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# INDUSTRIAL SYMBIOSIS OF BIODIESEL PLANTS AND AGRICULTURAL BIOMASS BASED ENERGY PLANTS VIA CO-GASIFICATION OF CRUDE GLYCEROL WASTE STREAMS WITH AGRICULTURAL RESIDUES: THE GLYCO BIO-DIESEL PROJECT

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# Biomass and Waste Group

## Main Research Activities

**Laboratory of Chemical Processes and Plant Design**
**Department of Chemical Engineering**
**Aristotle University of Thessaloniki.**

- **Applied & basic research** concerning **the thermochemical conversion** of **biomass** and **wastes** 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 softwares.**

- **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.**

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

# Goal of Biomass Group: Research Activities

**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

# PRESENTATION CONTENTS

- BIODIESEL & GLYCEROL PRODUCTION
- OLIVE KERNELS GENERATION & MANAGEMENT
- INDUSTRIAL SYMBIOSIS CONCEPT
- BIODIESEL PLANT INPUTS/OUTPUTS
- THE PROPOSED SYMBIOTIC SCHEME
- MATERIALS AND METHODS
- ENVIRONMENTAL PERFORMANCE
- CONCLUSIONS

# BIODIESEL & GLYCEROL PRODUCTION

- One of the best alternatives to efficiently reduce our dependence on fossil fuels
- In 2013 in EU almost 14Mtoe of biodiesel was used that represent an annual increase of 3% since 2012
- EU target to incorporate bio-fuels into the transportation at a rate of 10% by the year 2020
- Transesterification of vegetable oils and animal fats
- Biodiesel production generates about 10 wt% of crude glycerol. *As biodiesel production increases, so does production of the primary byproduct*

