a home icon, and menu items for 'Dateneingabe', 'Optimierung', and 'Hilfe'. A sidebar on the left contains navigation options: 'BASISDATEN', 'GEBÄUDEGEOMETRIE & RAUMINFORMATION', and 'GEBÄUDEKONSTRUKTIONEN' (which is currently selected).

The main content area is divided into two sections. The left section, titled 'Innere nichttragende Wand', shows a list of layers for an inner non-load-bearing wall. The right section provides a detailed view of the selected material, 'POROTHERM 30 PLAN (NATUREPLUS), DICKE: 30.0', including its description and various technical properties.

**Innere nichttragende Wand**  
Lehmziegel-Scheidewand, Hochlochziegel-Scheidewand, nichttragend

- Lehmputz; Kalkzementputz: StoDecolit K/R
- Lehmziegel; Hochlochziegel porösier: POROTHERM 10-50 N+F, Dicke: 10.0
- Lehmputz; Kalkzementputz: StoDecolit K/R

**Äußere tragende Wand**  
Einschaliges Mauerwerk mit Wärmedämmverbundsystem

- Innenputz: StoDecolit K/R
- Mauerwerk: POROTHERM 30 Plan (natureplus), Dicke: 30.0
- Dämmanteil des WDVS: steinopor 700 EPS-W20, Dicke: 1.0
- Putzanteil des WDVS: StoSil K/R/MP

**Äußere Fenster**: Gaulhofer Kunststofffenster TOPFIVE (3-5)

**Äußere Tür**: Holtsch Passivhaustüre

**POROTHERM 30 PLAN (NATUREPLUS), DICKE: 30.0**

**Description**: Der POROTHERM 30 Plan mit mörtelloser Nut und Feder-Stoßfugenverbindung ist ein auf die Anforderungen des Einfamilienhaus- bzw. Nutzbaues abgestimmter Planziegel für 30 cm dicke Außenwände mit Zusatzdämmung. (Verarbeitet mit POROTHERM Dünnbettmörtel)

|                        |       |
|------------------------|-------|
| thickness              | 30    |
| minThickness           | 0     |
| maxThickness           | 0     |
| acidificationPotential | 0,001 |
| globalWarmingPotential | 0,182 |
| notRenewablePEI        | 2,3   |
| thermalConductivity    | 0,18  |
| bulkDensity            | 923   |
| specificHeatCapacity   | 1.000 |

Navigation buttons at the bottom right: ← ZURÜCK and WEITER →

# SEMERGY: Target Value Specification

- ▶ Based on the given input data the energy consumption of the current building is computed
- ▶ In this step the user sets his constraints regarding Investment Costs, Energy Consumption, and Sustainability of the refurbishment project.

SEMERGY

Home Dateneingabe Optimierung Hilfe

Abmelden

RAHMENBEDINGUNGEN

AUSWAHL

ERGEBNIS

Der momentane Energieverbrauch Ihres Gebäudes beträgt 62 kWh/m<sup>2</sup>/Jahr. Unter welchen Rahmenbedingungen möchten Sie den Energieverbrauch optimieren?

Zielwert maximaler Investitionskostenfaktor:

Zielwert maximaler Energieverbrauch:

Zu optimierende Kategorien:

