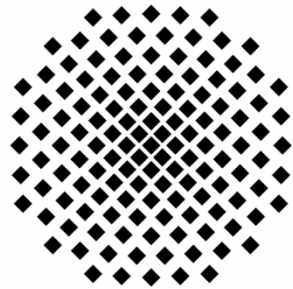


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# Biomass utilization from a life cycle perspective

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University of Stuttgart

Chair of Building Physics

---



Life Cycle Engineering

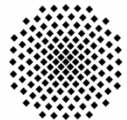
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# Biomass utilization from a life cycle perspective

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Seminar on sustainable biomass utilization  
National Academy of Agricultural Science  
Suwon, Republic of Korea

Jan Paul Lindner



University of Stuttgart

Chair of Building Physics

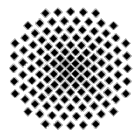
Life Cycle Engineering



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# Agenda

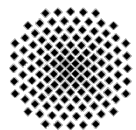
- ▶ Introduction to the GaBi team
- ▶ Introduction to life cycle assessment
- ▶ Biomass utilization from a life cycle perspective
  - Life cycle carbon balance
  - Example: Biogasmax
  - Global warming potential
  - Other impact categories
  - Land use impacts
- ▶ Summary



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# Introduction to the GaBi group

Seite 4



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Lehrstuhl für Bauphysik

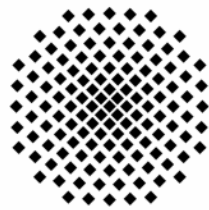
Ganzheitliche Bilanzierung



 **Fraunhofer**  
IBP

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# University of Stuttgart, Chair of Building Physics (LBP)

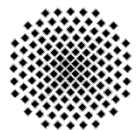


University of Stuttgart

Chair of Building Physics (LBP)  
Life Cycle Engineering (GaBi)



Seite 5



Universität Stuttgart

Lehrstuhl für Bauphysik

Ganzheitliche Bilanzierung

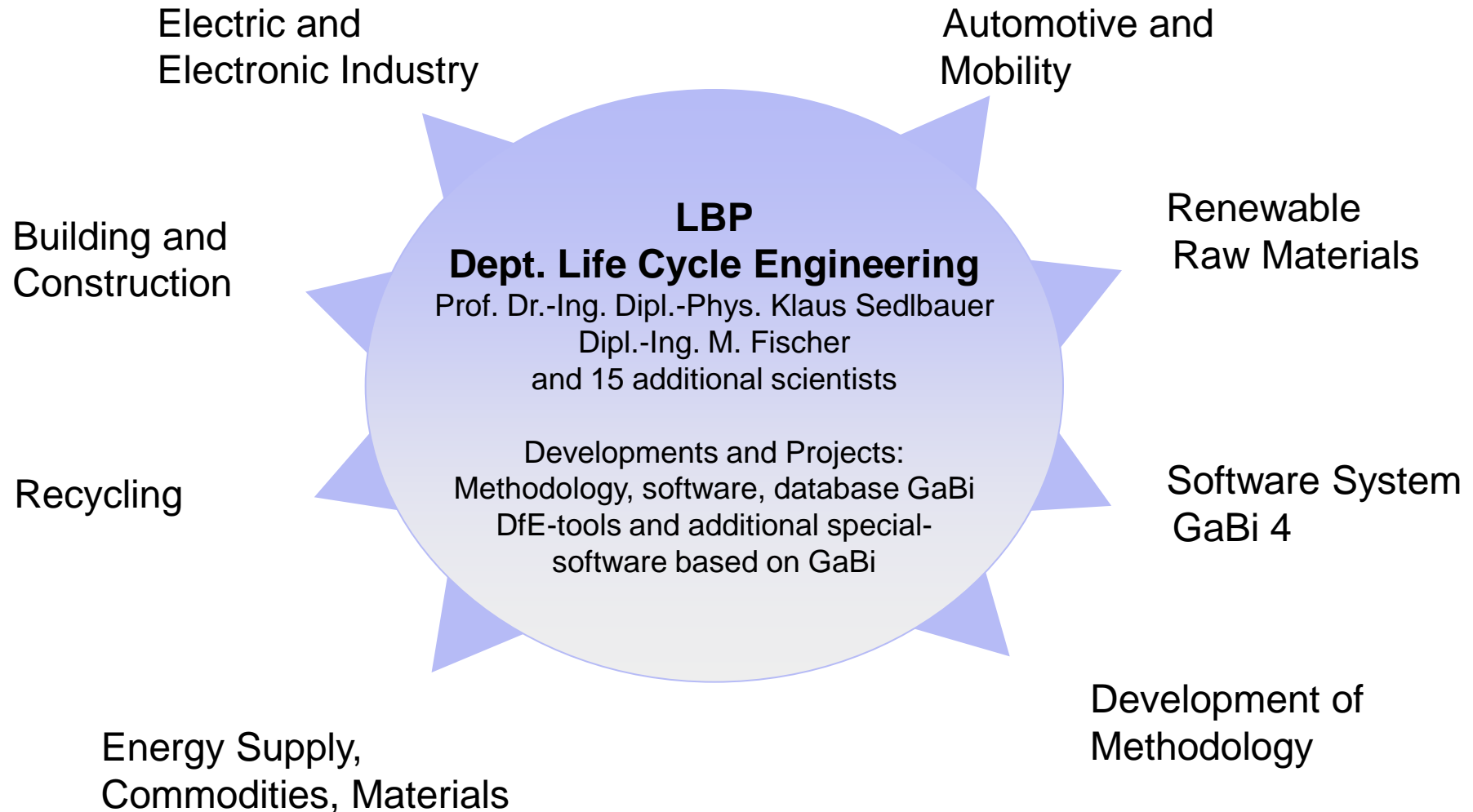


**Fraunhofer**

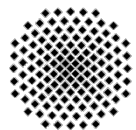
**IBP**

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# University of Stuttgart, Chair of Building Physics (LBP)



Seite 6



Universität Stuttgart

Lehrstuhl für Bauphysik

Ganzheitliche Bilanzierung



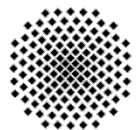
 **Fraunhofer**

**IBP**



# Fraunhofer

## IBP



# Fraunhofer Institute for Building Physics (IBP)

Project group Kassel



Institute Stuttgart

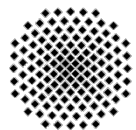


Kassel

Stuttgart

Holzkirchen

Institute Holzkirchen



Universität Stuttgart

Lehrstuhl für Bauphysik

Ganzheitliche Bilanzierung



Fraunhofer

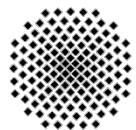
IBP

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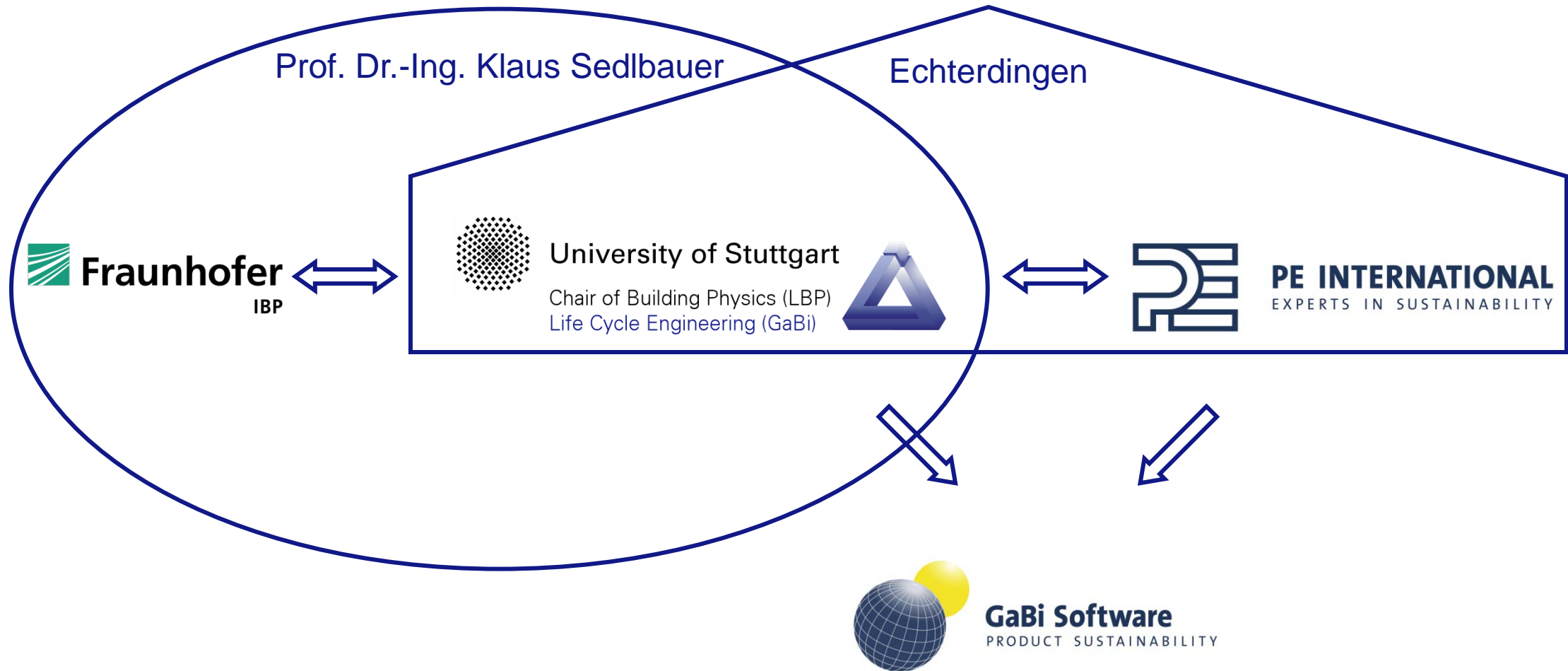
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**PE INTERNATIONAL**  
EXPERTS IN SUSTAINABILITY



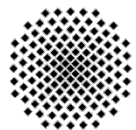
# The GaBi group



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# Methodology of Life Cycle Assessment (LCA)

Seite 11



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# LCA basics

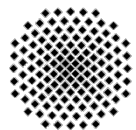


**Avoid**

**solving a problem...**



Seite 12



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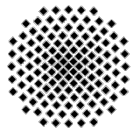
# LCA basics



