ARISTOTLE UNIVERSITY OF THESSALONIKI

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Biomass Group

LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

“Implementation of agrowaste bioenergy in Mediterranean countries with sustainability”

P. Manara, A. Zabaniotou

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ

ΑΝΤΑΓΩΝΙΣΤΙΚΟΤΗΤΑ ΕΠΙΧΕΙΡΗΜΑΤΙΚΟΤΗΤΑ
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΠΑΝ ΙΙ
η περιφέρεια στο επίκεντρο της ανάπτυξης

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη

Υπουργείο Παιδείας και Θρησκευμάτων, Πολιτισμού και Αθλητισμού
ΓΓΕΤ – ΕΥΔΕ-ΕΤΑΚ

Ε. Π. Ανταγωνιστικότητα και Επιχειρηματικότητα (ΕΠΑΝ ΙΙ), ΠΕΠ Μακεδονίας – Θράκης, ΠΕΠ Κρήτης και Νήσων Αιγαίου, ΠΕΠ Θεσσαλίας – Στερεάς Ελλάδας – Ηπείρου, ΠΕΠ Αττικής

Biomass &Waste Group

Main Research Activities

- **Applied & basic research** concerning **the thermochemical conversion** of **biomass** and **waste** into **energy** and **high added value materials.**
- **Thermochemical Valorization of Biomass and Waste both by pyrolysis and gasification: Lab and Pilot scale Experiments & Modeling and simulation of such processes using commercial software.**
- **Assessment of bio-energy plants** and renewable energy sources units **through detailed techno-economic studies**
- **Design of integrated energy systems of conjunct thermochemical processes with ICEs and fuel cells.**

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Goal of Biomass Group

Development of new processes & products for valorisation of biomass and waste

Thermochemical Conversion of recyclable and renewable materials

Research & Development

ENERGY

BIOFUELS

MATERIALS

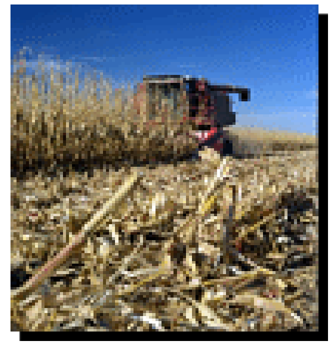
H2

INNOVATION

GREEN TECHNOLOGY

GREEN PRODUCTS

Biomass resources are prevalent and widespread all over the Mediterranean



Wood Residues

- Sawdust
- Wood chips
- Wood waste
  - Cotton gins
  - Vineyard Prunings
  - Olive tree prunings
  - Almond tree Prunings

Agricultural Residues

- Corn Stalks
- Rice hulls
- Olive kernel
- Peach Kernel
- Grape pomace/seeds

Energy Crop Residues

- Sunflower straw
- Soya
- rapeseed

The SMARt CHP concept

- A mobile BIOENERGY production unit able to utilize a variety of biomass residues streams generated in an energy efficient and environmentally friendly way → **Decentralized CHP**

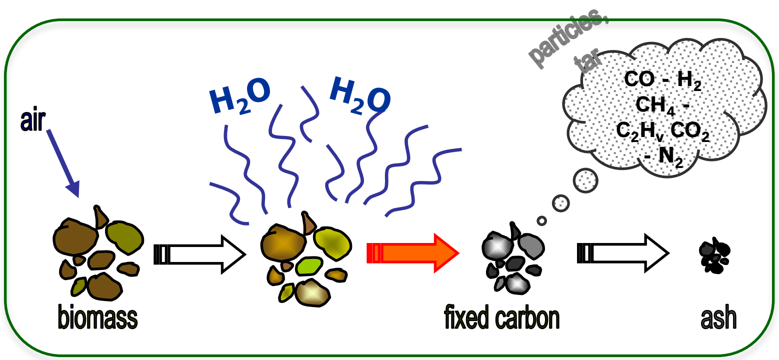
- Issues to be examined
  - *Fuel feed versatility*
  - *Bioenergy unit capability of handling wide variety of feedstock*
  - *Agricultural residue logistic management*