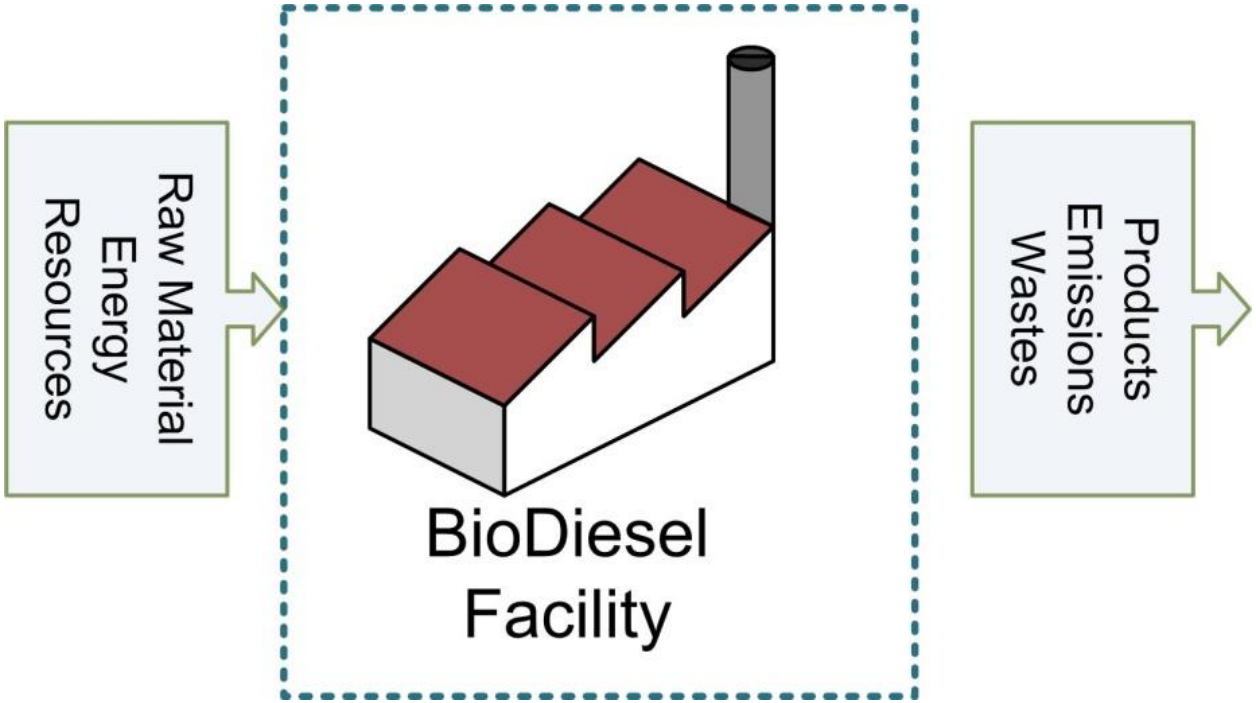
# BIODIESEL & GLYCEROL PRODUCTION

- The past years glycerol was a key product in many industries (e.g. cosmetics) and a high added value product
- The tremendous growth of the biodiesel industry created a glycerol surplus that has resulted in a decrease in crude glycerol prices
- The once considered valuable by-product is becoming a waste stream with a disposal cost attributed to it
- Waste glycerol valorization on-site for energy production is a key management strategy related to sustainability and environmental performance of the biodiesel production system

# OLIVE KERNELS GENERATION & MANAGEMENT

- Olive kernels is a waste stream of the olive extraction industry
- On average the process of 1 t of olive fruit is generating 125 kg of olive kernel
- The Olive Kernels are extracted from the moist pomace at Olive Oil Refineries
- ***Current Olive Kernel management practice*** → Combustion in furnaces or open fireplaces (heat & emits a thick smoke rich in $CO_2$ and particles)
- Take into consideration the olive oil yield in the Mediterranean countries it is quite obvious why the olive kernel disposal and management is still considered a major problem by the farmers and the olive oil industries

# INDUSTRIAL SYMBIOSIS CONCEPT



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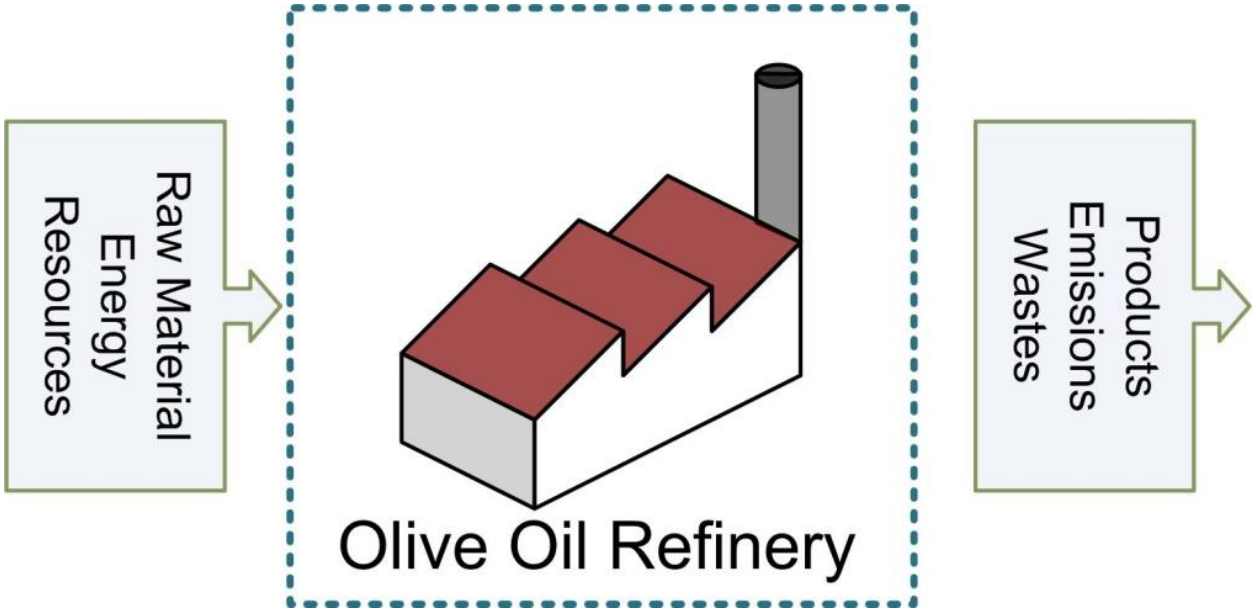