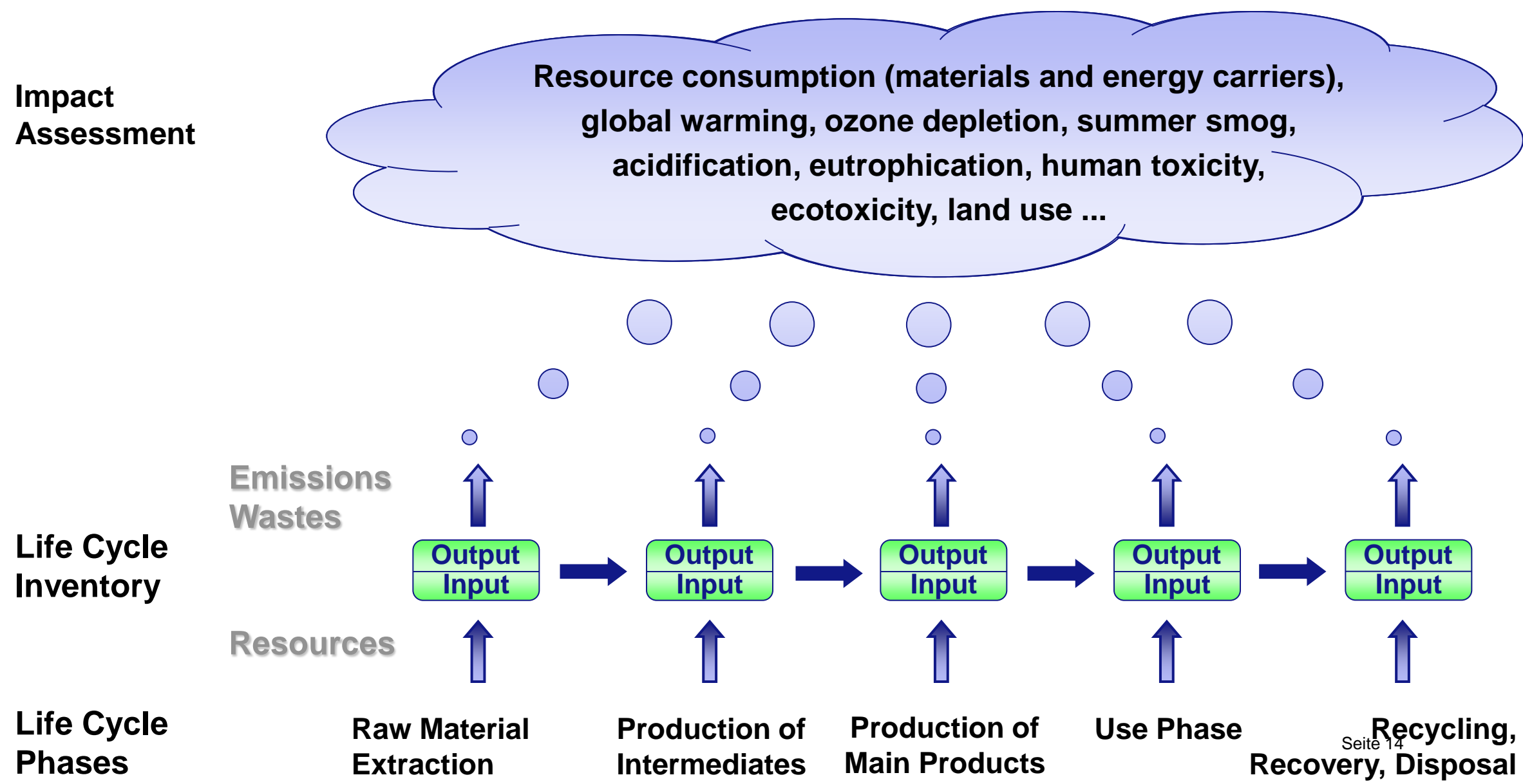
**Avoid**  
**solving a problem...**



**... by creating**  
**another one.**

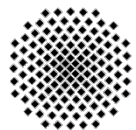
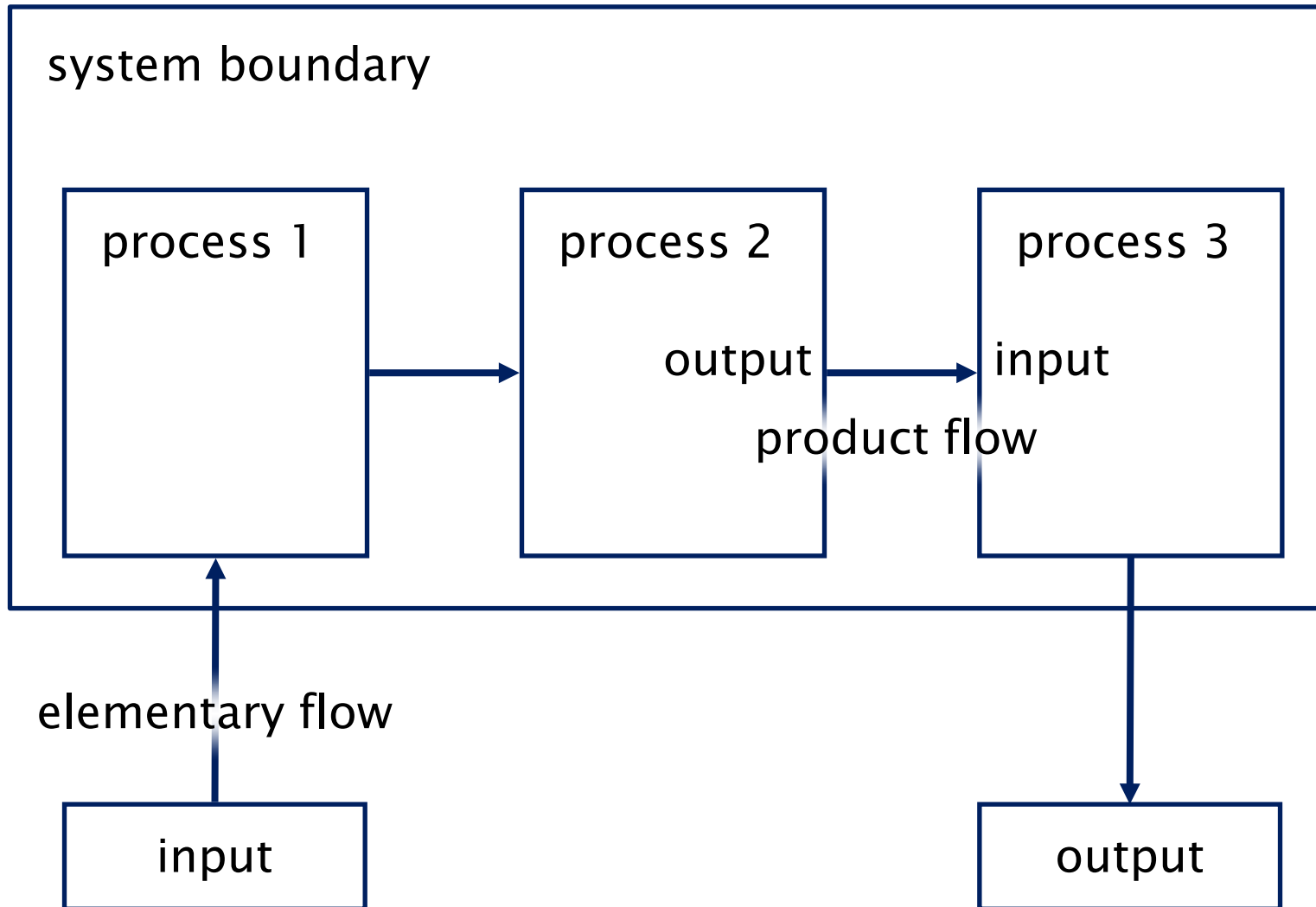


# LCA basics

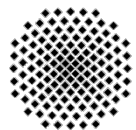
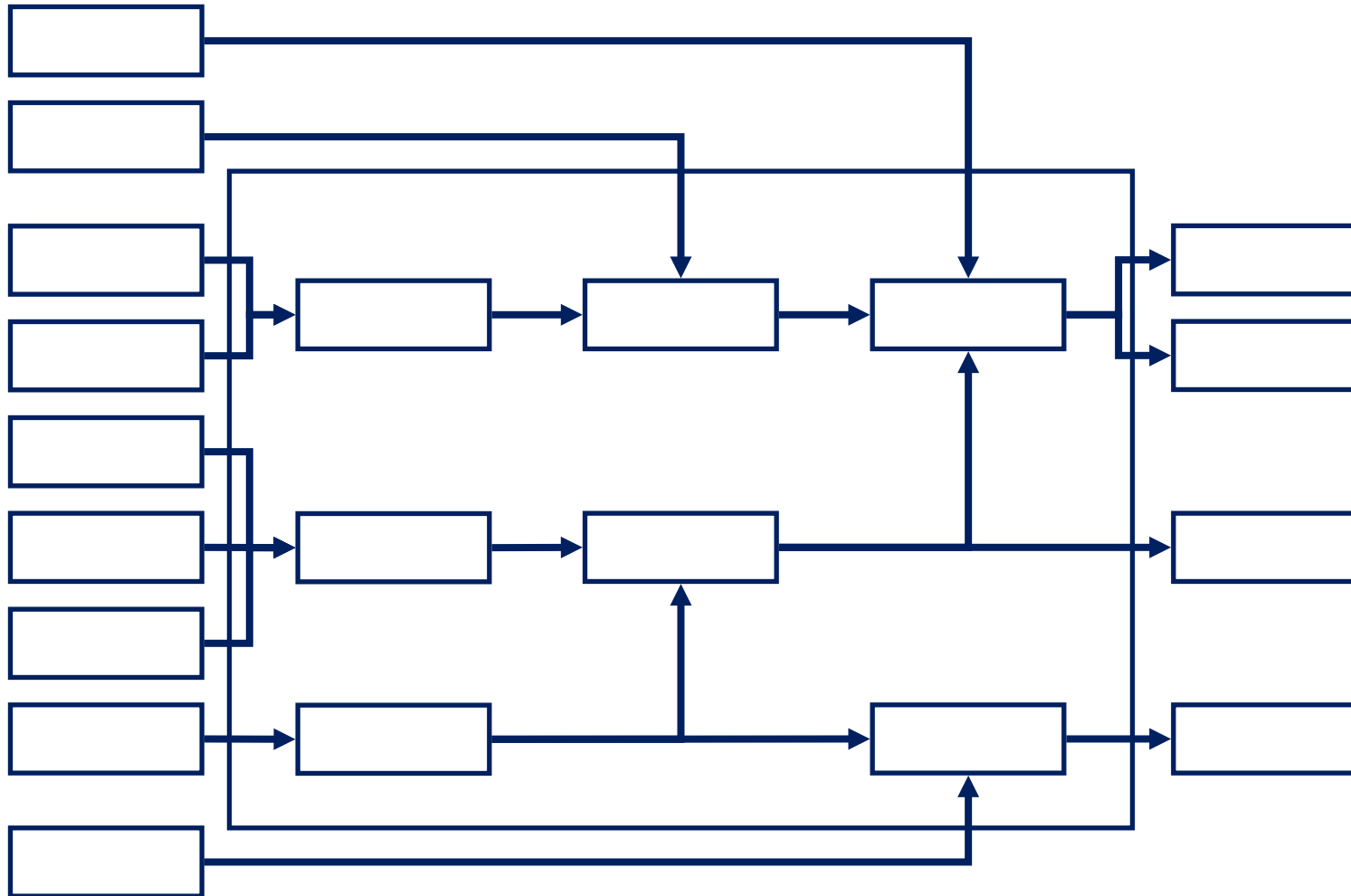


