AI-Autonomous Robots for Agriculture – Weeding with Laser

WeLASER Summer School

Ecological aspects of using autonomous robots for agriculture

Janusz Krupanek

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CSIC Consejo Superior de Investigaciones Científicas · FUTONICS · LZH Laser Zentrum Hannover e.V. · University of Copenhagen · AGREENCULTURE Smart robots for smart farming · COAG · Alma Mater Studiorum Università di Bologna · IETU Instytut Ekologii Terenów Uprzemysłowionych · Ghent University · van den borne aardappelen

Overview

1. Short biography
2. Introduction
3. Methodology of WeLASER Life Cycle Assessment
4. WeLASER assessment case study
5. Weeding strategies based on WeLASER
6. Conclusions

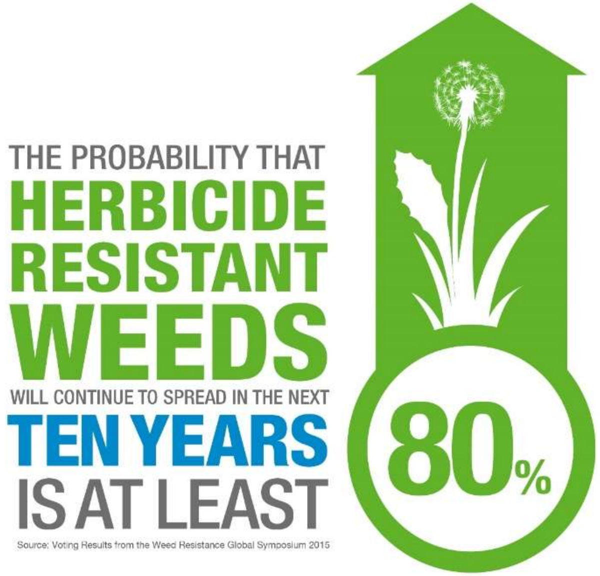
Short biography

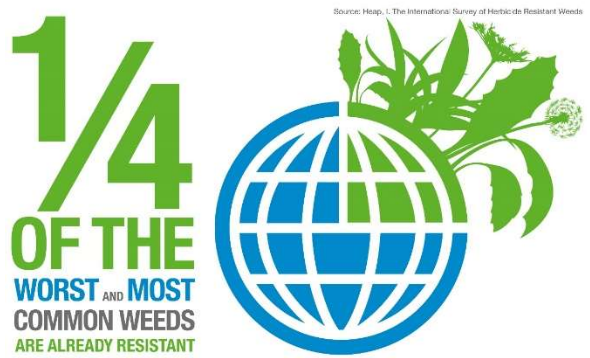
1. **Janusz Krupanek, PhD in economics (management and organisation in industry)**
2. **Position: Leading expert in environmental policies and management, Institute for Ecology of Industrial Areas**
3. **Fields of expertise:**
   - ❑ environmental assessment and management
   - ❑ Life Cycle Assessment
   - ❑ environmental performance of innovative technologies,
   - ❑ circular economy

Introduction

Sustainable weed management in agriculture with laser-based autonomous tools (WeLASER)

- WeLASER main objective is to eliminate the use of herbicides and their negative effect on the environment and health using a laser source as the active element for destroying weeds.
- In principle:
  - ❑ WeLASER fits in into EU policy in many dimensions
  - ❑ It addresses key challenge in agriculture
  - ❑ It is in line with precision agriculture and AGRICULTURE 4.0
  - ❑ It can have a wide impact on agriculture development and food quality in Europe

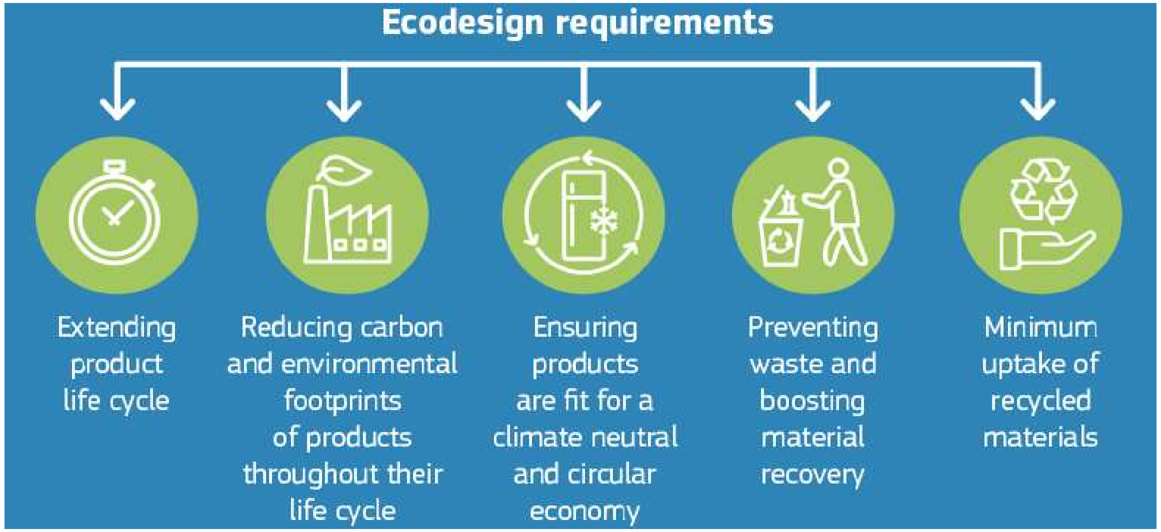




- **…. but is it a sustainable solution?**

Policy considerations

The European Union has committed itself to reducing the use of herbicides and preserving biodiversity and supporting agricultural production



Ecological aspects

- **Environmental impacts**
  - ❑ Emissions e.g. CO_2
- **Impact on biodiversity**
  - ❑ Impact on living organisms
  - ❑ better management of cultivated ecosystem
- **Impact on soil quality**
- **Risks for people, crops and wildlife**
- **Environmental and safety standards**
- **Environmental Performance in Life Cycle Perspective**

Environmental performance

- **Assessment of WeLASER Environmental Performance in Life Cycle Perspective with regard to agricultural needs and conditions of its application**

  - ❑ Which factors of WeLASER technique implementation should be focused on to achieve high environmental performance ?
  - ❑ What are the key environmental benefits and costs ?

