NoAW project

Innovative approaches to turn agricultural waste into ecological and economic assets

Horizon 2020 project : **2016-2020**

Coordinator: **Prof Nathalie GONTARD** (INRAE Research Director)

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 688338.

EU IDENTIFICATION CARD

ID card N°: H2020 688338

Full Name: Innovative Approaches To Turn Agricultural Waste Into Ecological And Economic Assets

Short name: No Agricultural Waste - NoAW

Coordinator: INRAE Montpellier France (N. Gontard)

Partners: 32 (16 academic, 16 private/associative) 5 from China main land, Hong Kong, Taiwan.

Total budget: 7.8 M€ - EC grant: 6.9 M€

Starting Date: 01/10/2016

Duration: 48 months

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EU IDENTIFICATION CARD

Driven by a « zero-waste » society requirement, NoAW is about developing a circular economy approach applicable to agricultural waste on a territorial and seasonal basis.

Objectives: NoAW aims to pave the way for a sustainable agro-waste bio-refinery concept by shifting from an *a*-posteriori environmental assessment to an early eco-design approach.

Target: to unlock the potential of agro-waste to be converted into a portfolio of eco-efficient products: bio-energy, bio-fertilizers, bio-packaging and bio-molecules, in symbiosis with urban waste conversion.

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What NoAW offers ?

NoAW aims to pave the way for **a sustainable agro-waste bio-refinery concept** by shifting from an a-posteriori environmental assessment to **an early eco-design approach**.

Agricultural residue is a huge pool of untapped biomass (50% of fresh harvested crops) that may even represent economic and environmental burdens.

NoAW targets to unlock the **potential of agro-waste to be converted into a portfolio of eco-efficient products**: **bio-energy**, **bio-fertilizers**, **bio-packaging** and **bio-molecules**, in symbiosis with urban waste conversion.

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What NoAW offers ?

- In circular economy, these conversion products are true resources to prevent from putting pressure on land, causing adverse effects on biodiversity and jeopardizing global food security.

- NoAW's solution aims to contribute to the 20% target of renewable energy and to reduce global warming as well as plastic particle contamination. It offers to **farme**r: additional incomes, biobased options instead of fossil-based plastic and gas; to **user**: eco-efficient substitutes; and to **citizen**: safe eco-friendly product alternatives.

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Concept of NoAW:

The concept of the NoAW consists in involving all agriculture chain actors at the territory level in order to:

- **Develop innovative eco-design and assessment tools of circular agro-waste management** strategies and address related gap of dialogue, knowledge and data;
- **Improve agro-waste resources use efficiency** by upgrading the most widespread mature technology and by eco-designing **innovative bio-processes and products**;
- Ensure and accelerate the **development of new business concepts and stakeholders** platform for **cross-chain valorisation of agro-waste** on a territorial and seasonal basis.

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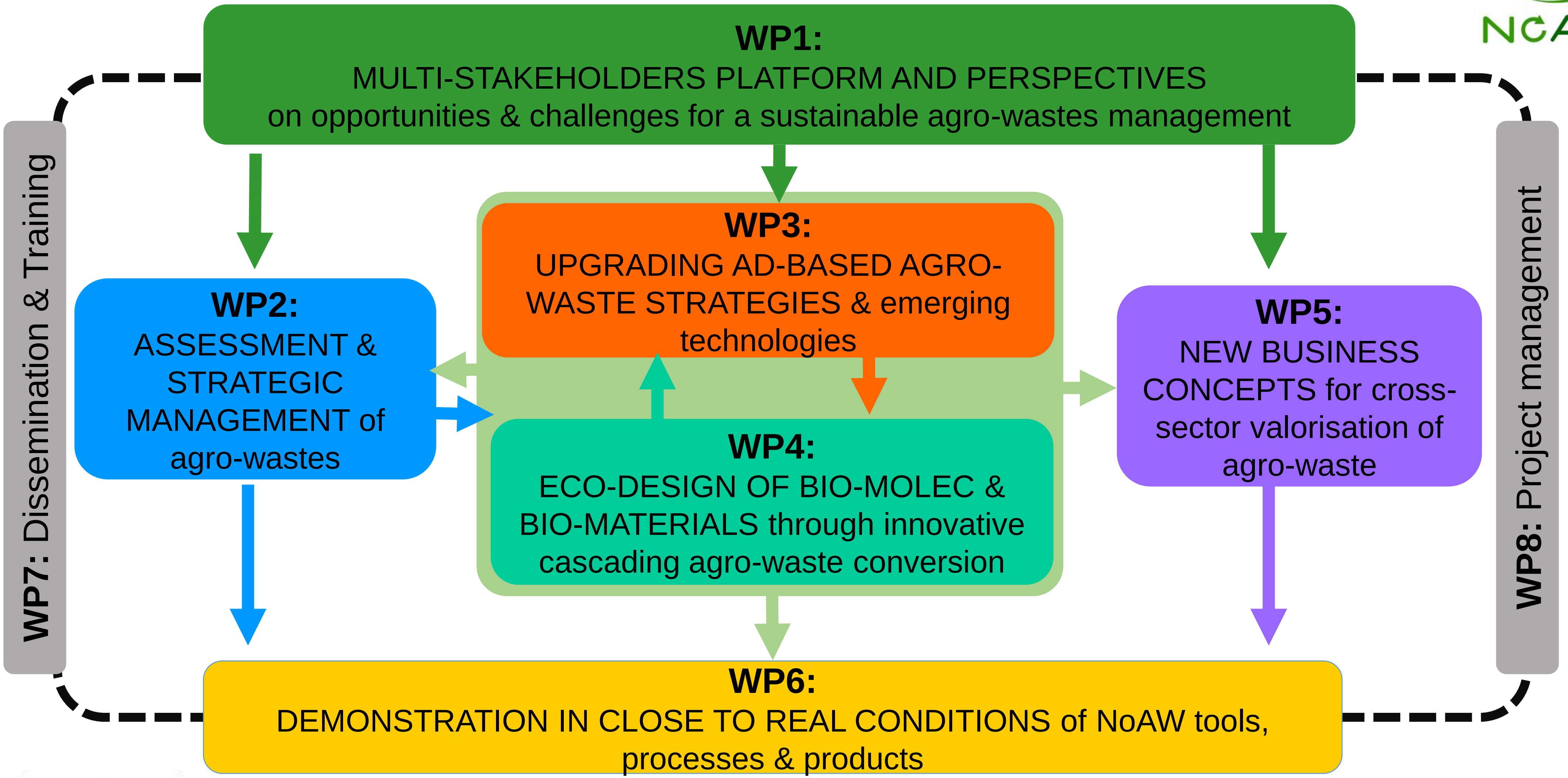
Structure of NoAW:



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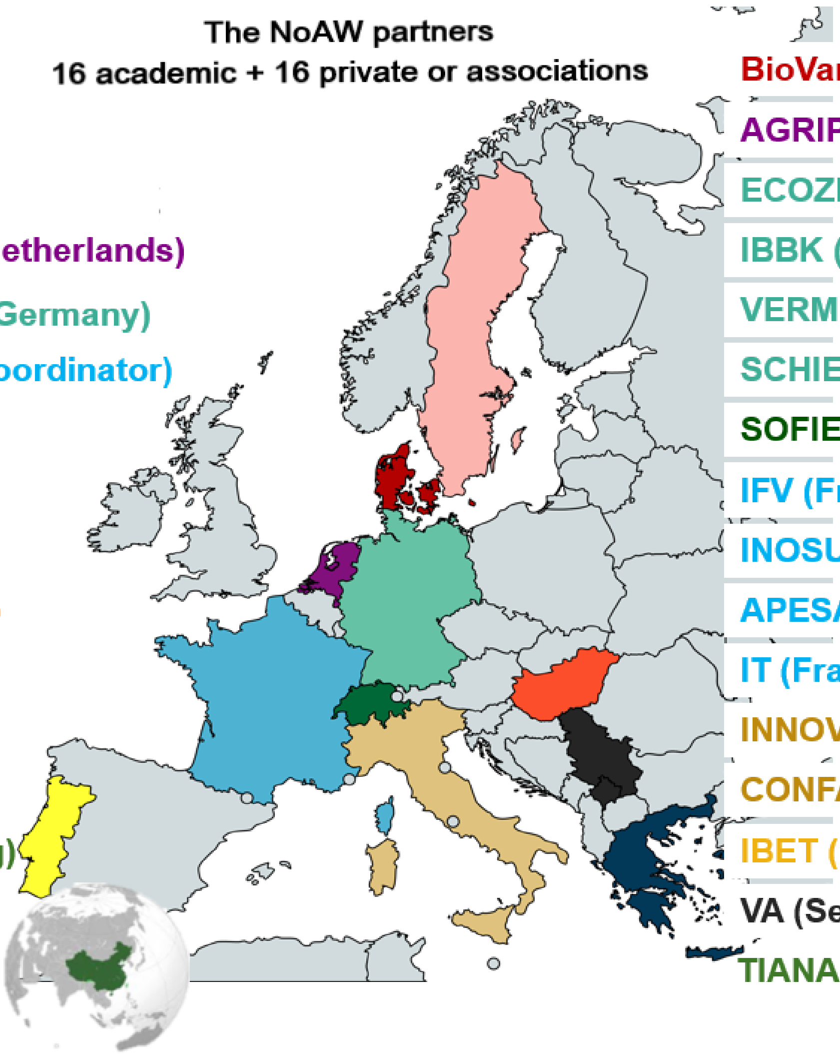
NoAW project partners

- RISE (Sweden)
- DTU (Denmark)
- AAU (Denmark)
- DLO-FBR (The Netherlands)
- FRAUNHOFER (Germany)
- INRA (France, Coordinator)
- UM (France)
- UNIROMA (Italy)
- UNIBO (Italy)
- CBHU (Hungary)
- IAUS (Serbia)
- NTUA (Greece)
- ITRI (Taïwan)
- SEE (Hong Kong)
- SYSU (China)
- IAPPST (China)



- BioVantage (Denmark)
- AGRIPORT (The Netherlands)
- ECOZEPT (Germany)
- IBBK (Germany)
- VERMICON (Germany)
- SCHIESSL (Germany)
- SOFIES (Switzerland)
- IFV (France)
- INOSUD (France)
- APESA (France)
- IT (France)
- INNOVEN (Italy)
- CONFAGRICOLTURA (Italy)
- IBET (Portugal)
- VA (Serbia)
- TIANAN (China)

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Overview of activities of NoAW project and the main results

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WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

- **Objectives:**
  - Establishment the **Knowledge Exchange Stakeholder Platform** (KESP)
  - Create opportunity to **build and share resources, d**ata, experiences, knowledge, skills and ideas
  - **Implementing GIS (Geographic Information System) applica**tion and tools for spatial /territorial analysis which **supports Strategic Environmental Assessments (SEA)**
    - To provide modern web-GIS tools for collecting, analysing, predicting, mapping and monitoring spatial information about agro-waste production in wine industry
  - **Harmonizing** key indicators and methodologies for assessing the impacts of waste management on soil, water, air quality and human safety

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WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

- **Achievements - KESP & survey highlights**
- **KESP platform established**, has already 39 members
- **Analyse stakeholders perception and opinion about proposed NoAW solutions**
  - Software platform (NoAWote) was developed.
  - Surveys:
    - Investigating preference of difference NoAW solutions, main expectations, potential obstacles
      - Biogas
      - Biofertilizer
      - Biomaterials
      - Biorefinery
    - Exploring of potential of NoAW biomaterials in agricultural application

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WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

- **Achievements - KESP & survey higlights**

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Preference of NoAW solutions by region

European countries preferred:

1. production of **bioenergy or biofertilizer**

Chinese region preferred:

1. production of **new biomaterial**
2. **extracting valuable** components for food applications and production of re-fined essential oil.

Main expectations:

1. Low economic costs

Main obstacles in regions:

- Europe:

1. **cost**

- In the Chinese region:

1. difficulties around **getting funds**
2. **collection** or
3. having **no market**

Business analysis and strategies developed by NoAW WP5 are an essential step of implementing new valorisation technologies!

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WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

- **Achievements –GIS applications**
  - **GIS and spatial data** was used at vineyards of Aleksandrović winery and other wineries of Oplenac wine region.
  - Each location of the vineyard is associated with many attributes important for the vineyard maintenance: parcel size, number of plants and planting age, variety, amount of pruning waste, etc.
  - Based on **field measurements, waste quantities were calculated** and estimated for wineries
  - These **calculations/estimations served as an input to identify current state of agro-waste management at regional level** as well as a basis for the development of a more objective Agro-Waste Management Plan.
  - **GIS database become a starting point for creating integral information waste management system**, enabling monitoring, updating data on waste and serve as a basis for planning the waste management strategy at the regional level, and potentially on the national level.

