A MULTI-REGION REPRESENTATION OF AN AUTOMOTIVE MANUFACTURING PLANT WITH THE TIMES ENERGY MODEL

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with the contribution of

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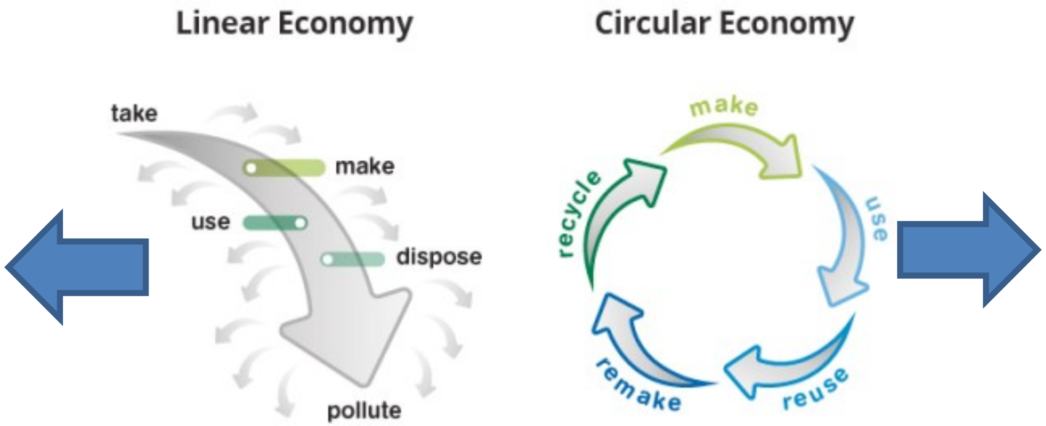
Contents

The research framework

The Circular economy requires a material-specific and systemic approach in the design and management of production processes (EC Action Plan, 2015), to promote global competitiveness, sustainable economic growth and create new jobs. Waste is considered as a resource which can be reintroduced in the production cycle.

- Reduction of resource availability
- A higher waste production
- Environmental pollution
- Higher releases of GHG emissions
- Climate change
- Intense competition among States for the control of raw materials

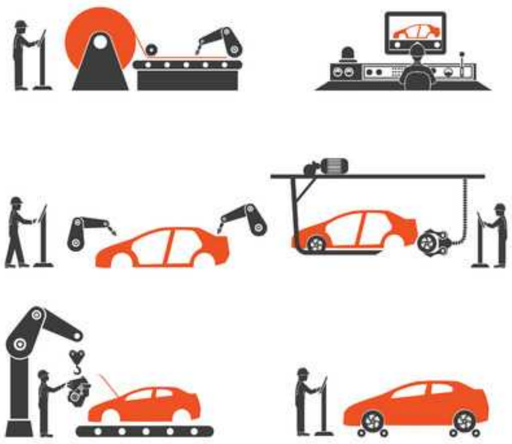


- Waste reduction
- A more efficient use of resources
- Fewer releases of carbon dioxide
- Higher competitiveness among enterprises

Aim of the study

To explore the potentialities of the circular economy approach in a real case study: the energy and materials system of an automotive industrial district (**TIMES4CARS**)

➡ implementation of a partial equilibrium model based on the IEA-ETSAP TIMES model generator and its validation on the time horizon 2015-2025



The **scenario analysis** allows to individuate the least-cost solutions based on the principles of the circular economy (sharing materials, waste valorisation, electricity production from renewable sources, energy efficiency increase)

The methodology: ETSAP TIMES

Models Coverage:

- Energy supply and end use sectors
- Spatial scale:
  - Global (e.g. TIAM)
  - Multi-region (e.g. TIMES Pan EU model)
  - National (one per each EU countries)
  - Local (Region/Province/Town)

User Interfaces

- VEDA-FE/BE (KANLO)
- ANSWER (Noble Inc.)