Life Cycle Assessment

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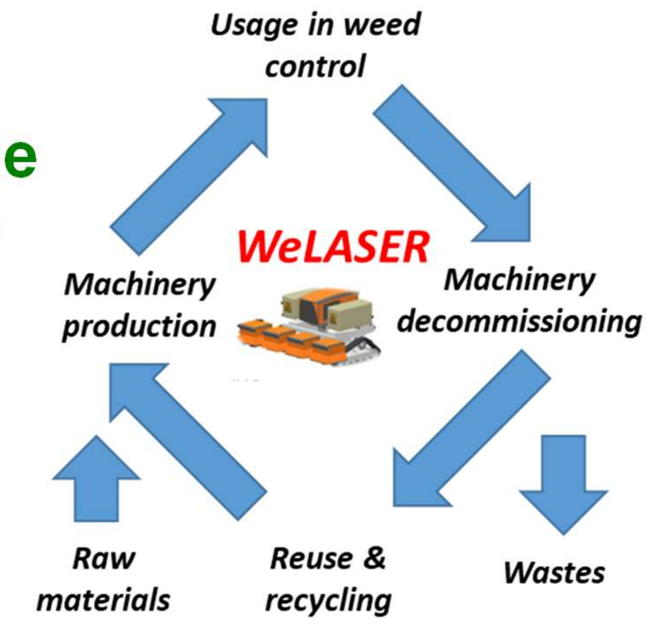
Life Cycle Assessment method

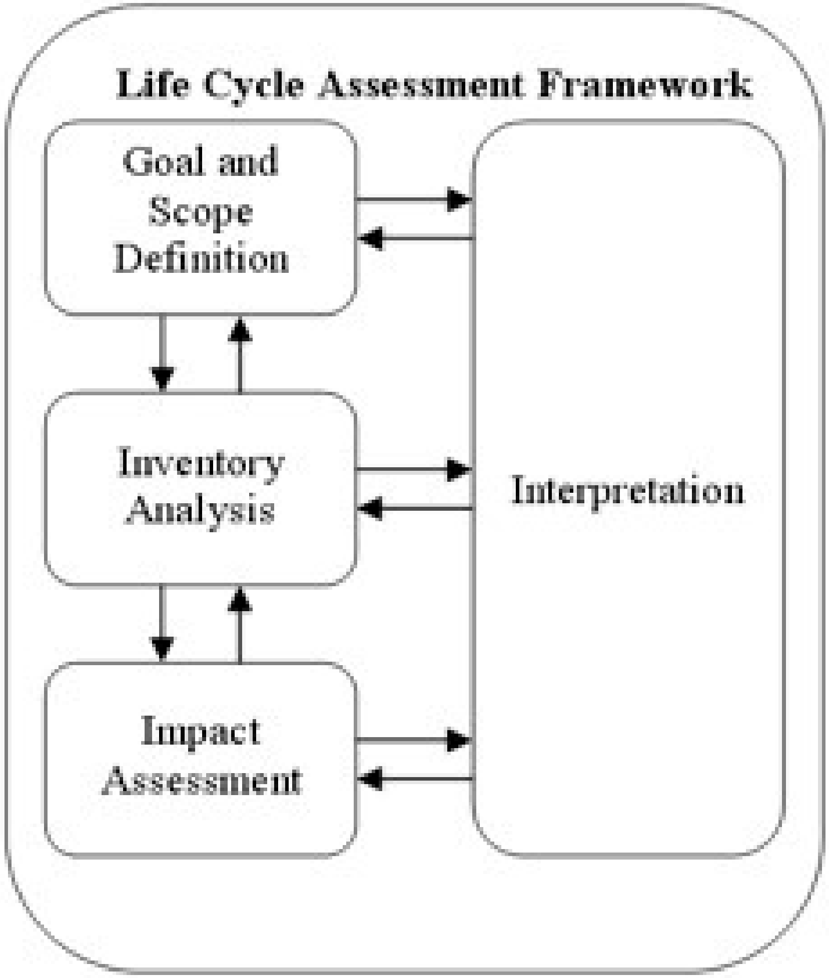
- **Life cycle assessment (LCA) is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process or service.**



- An LCA study involves a thorough inventory of the energy and materials that are required across the industry value chain of the product, process or service, and calculates the corresponding emissions to the environment.
- Widely recognized procedures for conducting LCAs are included in the 14000 series of environmental management standards of the International Organization for Standardization (ISO)