Seite 14

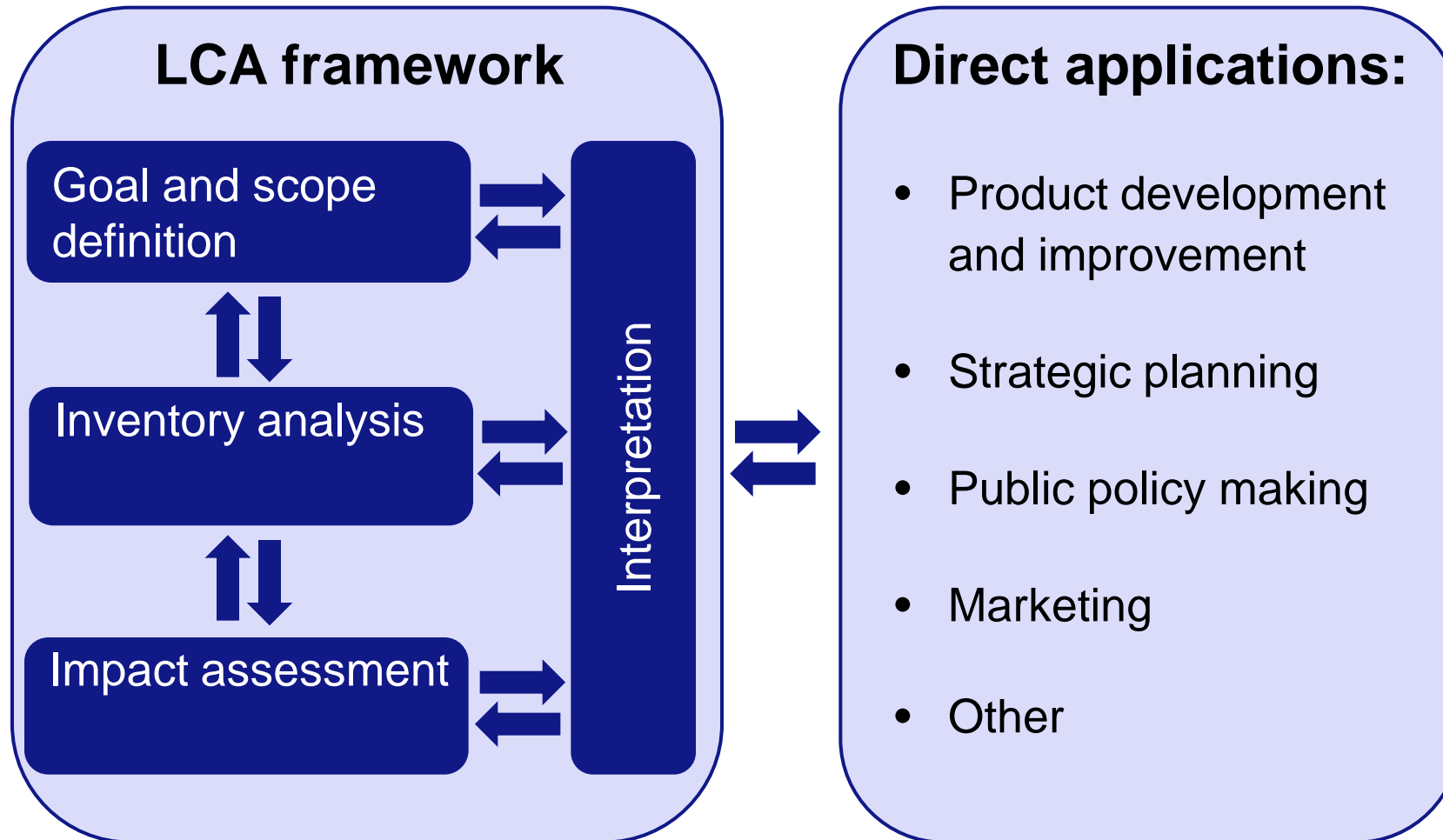
# LCA basics



# LCA basics

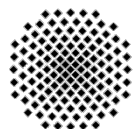


# LCA basics



source: ISO 14040, ISO 14044

Seite 17

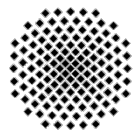


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# Biomass utilization

## from a life cycle perspective

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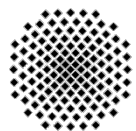
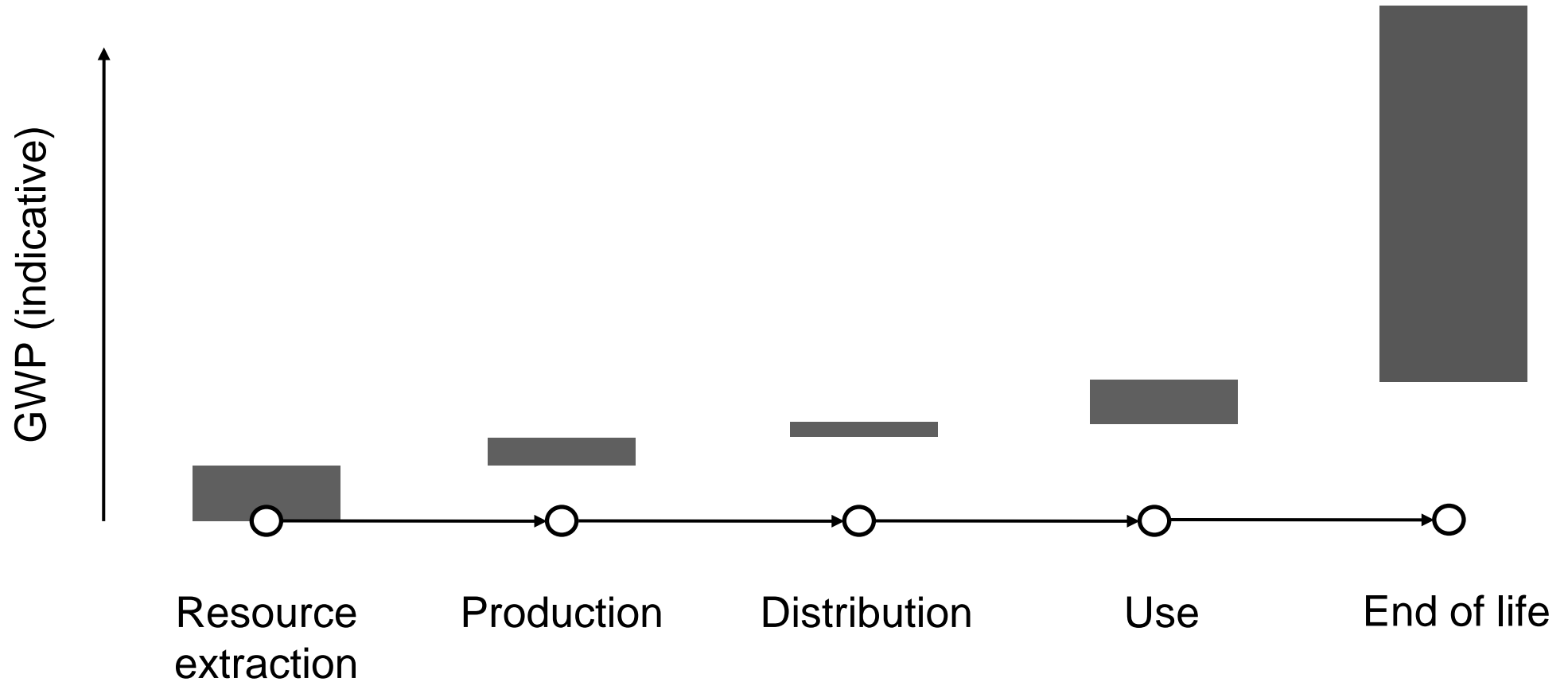
Ganzheitliche Bilanzierung



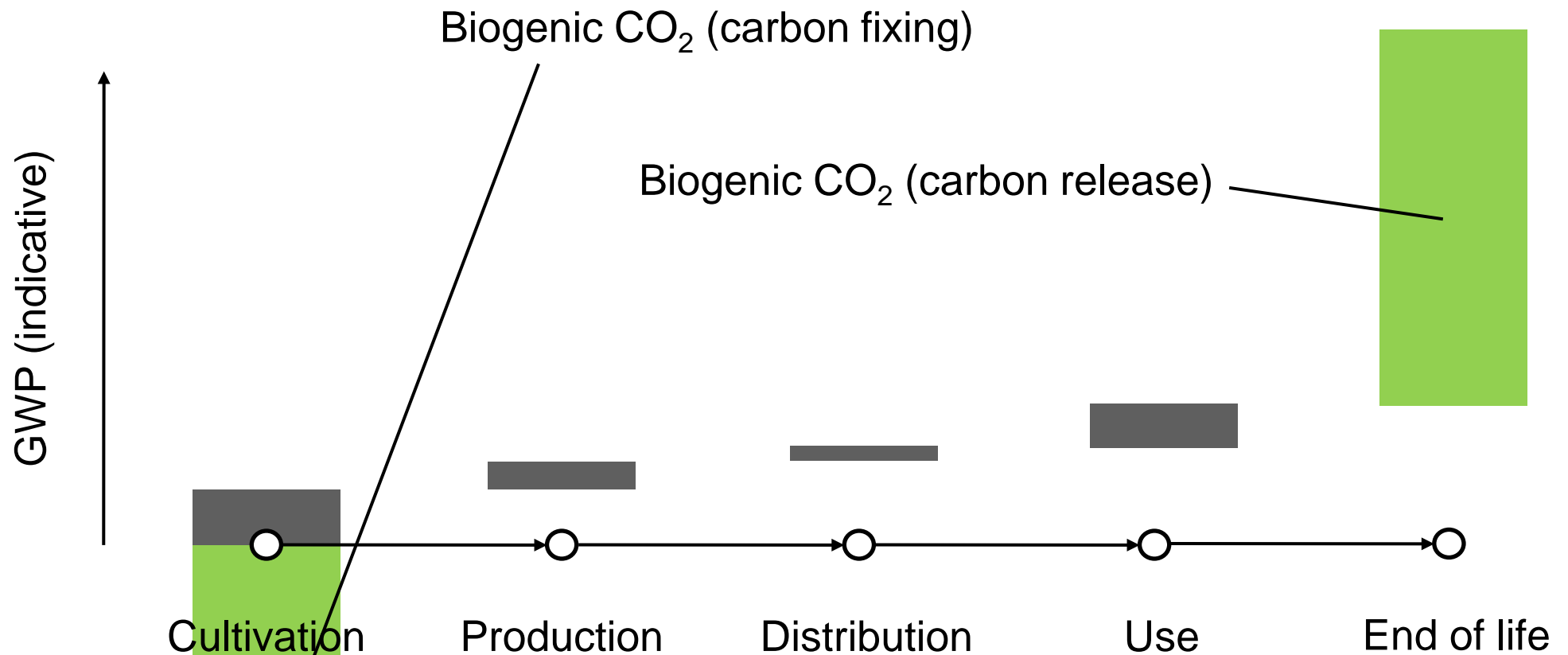
**Fraunhofer**

**IBP**

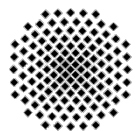
# Fossil-based products from a life cycle perspective



# Biomass utilization from a life cycle perspective



Seite 20

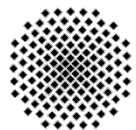


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# Biomass utilization from a life cycle perspective

## Example: Biogasmax

Seite 21



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Ganzheitliche Bilanzierung



 **Fraunhofer**  
IBP

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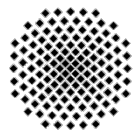
## Example: Biogasmax