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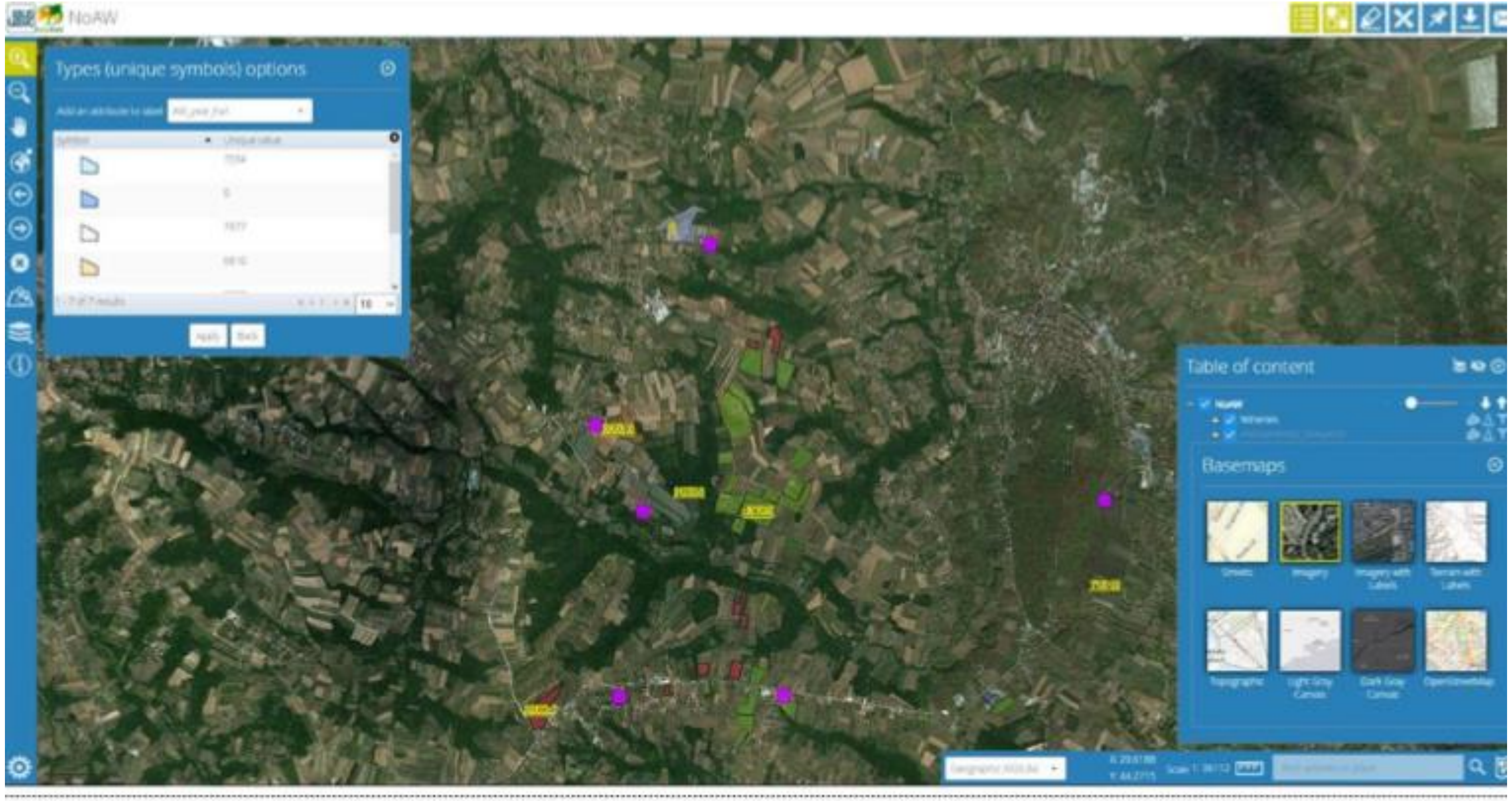
WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

NoAW



User created maps showing amounts of AW generated per year per ha within each Winery of Oplenac Wine Region

Prepared in form of a spatial geodatabase

Available:

https://cloud.gdi.net/visios/NoAW

This work triggered a change in practices in the surveyed region in Serbia:

- ✓ Until now, waste was discharged (and quite inappropriately …) and thanks to NoAW – work, economic actors became aware of the potential and prepare to use the waste for heating in the future

