# ENVIRONMENTAL IMPACTS OF BIOMASS CONVERSION BY INSECTS: LIFE CYCLE ASSESSMENT PERSPECTIVE

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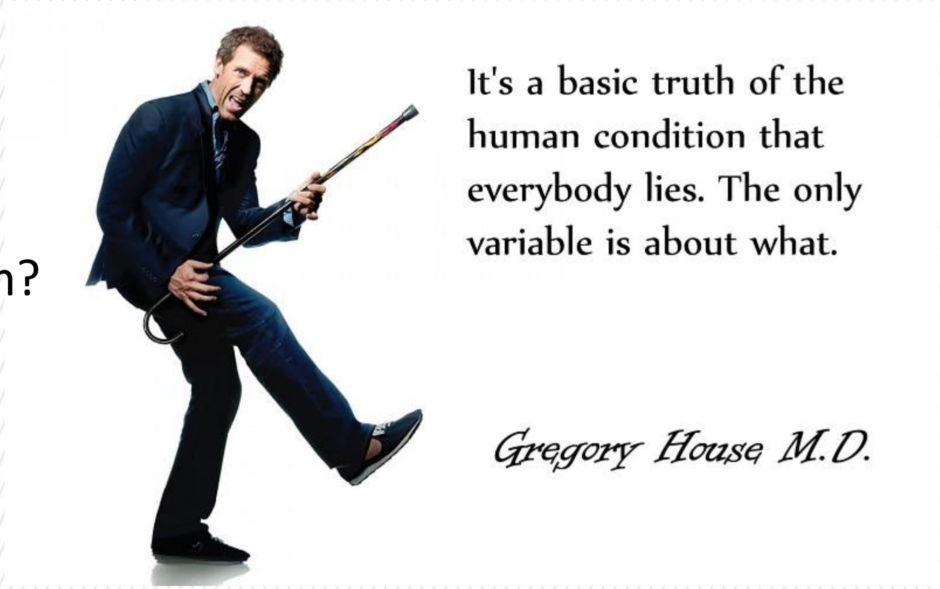
# LCA Perspective

- Are insects really sustainable?
- Can they make a difference…
  … in the complex food system?
- What are the strategies
  to deal with them?



# OVERVIEW
## FACTS & FIGURES

FOUNDED **1983**

MEMBERS **175**

EMPLOYEES **200**

LOCATIONS
- **QUAKENBRÜCK (GER)**
- **BERLIN (GER)**
- **KARLSRUHE (GER)**
- **BRUSSELS (BEL)**

LEGAL STATUS
**REGISTERED ASSOCIATION**

DIRECTOR
**DR. VOLKER HEINZ**

MISSION
**KNOWLEDGE FOR SUPERIOR FOODS**

# MEMBERS

# ORGANIZATION
## RESEARCH & BUSINESS DIVISIONS

# DIL FOOD TECH

**44**

national and international research projects, allowing research expenses of 12 mllions euro from 2014 to 2020

**9000m²**

research- and workspace dedicated tot he development of new foods methods and technologies

**2010**

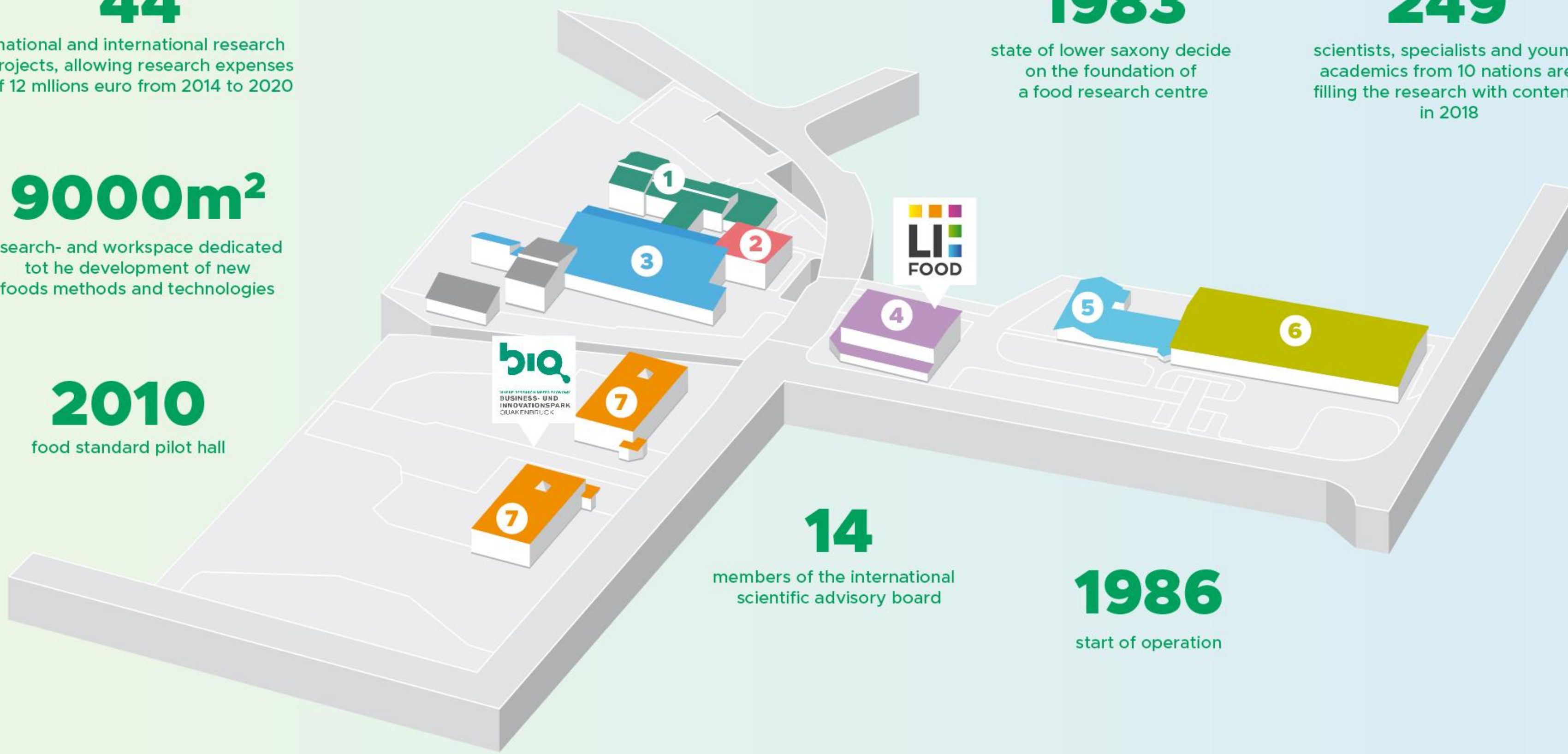
food standard pilot hall

**1983**

state of lower saxony decide on the foundation of a food research centre

**249**

scientists, specialists and young academics from 10 nations are filling the research with contents in 2018