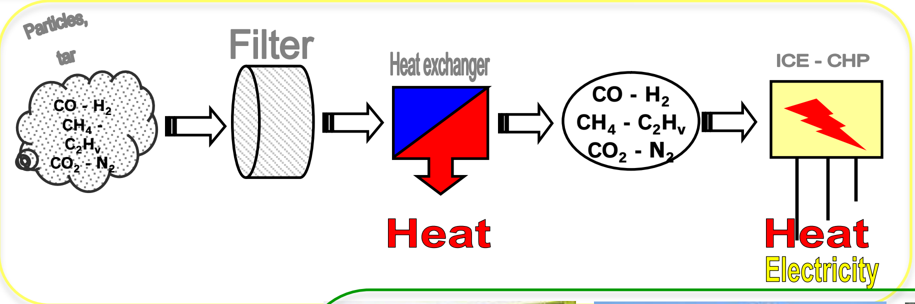

The Proposed Bioenergy System

Coupling two applied technologies

- Gasification



- Gasifier – ICE coupling



- Placement in a mobile unit

Mobile small scale bioenergy unit

Gasifier

ICE

Container

Bench scale biomass gasification unit

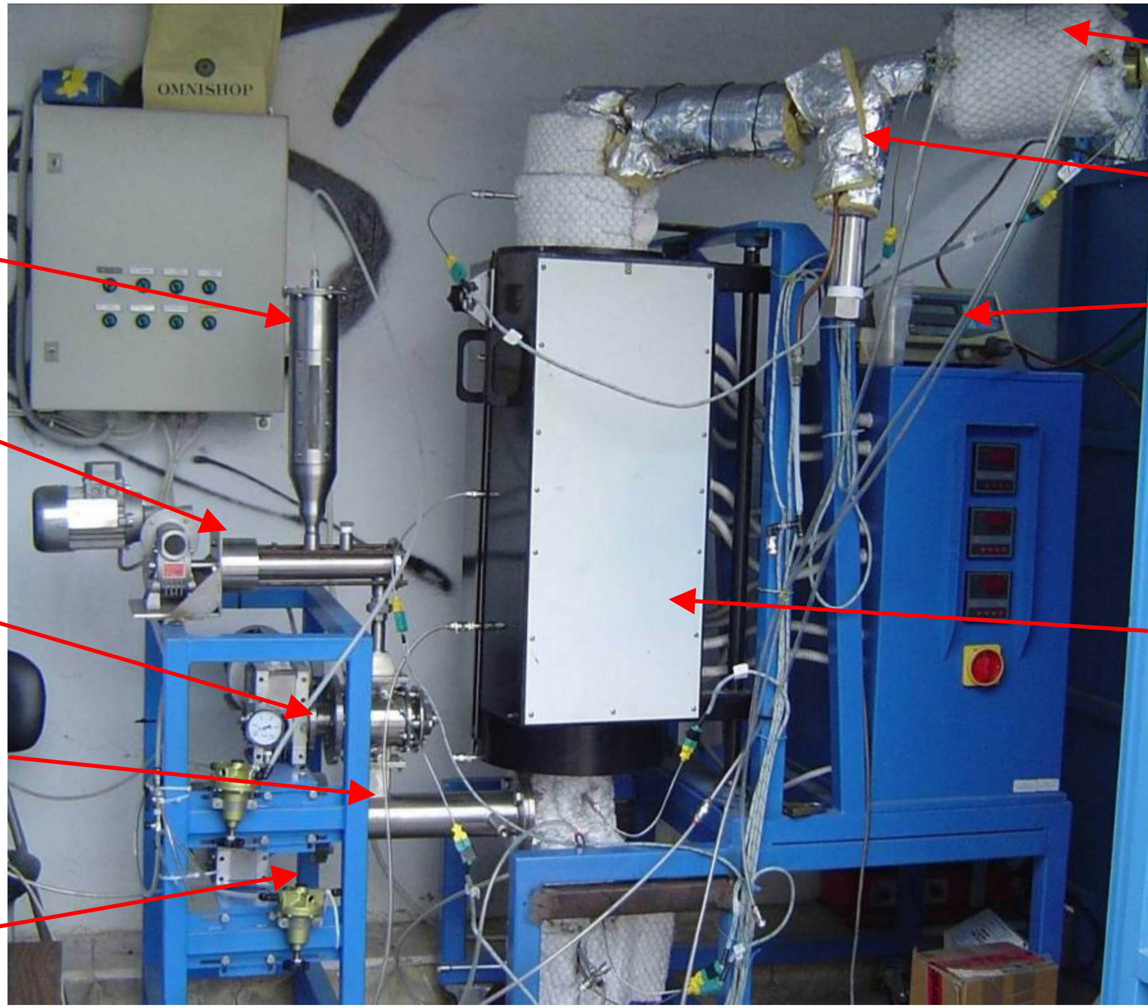
Biomass hopper

Screw feeder inverter

Rotary valve

Screw feeder

Pressure regulators



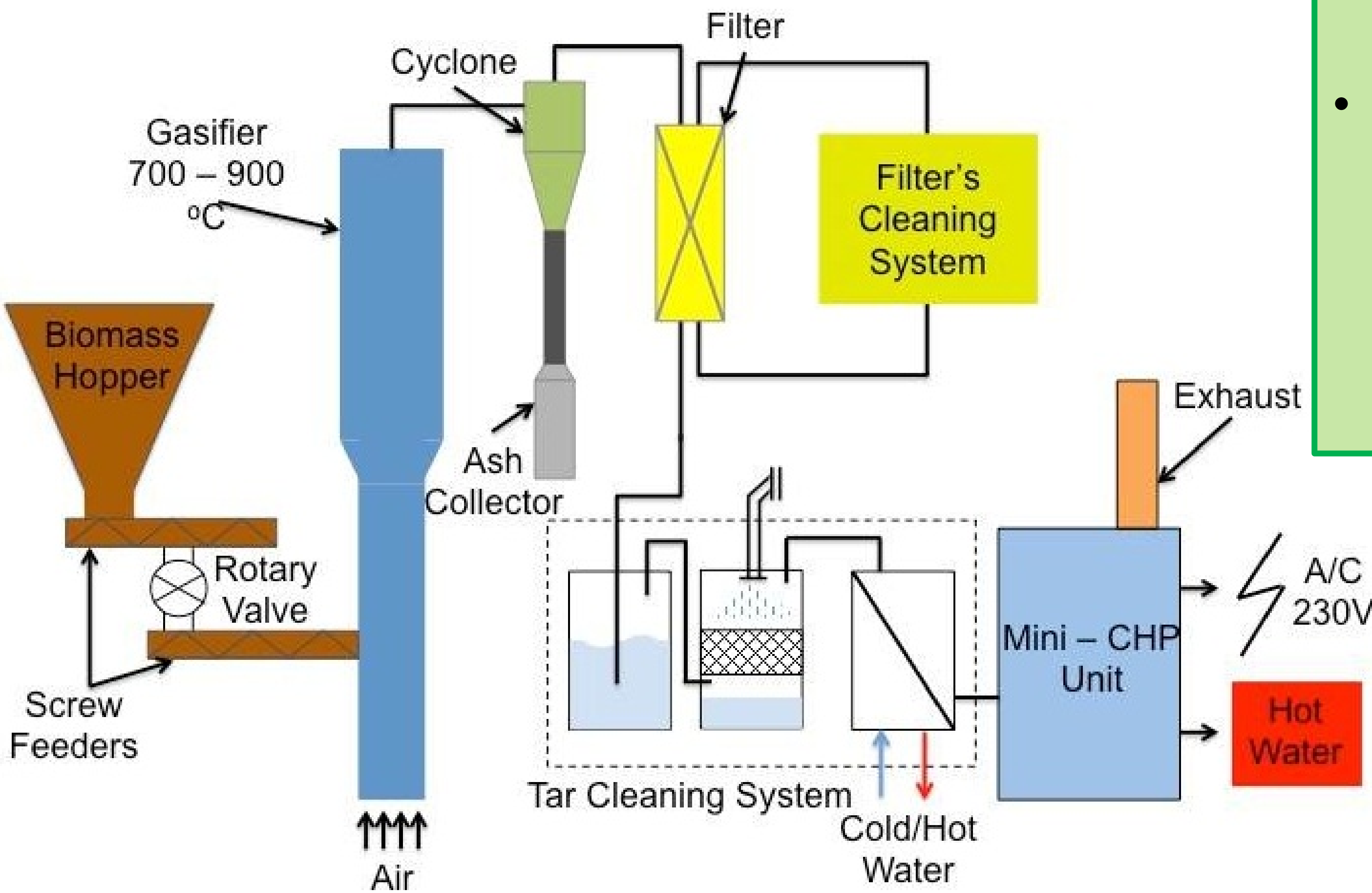
Particle trap

Cyclone

CO Analyzer

Electric furnace

The CHP unit



- **BFBG**
  - Fluidis. Material= olivine
  - Fluidis. Medium= air
- **ICE**
  - Spark ignition
  - 1-cylinder 272 cm^3
  - 1200 – 3600 rpm
  - LPG or NG
  - CHP capability
  - Max el. output 4.7 kWel
  - Max th. output 12.5 kWth