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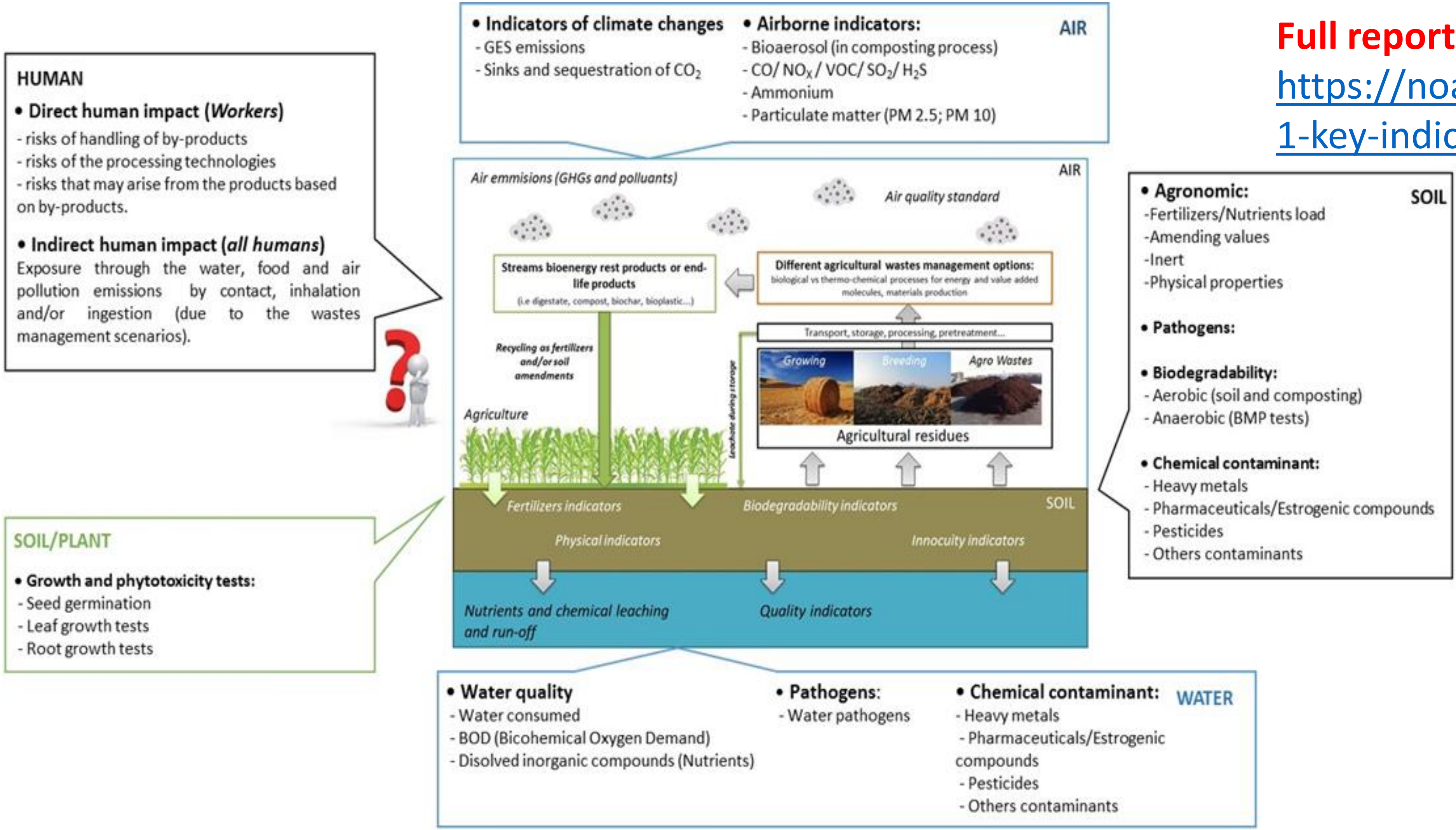
WP1: Multi-stakeholders platform and perspectives & challenges for a sustainable agro-wastes management

Achivements - Key indicators and methodologies for assessing the impact of waste management



Full report can be downloaded from: https://noaw2020.eu/deliverable/d1-1-key-indicators/

- **Key sustainability indicators** (i.e. environmental, human) for assessing the environmental and human impact of the agricultural wastes management routes have been selected.
- **Methodologies** have been determined that to be used to quantify or evaluate the indicators.

ıme under grant agreement No 688338.

WP2: ASSESSMENT & STRATEGIC MANAGEMENT of agro-wastes

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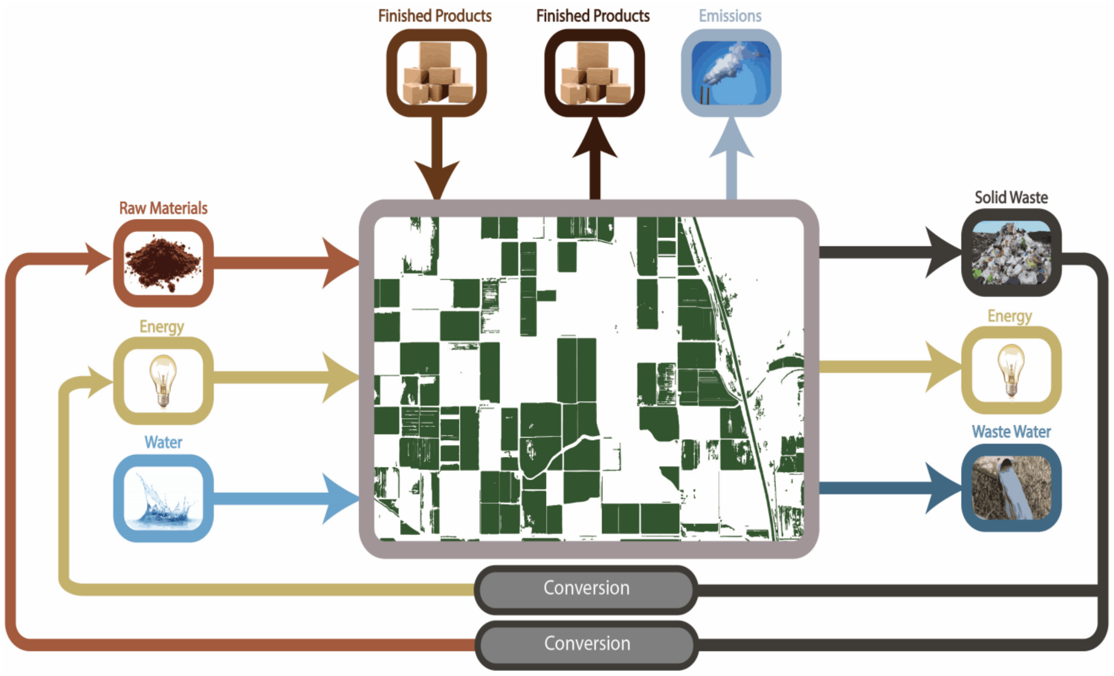
- **Objectives**
  - Develop decision support to guide technology development and
  - Choose the best strategy for valorisation of agro-industrial wastes

- **Achievements**
  - Methodologies to be used in decision support including **system boundaries and attributes** were defined and adapted



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WP2: ASSESSMENT & STRATEGIC MANAGEMENT of agro-wastes

- **Achievements - Argumentation software programming and data analysis**
- Argumentation platform was developed which permits to automatically analyse justifications associated with preferences and can led more precise decision making
- Argumentation and social choice was integrated in weighting factors used in LCA

- **Achievements - Multi-criteria evaluation tool (MCE) for process of strategic environmental assessment (SEA) for the Agro-waste management plan (AWMP)**
- MCE tool is analysing possible application of different methods of environmental impact assessment and their mutual complementation for the purpose of making optimal decisions on future waste management planning.

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WP2: ASSESSMENT & STRATEGIC MANAGEMENT of agro-wastes

NOAW

- **Achievements - Development of a Territorial Metabolism – Life Cycle Assessment (TM-LCA) method**
- The methods enables assessing the maximum savings in environmental impact at a regional scale
- It was tested in wo biorefinery alternatives
    - Biogas alone vs Biogas and polyhydroxyalkanoates (PHAs)
    - Two regions
- It showed that combining PHA and biogas production already a benefit
- Combined assessment methods can enable decision making process.