**14**

members of the international scientific advisory board

**1986**

start of operation

1 CEO and Business Management
Network Coordination
Food Data Group

2 Food Safety
Chemical Analysis Laboratories
Microbiological Analysis Laboratories
Quality Management

3 Equipment Design
Chemical Analytics

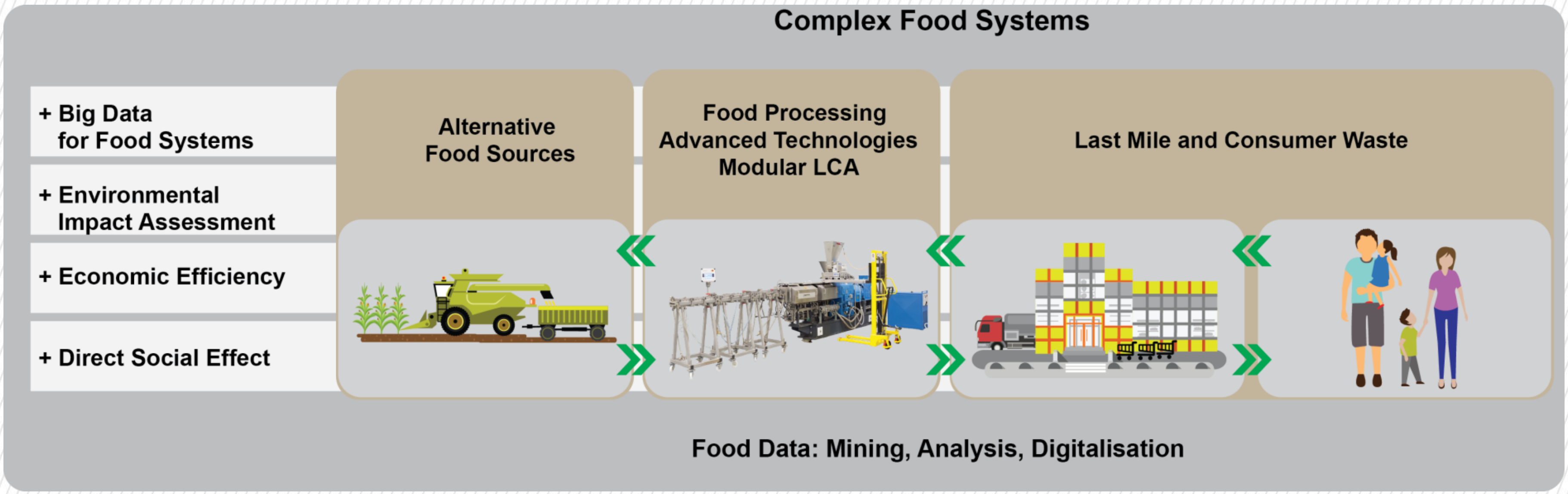
4 LI Food Office
Automation Technology
Petfood and Feed Technology

5 Centre of Food Physics
Structure and Functionally

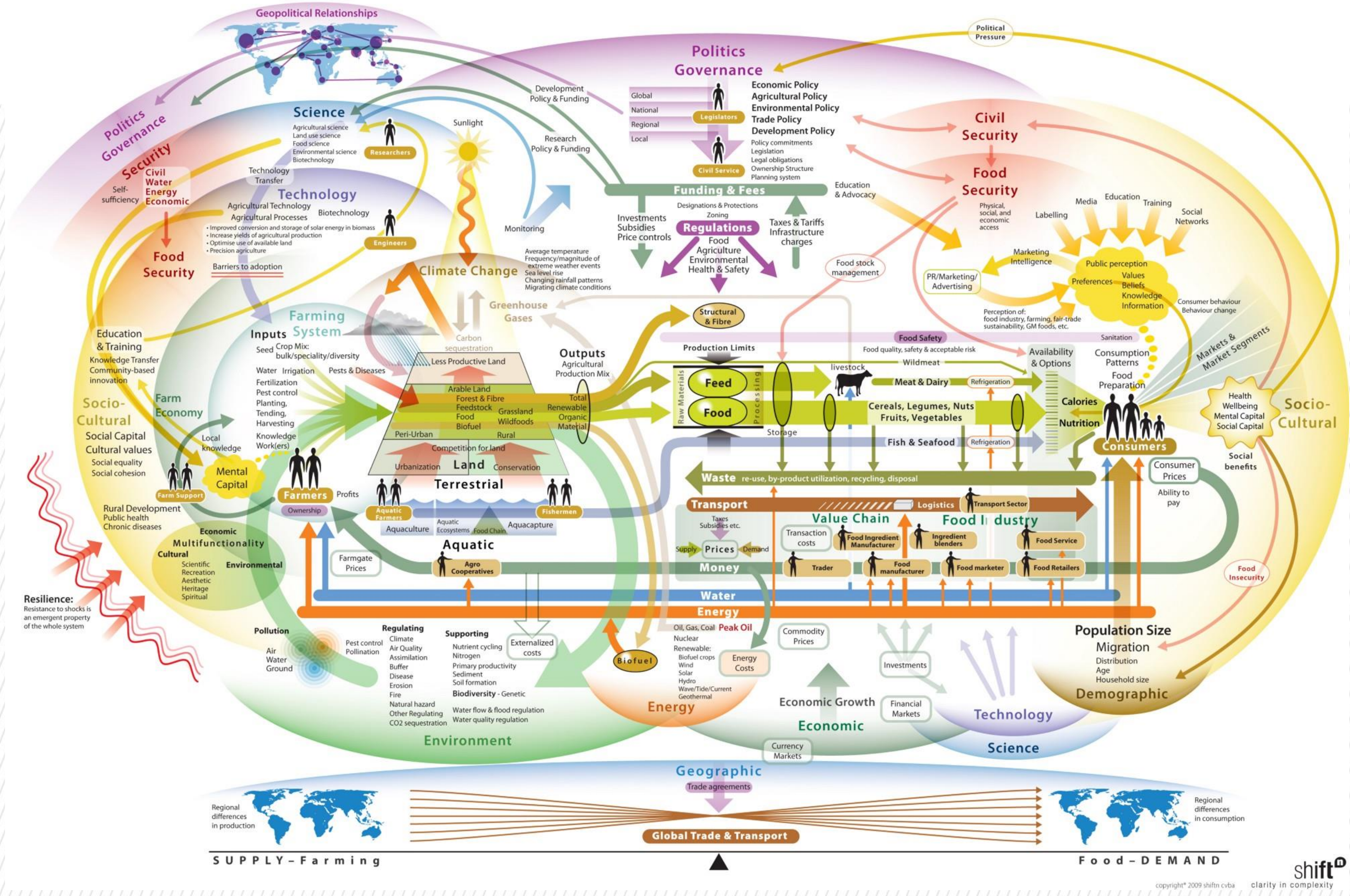
6 Pilot Hall
Biotechnology
High Pressure Application Center
Advanced Technology
Process Technology
Product Innovation
Meat Technology

7 Business and Innovation Park
Quakenbrück (BIQ)
Start-up Campus

# Research and development areas



# Complex food systems




Sergiy Smetana | DIL e.V.