Methodology

- Maximization of the total surplus (Cost minimisation)
- Partial equilibrium (only energy markets)
- Linear Programming/Dynamic Programming
- Technology and Energy oriented

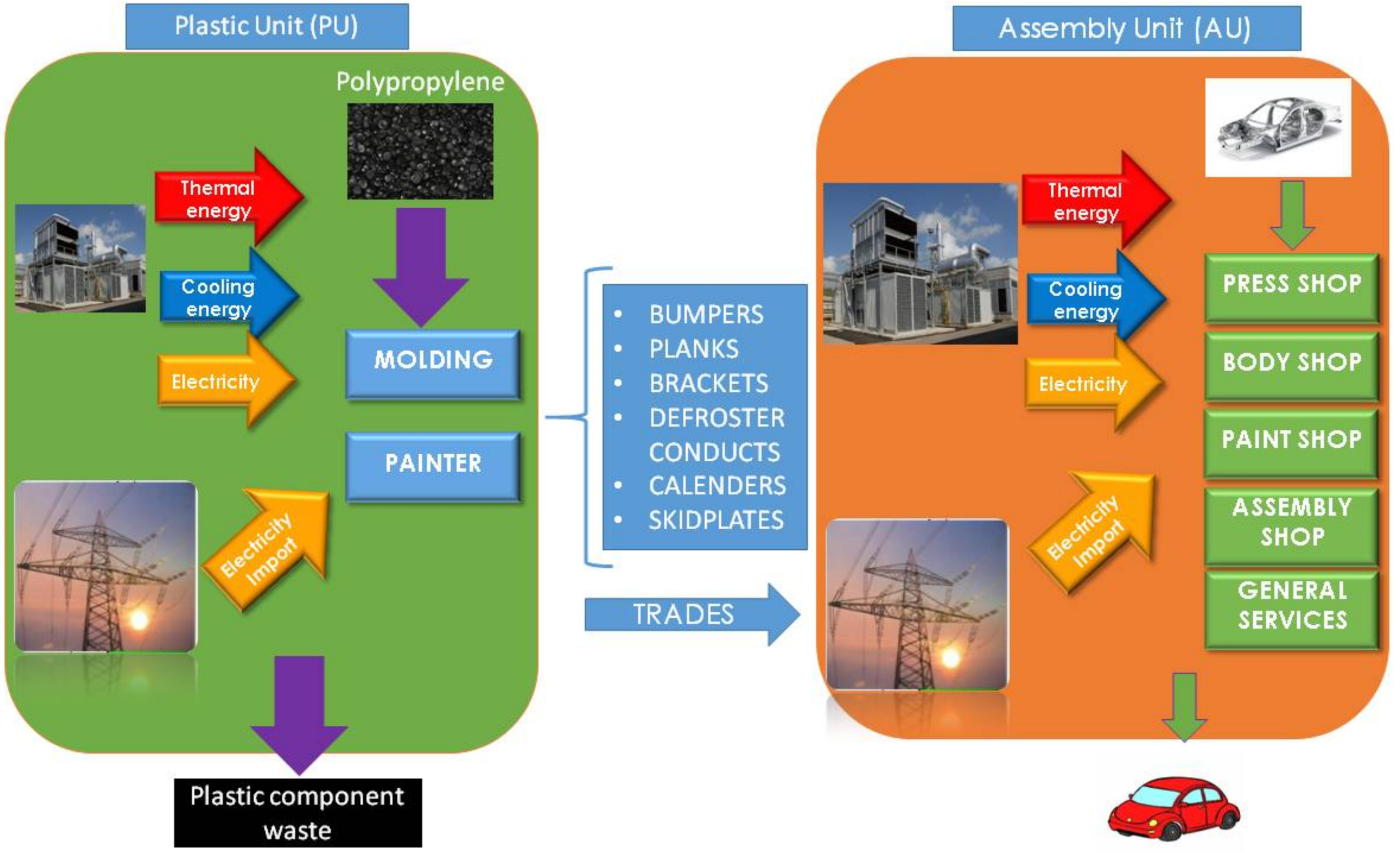
Purposes:

- Exploring (Energy prospective)
- Energy supply assessment:
  - Target-oriented integrated policy analysis and planning

Models Features:

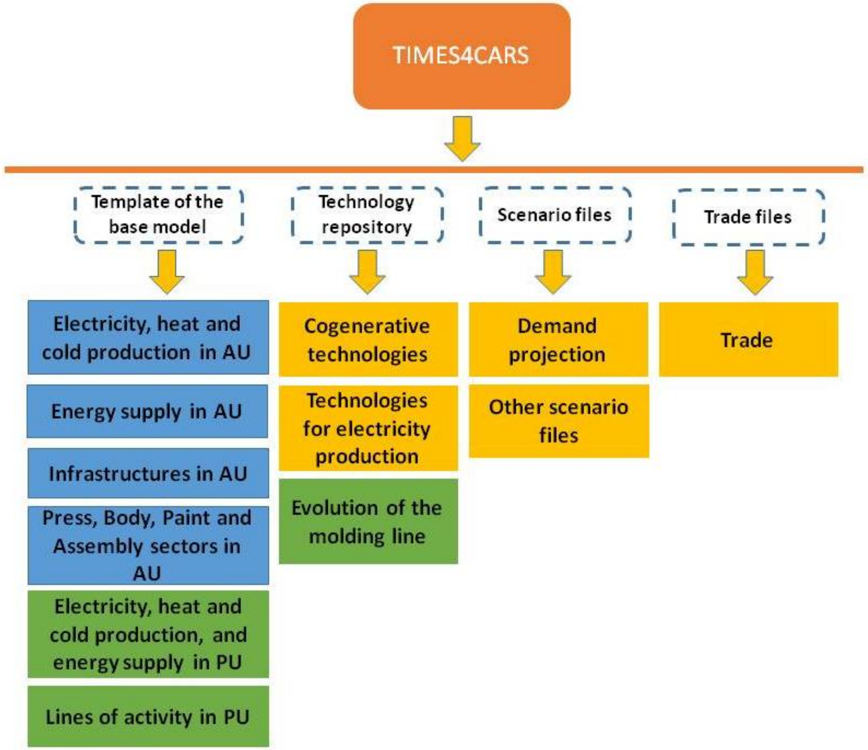
- Time horizon:
  - Medium to Long term (Multiperiod)
  - Time horizon with flexible time slices
- Focus on the energy sector: detailed description of end-uses and energy technologies
- Main exogenous inputs: information on the energy system structure, base-year energy flows and prices, demand projections/scenarios, environmental constraints
- Main outputs: Optimal energy-technology pathways by scenario, costs of energy system activities

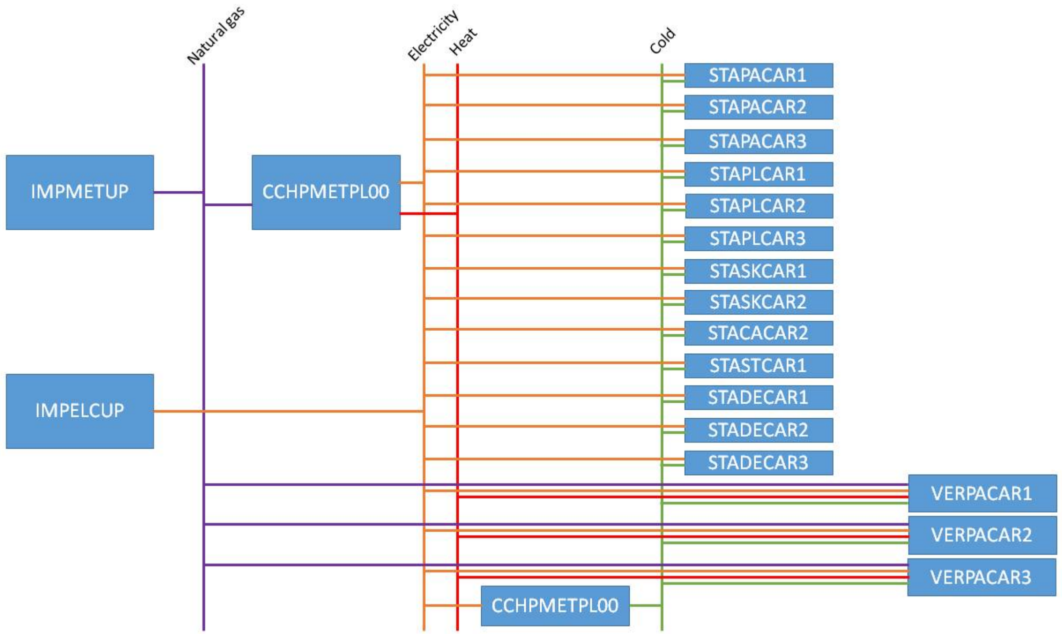
Methods: The TIMES4CARS Model (1/2)