### European project (6<sup>th</sup> framework programme)

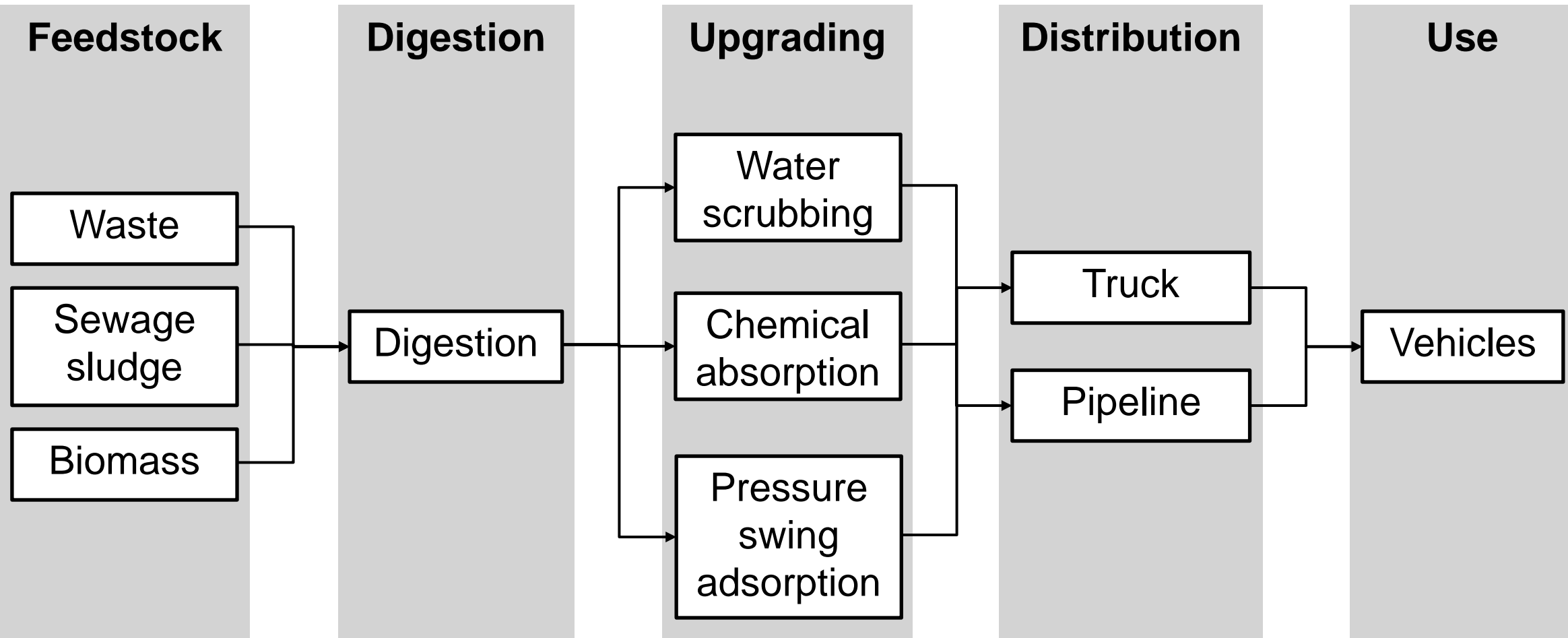
- ▶ Timeframe: 2006 – 2009
- ▶ Coordinator: municipality of Lille, France
- ▶ Partners: Municipalities, companies, research organizations from France, Germany, Italy, Poland, Sweden, Switzerland
- ▶ Total EU grant: ca. €7.5 million

### Aims

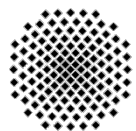
- ▶ Demonstration of biomethane from organic waste as a viable transportation fuel
- ▶ Know-how dissemination and development of local biomethane economies



# Biomethane product system



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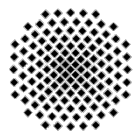
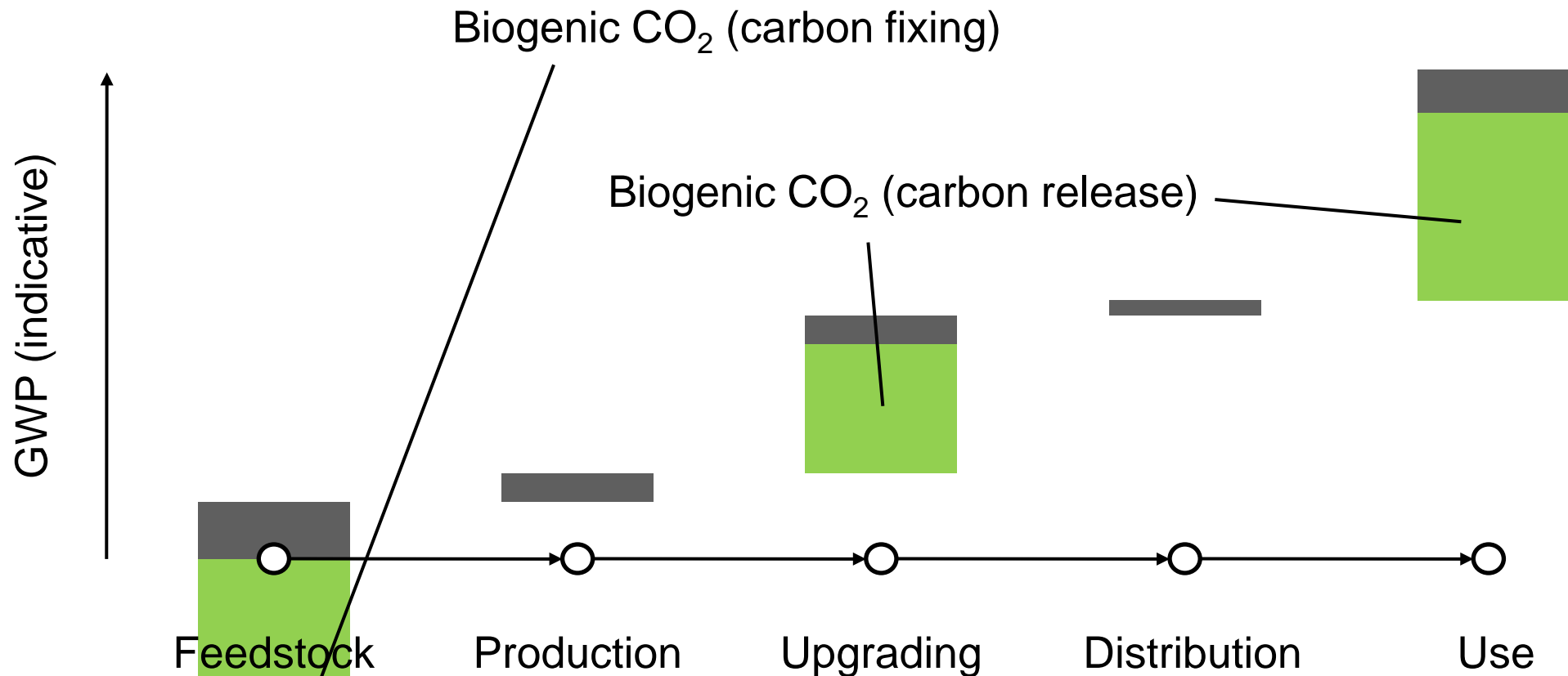
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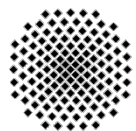
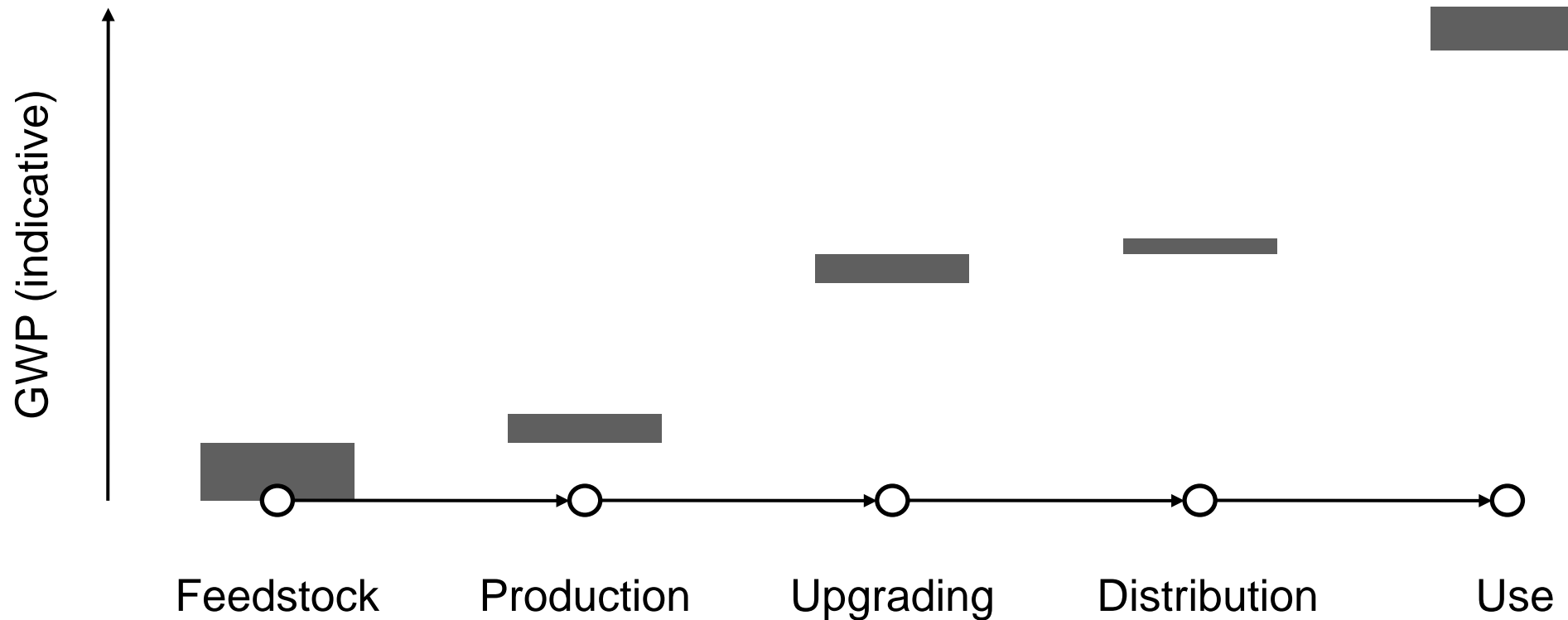
Fraunhofer

IBP

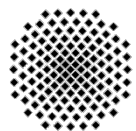
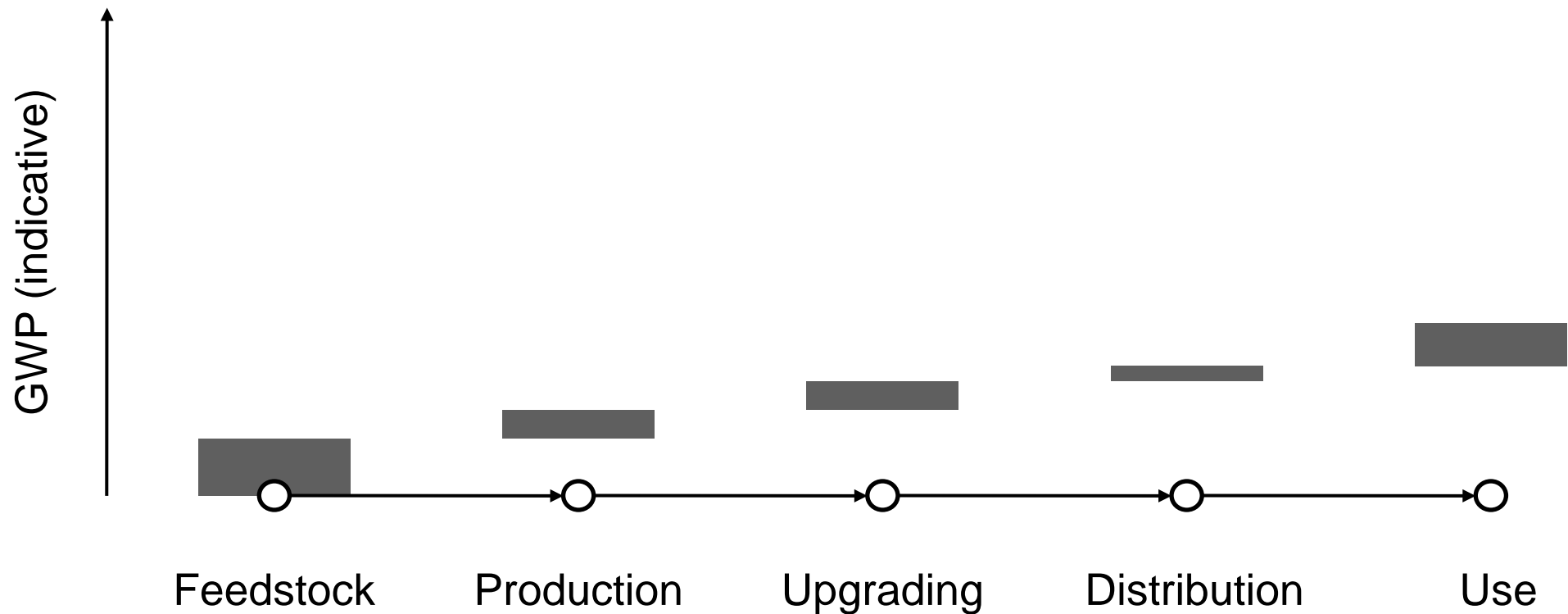
# Results – global warming potential