Minimierung Investitionskostenfaktor

Minimierung Energieverbrauch

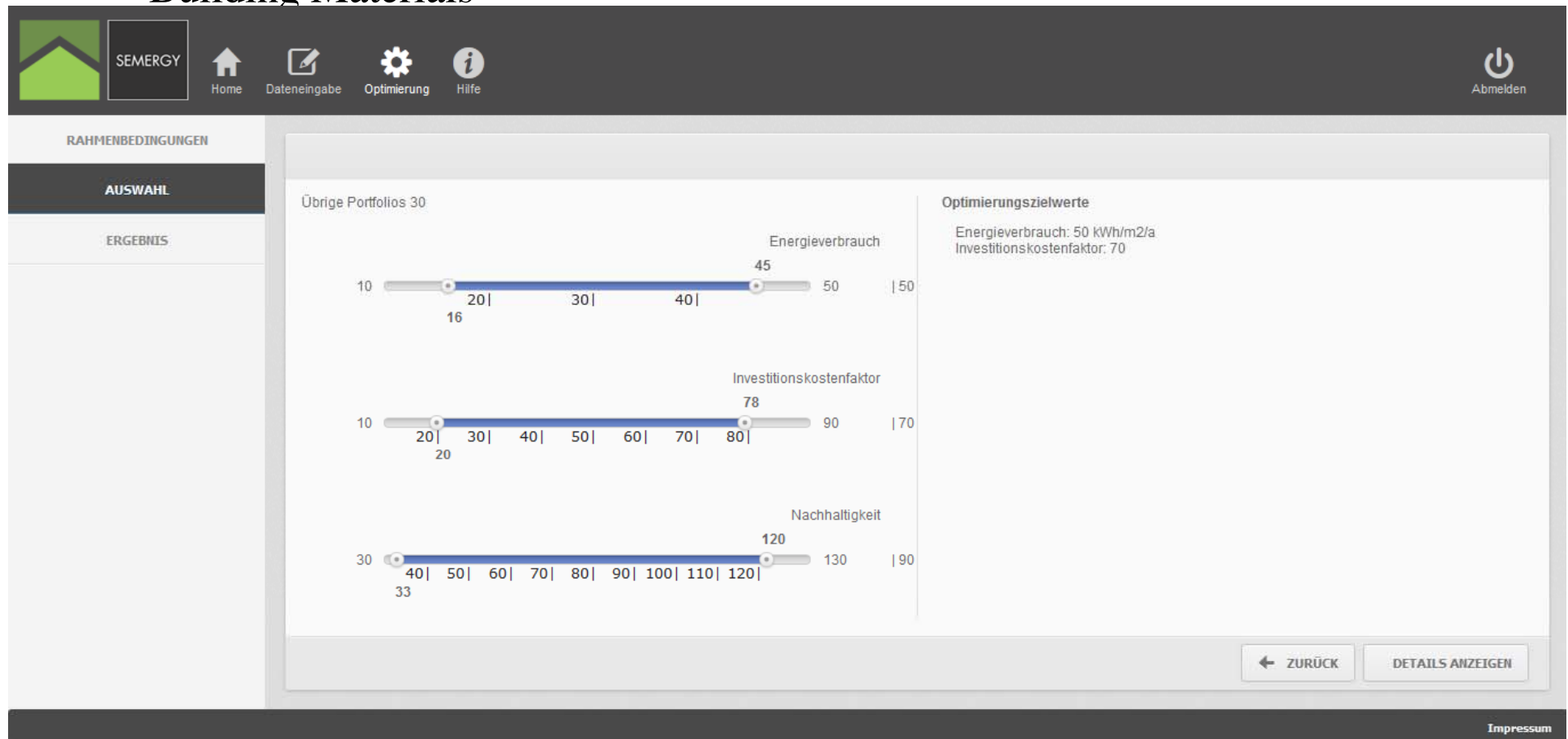
Maximierung Nachhaltigkeit

← ZURÜCK ⚙️ OPTIMIERUNG STARTEN

Impressum

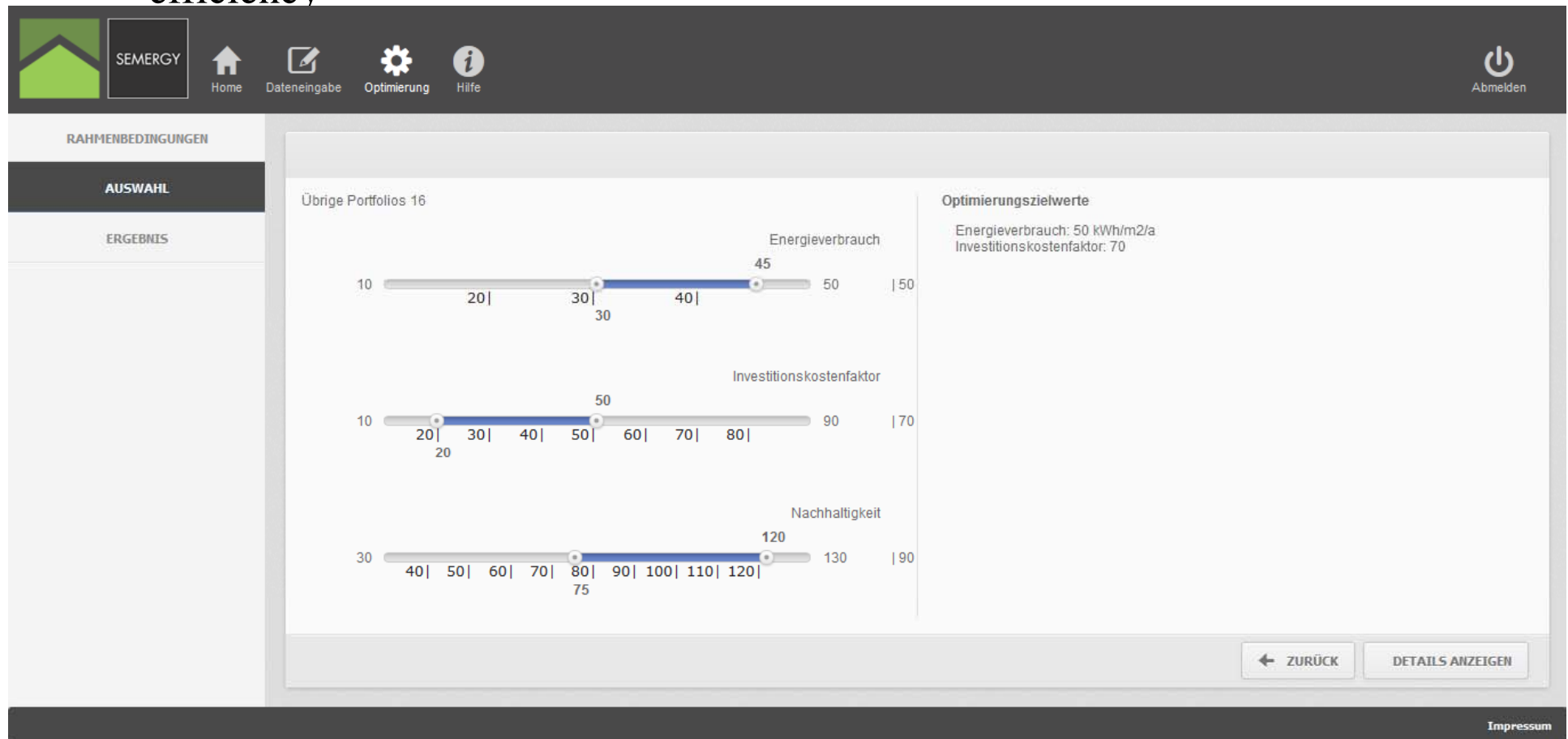
# SEMERGY: Multi-Object Optimization

- ▶ Based on provided constraints, SEMERGY computes potential refurbishment options which suit the individual needs
- ▶ For example: Budget, Acquiring Energy Efficiency, and Sustainability of Building Materials



# SEMERGY: Multi-Object Optimization

- ▶ SEMERGY allows user to interactively modify the constraints, and shows how changes in one category affect the remaining categories
- ▶ For example: Cheaper solutions will normally result in lower energy efficiency



# SEMERGY: Multi-Object Optimization

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- ▶ Main goal of optimization procedure is to identify alternative building design
- ▶ Alternative building design are generated through selecting different types of
  - ▶ Material
  - ▶ Products
  - ▶ ComponentsEach alternative design contributes to better insulation options
- ▶ Cost is classified as resource
  - ▶ Minimum cost but quality is maintained
- ▶ Aim of SEMERGY multi-object Optimization
  - ▶ Evaluating better components
  - ▶ Decision making



# SEMERGY: Final Results

- ▶ SEMERGY produces a list of concrete building materials for each construction that meets the individual requirements
- ▶ For example: Investment Costs, Energy Efficiency of the building, and Sustainability of Building Products