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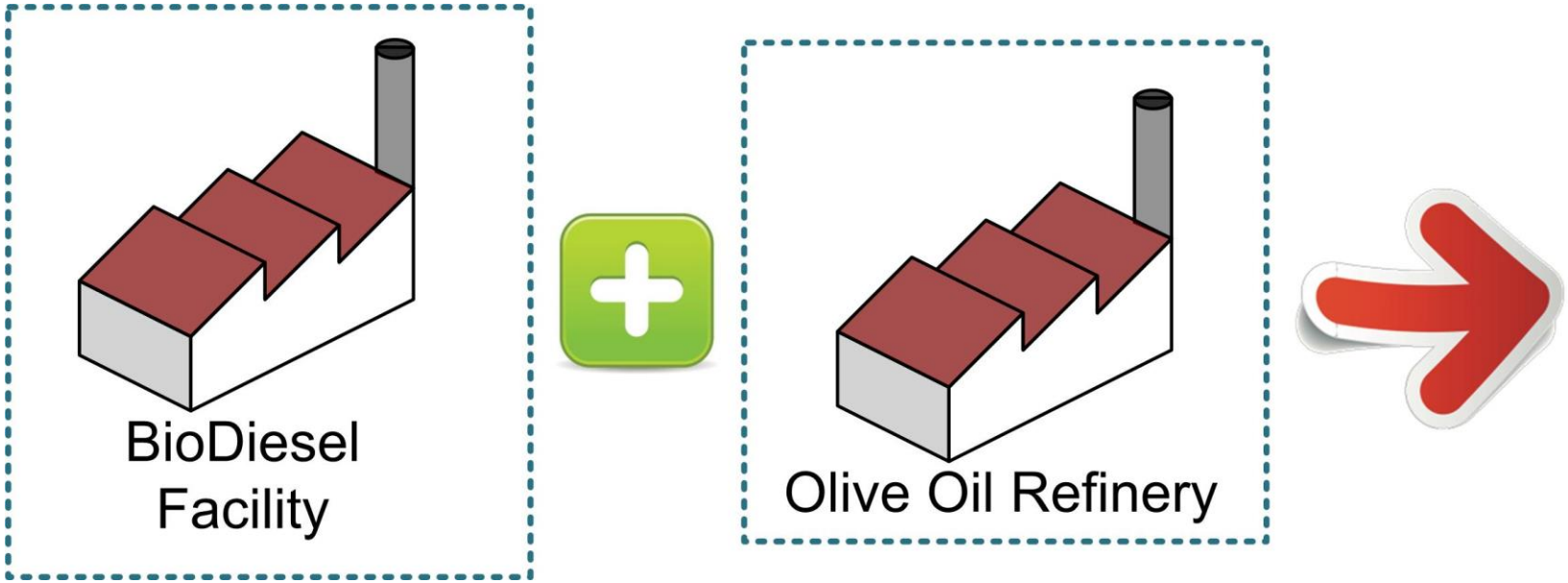