- **2 different regions (PU** and **AU)**
- Production of **5 types of cars** in the AU
- the final demand of cars drives the model on the examined time horizon (**2015-2025)**
- Reference year: 2015
- **Roadmap of cars production:**
  - **CAR1**, **CAR2** , **CAR3** produced in base year
  - **CAR4** produced from 2019
  - **CAR5** produced from 2020
- Model's calibration to 2015 (base year), 2016 and 2017

Methods: The TIMES4CARS Model (2/2)





Reference energy system of the PU

Methods: Scenario Analysis

➢ **The Business As Usual (*BAU*) scenario** represents the evolution of the current energy and productive system of the two units in order to satisfy the final demand over the time horizon 2015-2025.

➢ **Three "energy" scenarios**

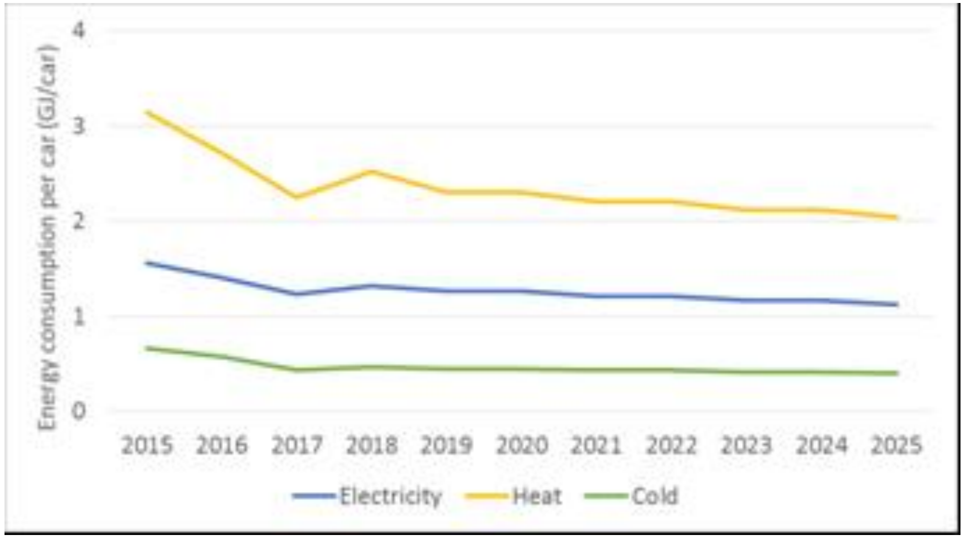
- '***Photovoltaic***' based on the introduction of photovoltaic systems both on the PU and on the AU in order to satisfy a part of electricity consumption such as lighting
- '***Energy recovery***' which assesses the economic feasibility and the effects in terms of energy of the introduction of Organic Rankine Cycle technologies for the energy recovery in the molding processes.
- '***Syngas production***', which assesses the introduction of a pyrogasification technology coupled to an internal combustion engine both in the AU and the PU, assuming an investment cost of 4,000 Meuro / GW). Three types of syngas are hypothesized on the basis of different concentrations in moles of polypropylene (20%, 40% and 60%) mixed with municipal solid waste