The screenshot displays the SEMERGY web application interface. At the top, there is a navigation bar with the SEMERGY logo and icons for Home, Dateneingabe, Optimierung, and Hilfe. A power icon labeled 'Abmelden' is in the top right corner. Below the navigation bar, a sidebar on the left contains three menu items: 'RAHMENBEDINGUNGEN', 'AUSWAHL', and 'ERGEBNIS', with 'ERGEBNIS' selected. The main content area shows the results for 'Ergebnis Nummer 15'. It lists three key metrics: 'Investitionskosten: 50', 'Energieverbrauch: 30kWh/m²/a', and 'Nachhaltigkeit (OI3): 75'. The results are organized into three sections:

- Innere nichttragende Wand**  
Lehmziegel-Scheidewand, Hochlochziegel-Scheidewand, nichttragend
  - 1. Lehmputz; Kalkzementputz: FILZPUTZ CLASSIC
  - 2. Lehmziegel; Hochlochziegel porösier: BRENNER PLAN THERMO-RAPID 12X50 N+F (NA ...
  - 3. Lehmputz; Kalkzementputz: KALKIN FEIN W (KALKFEINPUTZ W)
- Äußere tragende Wand**  
Einschaliges Mauerwerk mit Wärmedämmverbundsystem
  - 1. Innenputz: STODECOLIT K/R
  - 2. Mauerwerk: POROTHERM 25 SSZ HD, DICKE: 25.0
  - 3. Dämmanteil des WDVS: EXTRAPOR EPS - W 20 100 KPA, DICKE: 3.0
  - 4. Putzanteil des WDVS: STOSIL K/R/MP
- Äußere Fenster**  
GAULHOFER HOLZFENSTER IV70/02 FICHTE (V ...

# SEMERGY: Software (Overview)

The screenshot displays the SEMERGY software interface. On the left is a dark vertical sidebar with icons and labels: a house icon for 'Bericht', a document icon for 'DASHBOARD', a pencil icon for 'DATENEINGABE', a bar chart icon for 'ANALYSE', and a power icon for 'LOGOUT'. The main content area has a green header with the title 'Bericht' and the text 'Die von Ihnen gewählten Sanierungsmaßnahmen können nun als PDF Bericht heruntergeladen werden.' Below this is a white box with a grey header 'Report' containing the text: 'Der generierte Bericht enthält den von Ihnen ausgewählten Lösungsvorschlag. Sie können mittels Klick auf den Download-Button den Bericht erneut herunterladen. Zusätzlich können Sie jederzeit den Bericht im Dashboard einsehen.' A 'DOWNLOAD' button is present, with a yellow tooltip labeled 'Download' appearing over it. At the bottom right of the main area are two buttons: 'ZURÜCK' and 'ABSCHLIESSEN'.

# Outline

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Introduction

Motivation and Goals

Design - Barriers and Expectation

**SEMERGY: Concept**

○ **Objective**

§ **Structure**

U **User Interface**

○ **Ontology**

B **Book**

R **Reasoning Interface**

W **Workflow**

B **Building Data Model**

B **Basic Information**

S **Software overview**

**Conclusion**

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# Conclusion

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- ▶ Increasing energy efficiency is the key to a greener future
- ▶ Increasing building's energy efficiency is a major component of upcoming energy efficiency strategies
- ▶ SEMERGY enables the user to understand how building geometry and materials affect its energy efficiency
- ▶ SEMERGY provides concrete suggestions to improve the building's energy efficiency



# SEMERGY: Ongoing Activities & Challenges

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- ▶ BIM import possibilities for expert users
- ▶ Cost estimation
- ▶ HVAC
- ▶ GIS data