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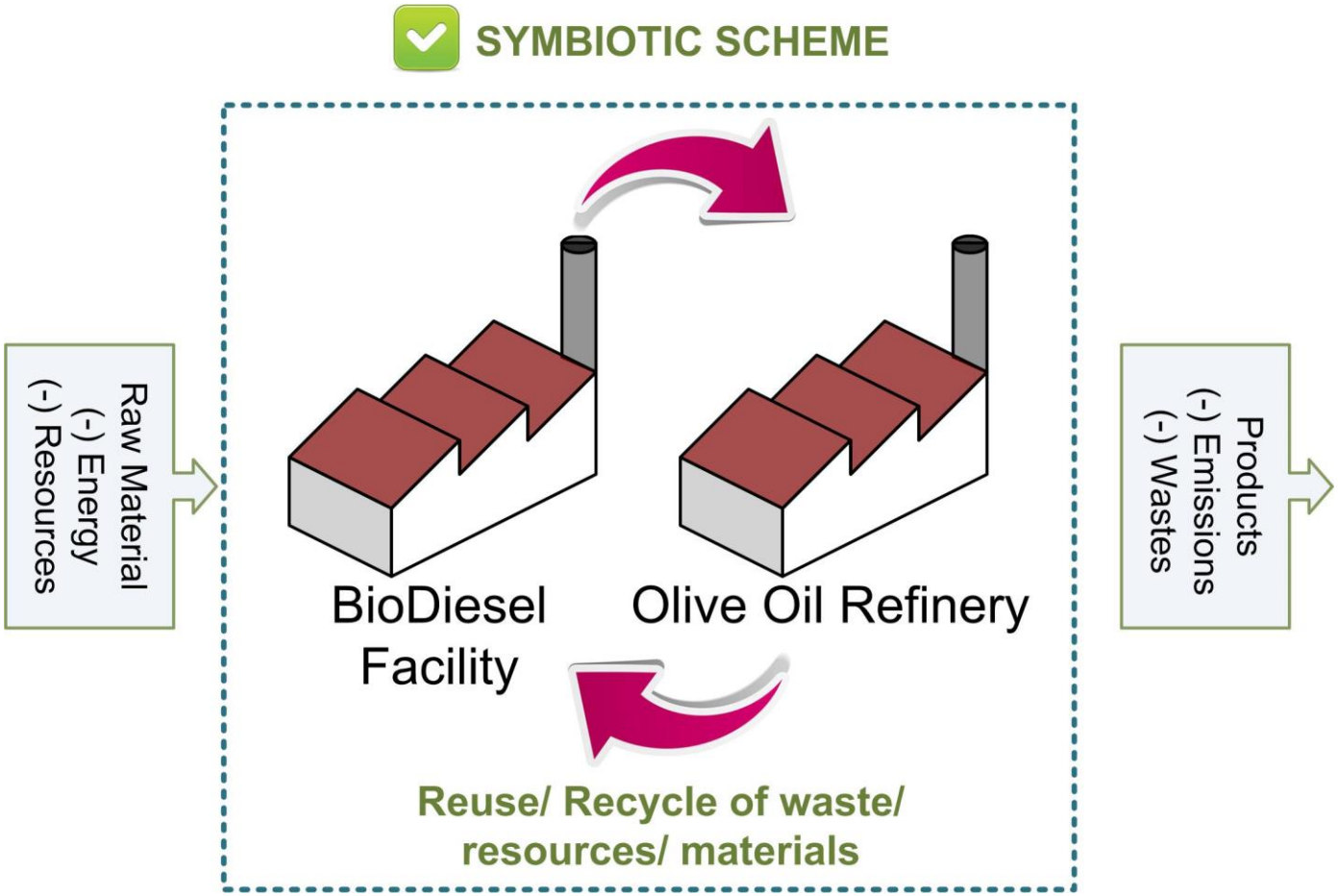
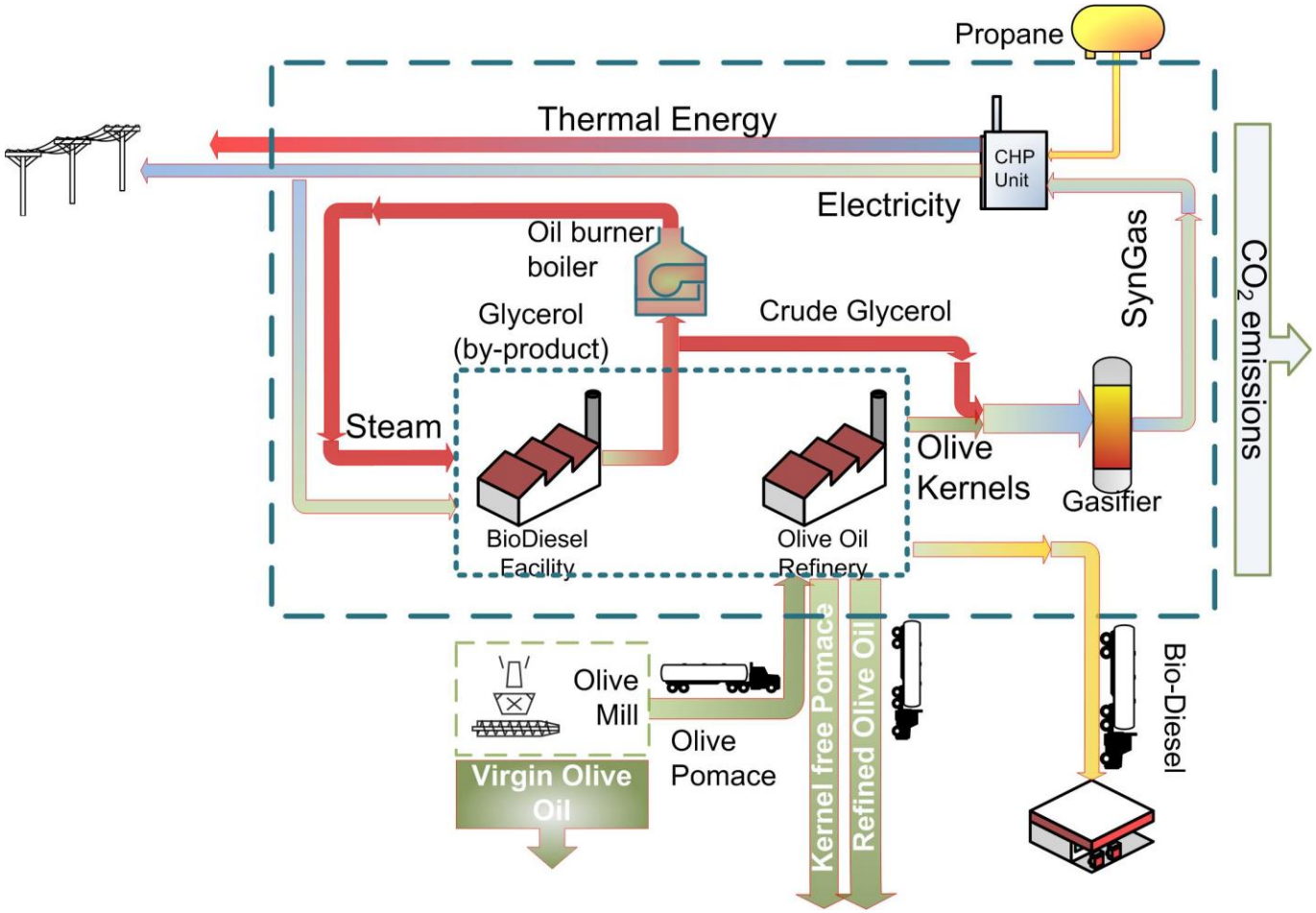