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WP3: UPGRADING AD-BASED agro-waste strategies & emerging technologies

- **Objectives:**
  - Optimised use of nutrients in anaerobic digestate from agro-waste
  - Improve biogas technologies: enlarge possible feedstocks for biohythane production, biogas upgrade, sustainable PHA production

Wet oxidation pre-/post- treatment of lignocellulosic biomass

Enlargement of feedstocks portfolio

H_2, biomethane, VFA & PHA production

Widening the products portfolio

Nutrients recycling to fields (crops)

Safe use of digestate

WP3: UPGRADING AD-BASED agro-waste strategies & emerging technologies

- **Achievements-Enlargement of feedstocks portfolio**
  - The pre-treatment of straw and other fibrous biomasses in a monitored demonstration-scale **wet explosion pre-treatment** (AD BoosterTM, Denmark) integrated in the biogas process
  - In Greece, **enzymatic tests and chemical delignification** of wheat straw with enzymatic hydrolysis for the production of biodegradable sugars have been also performed at lab and pilot scale levels.
  - The work demonstrated that it is **possible, both at pilot and demo scale**, to use chemico-physical-biological pre- / post-treatments of ligneocellulosic substrate **to increase the bio-conversion into biogas**.

AD BOOSTER technology application at Ribe biogas plant

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WP3: UPGRADING AD-BASED agro-waste strategies & emerging technologies

- **Achievements- the production of biohythane and biomethane from waste:**
  - Pilot scale plant for the production of **biohythane** (H_2+CH_4) from waste and effluents generated by a **wine-vinasses distillery** was studied in Narbonne, France.
  - Studies on biohythane optimization production were conducted both in mesophilic and thermophilic conditions: **energy recovery was significant as it was the generation of methane and hydrogen.**
  - Production of bio-hythane was achieved from manure, crops residues, winery waste which is a **bio-fuel for the automotive sector**.
  - The bio-upgrade of biogas to **biomethane via bio-electro process**es was also studied at (large) lab scale.
  - An energy efficient tool was developed to **refine biogas into bio methane**.

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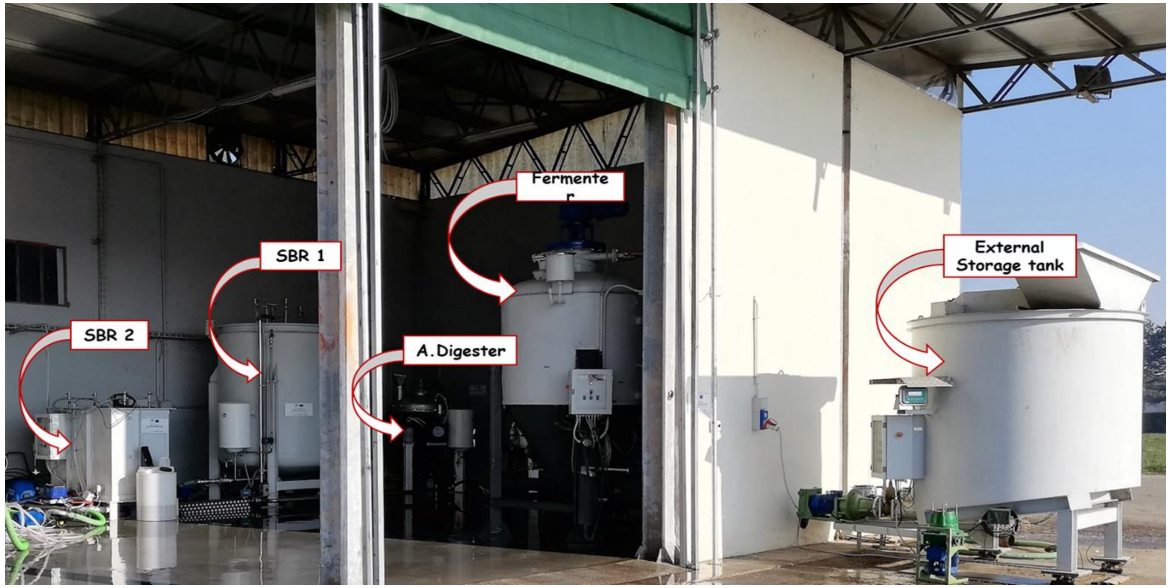
WP3: UPGRADING AD-BASED agro-waste strategies & emerging technologies

- **Achievements –Higher added value products**
- **Pilot plant**s were established:
- for innovative technology → for producing Hydrogen, biogas, VFA, PHA and bio-methane in the same plant
- VFAs, which are good precursor molecules, could be used for the successive production of PHAs (Polyhydroxyalcanoates), which have a good potential in the bioplastic market.
- The production of the polymer was achieved in the same plant based on aerobic **PHA accumulation from a microbial mixed culture by using an effluent rich in VFAs** content coming from the fermentation process.



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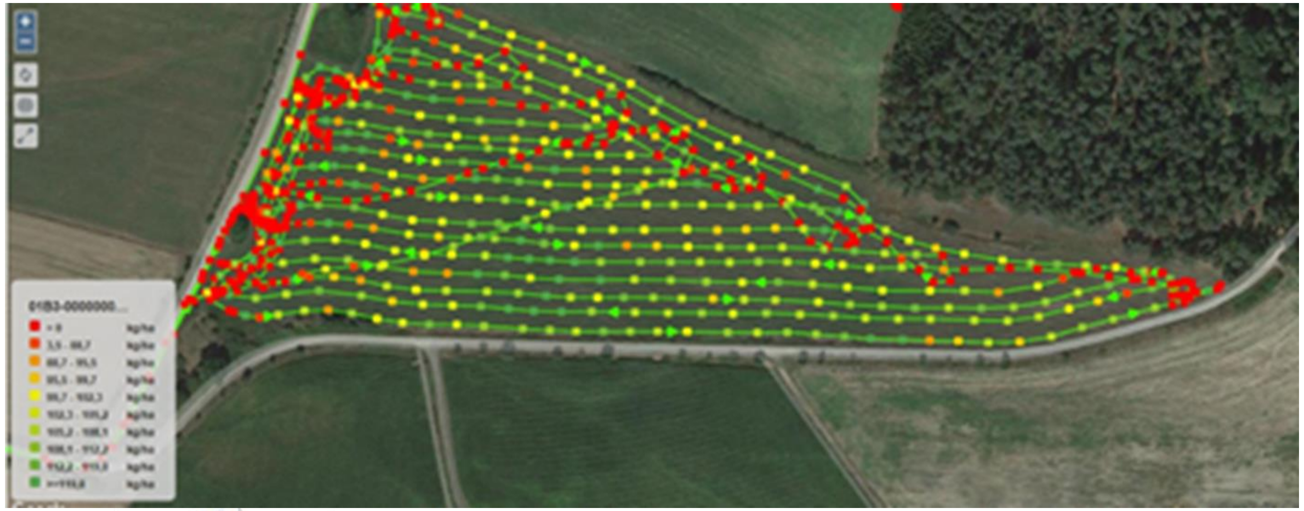
WP3: UPGRADING AD-BASED agro-waste strategies & emerging technologies