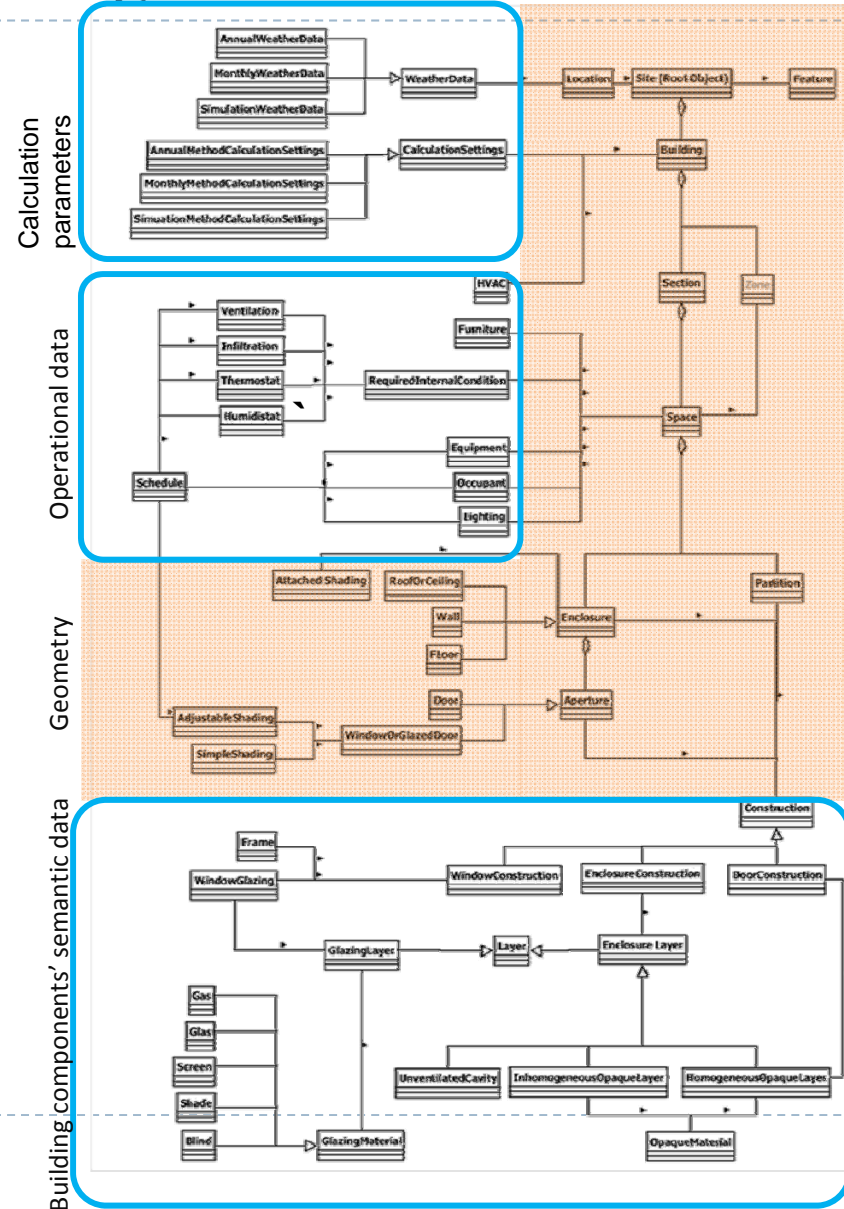
Generation of an SBM model based on this data

- ▶ Development of a data release format for product manufacturers to enable uniform retrieval of product information
- ▶ Current estimated product cost



# SEMERGY: Future Building Data Model

- ▶ Requirements:
  - ▶ Compliance with integrated computational engines
  - ▶ Extensibility for future
  
- ▶ Study of some existing building data formats:
  - ▶ IFC
  - ▶ gbXML
  - ▶ Shared Object Model for SEMPER



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# SEMERGY: [www.semergy.net](http://www.semergy.net)

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The first step in the design process is to define the project goals and objectives. This involves understanding the client's needs and requirements, and determining the scope of the project. The next step is to conduct a site analysis, which involves assessing the site's location, topography, and existing infrastructure. This information is used to develop a conceptual design, which is a preliminary plan for the project. The final step is to develop a detailed design, which includes all the necessary details for construction.

► an initial plan for construction.

# Q&A

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