➢ **Two scenarios related to the Plastic materials**

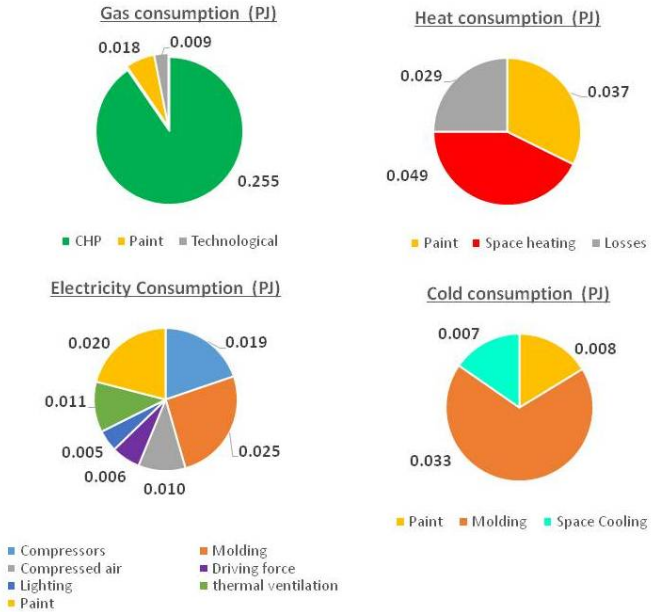
- '***Pigmented***' which assesses the convenience of using pigmented polypropylene during the molding phase.
- '***Recycling***' which assesses the convenience of the recycling system taking into account the investment costs and the quantities of waste produced in the PU.

Results: BAU scenario

Starting from 2019, the current cogeneration systems are replaced by **two steam turbines with bleed and cogeneration condenser** for both the two Units, characterized by higher efficiencies (0.38) than those existing in the base year (0.25).



Energy consumption per car (GJ/car) - AU



Breakdown of energy consumption by 2025 by use (PJ) - PU

Results: Energy scenarios (1/2)

Photovoltaic scenario

- Total cost increases by **1.2%** for the AU and by **0.8%** for the PU respect to the BAU scenario;
- A lower natural gas consumption of **1.2%** and **2.8%** respectively for the AU and PU respect to the BAU scenario;
- CO_2 emissions drop by **1.1%** and **2.6%** respectively for the AU and PU respect to the BAU scenario

Syngas production scenario

- The model prefers to use the **syngas type 3** (60% of moles concentration of polypropylene);
- The total system cost decreases by **3%** compared to that of the BAU scenario
- A pyrogasification technology is activated from 2019 with a capacity of 0.035 MW both for the AU and PU;
- An annual electricity production of **$0.7*10^{-3}$ PJ** is obtained;
- In the AU there is a reduction of natural gas consumption of **0.1%** compared to the BAU scenario,
- In the PU there is a reduction of natural gas consumption of **0.7%** compared to the BAU scenario

Results: Energy scenarios (2/2)