Life Cycle Assessment Framework

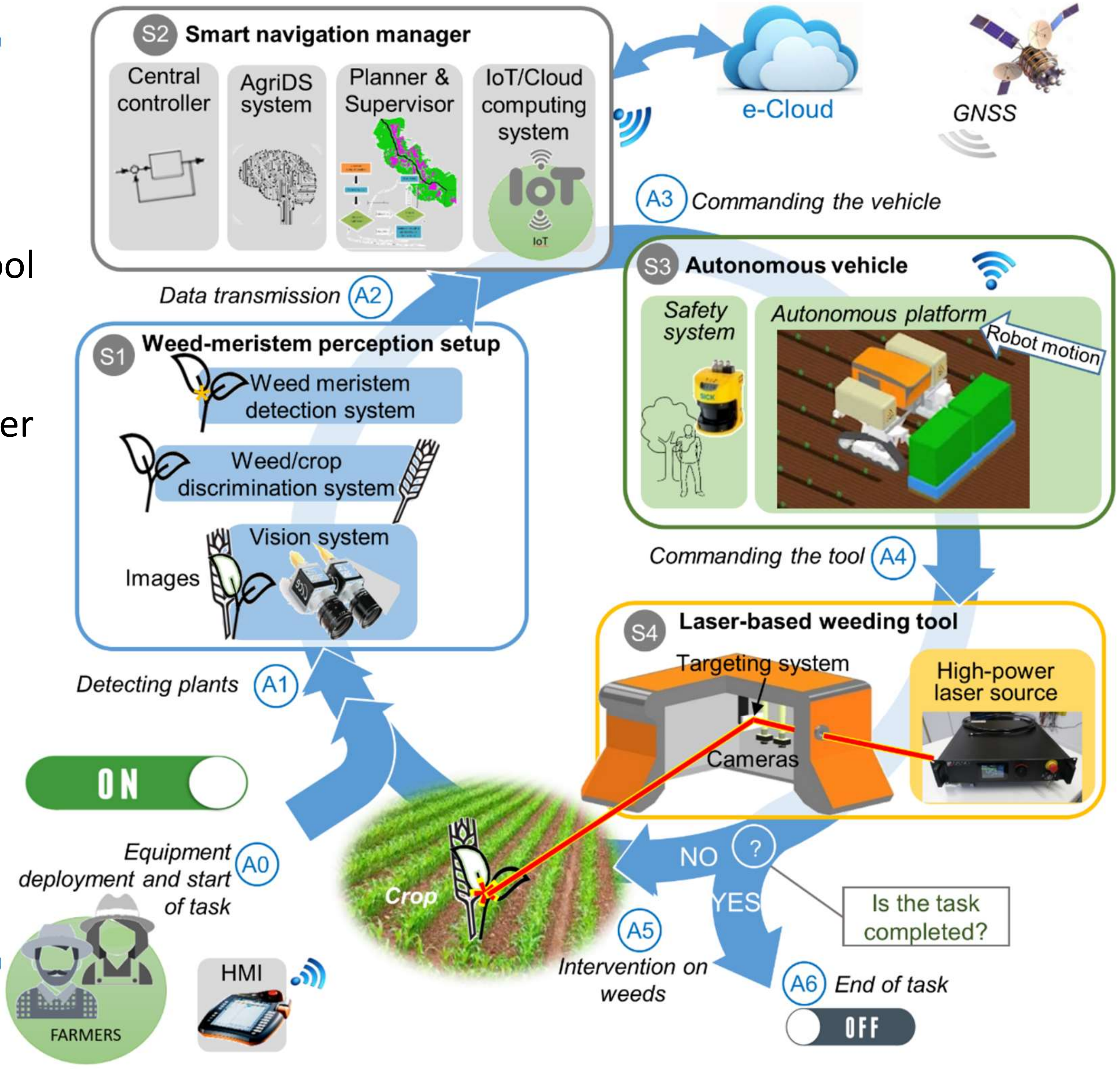
- Defining key assumptions (system boundaries, functional unit)
- Developing reference and WeLASER application scenarios
- Life Cycle Inventory for WeLASER technique and competing techniques based on LCA database, interaction with partners related to key features of WeLASER



Subject of LCA

Basic subsystems of the weeding system

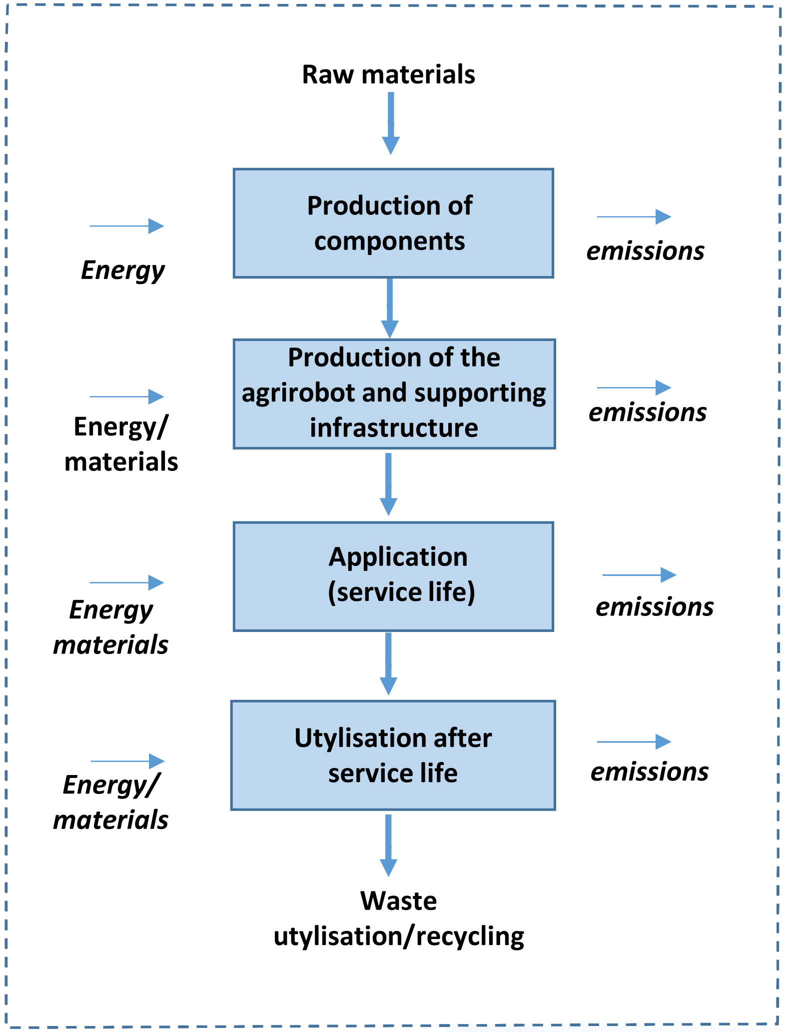
- ❑ Laser based weeding tool
- ❑ Weed-merystem perception setup
- ❑ Smart navigator manager
- ❑ Autonomous vehicle