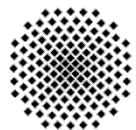
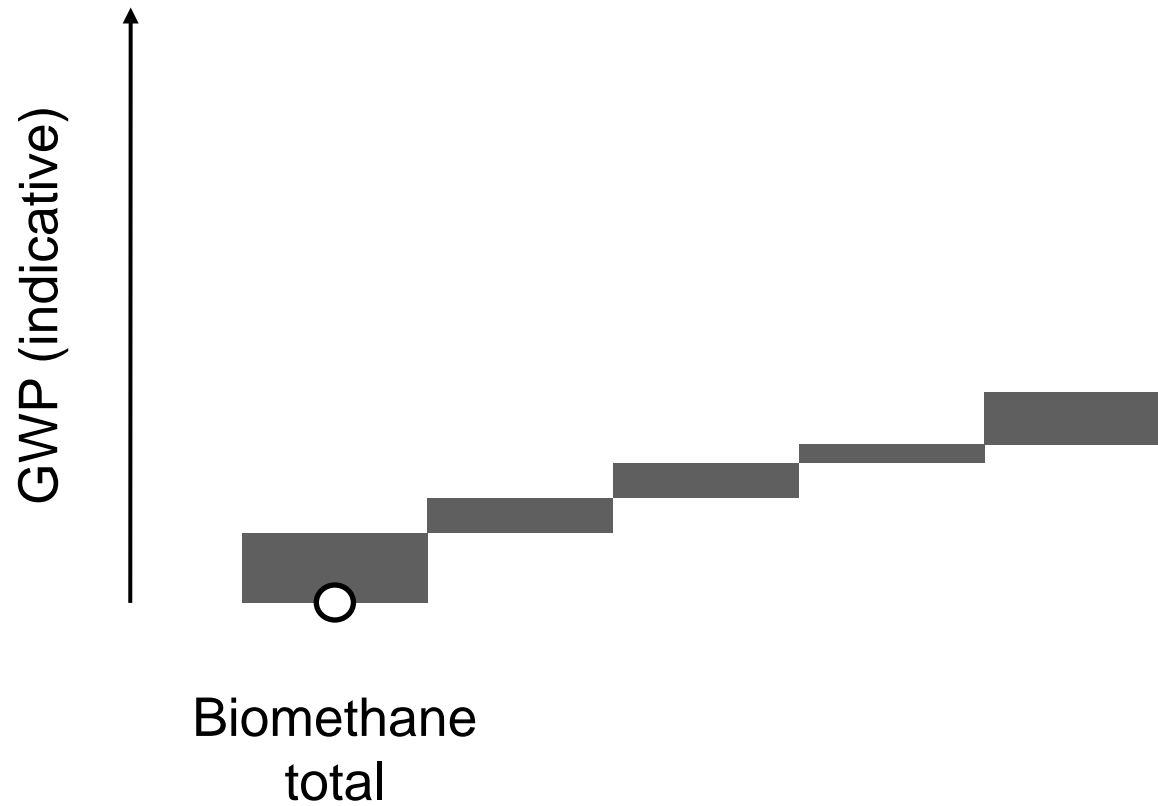
# Results – global warming potential



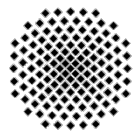
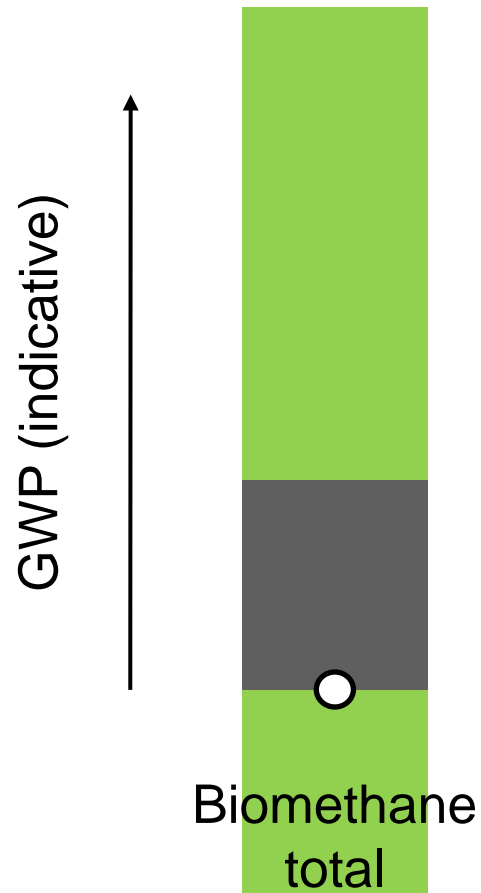
# Results – global warming potential

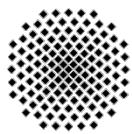
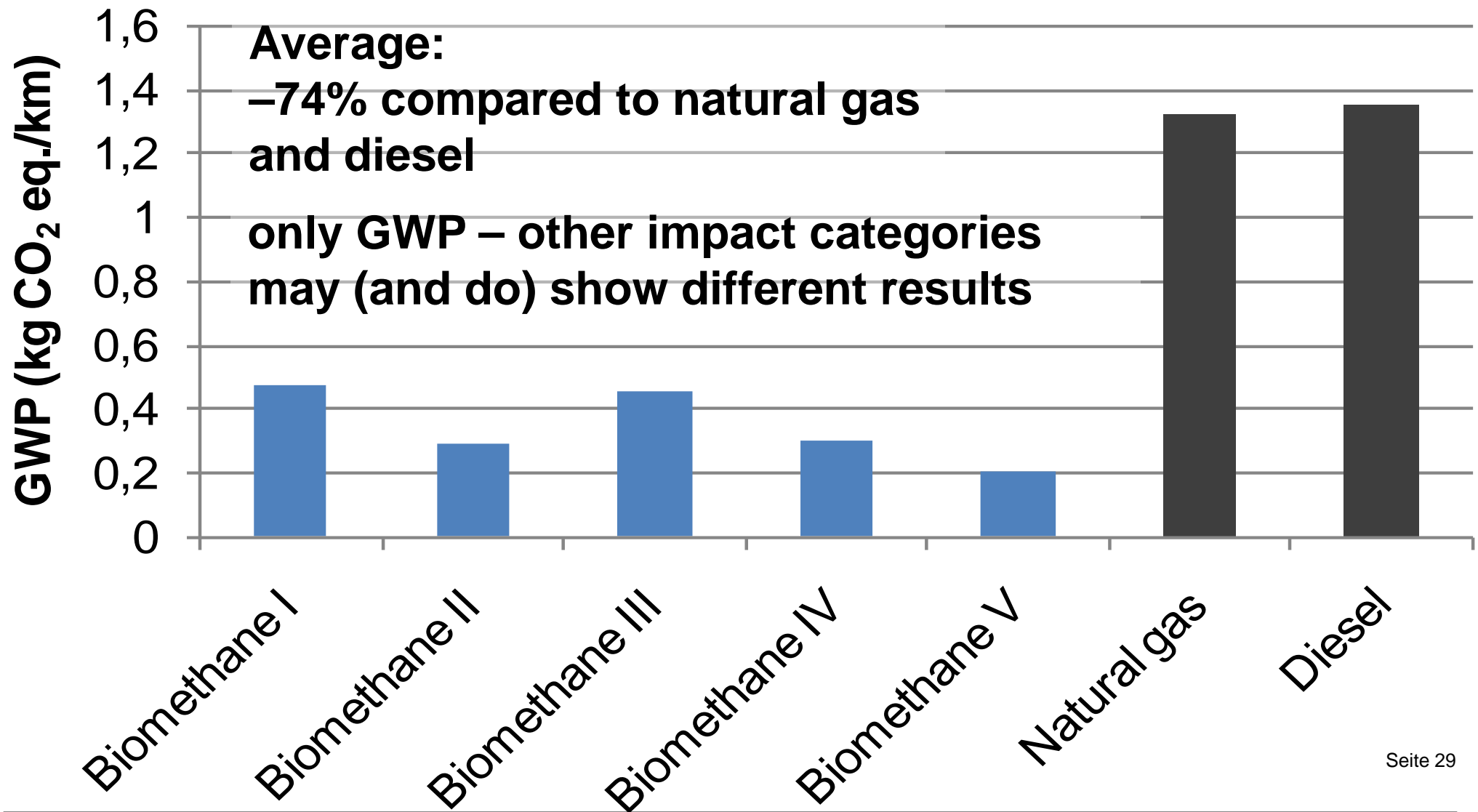


# Results – global warming potential



# Results – global warming potential



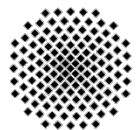


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## **Biomass utilization from a life cycle perspective**

**Global warming potential is fine – what about other impacts?**

Seite 30



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Ganzheitliche Bilanzierung



 **Fraunhofer**  
IBP

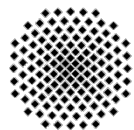
# Characteristics of agrarian systems

## Differences of agrarian systems compared to industrial processes:

- ▶ No technically determined border to the environment
- ▶ Complex and indirect dependence of the output (harvest, emissions) from the input (fertilizers, location conditions, etc.)
- ▶ The variety of different locations, climatic regions etc.
- ▶ Soil variability within and between locations
- ▶ The large amount of farms
- ▶ The variety of agricultural practices
- ▶ Variable weather conditions within and between different years
- ▶ Great variation in pests and parasites, diseases, weeds
- ▶ Different crop rotations (to consider especially in LCAs for annual crops)



Seite 31



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Ganzheitliche Bilanzierung



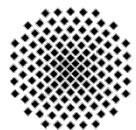
 **Fraunhofer**  
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## The agrarian model in GaBi – overview (1/2)

A model for agrarian and plantation processes was developed and implemented in the GaBi software. This allows the user to effectively meet many of the client needs mentioned earlier.

- ▶ Can model different locations worldwide farming systems; it accounts for
  - ▶ Variations in rainfall and temperature, soil,
  - ▶ Chemical fertiliser and manure use
  - ▶ Use of agrochemicals (pesticides, herbicides, fungicides, etc.)
  - ▶ Mechanical operations (ploughing, seeding, harvesting, irrigation, etc.)