Methodology

Sustainability assessment methodology included:

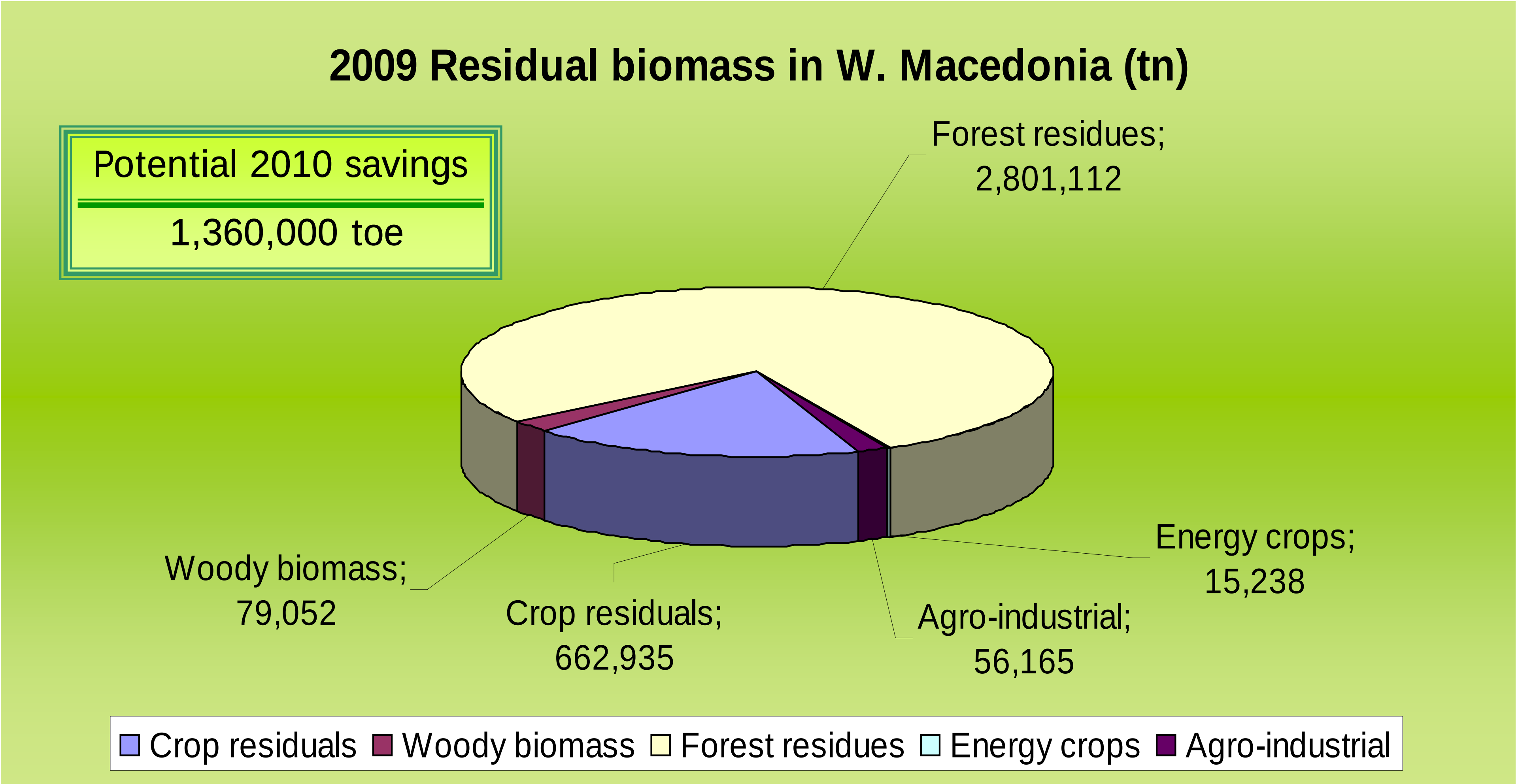
- **the definition of the region's biomass availability profile,**
- **the demonstrative operation and finally the**
- **economic, environmental and social impact analysis**

By

SELECTING, DEVELOPING and MEASURING

METRICS AND INDICATORS.

Residual biomass availability in W. Macedonia



Demonstrative operation

- Location: Thessaloniki & W. Macedonia
- Demonstrative operation at 4 locations for 2 weeks each

Aims

- ❑ **Technology application in real conditions**
- ❑ **Promotion to local actors & entrepreneurs**
- ❑ **Biomass energy potential evaluation**