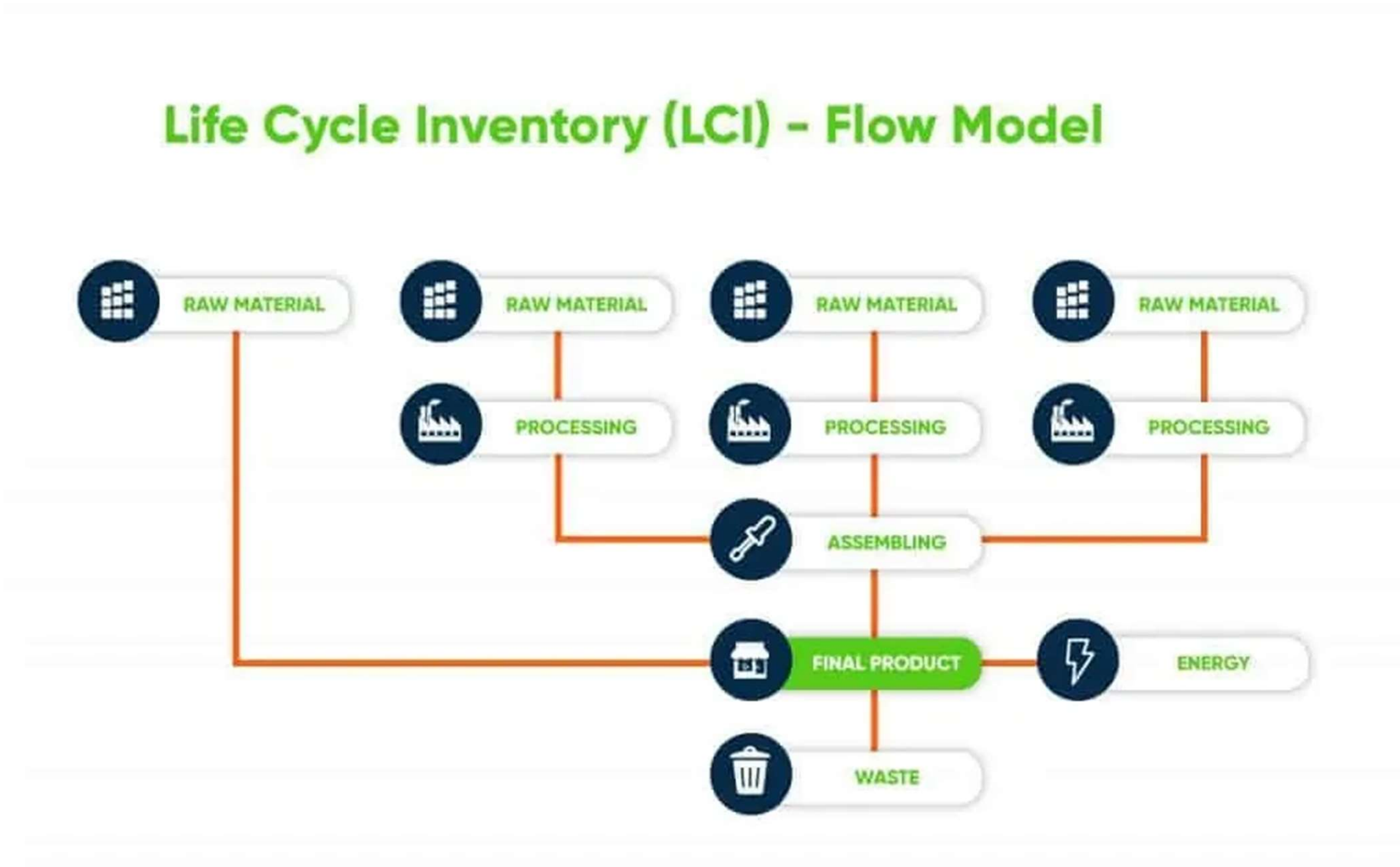
Goal and Scope

Environmental Life Cycle Assessment goals:

- Quantify potential environmental benefits by comparing scenarios (chemical vs laser weeding) for selected environmental impacts
- Identifying of weak and strong points in the WeLASER – areas for further improvement
- Identification of the most impactful components and operations in the context of:
    - WeLASER robot design
    - conditions of operations