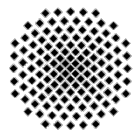
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## The agrarian model in GaBi – overview (2/2)

A model for agrarian and plantation processes was developed and implemented in the GaBi software. This allows the user to effectively meet many of the client needs mentioned earlier.

- ▶ Covers a range of environmental issues
  - ▶ Considers land use changes (deforestation, slash and burn)
  - ▶ Carbon sequestration (the carbon balance is properly assessed)
  - ▶ Covers impacts such as eutrophication, which play a major role in agricultural production systems
- ▶ The model is technically robust and comprehensive; accounting for
  - ▶ all renewable energy in the biomass (particularly relevant for crops grown for energy)
  - ▶ emissions from erosion, fire clearing and background emissions (soil emissions that would occur whether a crop was planted or not)
  - ▶ the balance of nutrient transfers within crop rotations and the use of cover crops

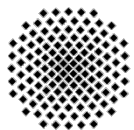
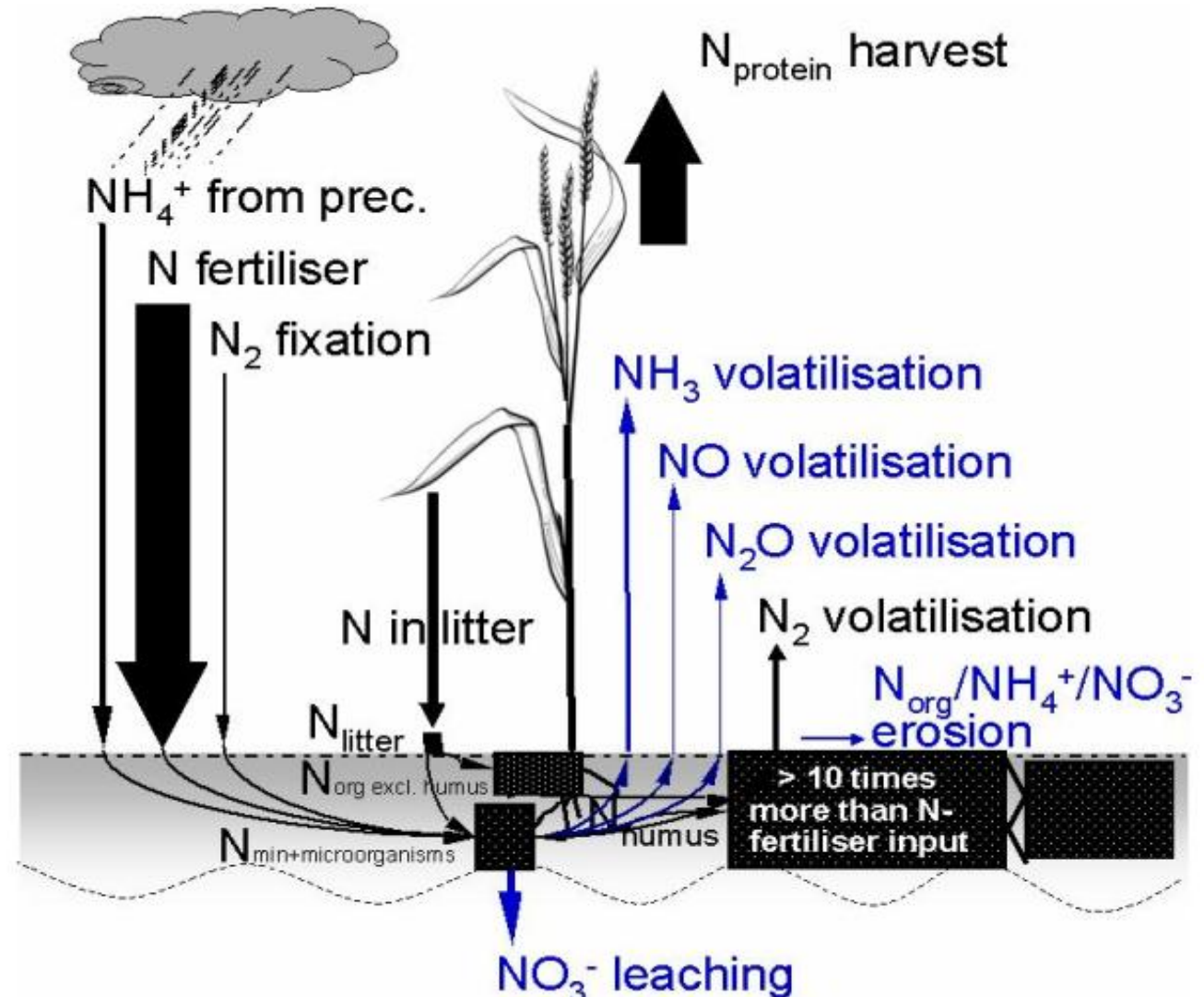
Seite 33



# The agrarian model in GaBi – nitrogen cycle

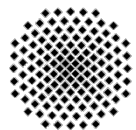
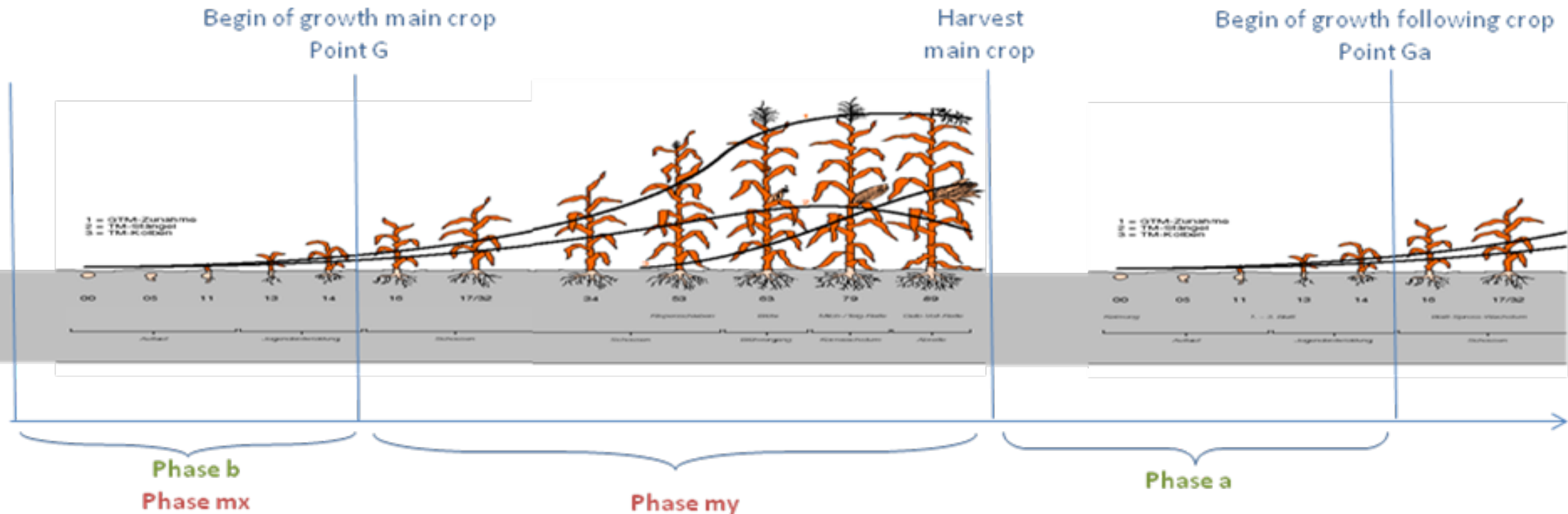
- ▶ The model also accounts for **the nitrogen cycle**: This is the most complex aspect of the model and affects a number of key emissions having environmental relevance in most LCA studies including  $\text{NO}_3^-$  in water and  $\text{N}_2\text{O}$ ,  $\text{NO}$  and  $\text{NH}_3$  into air

- Many forms of N involved
- N-based emissions affect several important impact categories
- Small differences of inputs can lead to large variations in LCA-relevant emissions and outputs
- Important balance numbers are known only imprecisely



# The agrarian model in GaBi – growth cycle

- ▶ The model also accounts for **time dependent features** such as rainfall and fertiliser application during parts of the plant growth cycle





Ga

GaBi 4  
Database Edit Extras View Help

Rapeseed Methylester\_RME\_[Balances] -- Bilanz

Object Edit View Tools Help

Name Rapeseed Methylester (RME) Rows 2 Columns Alle agg.

Quantity Weighting  Quantity view Unit Normalization  In/out aggregation Relative contribu

CML2001 - Nov. 09, Global Warming Potential (GWP 100 ye) kg CO2-Equiv. not filtere

LCA LCC LCWE

Inputs  Just elementary flows  separate IO tables Diagram -

	DE: Rapeseed
<b>Flows</b>	<b>100 %</b>
<b>Resources</b>	<b>100 %</b>
<b>Material resources</b>	<b>100 %</b>
<b>Renewable resources</b>	<b>100 %</b>
Carbon dioxide	100 %

Outputs Diagram -

	DE: Rapeseed
<b>Flows</b>	<b>100 %</b>
<b>Emissions to air</b>	<b>100 %</b>
<b>Inorganic emissions to air</b>	<b>90,3 %</b>
Carbon dioxide	51,8 %
Carbon dioxide (biotic)	0,0741 %
Nitrous oxide (laughing gas)	38,4 %
Sulphur hexafluoride	1,87E-006 %
<b>Organic emissions to air (group VOC)</b>	<b>9,7 %</b>
<b>Group NMVOC to air</b>	<b>0,0113 %</b>
Methane	9,69 %
VOC (unspecified)	0,000133 %