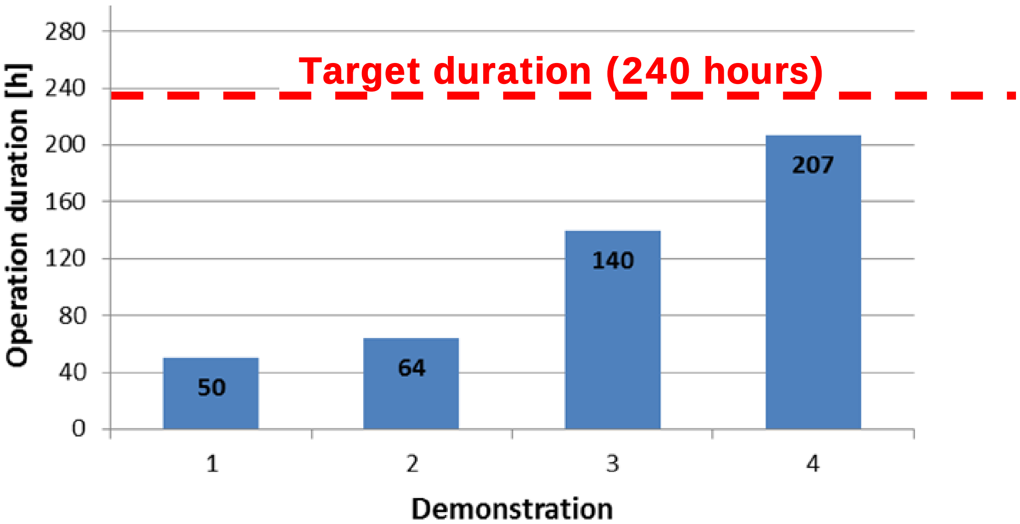
Operation in an agro-industrial environment

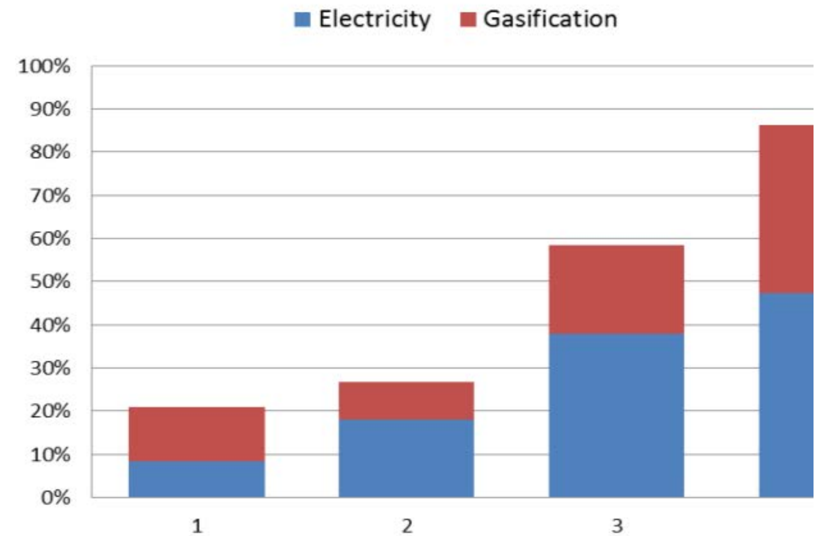
Extensive wine, oil & fruit production in all Mediterranean →

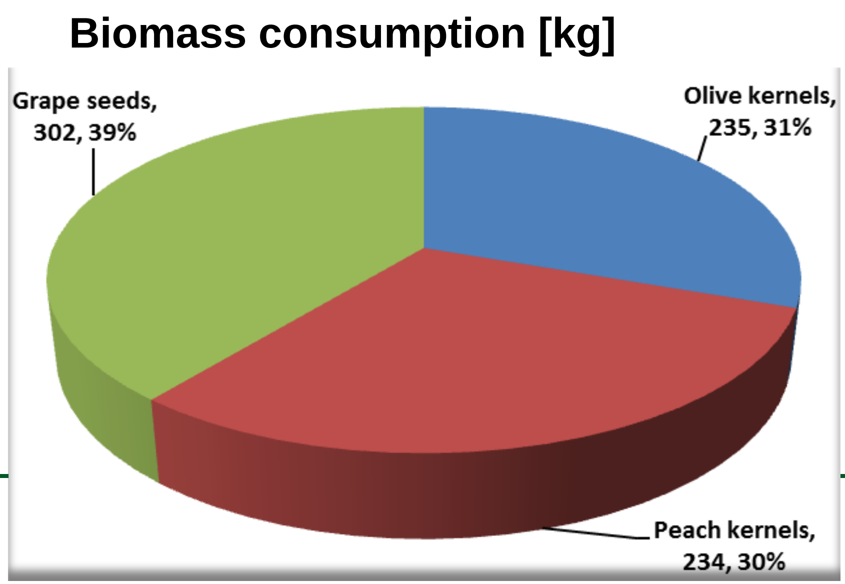
Application at:

- ❖ A winery
- ❖ An olive oil production industry
- ❖ A fruit industry

Bioenergy System Performance Evaluation







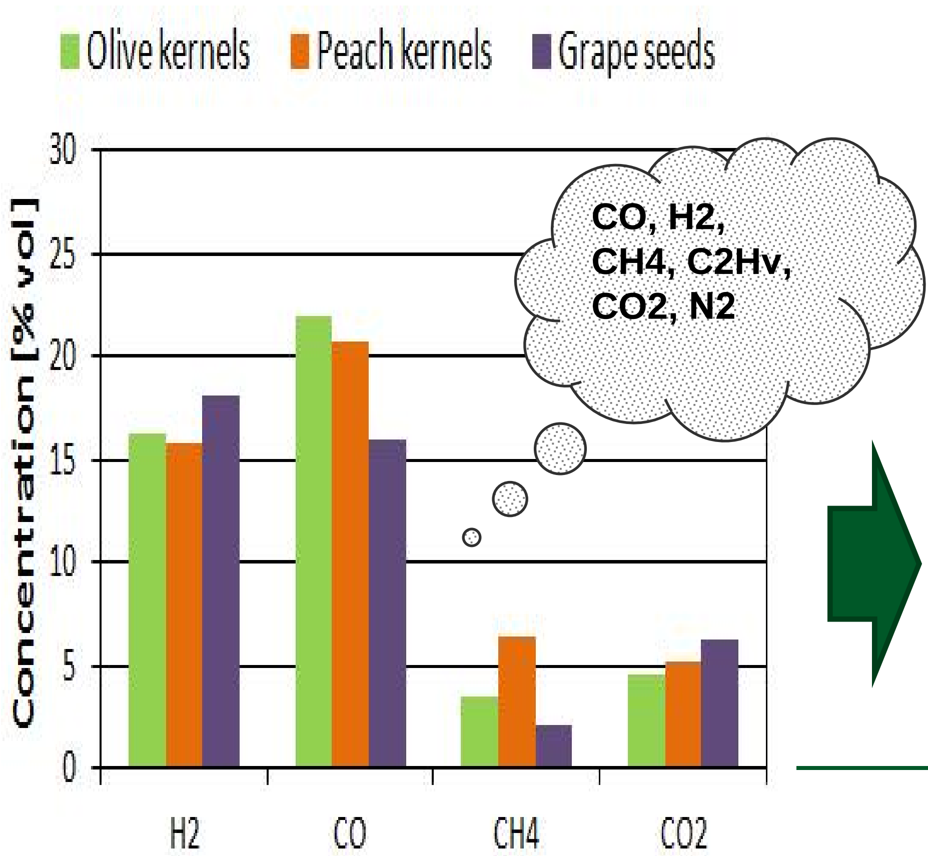
Key factors for successful operation:

- Stability in long term operation
- Efficiency
- Fuel feed versatility

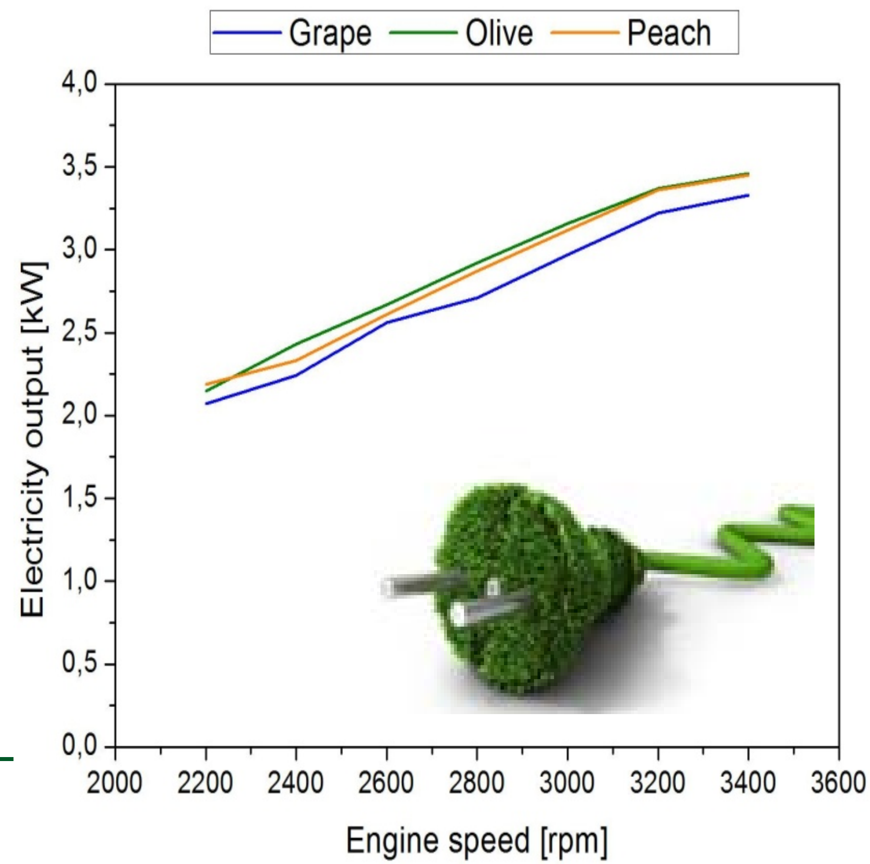
Waste biomass to “Green” electricity

Demonstration results

Producer gas Composition, %vol



Electricity production, KWel



Sustainability considerations:

Environment, society, economy

Bioenergy plans should be promoted and developed according to sustainability criteria

Sustainability considerations are taken into account ***in the production, promotion and use of bioenergy***, with a view ***to minimize risks of negative impacts and maximize benefits***, in the immediate and long term life of the plants.