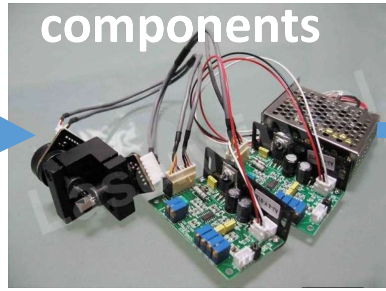


Life Cycle Inventory



Life Cycle Inventory - WeLASER

Production phase



Use phase

Materials and processes

and

Dismantling, reuse and recycling phase

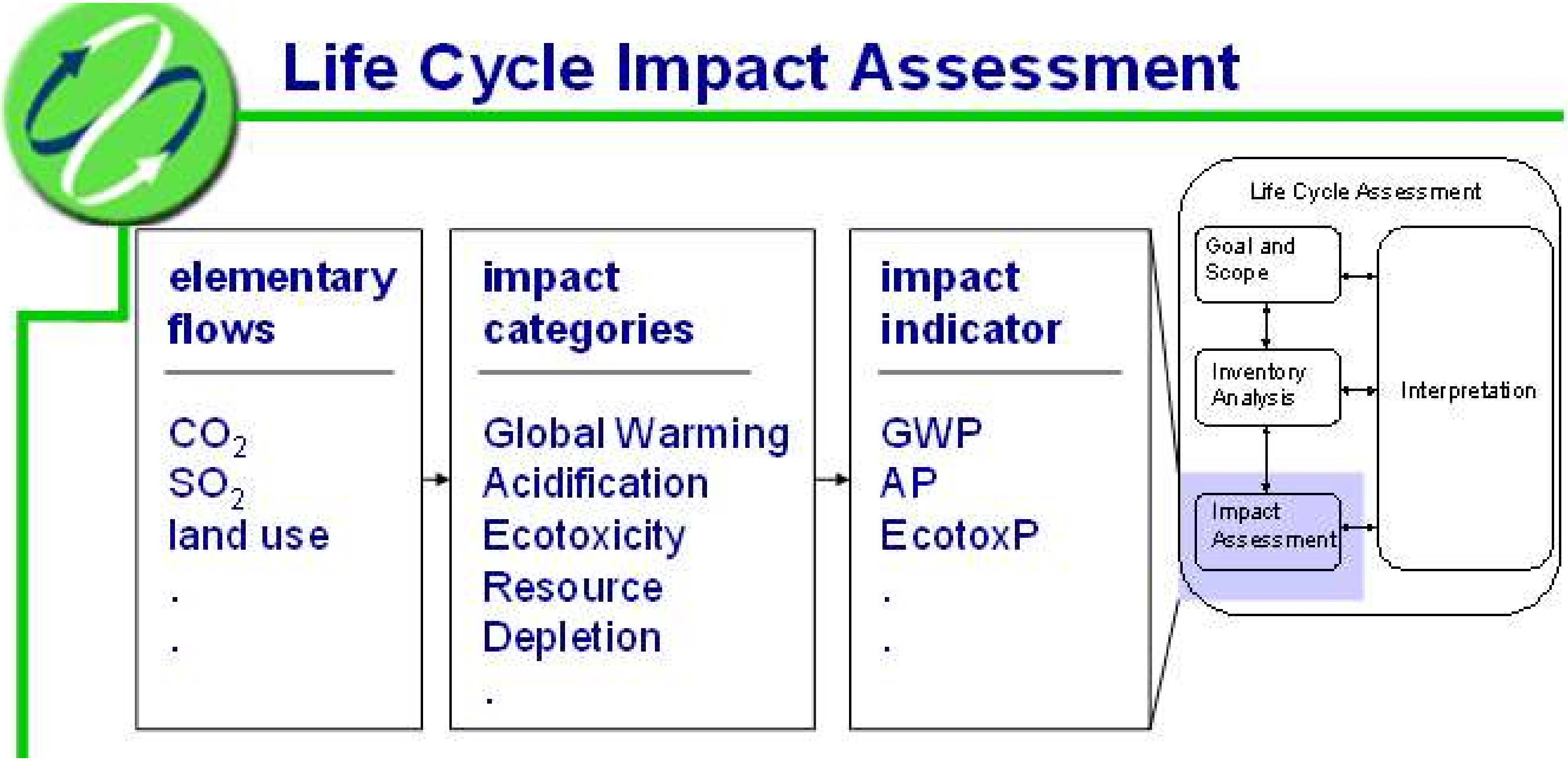
or

Reuse

Selected parameters

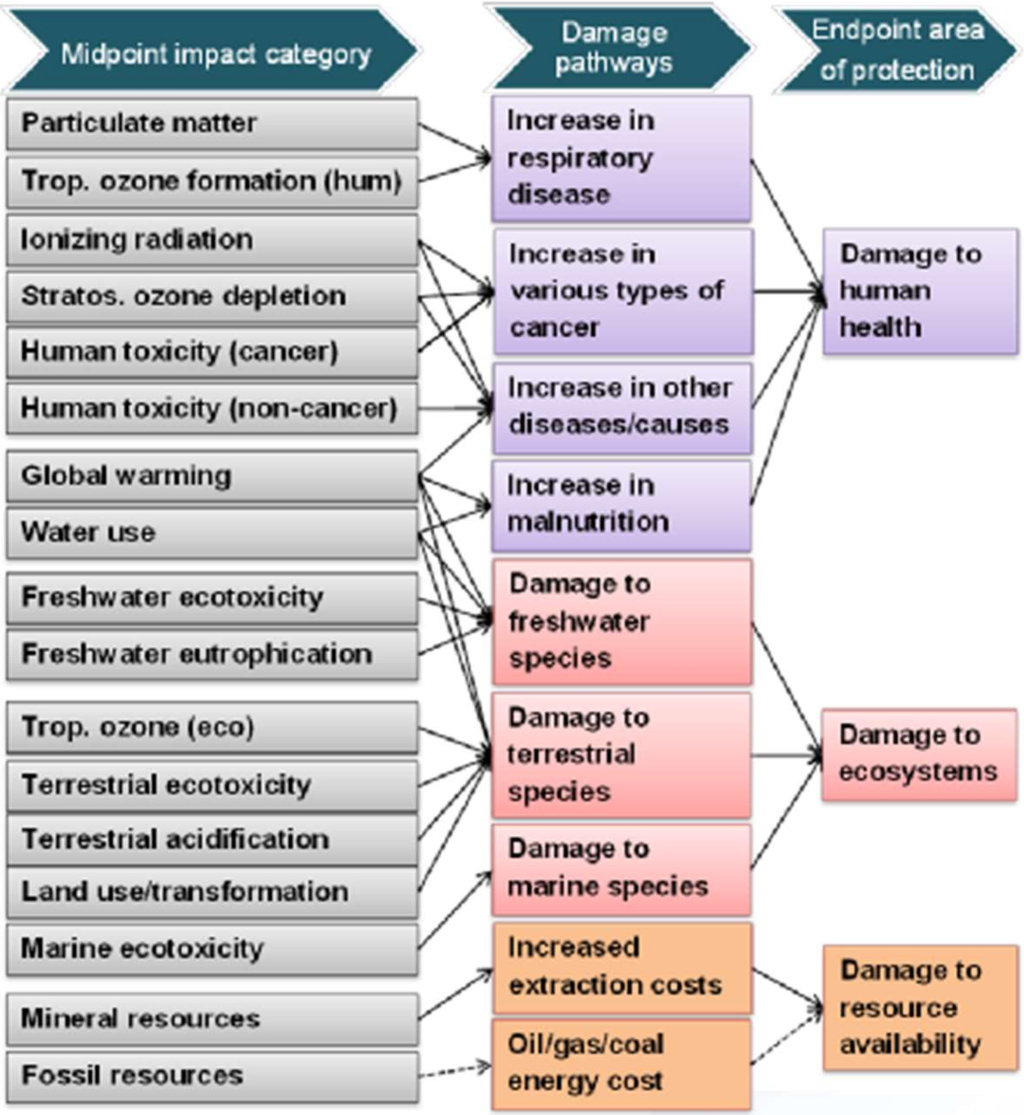
Parameter	value
Total weight	1492 kg
Effectiveness of weeding process	65%
Weeding speed	~2 km/h
Weeding performance	9,6 ha/day
Operational width	2.2 m
Accuracy of positioning	+- 3 mm
Interspacing of rows	>25 cm
Speed of weeding process	~2 km/h
Power	19 kW

Impact assessment



Interpretation

- Variety of methods applied
- ReCiPe is a method for the impact assessment (LCIA) in a LCA.
- Life cycle impact assessment (LCIA) translates emissions and resource extractions into a limited number of environmental impact scores by means of so-called characterisation factors.