System: Changed. Last change: System, 13.12.2011 06:46:13

Contacts technology mix | production mix, at producer  
Projects

DE Hemp short fibre agg PE 31.07.2010

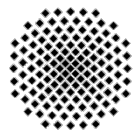
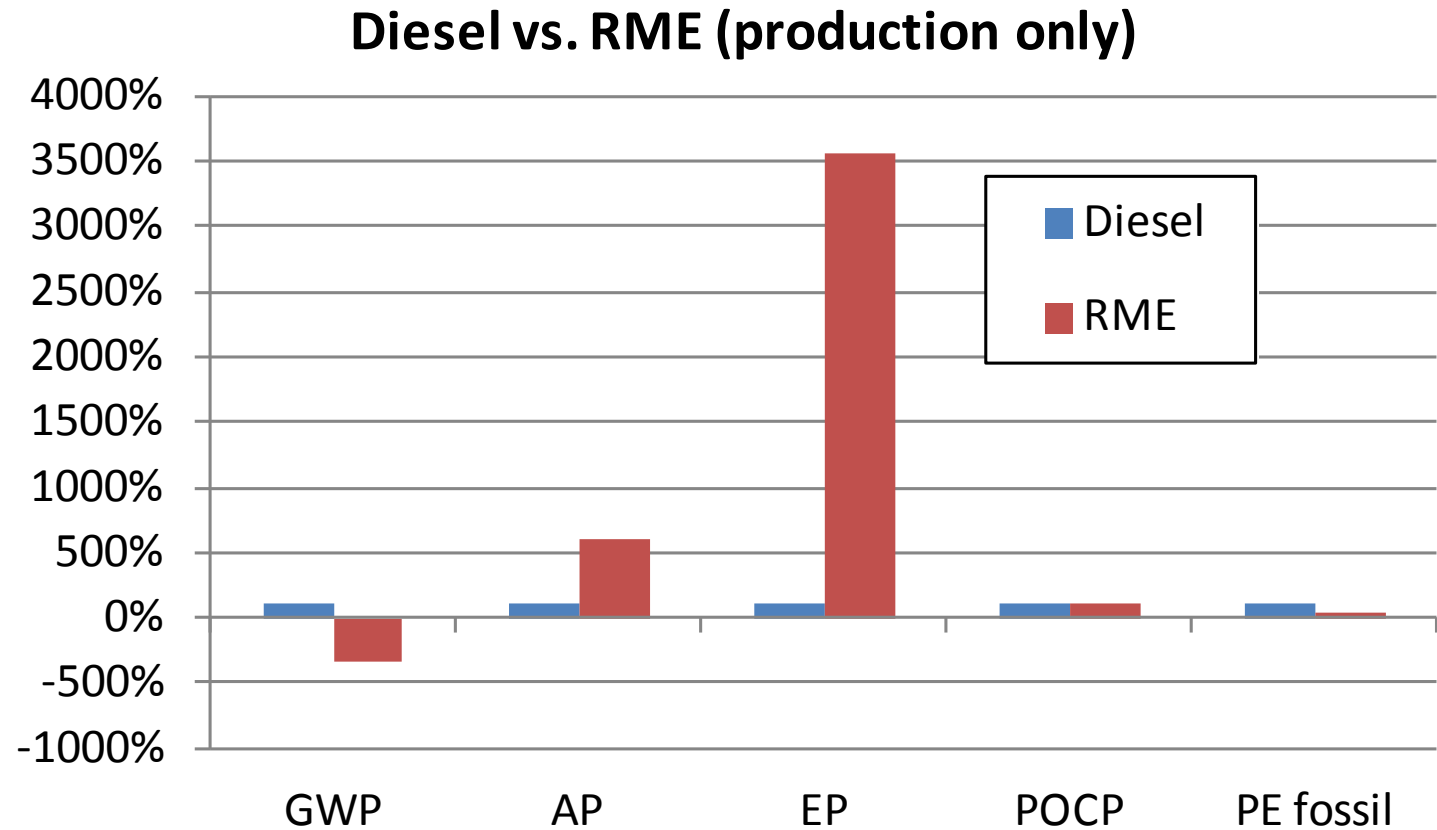
System: No project

site 37

er  
IBP

# GaBi dataset example – other impact categories

Production	Diesel	RME
GWP	100%	-347%
AP	100%	607%
EP	100%	3551%
POCP	100%	118%
PE fossil	100%	29%

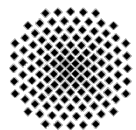


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# Biomass utilization from a life cycle perspective

## Land use impacts

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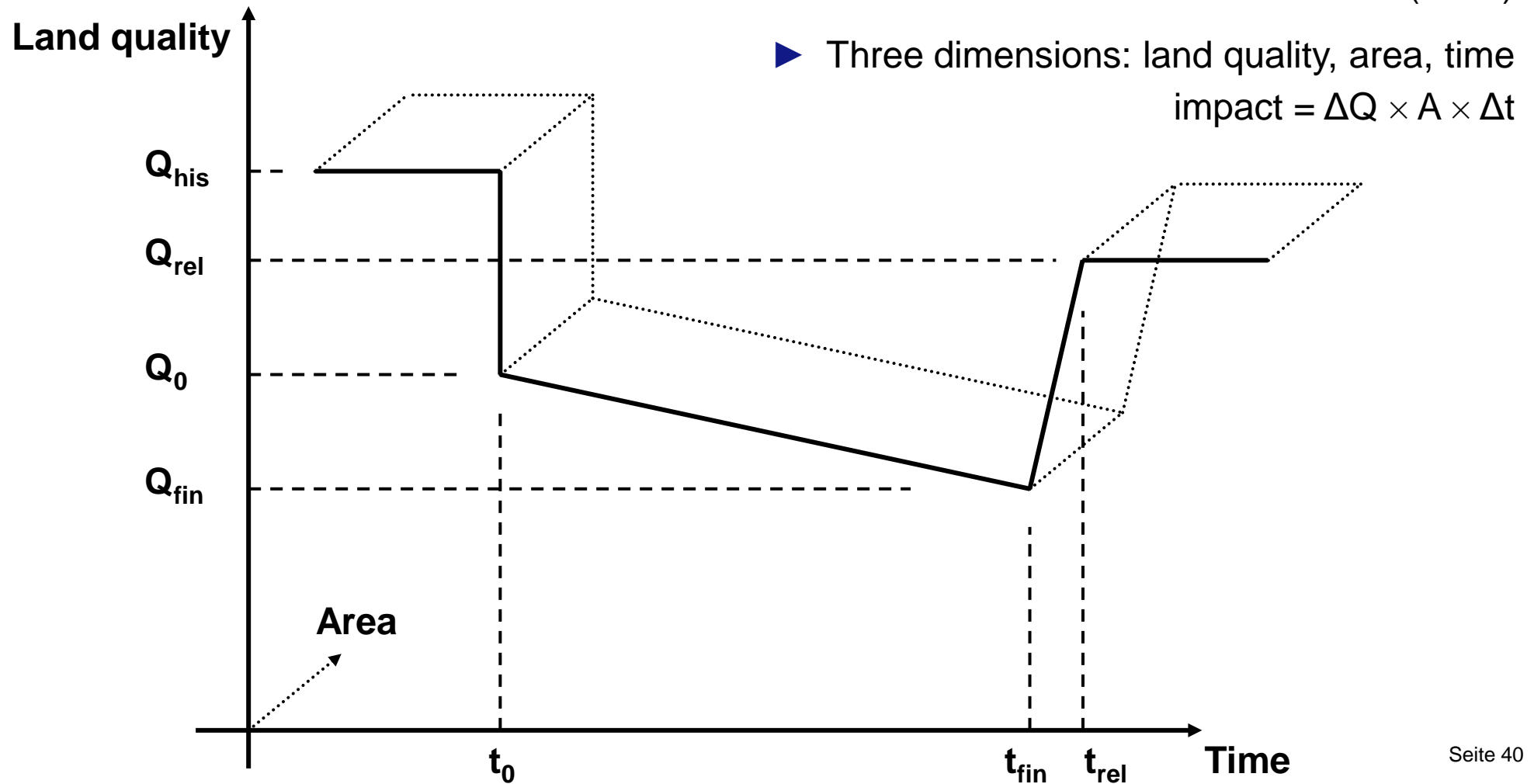
Ganzheitliche Bilanzierung



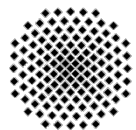
 **Fraunhofer**  
IBP

# Land use in LCA

- ▶ Framework by UNEP-SETAC Life Cycle Initiative  
Milà i Canals et al. (2007)



Seite 40



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Ganzheitliche Bilanzierung



Fraunhofer

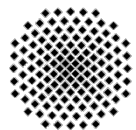
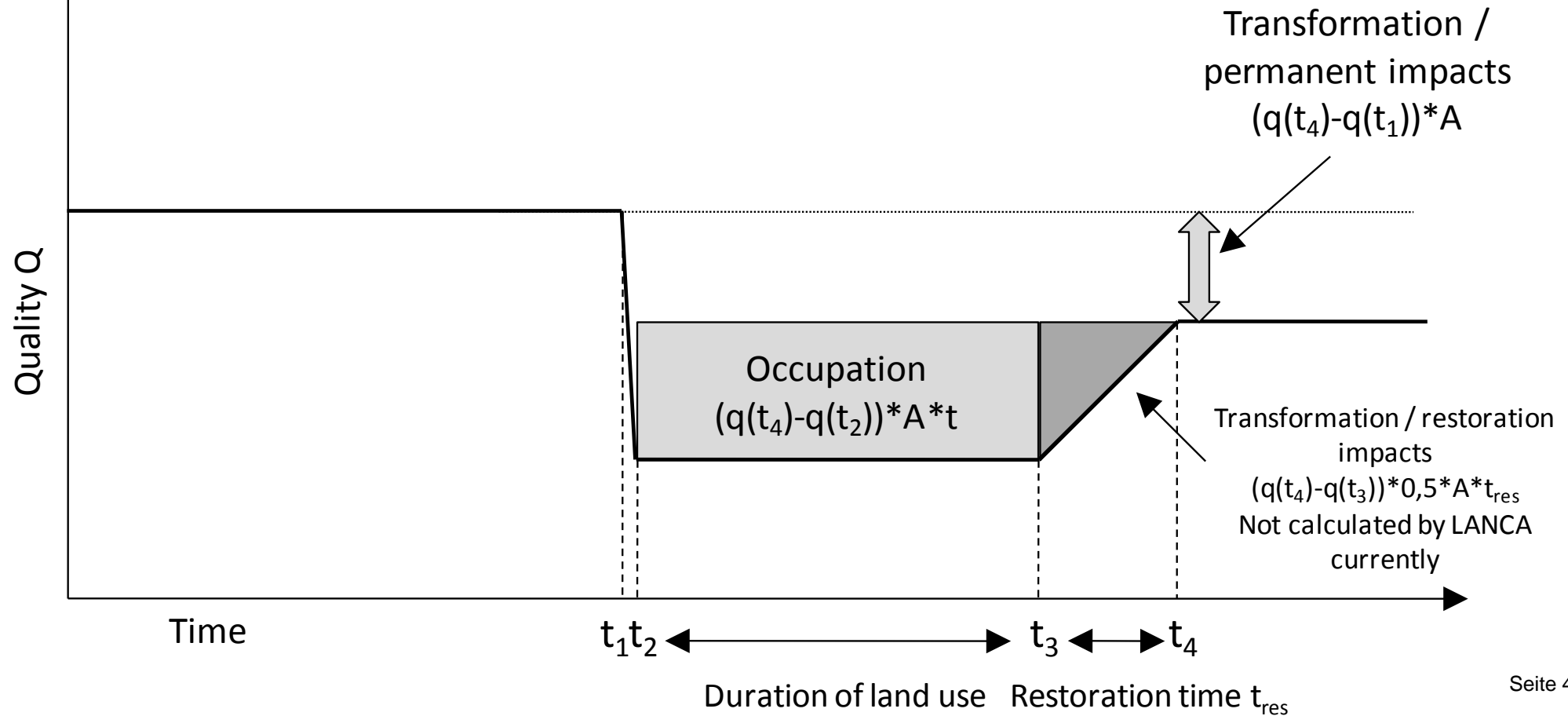
IBP