# BIODIESEL PLANT INPUTS/OUTPUTS

- Energy Requirements
  - Steam: 0.337kWh/lt of Biodiesel
  - Electricity: 0.0255kWh/lt of Biodiesel
- Biodiesel Production: 3,000 $m^3$
- Crude Glycerol Generation: ~ 400 $m^3$

# THE PROPOSED SYMBIOTIC SCHEME

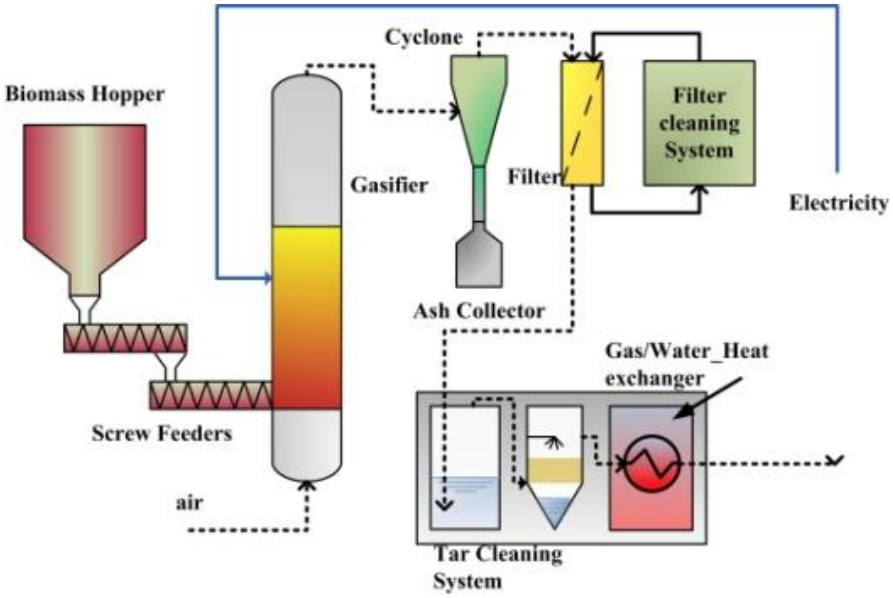


# MATERIALS AND METHODS

- **Innovative co-gasification unit of crude glycerol and waste biomass**
- **Feedstock Characteristics and synthesis gas Yield**

# Innovative co-gasification unit of crude glycerol and waste biomass

## The Gasification System Layout




## The SMARt-CHP System

SMARt-CHP Project, LIFE08 ENV GR 000576 SMARt-CHP, http://smartchp.eng.auth.gr

# Innovative co-gasification unit of crude glycerol and waste biomass

- Bubbling Fluidized Bed Gasifier (BFBG)
  - bottom part (fluidized bed)
  - upper part (freeboard)
  - feeding system consist of a silo, a biomass hopper and two screw feeders
  - cleansing system of a cyclone and a ash collector, a filter of 99% efficiency and a water scrubber
  - the synthesis gas is entering a heat exchanger to reduce its temperature at the desired levels
- A CHP Internal Combustion Engine (ICE)

# Feedstock Characteristics and synthesis gas Yield

- Feedstock: ***Crude Glycerol & Olive Kernels Mixture***
- In order to *maintain the rheological characteristics* of the mixture at the required levels for its use in the gasifier, the glycerol content in the fuel mix kept less than **25 wt %**

| Elementary analysis of the Crude Glycerol/ Olive Kernel (CG-OK) mixture | |
|---|---|
| | **25 wt % of CG & OK** |
| C | 47.59 |
| H | 7.14 |
| O (by Difference) | 44.56 |
| N | 0.71 |
| HHV (MJ/kg) | 20.15 |
| Moisture content (wt%) | 10.40 |

# Feedstock Characteristics and synthesis gas Yield

- The gasification temperature set at 800 $^{o}C$ and the equivalence ratio kept constant during operation at ER: 0.3

**Synthesis gas Yield (gr/gr of feedstock)**

| Gasification Input | | Gasification Yield | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Synthesis Gas | | | | | | |
| $C_{67}H_{10}O_{63}N$* | Air | $N_2$ | $CO_2$ | CO | $H_2$ | $CH_4$ | $C_2H_6$ | $C_2H_4$ |
| 1,0 | 0,852 | 0,68 | 0,78 | 0,272 | 0,022 | 0,031 | 0,012 | 0,003 |
| | | Synthesis Gas Energy: 4704 (kJ/kg) | | | | | | |