- **Achievements–Optimize the use of nutrients recovered from anaerobic digestate**
- An intelligent use of digestate was defined: a **near-infra-red system allowed for the proper management of nutrients** streams on fields.
- Nutrient studies on filed showed that NIR application helps the better use of nutrients for AD digestate



- wise use of nutrients,
- low level of micropollutants,
- no Salmonella,
- uncritical amounts of E. coli and Clostridium perfringens spores

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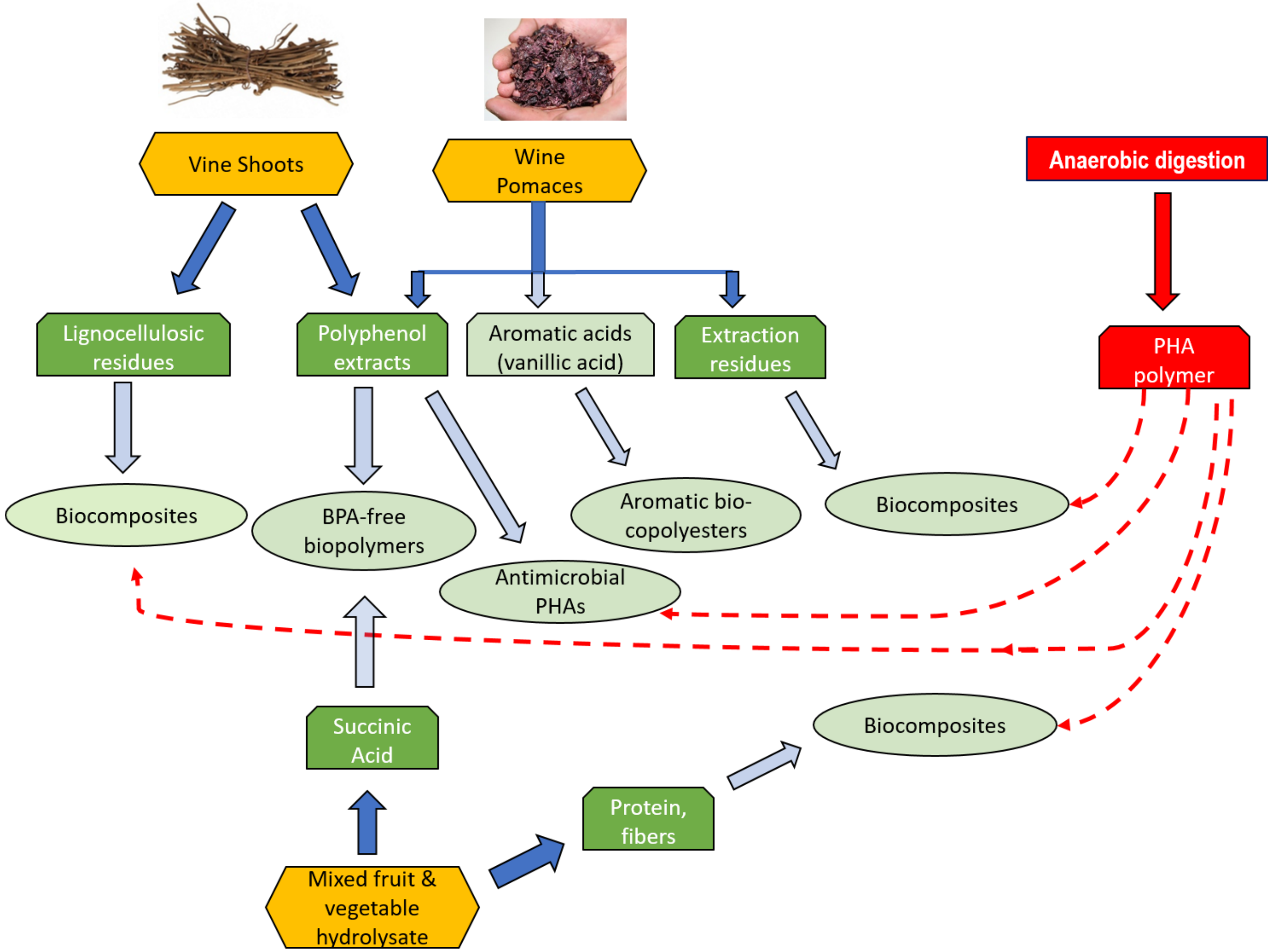
WP4: ECO-DESIGN OF BIO-MOLEC & BIO-MATERIALS through innovative cascading agro-waste conversion

- **Objectives :**
  - To develop cascading activities to convert agro-wastes and AD by products into biomolecules, chemicals, building block
  - Develop high value added final products in order to substitute non-renewal equivalents



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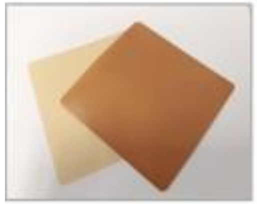
WP4: ECO-DESIGN OF BIO-MOLEC & BIO-MATERIALS through innovative cascading agro-waste conversion

- **Achievements – NEW PRODUCTS - Winery value chain**

- **Valorisation of vine shoots**
  - **Depolimeriziation of condensed tannins to prepare new building blocks as new, sustainable epoxi-resins** (e.g: to replace bisphenol A)
  - Preparation of **PHA & cellulose based bio-composites**



- **Wine pomace**
  - Polyphenols extracted from wine pomace are suitable for **coating applications**, that resulted a good option to produce an antioxidant/antibacterial packaging