# SYSTEM CHANGE ?

## SUSTAINABLE TRANSITION


Image after Banksy

LCA FOOD 2020

DIL

# LIFE CYCLE ASSESSMENT

**Main Objective**

Estimate sustainability degree of technologies and products in environmental perspective

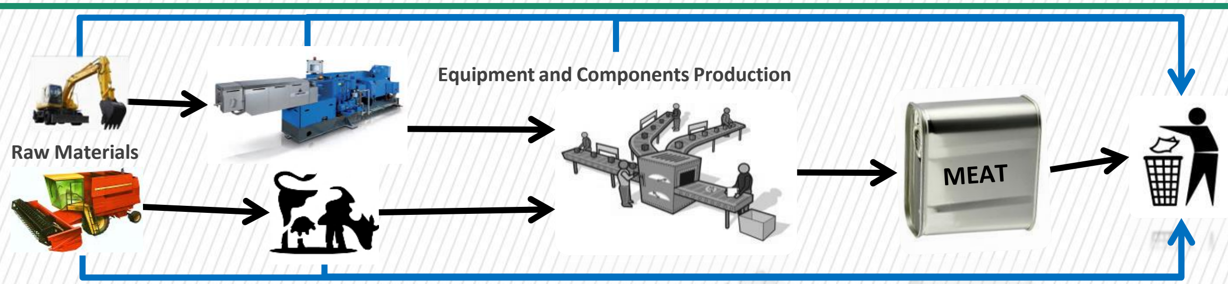
**Basis**

Life Cycle Thinking

ISO

DIN

ISO DN 14040-14044




SimaPro

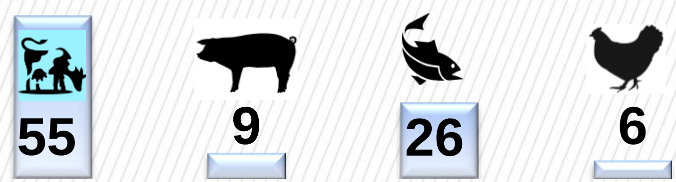
**Results**

Inventory and Analysis


Technologies and Products
Comparative Possibilities

Sustainable Degree of Product, Pt

1 t of Meat/Fish




Impact Categories

- Climate Change
- Human Health
- Resource Depletion
- Ecosystem Quality
- Land Use
- Water Use
- Acidification
- Eutrophication
- Minerals Use
- Fossil Fuel Use
- Carcinogens ...

**Consumer benefits**

Quantified Data

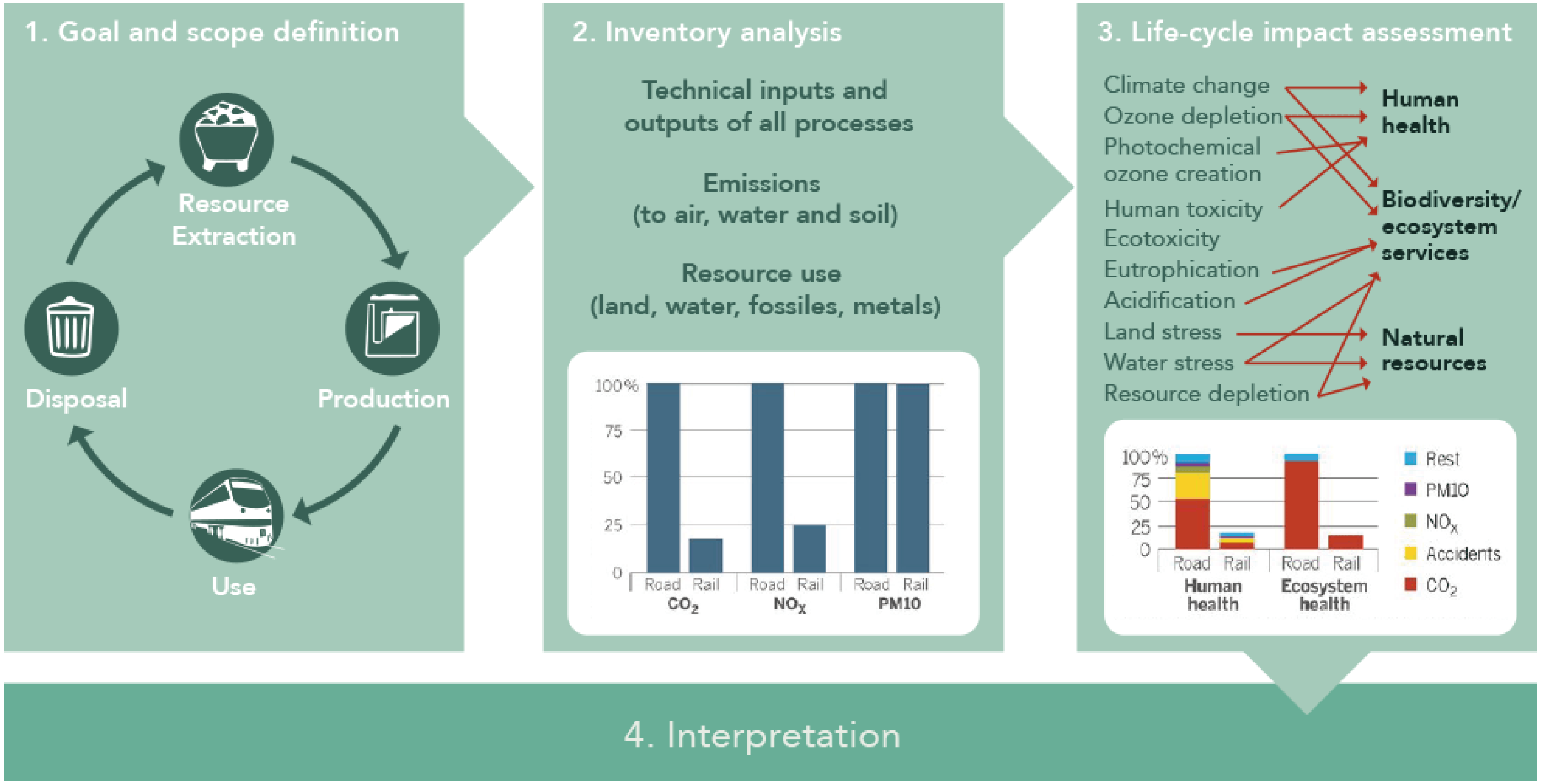
More Sustainable Equipment Selection
Product Sustainability Determination
Environmental Labeling
Technologies Improvement
Food Innovation