*Empirical formula

# ENVIRONMENTAL PERFORMANCE - The current situation

- **Input (Biodiesel plant Operation)**
  - **Energy from Electricity (76MWh)→ $CO_2$:** 74894kg (emission factor, 0.979kg/kWh)
  - **Energy from Diesel Oil for Steam (1GWh) → $CO_2$:** 315261kg (emission factor, 0.2494kg/kWh)
- **Output**
  - **Thermal Energy from Glycerol Combustion, ~ 330t (2.5GWh) → $CO_2$:** 817826kg (emission factor, 0.338kg/kWh)
  - **Thermal Energy from Olive Kernel Combustion, ~ 995t (5.4GWh) → $CO_2$:** 2783341kg (emission factor, 0.508kg/kWh)
  - **Biodiesel Energy (28.8GWh) → $CO_2$:** 390155kg (emission factor, 0.014kg/kWh)
- **Total Emission Factor: 0.109kg/kWh**

# ENVIRONMENTAL PERFORMANCE - The proposed SYMBIOTIC scheme

- **Gasification "Plant" Yield**

(The plant valorizes ~ 995t of Kernels & ~ 330t of crude glycerol)

  - **Electricity (1.3GWh) → $CO_2$:** 774741kg (emission factor, 0.585kg/kWh)
  - **Thermal Energy (3.4GWh) → $CO_2$:** 2016605kg (emission factor, 0.585kg/kWh)

# ENVIRONMENTAL PERFORMANCE - The proposed SYMBIOTIC scheme

- **Input (Biodiesel plant Operation)**
  - **Electricity from gasification → $CO_2$:** 44795 kg (emission factor, 0.585kg/kWh)
  - **Energy from Glycerol Comb. for Steam → $CO_2$:** 1450565 kg (emission factor, 0.270kg/kWh)
- **Output**
  - **Electricity Surplus from ICE (470MWh)→ $CO_2$:** 274216_kg (emission factor, 0.558kg/kWh)
  - **Thermal Energy from ICE (3.4GWh)→ $CO_2$:** 2016605kg (emission factor, 0.585kg/kWh)
  - **Biodiesel Energy → $CO_2$:** 1495361 kg (emission factor, 0.052kg/kWh)

# ENVIRONMENTAL PERFORMANCE - The proposed SYMBIOTIC scheme

- **$CO_2$ Mitigation**
  - **Electricity from the Grid →**

    **$CO_2$:** ***458463*** kg (emission factor, 0.979kg/kWh)
  - **Thermal Energy from Diesel Combustion →**

    **$CO_2$:** ***918552*** kg (emission factor, 0.249kg/kWh)
- **Total Emission Factor: 0.084kg/kWh**

# CONCLUSIONS

- The proposed Symbiotic scheme valorizes in total 1,250t of waste streams (995t of olive kernel & 330t of crude glycerol)
- The biodiesel plant could cover its own energy needs by materials that otherwise are considered as waste streams
- The Symbiotic scheme produces an electricity surplus of 470MWh & 1.4GWh of thermal energy that could utilized inside the Biodiesel Plant or in the Olive Oil Refinery

# CONCLUSIONS

- Its environmental efficiency is well established as its total emission factor is minimized by 0.025kg $CO_2$ per produced kWh.
- Avoids the purification costs of Glucerol and together generates an additional income from the Electricity surplus delivered to the grid
- The Symbiosis concept seeks to improve biodiesel production plant's energy balance, resource efficiency and to offer a solution for waste materials (crude glycerol, agro-wastes) recovery.