→ **METRICS & INDICATORS**

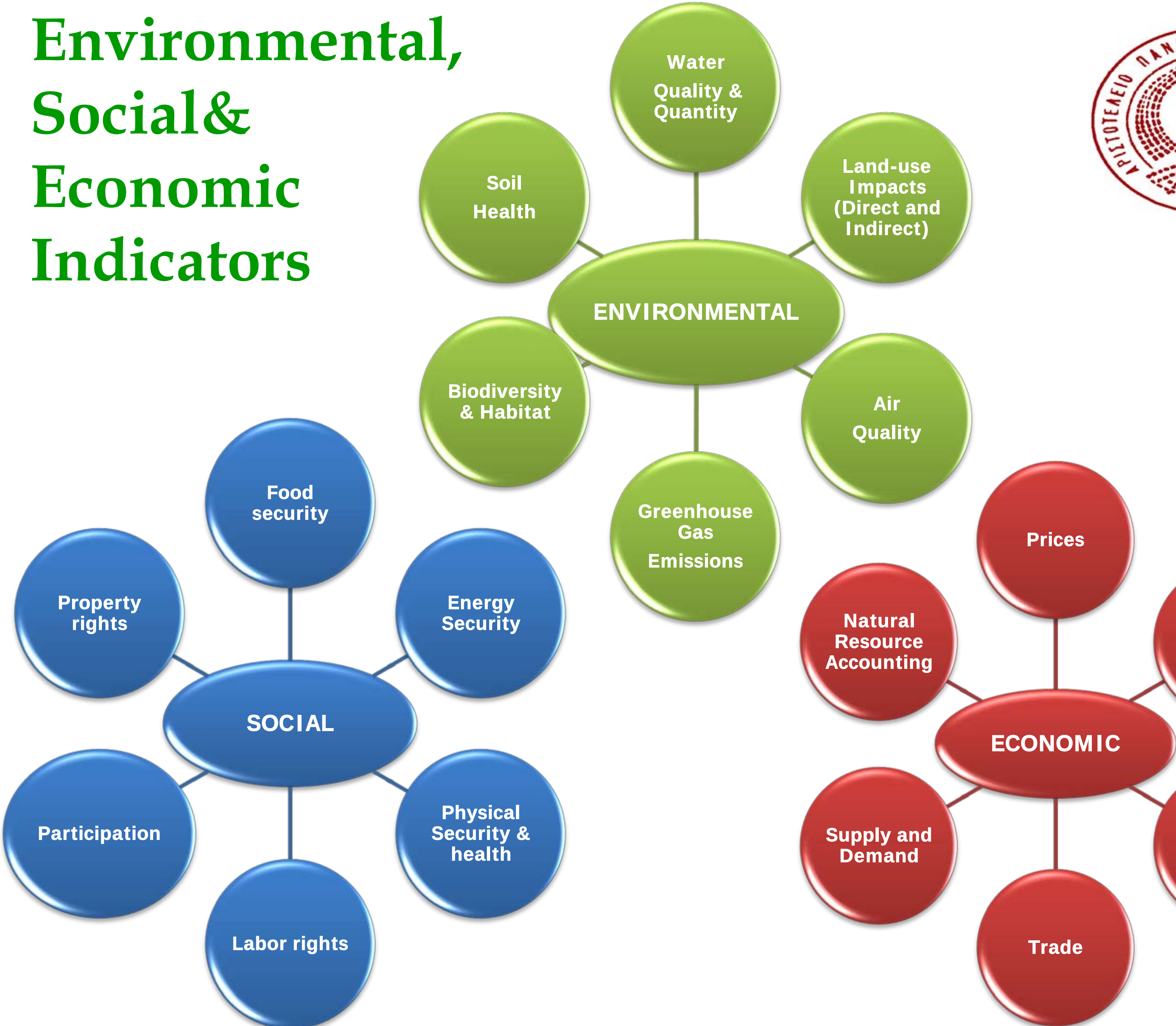
Metrics & Indicators

- ✓ Quantitative or qualitative factors
- ✓ Formulated to convey a single meaningful message &
- ✓ Should be judged on the scale of acceptable standards of performance

Metrics &Indicators provide means to :

- ❖ measure the degree of achievement,
- ❖ reflect changes - demonstrate trends –verify replicability
- ❖ assess performance or compliance.

Environmental, Social& Economic Indicators



CHP Bioenergy System boundaries

residues and not crops

- **Feedstock Production**
  - Land conditions
  - Feedstock Type
  - Land Management
- **Feedstock Logistics**
  - Harvesting and collection
  - Processing
  - Storage
  - Transport
- **Conversion**
  - Fuel Type
  - Conversion Process
  - Co-products
- **Biofuel Distribution**
  - Transport
  - Energy
- **End Use**
  - Engine Type
  - Blend conditions

treatment in site
by moving the CHP unit

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Environmental Sustainability

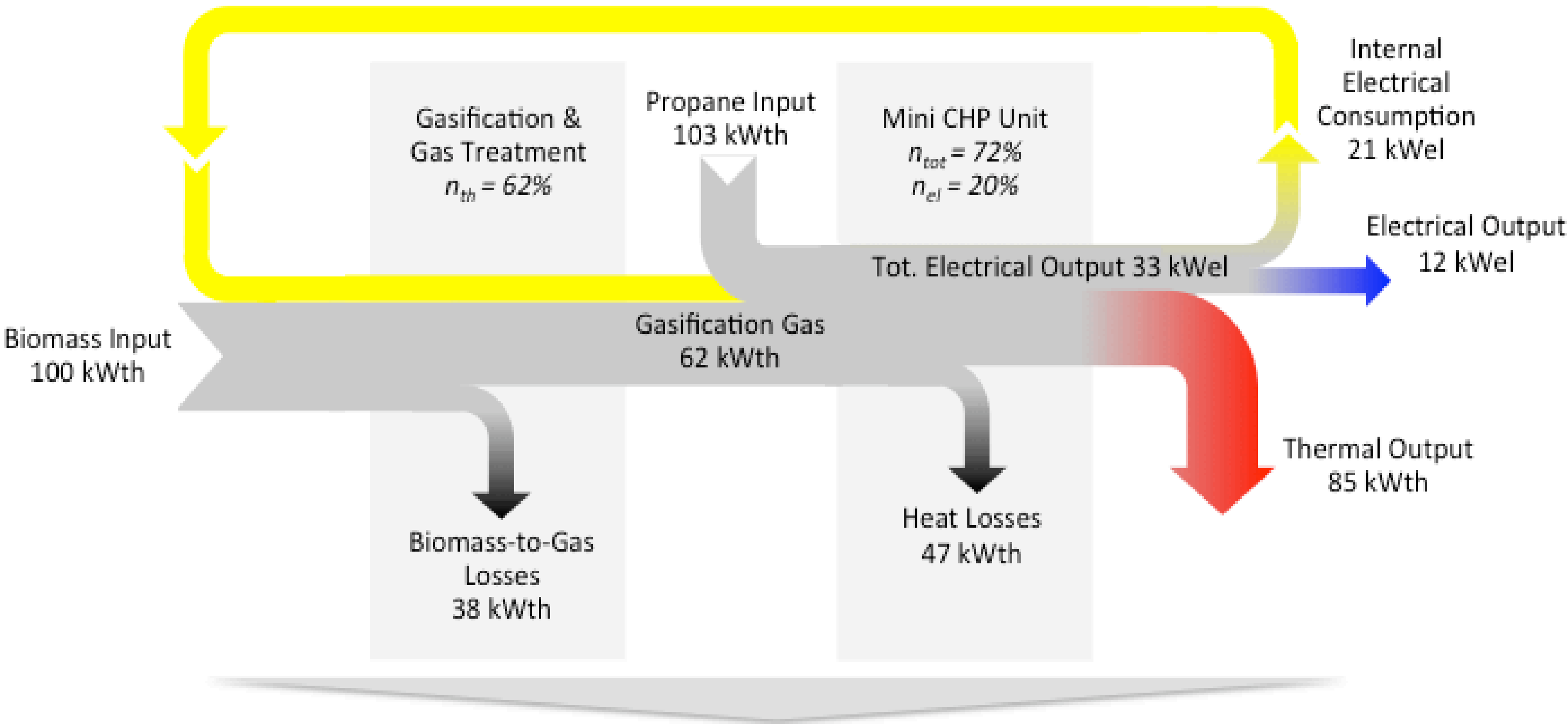
Environmental sustainability is related to energy, resources and emissions savings, “carbon footprint”, waste production

Three basic categories of metrics:

- **Thermodynamic (efficiency)**
- **Green House Gas Emissions**
- **Waste production**