More efficient, less
harmful and less resource
consuming products

PEF

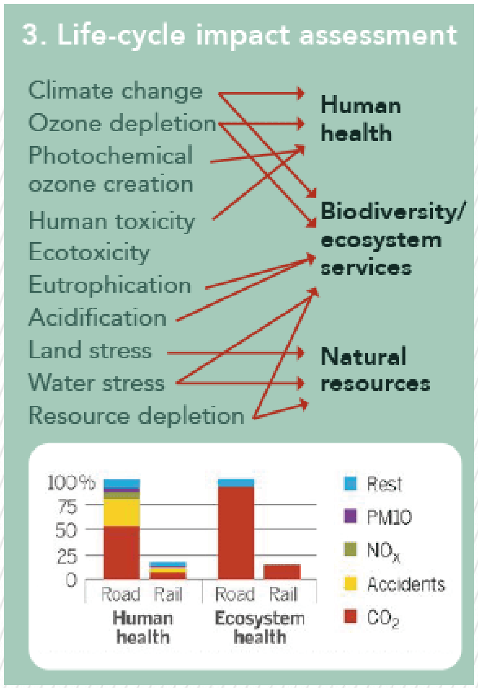
European Commission

# LIFE CYCLE ASSESSMENT




Adapted from Hellweg & Milà i Canals (2014)

# LIFE CYCLE ASSESSMENT

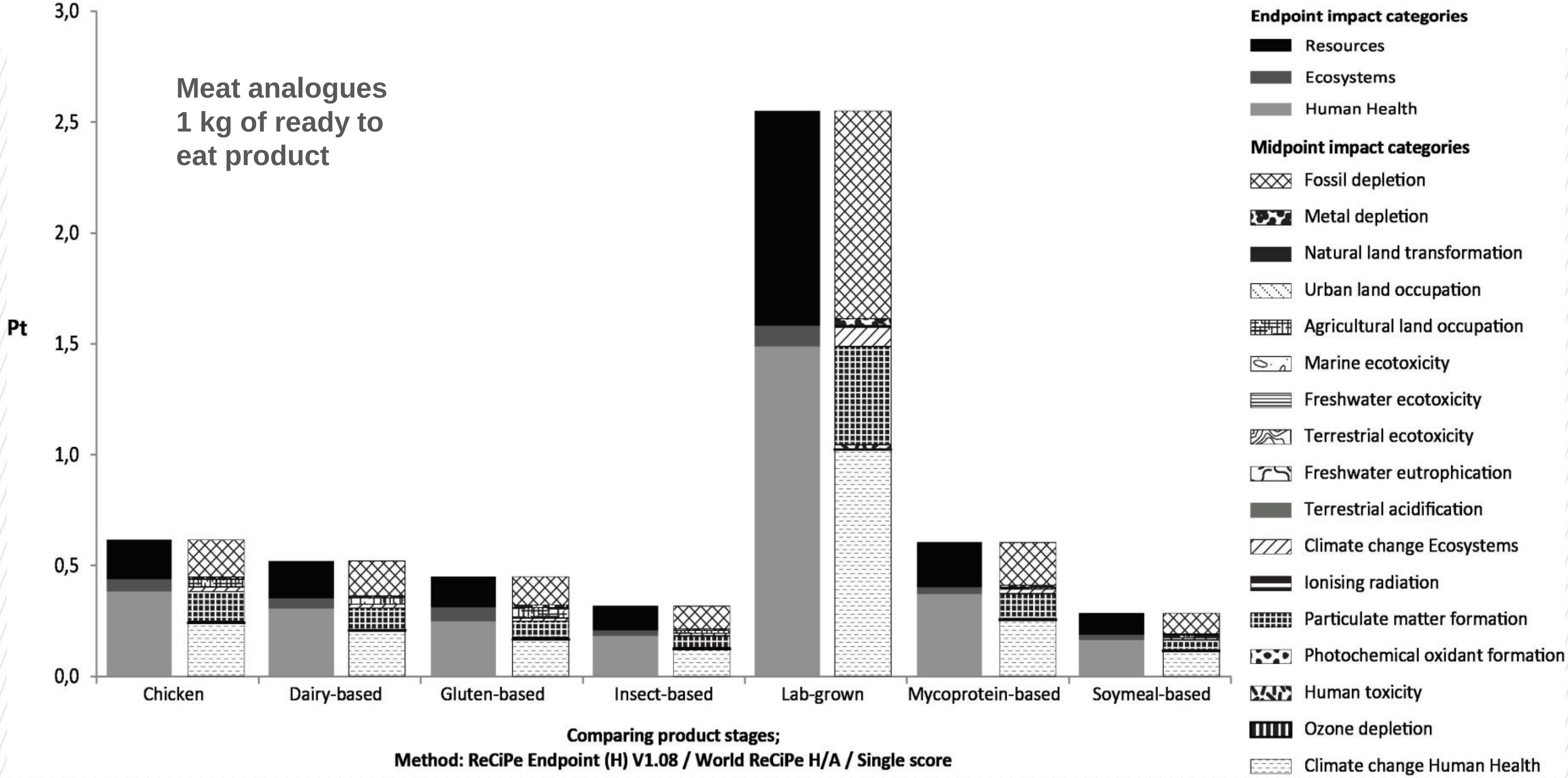



- **Characterization model selection**:
  - TRACI 2.1, IMPACT 2002+, eco-indicator 99,…
- **Impact category selection**:
  - GWP, AP, EP, ETP, HHNCP, HHCP HHCAP, ODP, SCP
- **Category indicator selection**:
  - kg $CO_2$-eq for GWP, kg $SO_2$-eq for AP, kg N-eq for EP, etc…
- **Classification**:
  - $NH_3$ (Ammonia) → Acidification, HH Particulates, Eutrophication
- **Characterization**:
  - Acidification: $(x\ kg\ NH_3\ released)\left(\frac{1.88\ kg\ SO_2-eq}{kg\ NH_3}\right) = 1.88x\ kg\ SO_2 - eq$
  - Particulates: $(x\ kg\ NH_3\ released)\left(\frac{0.067\ kg\ PM_{2.5}-eq}{kg\ NH_3}\right) = 0.067x\ kg\ PM_{2.5} - eq$
  - Eutrophication: $(x\ kg\ NH_3\ released)\left(\frac{0.12\ kg\ N-eq}{kg\ NH_3}\right) = 0.12x\ kg\ N - eq$