# LANCA<sup>®</sup> Framework

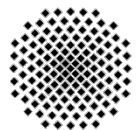
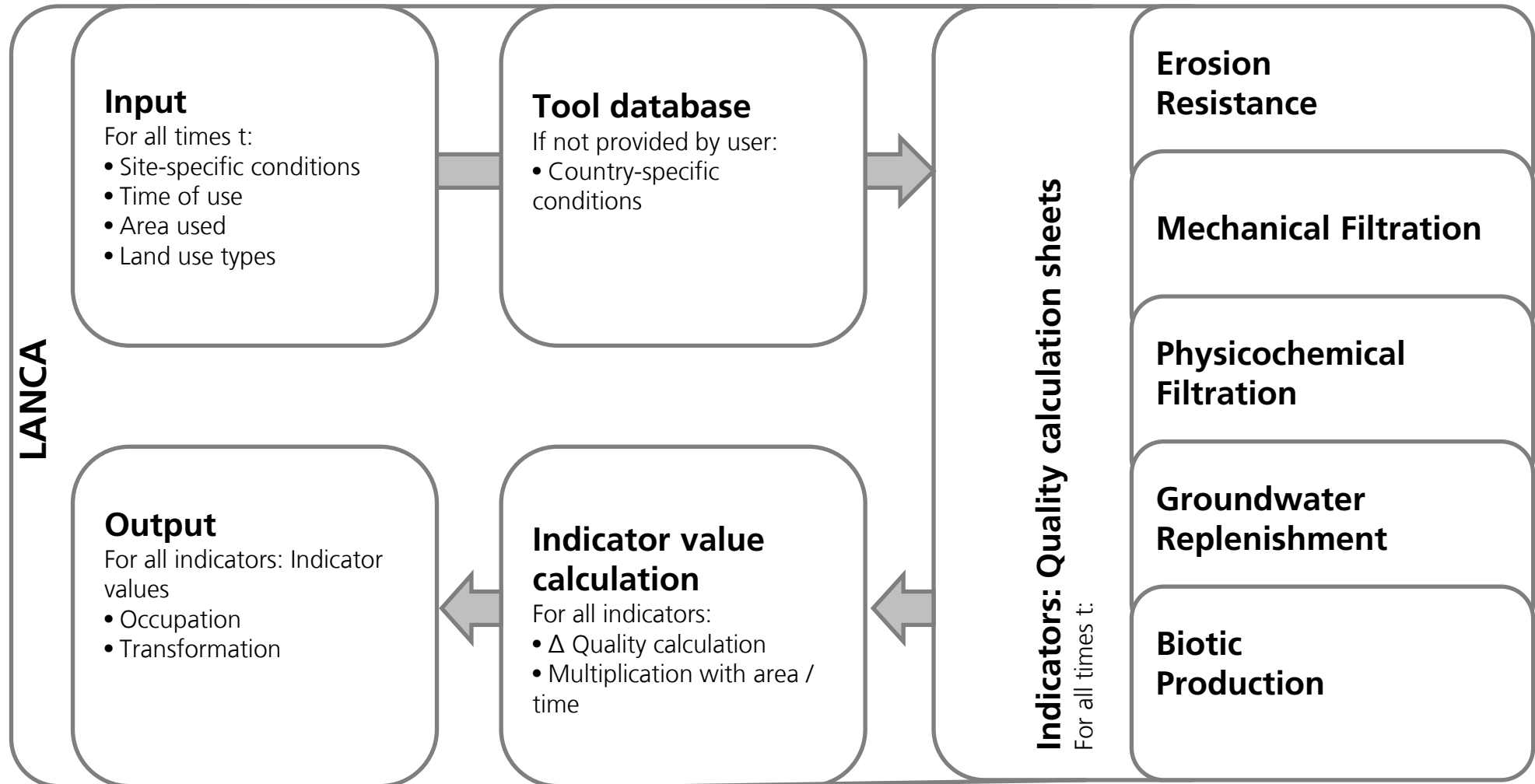
## Occupation and Transformation

Occupation indicator values =  $(Q(t_4) - Q(t_2)) * \text{area} * \text{time of occupation}$

Transformation indicator values =  $(Q(t_4) - Q(t_1)) * \text{area}$



# LANCA<sup>®</sup> Framework



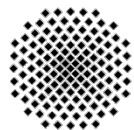
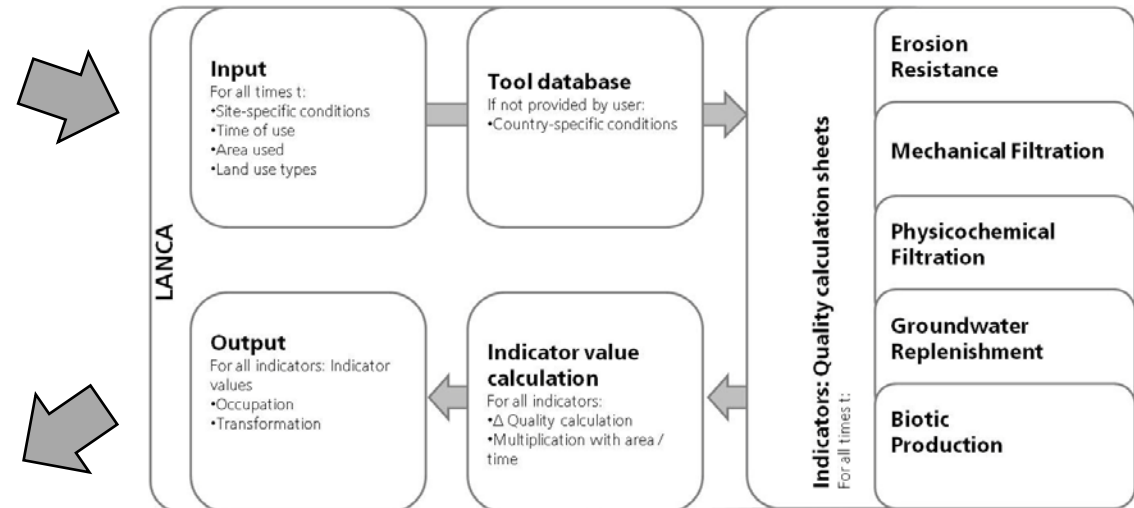
# LANCA® Framework

Site-specific input data, e.g.

- Soil texture
- Distance between surface and groundwater
- Land use type → degree of sealing

Duration of land use  
Area

Aggregable Indicator values  
included in  
GaBi software as „indicator value  
flows“ = characterized values



Ga

GaBi 4  
Database Edit Extras View Help

Object Edit View Tools Help

Rapeseed Methylester\_RME\_ - Balance view: Standardbilanz\_111212 -- Balance

Name Rapeseed Methylester (RME) Rows 2 Columns All agg. < ▾

Quantity Weighting  Quantity view Unit Normalization Absolute values ▾

Mass [kg] kg not filtered ▾

LCA LCC LCWE

Inputs/Outputs  Just elementary flows  separate IO tables Diagram -

	DE: Rapeseed
<b>Quantities</b>	
<b>Environmental quantities</b>	
<b>Land use quantities</b>	
Biotic Production Indicator (BP (Occ.)) [kg]	1,2077E-006
Biotic Production Indicator (BP (Transf.)) [kg/a]	6,0377E-007
Erosion Resistance Indicator (ER (Occ.)) [kg]	2,2695E-005
Erosion Resistance Indicator (ER (Transf.)) [kg/a]	-6,8905E-008
Groundwater Replenishment Indicator (GWR (Occ.)) [mm²m²]	0,00054018
Groundwater Replenishment Indicator (GWR (Transf.)) [(mm²m²)/a]	-0,00012772
Mechanical Filtration Indicator (MF (Occ.)) [cm³m³]	0,048486
Mechanical Filtration Indicator (MF (Transf.)) [cm³m³/d]	-6,8769E-006
Physicochemical Filtration Indicator (PCF (Occ.)) [(cmol²m²a)/kg]	2,7439E-005
Physicochemical Filtration Indicator (PCF (Transf.)) [(cmol²m²)/kg]	-1,3202E-006

System: Changed. Last change: System, 13.12.2011 07:24:02

technology mix | production mix, at producer

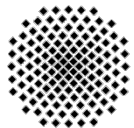
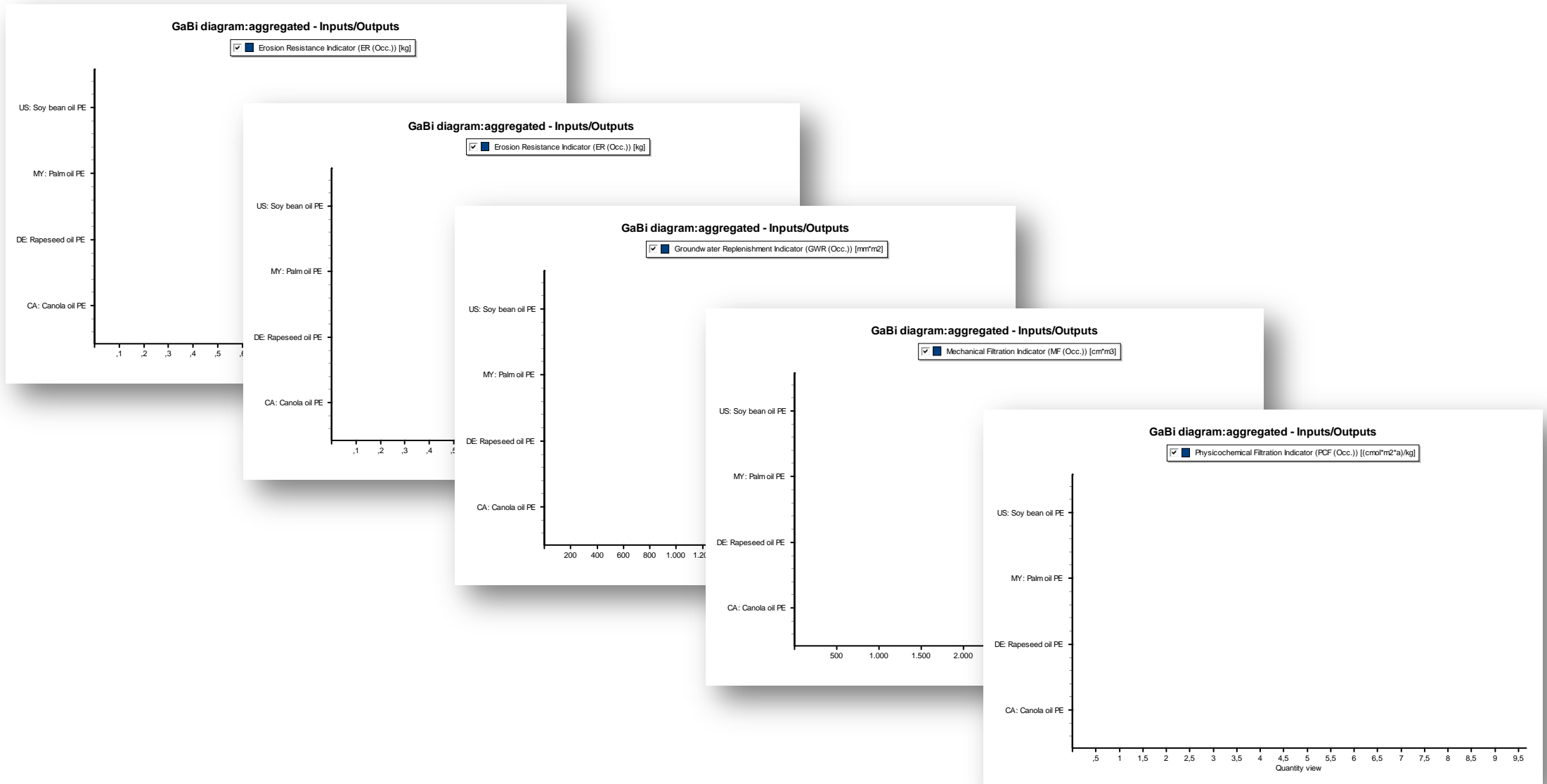
DE Hemp short fibre agg PE 31.07.2010

System: No project

site 44

er  
IBP

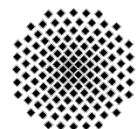
# GaBi dataset with land use quantities



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# Summary

- ▶ Biofuels/biomaterials are interesting because of the carbon balance
  - GWP tends to be low compared to fossil-based fuels/materials
  - Pay attention to cultivation, conversion steps
- ▶ Modelling plant cultivation is challenging
  - Agronomic parameters
  - Nitrogen balance
- ▶ LCA community is just starting to get a grip on land use
  - Structural changes to soil and landscape



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# Contact

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