- There are two mainstream ways to derive characterisation factors, i.e. at midpoint level and at endpoint level. ReCiPe calculates:
  - 18 midpoint indicators
  - 3 endpoint indicators

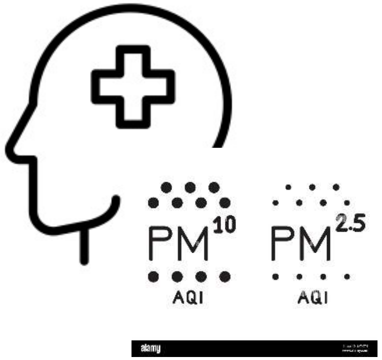


Assessing WeLASER weeder
The results

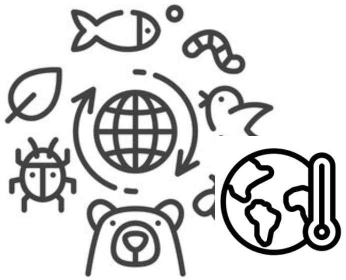
Fot. R. Słupek

Key identified impacts

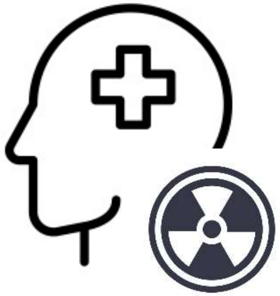
Climate change
Human health



Particulate matter



Climate change
ecosystems



Human toxicity

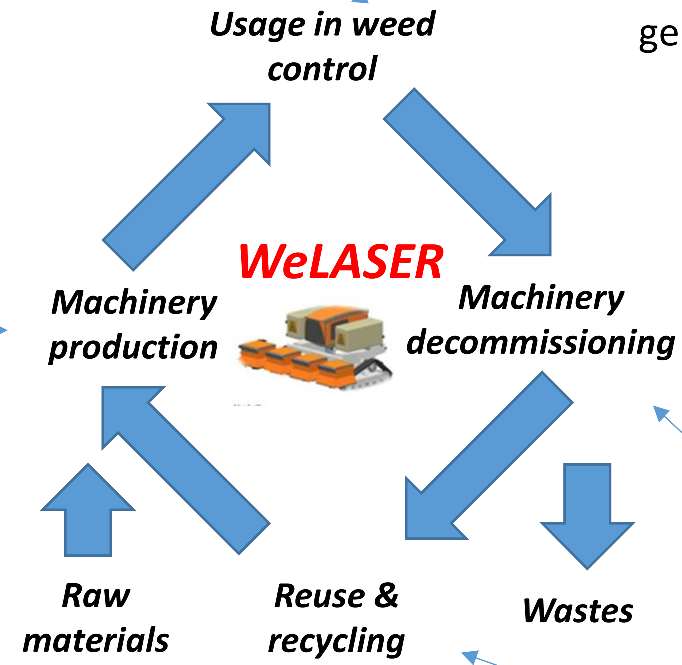
Resources depletion

Life cycle phases

- ## Environmental impact

Very high impact

The impact in human health and resource depletion related predominantly to energy generation through non-renewable sources