Repeat for each flow, sum results in each impact category

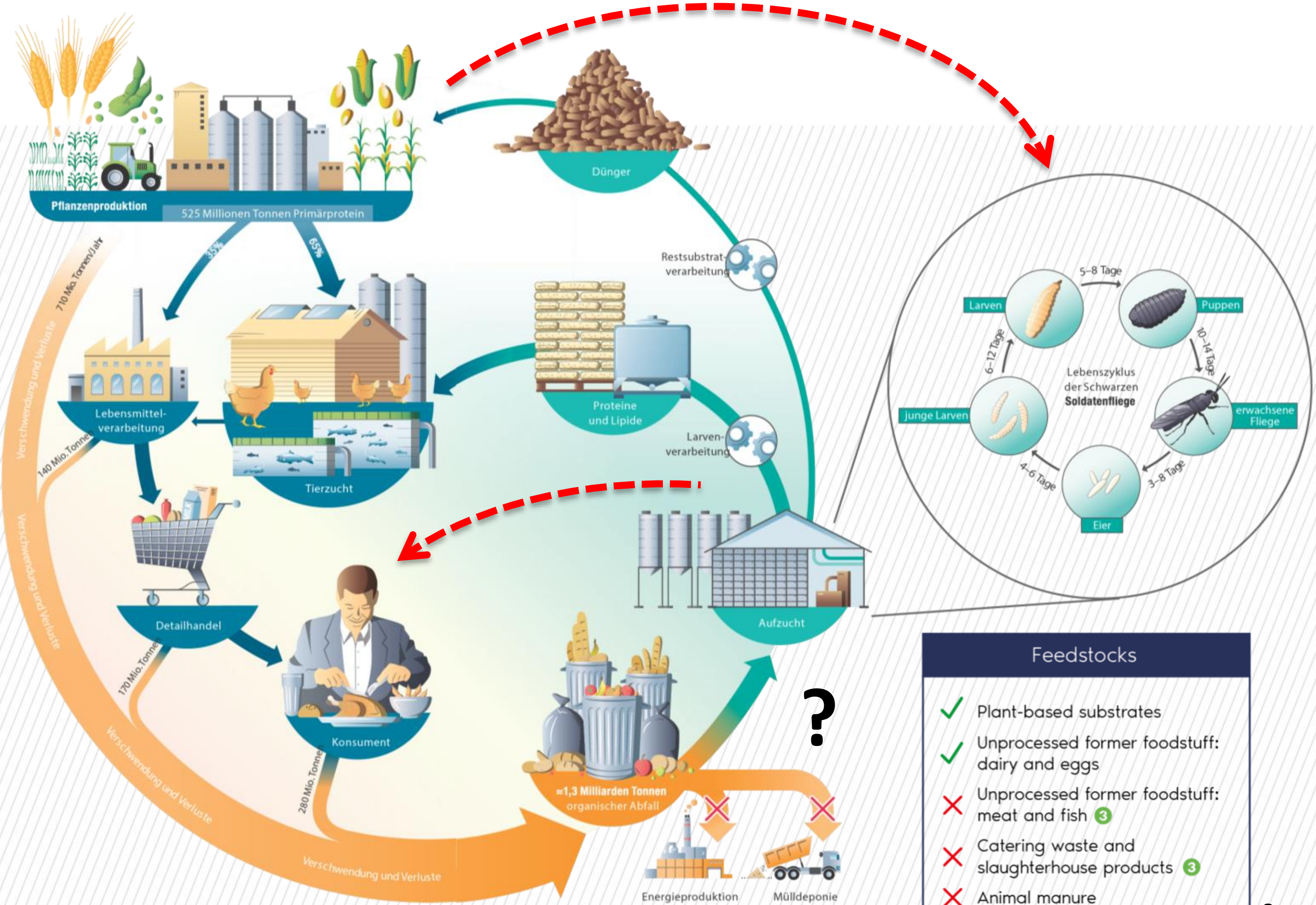
**Characterization factor**

# ENVIRONMENTAL IMPACT




Smetana et al., 2015

# INSECTS and FEED-FOOD SYSTEM




**Feedstocks**

- ✓ Plant-based substrates
- ✓ Unprocessed former foodstuff: dairy and eggs
- ✗ Unprocessed former foodstuff: meat and fish ❸
- ✗ Catering waste and slaughterhouse products ❸
- ✗ Animal manure

Source: IPIFF, 2019

Adapted from Diagram (2018), Buehler Magazin; Andreas Baumann, Daniel Röttele

# Insect projects in DIL

- “Sustainability transitions in food production: alternative protein sources in socio-technical perspective” supported by Ministry for science and culture of Lower Saxony (Vorab programme) and Volkswagen foundation
- “Application of edible insects in western food products (EntomoFood)” (CORNET AiF 154 EN)
- “Valorisation of agri-food residuals with insect technologies (EntoWaste)” (ERA-NET LAC)
- “SUSINCHAINS” (H2020)

# STUDY

Resources, Conservation & Recycling 144 (2019) 285–296

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ELSEVIER

Full length article

Sustainable use of *Hermetia illucens* insect biomass for feed and food: Attributional and consequential life cycle assessment

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- Type of LCA
- Environmental impacts of intermediate products (feed and food)
- Industrial multi-season data (2015–2017, Protix, Dongen, The Netherlands)
- Identification of potential scenarios for further development
- Market reaction

# TYPE OF LCA

- Attributional (A-LCA) – with economic allocation
- Consequential (C-LCA)

  - LCA standards (ISO 14040, 2006; ISO 14044, 2006)
  - SimaPro v8.2.0.0 (PRé Consultants B.V., Amsterfoort, The Netherlands)
  - adapted ecoinvent 3.1 datasets (ecoinvent, Zurich, Switzerland) and Agri-footprint database (Blonk Consultants, Gouda, The Netherlands)
  - IMPACT2002+ (Jolliet et al., 2003)
  - IMPACT World+Midpoint V0.04 for Water footprint (Boulay et al., 2011)
  - ReCiPe methodology (Goedkoop et al., 2013) for sensitivity analysis
  - Uncertainty analysis (Monte Carlo simulation analysis with 1000 runs performed for mid-point and end-point categories)

Smetana, Schmitt, Mathys, 2019

# C-LCA

Purpose – make decisions between scenarios for:

1. application of protein-rich side-streams of food processing for *H. illucens* diets (with increased demand for other protein feed sources)
2. potential reactions of the market on the increased production of insect meal as a source of feed and food proteins.