# AKNOWLEDGEMENTS

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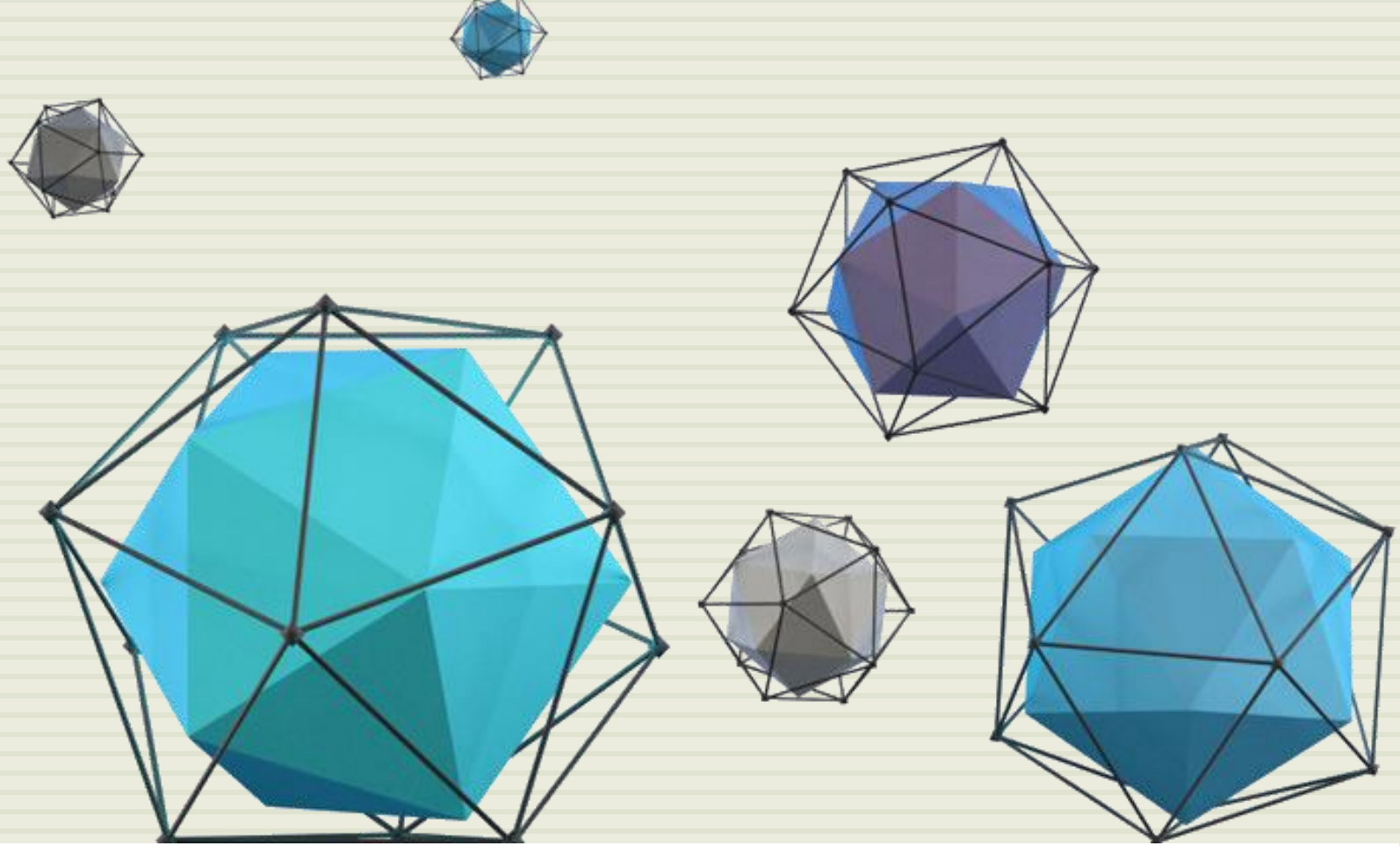

# Thank You for your Attention

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