- **Solid residues of winery wastes**
  - **PHBV based composites,** containing lignocellulosic fillers derived from vinery waste have been prepared
  - Green approach without using solvents or additives.
  - Materials are homogeneous, with mechanical properties are only mildly reduced. Rigid tray application was developed for packaging

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WP4: ECO-DESIGN OF BIO-MOLEC & BIO-MATERIALS through innovative cascading agro-waste conversion

NCAW

- **Achievements – Fruit and vegetable value chain**
- **Vegetable waste**
  - **Succinic acid** can be produced **from fruit & vegetable waste** hydrolysate by using an engineered Yarrowia lipolytica.
  - Succinic acid is a chemical with numerous industrial applications, such as building block for polymers.
- **Potato waste**
  - Potato residue is rich in **pectin which can be used as a good raw material for pectin extraction**. Potato pectin is a natural emulsifier in the food industry.
  - **Potato residues have been used to obtain novel PHA-based bio-composites** (trays). The composites are new, based on the idea that fibres contained in agro-waste residues can be good fillers for PHAs polymers.

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WP4: ECO-DESIGN OF BIO-MOLEC & BIO-MATERIALS through innovative cascading agro-waste conversion

- **Achievements – Digestate valorisation**
- Solid fraction of digestate from agricultural biogas plant was selected and converted to value-added products through innovative valorisation routes
  - by production of bioethanol
  - by pyrolysis

- **New chemico-mechanical pre-treatment** in enhancing bioethanol and biochar production was developed
  - Production **sugars and bioethanol from digestate** was achieved
  - **Biochar was produced**

- This will increase the value of digestates and develop a new ways of digestate valorisation which could be influence the cost of the process

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WP4: ECO-DESIGN OF BIO-MOLEC & BIO-MATERIALS through innovative cascading agro-waste conversion

- **Achievements –PHA production from VFA**
- An anaerobic photosynthetic bioreactor was successfully enriched in **phototrophic purple bacteria (PPB) capable of converting VFA into PHA**
- Under simulated solar illumination, S and P limitation enabled purple bacteria to outgrow competing microalgae and accumulate up to 30% PHA in accumulator reactors.

- VFAs can be valorised into PHA using PPB that do not require aeration, lowering operation costs.
- Anaerobic operation increases carbon conversion yield in comparison to aerobic processes.
- Utilization of fermented agricultural wastes as feedstock will allow further costs decrease.

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WP5: NEW BUSINESS CONCEPTS for cross-sector valorisation of agro-waste

- **Objectives:**
  - Understanding existing business models and key success and failures factors for cross sector valorisation of waste streams
  - Conceive collective and individual business and marketing strategies for valorising agro-waste and by-products
  - Preparation policy recommendations for facilitating the development of clustered cross sector activities when optimizing energy, waste streams and by-products.

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WP5: NEW BUSINESS CONCEPTS for cross-sector valorisation of agro-waste

- **Achievements:**
  - **Inventory of existing clusters** and waste valorisation initiatives (worldwide):33 initiatives analysed
    - Long-list of success and failure factors (situation related)
  - Preparing **market/business analysis** of NoAW cases
    - Inventory of initiatives + status + prices
  - **Market study highlights**:
    - To fit in B2B context, large production volumes are essential
    - Competition on price will be difficult, even after optimizations. Still cost price reduction will be necessary.
    - List of potential applications for PHBV and Epoxy Resins
    - Amongst these are some plastics that largely end as micro-plastics in nature!!

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WP5: NEW BUSINESS CONCEPTS for cross-sector valorisation of agro-waste