Moderate/low impact

The impact in human health and resource depletion related to processing of critical materials - non ferrous metals

Negligible impact/positive effects

Benefits related to proper management of wastes and recycling systems in Europe

Key subsystems

- **Energy generation and its use by high power laser and for the mobile platform propulsion during operations**

\+

Basic components	Overall impact
Laser based weeding tool	high
Weed-merystem perception setup	low
Smart navigator manager	Very low
Autonomous vehicle	high

Weeding techniques - comparison

- **Total environmental impact assessed for functional unit of 1 ha of cultivated area – example sugar beet system**

Mechanical weeding

Impact low/moderate/high

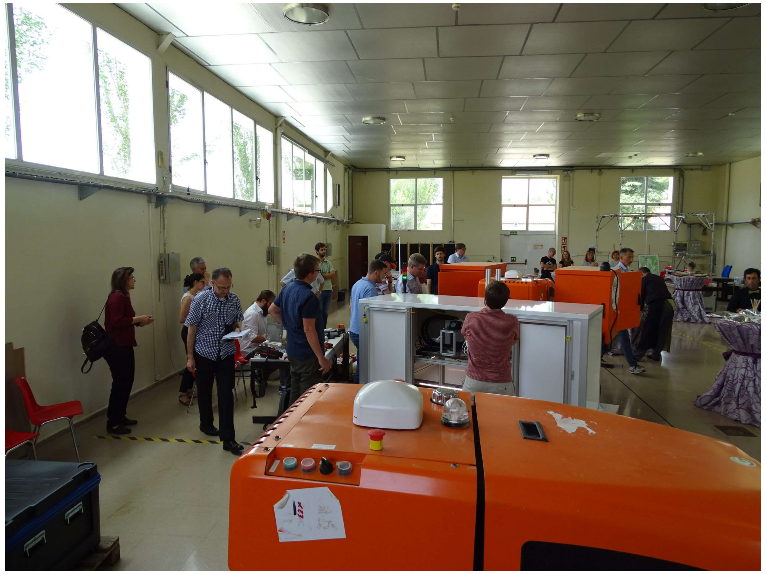
Chemical weeding

Impact low

WeLASER weeding

Impact moderate

Weeder production phase



- Apply Eco-design for a complex system including Circular Economy requirements (reuse, recycle)
- Energy options for the robot (renewables, electric, hydrogen, methane) and associated infrastructure (e.g impact of cloud computing)

- Wholistic approach to sustainability: efficiency, economy, ergonomics (social aspects) and ecology
- Production processes play a lesser role in comparison to impact of materials
- Avoiding/minimizing use of hazardous substances and materials with high impact

Robot use in agriculture

- Design determine environmental impacts of operations, maintenance and energy efficiency
- Optimisation of the operations based on other techniques of precision agriculture (mapping)

- Smart planning of operations based on field parameters and measurements accordingly to specific conditions of the robot use
- Effective weeding and combining techniques reducing number of passages and raising overall efficiency

Robot decommissioning and recycling

- Design of the final product to support dismantling, recycling and reuse
- Business models of producers and dealers
- Legal requirements and the waste management system for agriculture

- Establish common solutions for precision agriculture regarding Circular Economy
- Reuse opportunities as some components have a long life performance

Weeding strategies

Fot. R. Słupek

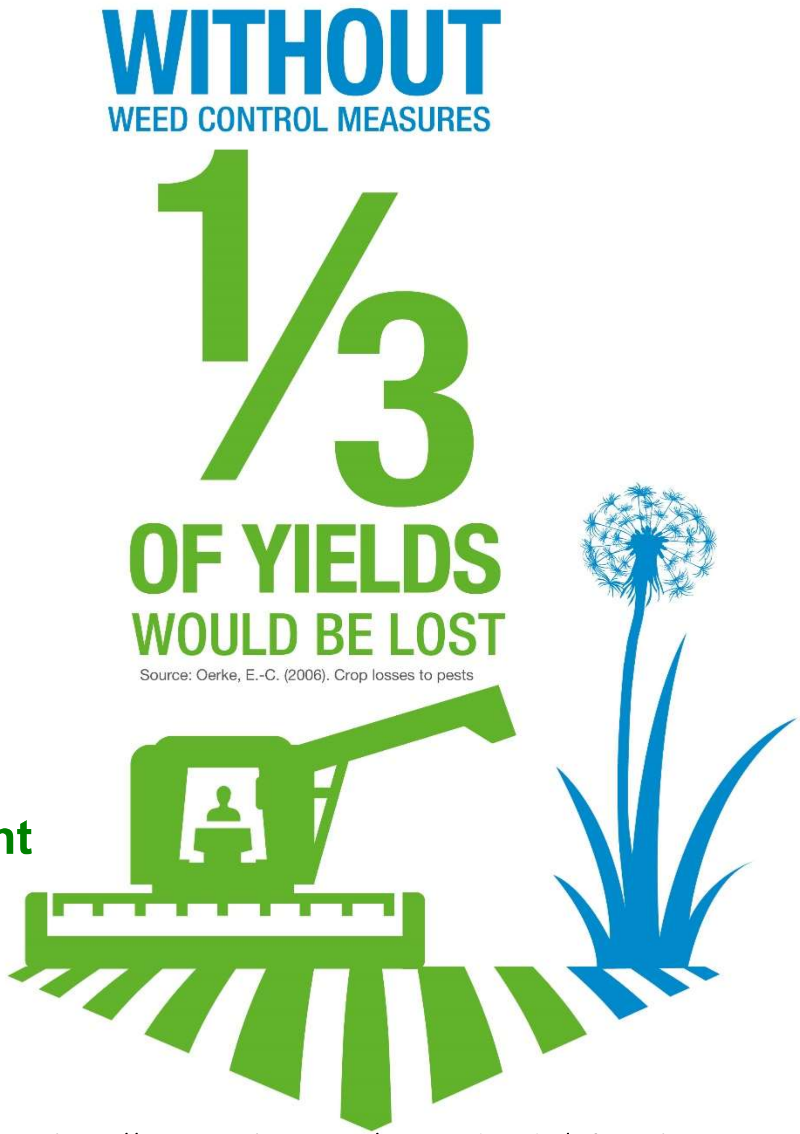
- **Which issues would be crucial for the implementation of innovative weeding technologies such as WeLASER in crop production systems?**