Smetana, Schmitt, Mathys, 2019

# C-LCA

Scenarios:

1. the **increase of *H. illucens* production**, with diet based on side-streams from alcohol and beer production, will trigger **the increase in the need to produce other commercial sources of feed for other animals** (cattle, pigs and poultry), as currently available side-streams are used as a feed for animals (communication to feed experts)

2. **Increased production of BSF** (for food or feed purposes) will generate organic fertilizer, fresh BSF puree and protein concentrate, thus **reducing the demand for analogous products on the market** (organic fertilizer, chicken meat, feed protein ingredients).

Smetana, Schmitt, Mathys, 2019

# FU

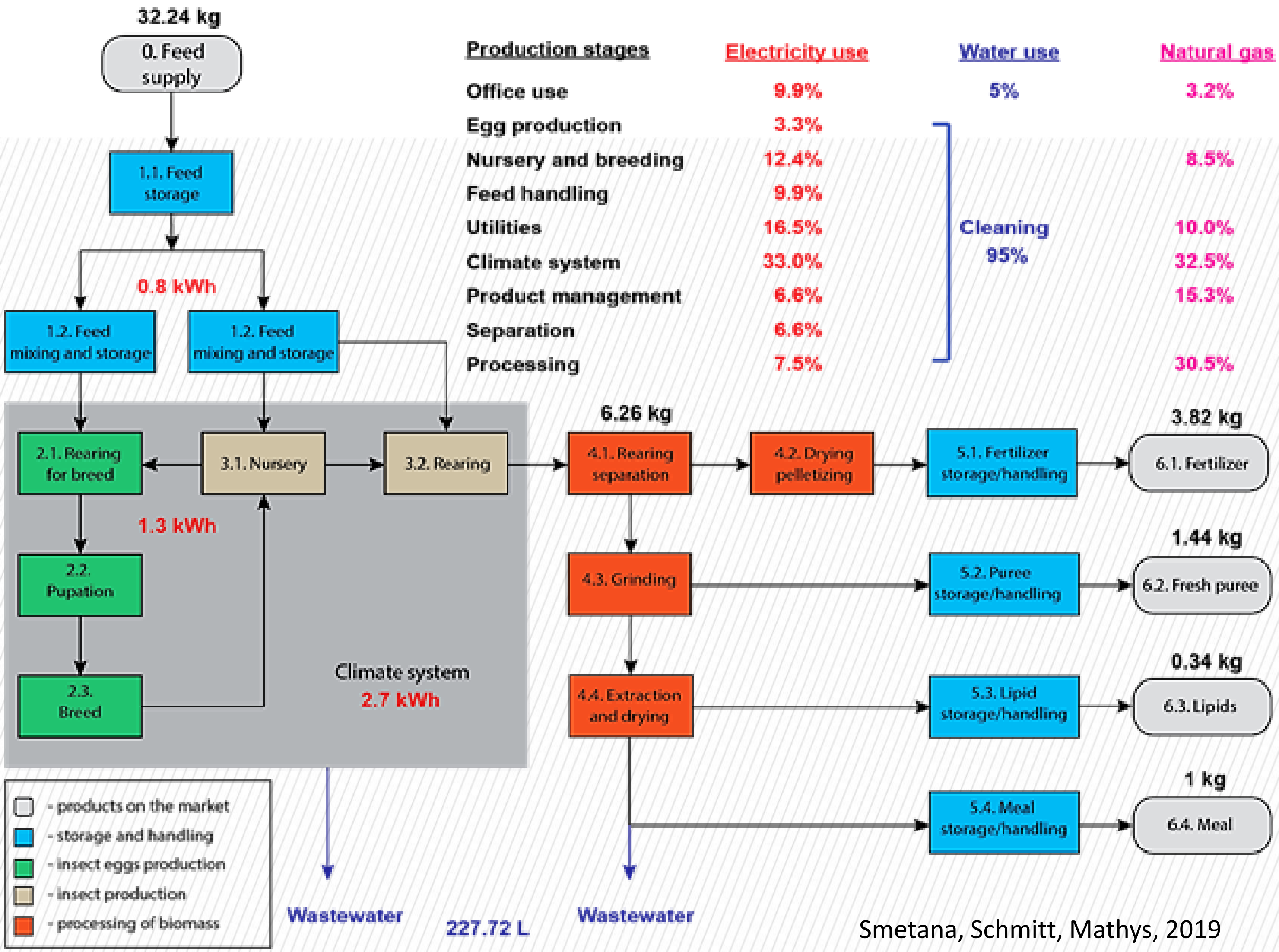
- 1 kg of dried and pelletized organic fertilizer (FU1);
- 1 kg of fresh BSF biomass (puree) used as a component for pet food production (FU2);
- 1 kg of protein concentrated meal used as feed ingredient (and potentially for food) (FU3);
- 1 kg of BSF fat used as feed additive for pork production (FU4)

- Plus analysis on DM basis and fresh insects.