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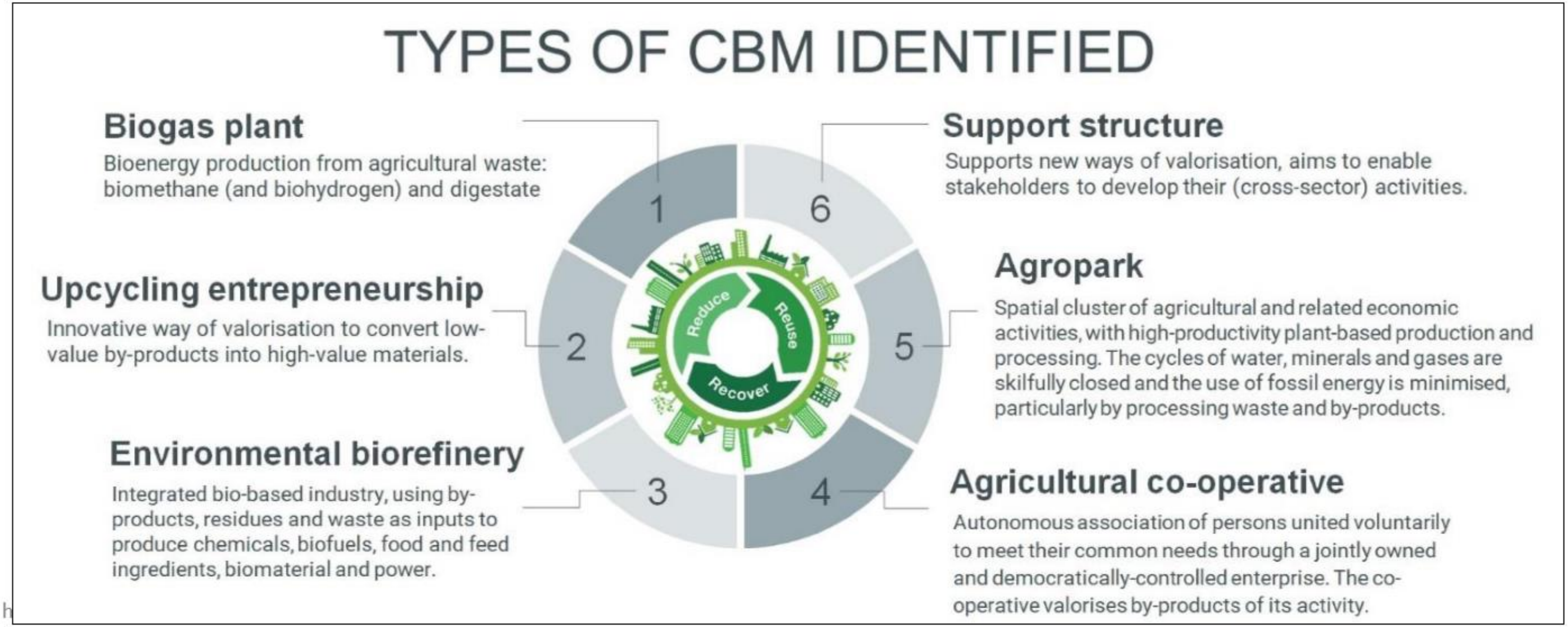
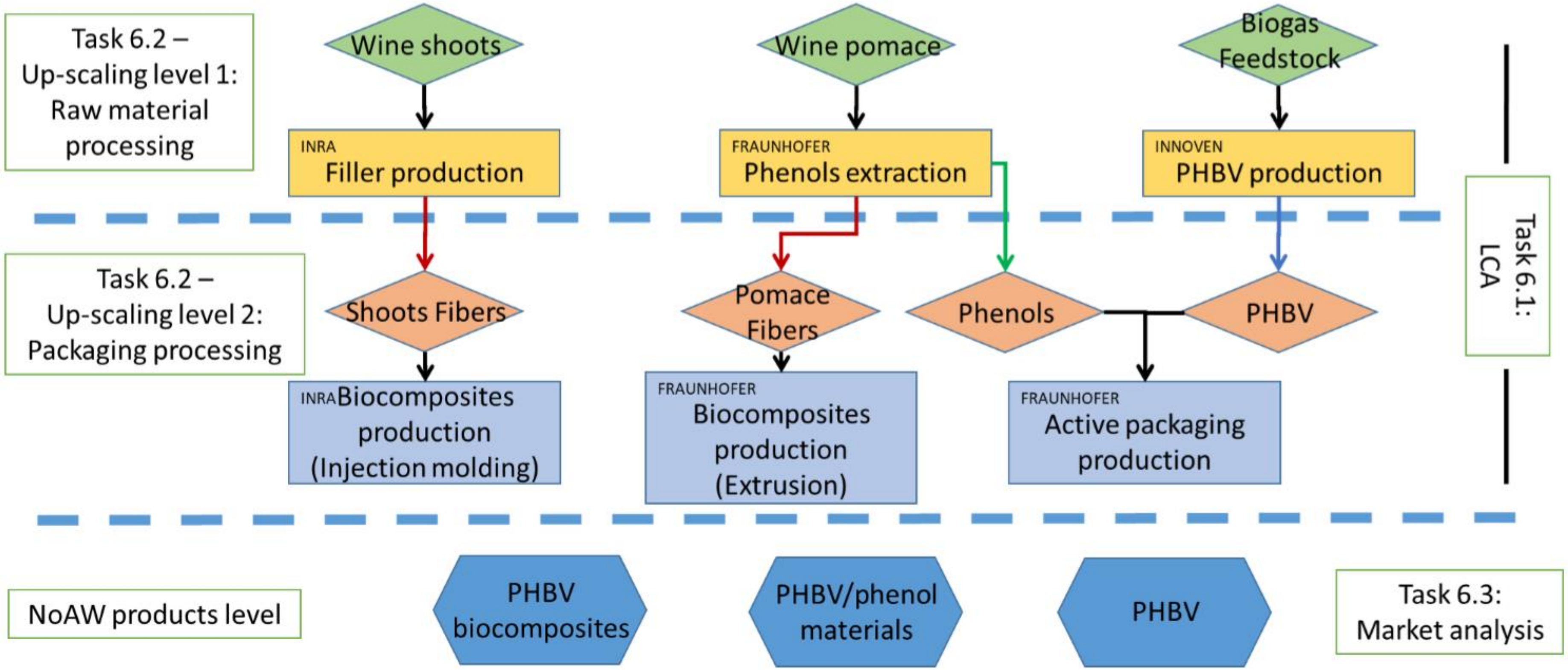
Typology of “circular business models” for valorizing agro-waste



WP6: DEMONSTRATION IN CLOSE TO REAL CONDITIONS of NoAW tools, processes & products

- **Objectives:**
  - Technological validation of one selected conversion chain and platform developed in WP3 and WP4
- **Achievements:** The technologies for upscaling was selected and this task is in progress



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WP7: Dissemination & Training

- **Objectives:**
  - ensure that the results of the project are communicated to the main stakeholders, through appropriate methods and format for them
  - which enable the effective use of the new knowledge.
- **Achievements:**
  - project website with two different levels of access was developed
  - activities such as papers, workshops, NoAW research summary sheets etc. also contributed to create awareness of the project
  - Twitter, and LinkedIn pages ensure social media coverage, will reach different target audiences.
  - group young NoAW researchers was established and involved into numerous activities in EU and China.


No Agro-Waste: Innovative approaches to turn agricultural waste into ecological and economic assets

Moreover, the process is very convenient to set up, as it requires no extraordinary technology. Briefly, an acidic alcoholic solution containing the sylvan is poured directly on the plant raw materials or a tannin extract during 2 h at 35°C in a stirred reactor. Then, the solution containing the depolymerized tannins is neutralized with sodium bicarbonate, filtered and the solvents are evaporated. The methanol/sylvan mix can be recycled thanks to the low boiling point of these compounds (around 65°C for both). The depolymerized tannins undergo liquid/liquid extraction with water and ethyl acetate. The final product is a brown powder containing the depolymerized condensed tannins and other polyphenols.

Breakthroughs, benefits and added value

Further information on NoAW project

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WP7: Dissemination & Training

- **Achievements – tools, materials, activities to join**
- Best practice guideline for farms and businesses on agro-waste management – available on NoAW homepage
- Trainings on best practice in 6 countries: France-INRA, IFV, Portugal IBET, Germany-IBBK, China-IAPPST, Italy- GCIA, Hungary-CBHU
- Final workshop in Montpellier
- Project videos:
  - NoAW mid-term results presentations: https://youtu.be/5cpxtI15BmM
  - Video about the stakeholder event in China: https://youtu.be/f9gmKZ45K-U
  - WP2 meeting in Serbia: https://youtu.be/BI0IZ6-ZVxI
  - "Ensuring the environmental performance of an emerging bio-economy" on WP2 activities at DTU: https://youtu.be/b_pb3uqE8pI
  - "System change or Climate change" on WP2 activities at DTU: https://youtu.be/BTC8P94w6oc
  - NoAW animated video: https://www.youtube.com/watch?v=VGnYsMhsWuU

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Thank you for your attention

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