Thermodynamic metrics

Shankey Diagram



metrics

$$n_{el} = 6\%$$

$$\frac{\textit{Tot. Electrical Output} - \textit{Internal Electrical Consumption}}{\textit{Biomass Input} + \textit{Propane Input}}$$

$$n_{th} = 42\%$$

$$\frac{\textit{Thermal Output}}{\textit{Biomass Input} + \textit{Propane Input}}$$

$$n_{tot} = 48\%$$

$$\frac{\textit{Tot. El. Output} - \textit{Internal El. Cons.} + \textit{Thermal Output}}{\textit{Biomass Input} + \textit{Propane Input}}$$

Green house gas emissions

Nitrous oxide (N2O) emissions and carbon dioxide (CO2) emissions were considered to calculate CO_{2eq}/year

On line emission analysis Results:

Reduction in greenhouse gas emissions (GHG)	**~0.55 kg/kWh**
Carbon footprint	**3.500 kg CO_{2eq}/year**
Resource savings (e.g lignite for Region of W. Macedonia)	**~1.59 kg/kWh**

Emissions from crop harvesting and soil carbon balances are out of our system boundaries that are defined from waste storage to end use.

Waste production

Tars & solid waste:

- Tars could treated within the waste water treatment plant of an agro-industry or disposed off as waste for offsite controlled treatment

  →tar disposal cost 0.9-1.3 €/kg (field research)

- Solid waste (ash, accumulated particles downstream the gas cleaning system) are nutrient sources for soil fertilization (biochar)

Social Sustainability

Social sustainability is related to **employment** and **stability of livelihood** in the local communities, whereas from the point of consumers' view, is related to **product quality** and **public acceptance** of biomass activities.

Social sustainability indicators are difficult to quantify and are often qualitative.

Social Metric

Employment creation

1-4 Jobs/ CHP unit

- **Part or full time jobs**, **skilled, high level educated personnel**.
- The **number** of personnel depends on the **unit's automation system**, as well as **on the scale**.

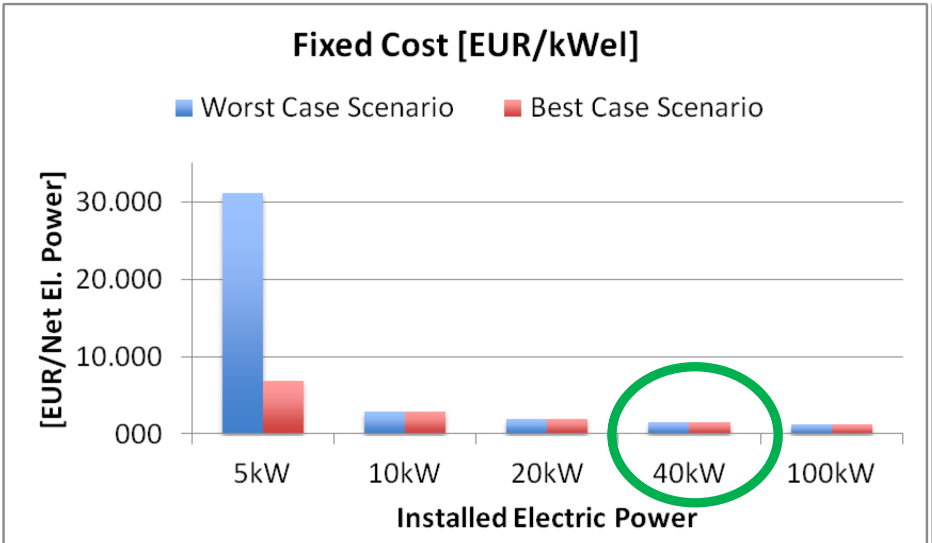
Economic Sustainability

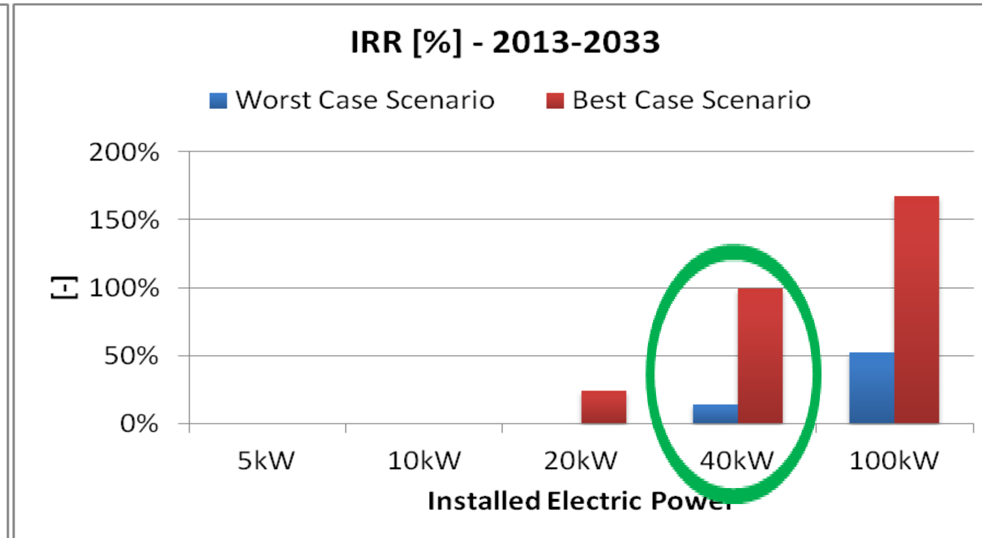
Economic sustainability is analyzed through internal functions of the company or by the external effects on society and environment.