Smetana, Schmitt, Mathys, 2019

# System Boundaries and LCI

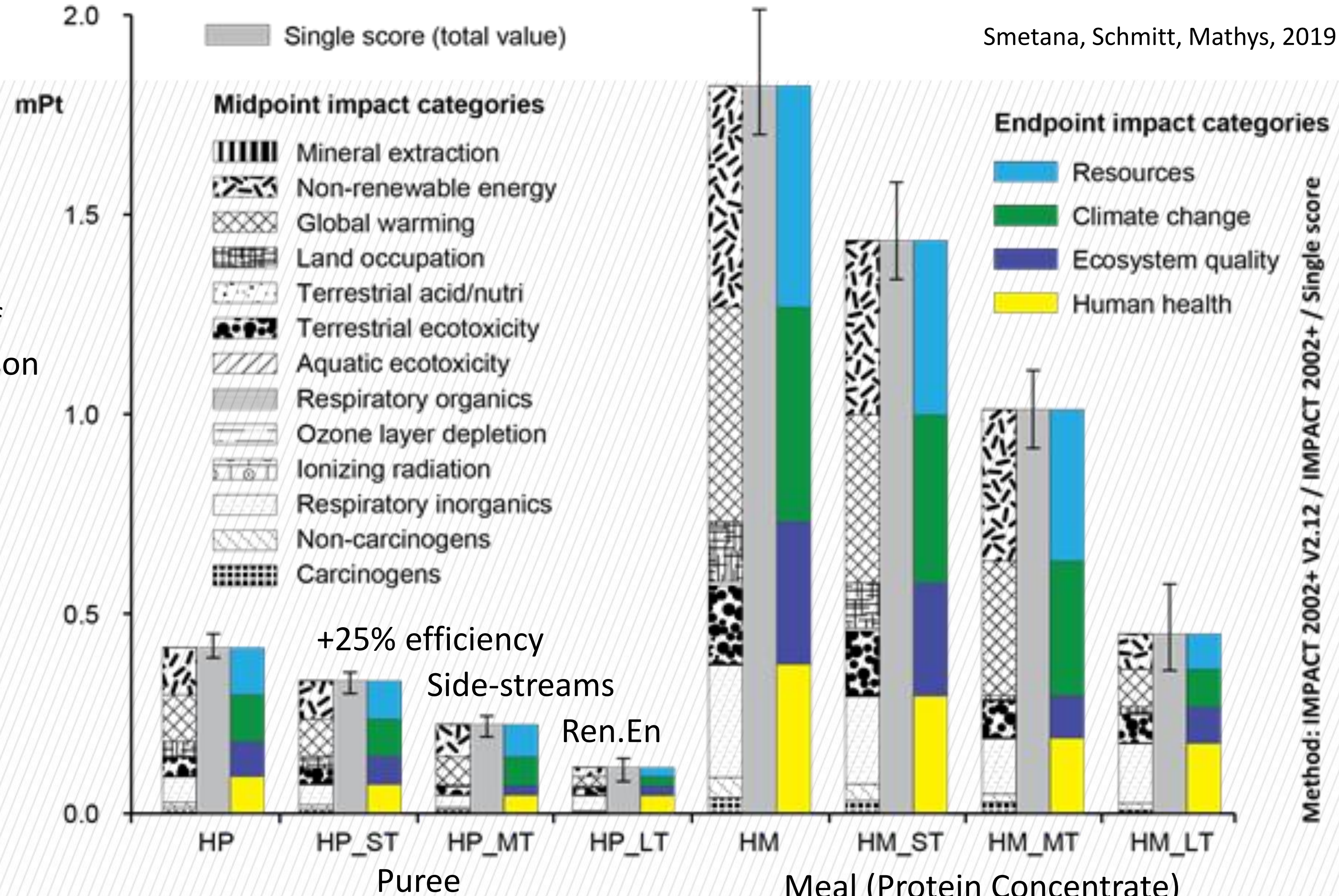
| Production stages | Electricity use | Water use | Natural gas |
|---|---|---|---|
| Office use | 9.9% | 5% | 3.2% |
| Egg production | 3.3% | | |
| Nursery and breeding | 12.4% | | 8.5% |
| Feed handling | 9.9% | | |
| Utilities | 16.5% | Cleaning 95% | 10.0% |
| Climate system | 33.0% | | 32.5% |
| Product management | 6.6% | | 15.3% |
| Separation | 6.6% | | |
| Processing | 7.5% | | 30.5% |



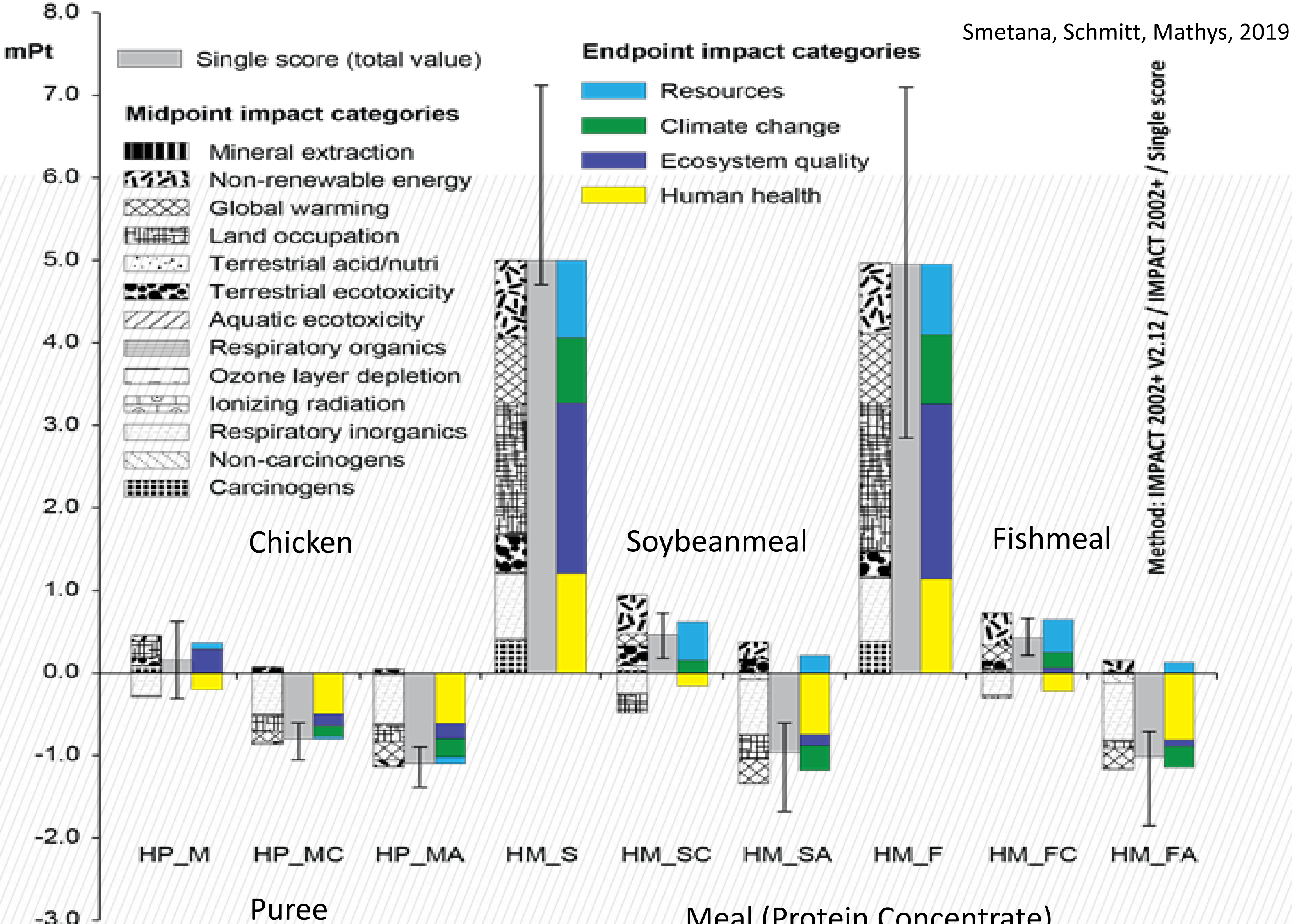

Smetana, Schmitt, Mathys, 2019

# A-LCA with scenarios

1 kPt =
= annual
impact of
1 EU person



# C-LCA Scenarios



# Impact of main protein sources

(per 1 kg of product)