Testing WeLASER in crop systems

Testing and assessment for three crop systems

Weed control methods

- **Biological Control – using beneficial creatures such as insects or fungi that damage the weeds common**
- **Mechanical – Burial | Cultivation | Tillage | Mowing**
- **Controlled Burning**
- **Grazing – use of animals such as sheep or goats that will eat weeds and weed seeds**
- **Crop competition – planning your planting so that crops have the competitive advantage over weeds**
- **Crop rotation – rotating your crops from year to year and season to season to take away competitive advantage from weeds of the previous years crop**
- **Chemical – Herbicides: inorganic | organic; selective | non-selective; contact | systemic; defoliant | desiccant; plant growth regulator**
- **Automation, including machine learning technologies – detection of weeds and pests in crops**



https://www.iwm.bayer.com/news-and-media/infographics

WeLASER application

Agricultural production system
WeLASER scenario
– sugar beet, wheat, maize

Comparison between alternative production schemes & weeding operations

Agricultural production system
reference scenario
– sugar beet, wheat, maize

Scenarios:

- ❑ Reference scenario herbicides use
- ❑ WeLASER application instead of chemical weeding
- ❑ WeLASER application instead of chemical weeding and partially mechanical weeding
- ❑ WeLASER application in combination with other techniques in crop production cycle
- ❑ WeLASER combination with other techniques in one passage mechanical inter row and WeLASER in-row weeding
- ❑ Combining WelASER with other processes: fertilisation, insecticides application

WeLASER application in sugar beet system

- **Total environmental impact assessed for functional unit 1 kg of sugar beet**

Weeding approaches - comparison

- **Functional unit 1 kg of sugar beet**

Refference: mechanical and chemical

+

Impact high

Combined WeLASER and mechanical

+

Impact high

Smart combinations: WeLASER and mechanical weeding

+

Impact low/moderate

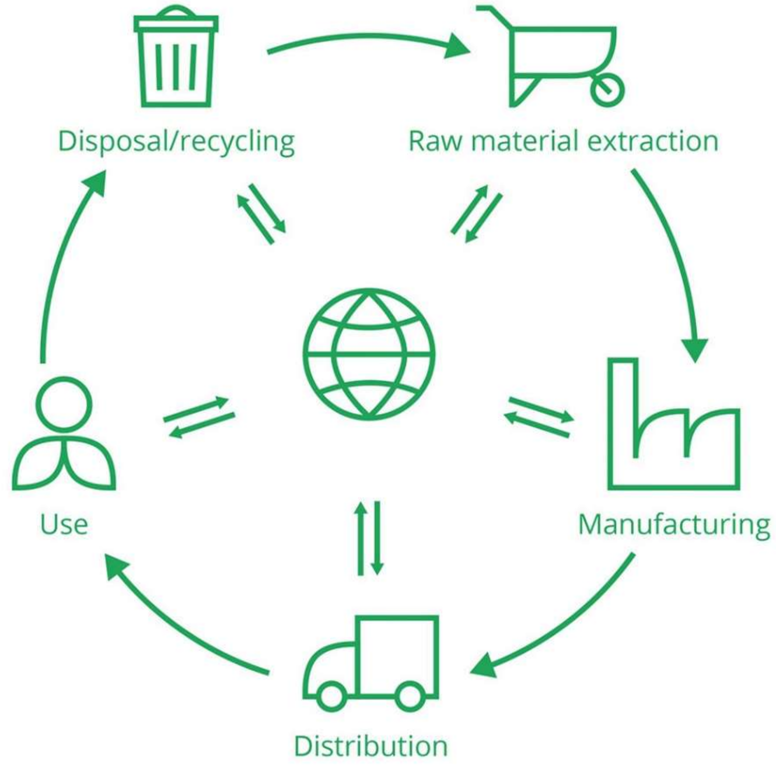
Conditions of efficiency

Boundary conditions of WeLASER robot performance and its flexibility of application/efficient usage:

- consider stage of weed development when it can be applied effectively
- the temporal window of operation
- essential parameters of track width, operating mode on slopes
- combination and integration of techniques (intra and inter row weeding) inluding chemical, mechanical and laser
- flexible use of the implement in tractors or change of implements on the autonomous vehicle
- address other plant pathogens (fungi, insects)
- address specific needs of organic farming and crop production systems
- mind the conditions in the field (wheather)

Summary

- WeLASER should be implemented according to Integrated Pest Management (IPM) rules and crop protection measures
- WeLASER should be assessed in a broad context of transformation of Agriculture 4.0 and its environmental improvement potential
- For securing WeLASER environmental performance, there are required appropriate socio-economic and environmental policy conditions related to raw materials and components, and post-service life management
- There is a wide potential for smart application of the system and enhancing its environmental performance (renewable energy sources)



THANK YOU FOR ATTENTION

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j.krupanek@ietu.pl

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