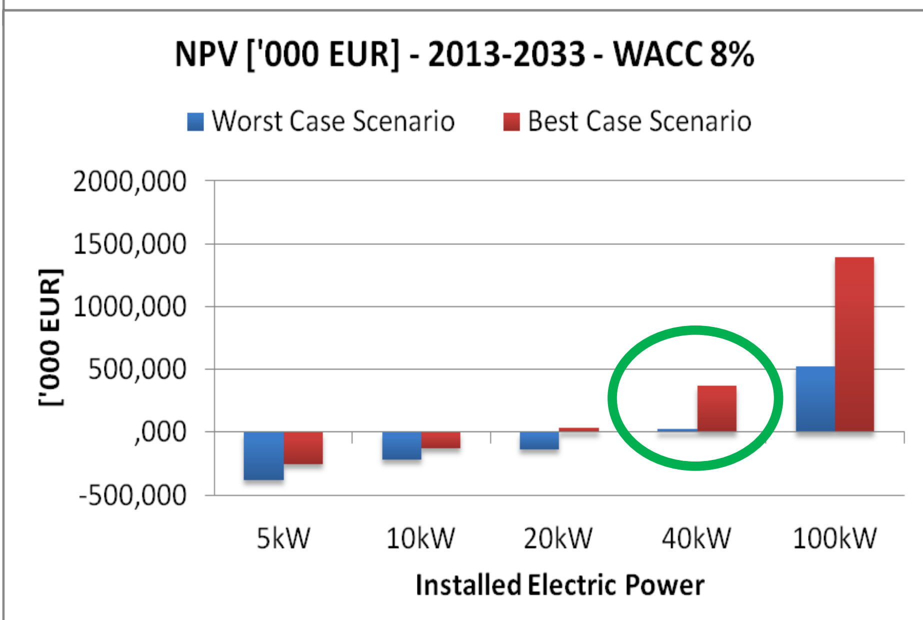
- From the internal point of view the financial performance of a company and capability to manage assets are the most important factors leading to economic sustainability.

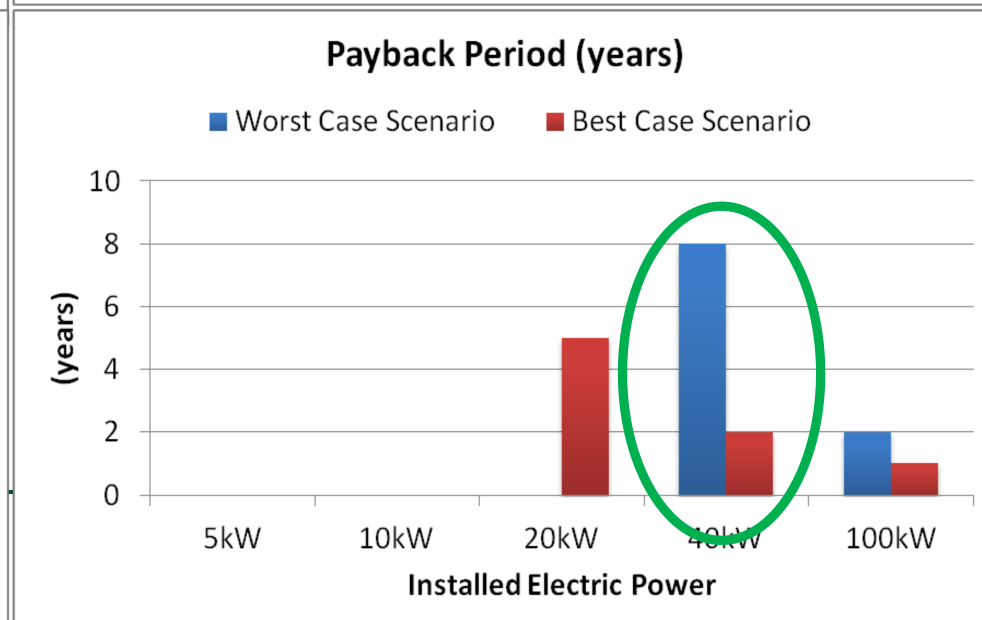
- Analysis of the external implications of economic sustainability management focuses on the company`s influence on the wider economy and how the company manages social and environmental impacts.

Microeconomic Analysis









Microeconomics

- **5 kWel worst case scenario represents the analysis for the actual demo unit**
- **40 kWel installed electrical capacity represents the most realistic and promising scenario for future commercialization (based on existing design)**

Best case scenario- 40 kWel

Metrics	Value
Investment cost per bioenergy unit	**~1,500 €/kWel**
Gross Profit	**up to 75,000 €/year**
Profitability	**up to 56,000 €/year**

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In case of system improvements; automated system performance, 3 full time operators, 10units construction (40kWel installed capacity)- best case scenario

Macroeconomics

Best case scenario- 40 kWel

Metrics	Value
Total value added to the economy (labor income + taxed profit)	**92,000 €/unit (annual basis)**
Energy diversity	**up to 100 kWel/unit investment**

- **The total value added reflects the added value per unit due to the additional income from sales and employment**
- **Change in diversity of total primary energy supply due to bioenergy.**

SWOT (Internal factors)

Major Strengths	Major Weaknesses
➢ Zero Waste and decreased GHG emissions process	➢ Demand for Producer gas cleaning
➢ Integrated technology	➢ Operation difficulties – System stabilization
➢ Mature technology	➢ Lack of demo data - lack extended pilot line runs
➢ Demonstrative operation	➢ Economy of scale favors large scale operations
➢ High energy efficiency	➢ Economic viability dependent on regulated tariffs
➢ Ability to operate with different feedstock	
➢ Potential co-processing with other wastes	
➢ Potential subsidy & Enhanced feed in tariff	
➢ Raw Material Availability	
➢ Legislation for Renewables Energy Production	
➢ Business opportunities	
➢ Development of rural areas	
➢ Energy independence	
➢ Diversity of energy supply	

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SWOT (External factors)

Major Opportunities	Major Threats
➢ Market growth perspectives	➢ Competition with fossil fuels and other renewable sources
➢ Energy and climate change priority on policy making	
➢ Waste to energy- Towards independence from fossil fuel markets	
➢ Funding – Entrepreneurship	
➢ Revenues are protected by feed in tariffs and by ensured access to the grid	
➢ Sustainable development	

Conclusions

- Combined heat and power production increases the overall energy efficiency.
- The total system energy efficiency reaches the value of 48%.
- The unit operates having low greenhouse gas emission profile.
- Social and economic metrics show the potential gains from the implementation of the present technological scheme in the local communities.
- The innovative proposed technological scheme seems of great potential.
- At the moment, commercial success depends on capital reduction instruments such as subsidies, electricity feed in tariff, biomass price, scale.

New Thinking

Waste glycerol- a biodiesel production by product

Incorporating waste glycerol with biomass

Fuel substitution with glycerol to upgrade the alternative fuel and to increase sustainability

Acknowledgements

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Thank you for your attention!

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