| | DM % | Protein, % | GWP,<br>kg $CO_2$ eq. | OD,<br>mg CFC11 eq. | AC,<br>g $SO_2$ eq. | EU,<br>g N eq. | ED,<br>MJ | FD,<br>$m^3$ | LU,<br>$m^2a$ |
|---|---|---|---|---|---|---|---|---|---|
| **Soybean meal** | 87.5[1] | 49.1[1] | 0.34-0.72[1]<br>6.52[19] | 0.2-0.3[1,17] | -1.2 – 3.1[1]<br>11.4[17] | -81-2[1] (g $NO_3$ eq.) | 5.37[6]<br>25.5[19] | 0.04[6] | 3.26[6] |
| **Rapeseed cake** | 89[1] | 34.8[1] | 0.37-0.57[6] | 0.004-0.05[6] | 6.8-7.5[6] | 8.9-9.1[6] | 3.3-3.8[6] | 0.001-0.03[6] | 1.5-1.6[6] |
| **Pea protein meal** | n/a | n/a | 0.44[6]<br>4-10[8] (pulses) | 0.057[6] | 21.8[6] | 7.94[6] | 5.25[6] | 0.03[6] | 2.85[6] |
| **Fishmeal** | 90[4] | 60-72[5] | 0.12-0.58[18]<br>0.65-1.8[14,3,4,13]<br>0.48-5.6[15,16]<br>5.37[17] | 0.016-0.073[18]<br>0.83[3]<br>0.947-1.03[17,4] | 0.12-8.7 [14,18]<br>7.0[13]<br>15.9-18.0[4.16]<br>56.7-62.6[19,3] | -16[4]<br>0.4-0.87 [3.18] | 2.13-17.1[18,4,3]<br>21[13]<br>79.8[17]<br>120[16] | 0.0002-0.0016[18]<br>0.0036[3]<br>0.347[4] | 0.0005-0.0052[18,3]<br>0.6-1.1[14] |
| **HM (this study)** | 96.6 | 56 | 5.3 | 0.43 | 21.3 | 17.9 | 84.18 | 0.0028 | 1.89 |
| **HP (this study)** | 30 | 17 | 1.16 | 0.091 | 5.3 | 4.6 | 17.9 | 0.0006 | 0.48 |
| **Fresh meat (chicken)** | 25-30 | 23-24 | 1.62-3.12[10] | 1.8[10] | 44.25[10] | 75[10] (g $NO_3$ eq.) | 18.5-65[10] | 0.053-0.155[11] | 19.5-31.3[11] |
| **Whey concentrate** | 86-89[3] | 60[3,7]<br>80[11,kp] | 7.48[7]<br>0.8-7.4[6]<br>12.1[2]<br>28–43[8,kp]<br>40.6[11,kp] | 0.01-0.06[9]<br>3.33[7]<br>3.8[11,kp] | 0.05-1.5[6]<br>56.6[7] | 1.14[6]<br>37.3[2]<br>3.59-101[9]<br>229.3[11,kp] | 58.1[2]<br>83.3[7]<br>10.7-39.4[6] | 0.003-0.066[6]<br>1.45[2]<br>9.58[7] | 0.26-8.27[6] |
| **Egg protein concentrate[9]** | 85 | 80 | 23.4 | 1.01 | 4000 | 139 | 183 | 2.65 | 40.1 |
| **Microalgae[9]** | 96 | 55 | 14.7-245.1 | 0.9-19.8 | 260.5-1407.5 | 40.6-105.3 | 217.1-4181.3 | 0.3-3.9 | 1.7-5.4 |

Smetana, Schmitt, Mathys, 2019

Sources: [1] – (Dalgaard et al., 2008); [2] – (Kim et al., 2013); [3] – own calculations, [4] – Danish LCA Food Database; [5] – (Hall, 2011); [6] – ecoinvent 3 and Agrifootprint databases; [7] – (Smetana et al., 2016); [8] - (Nijdam et al., 2012); [9] – (Smetana et al., 2017); [10] – (González-García et al., 2014; Weidema et al., 2008); [11] – (Wiedemann et al., 2017); [12] – (Bacenetti et al., 2018); [13] – (Papatryphon et al., 2004); [14] – (Samuel-Fitwi et al., 2013); [15] – (Cashion et al., 2017); [16] – (Smárason et al., 2017); [17] – (Silva et al., 2017); [18] – (Fréon et al., 2017); [kp] – per kg protein. Note: HP – *H. illucens* puree (fresh insect production); HM – *H. illucens* meal (de-oiled protein concentrate); DM – dry mass, GWP – global warming potential; OD – ozone depletion; AC – acidification; EU – eutrophication; ED – energy demand; FD – freshwater depletion; LU – land use.

Smetana, Schmitt, Mathys, 2019

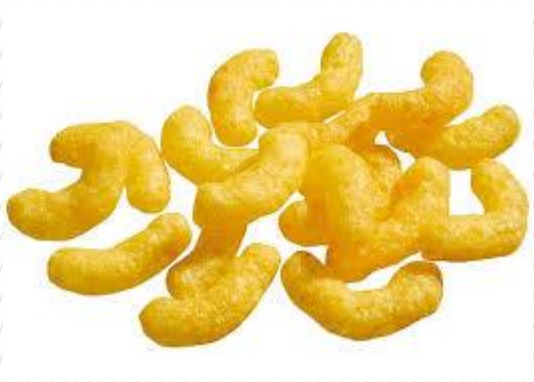
# HIGH-MOISTURE EXTRUSION

**Raw material** **Semifabricates** **Product**

Milling Drying Defatting Extraction Extrusion Shear Cell Functionalization Fermentation Spinning Cutting Marination Cooking Formulation

Peter Halzas, DIL e.V.

# Insect product opportunities



LCA FOOD 2020

- **Scientific and applied sessions**
- **Workshops and challenges**
- **Sponsors and exhibitors**

12th International Conference on Life Cycle Assessment of Food

# Towards sustainable agri-food systems

**22 – 25 September 2020**
**Berlin / Germany**

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# Take-Away Messages

- Efficiency of insect production is increasing
- A-LCA - *H. illucens* production had lower environmental impacts than similar sources of animal biomass for food.
- Fertilizer production was more environmentally favorable compared to conventional organic fertilizer.
- Viable steps for efficiency improvement and environmental impact reduction:

Upscaling of insect production (improved efficiency of feed conversion and processing)

Further application of non-utilized side-streams or alternative sources of energy

- C-LCA indicated that transforming organic residuals
  into *H. illucens* biomass could result in lower environmental impacts if composting or anaerobic digestion (as a waste treatment technology) is avoided.