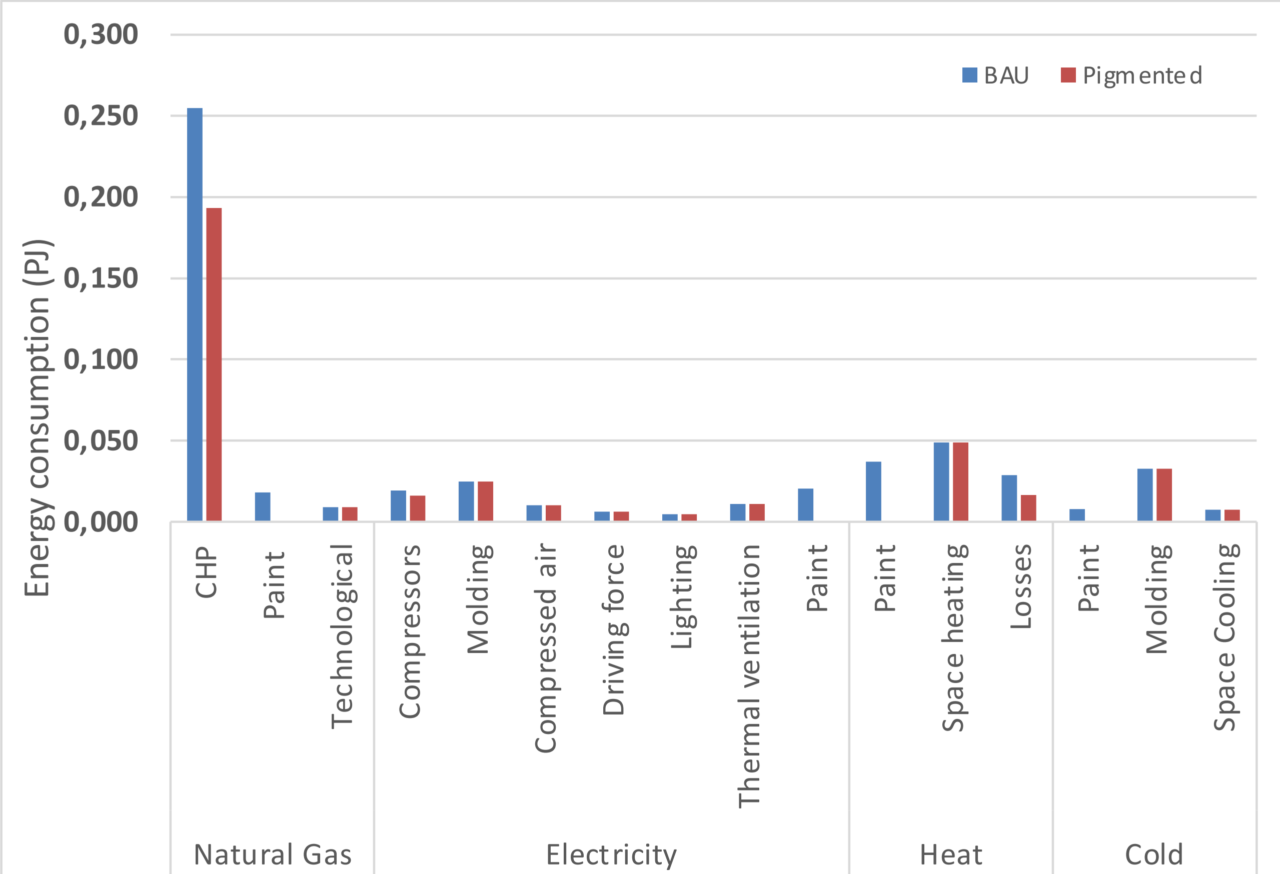
Energy recovery scenario

- The **Organic Rankine cycle (ORC) technologies** for energy recovery in the molding phase are not selected due to their high investment costs;
- If a superimposed exogenous constraint forces the use of the ORC technologies, the system **chooses to activate those not integrated with a renewable source;**
- A **30% electricity and cooling savings** are obtained for 2025 in the molding process compared to the BAU scenario
- It is observed a **lower electricity production** by the steam turbine (-9%) and a **lower import of natural gas** (8%) by 2025 compared to the BAU scenario
- The compressors for cold production show also a **17% reduction** in electricity consumption by 2025.
- CO_2 emissions decreases of **9%** in 2025 compared to the BAU scenario.
- **There are no changes** in heat production and consumption.

Results: scenarios related to Plastic materials (1/2)

Pigmented scenario

- -**30.4**% of natural gas purchase in 2025 compared to the BAU scenario;
- -**24%** of natural gas consumption for cogeneration system;
- **-43%** of heat losses;
- **-16%** of electricity consumption in compressors for cold production;
- **-40%** of CO_2 emission from combustion
- **Zero emissions** (VOC and CO_2) from the painting process



Energy consumption by use – year 2025

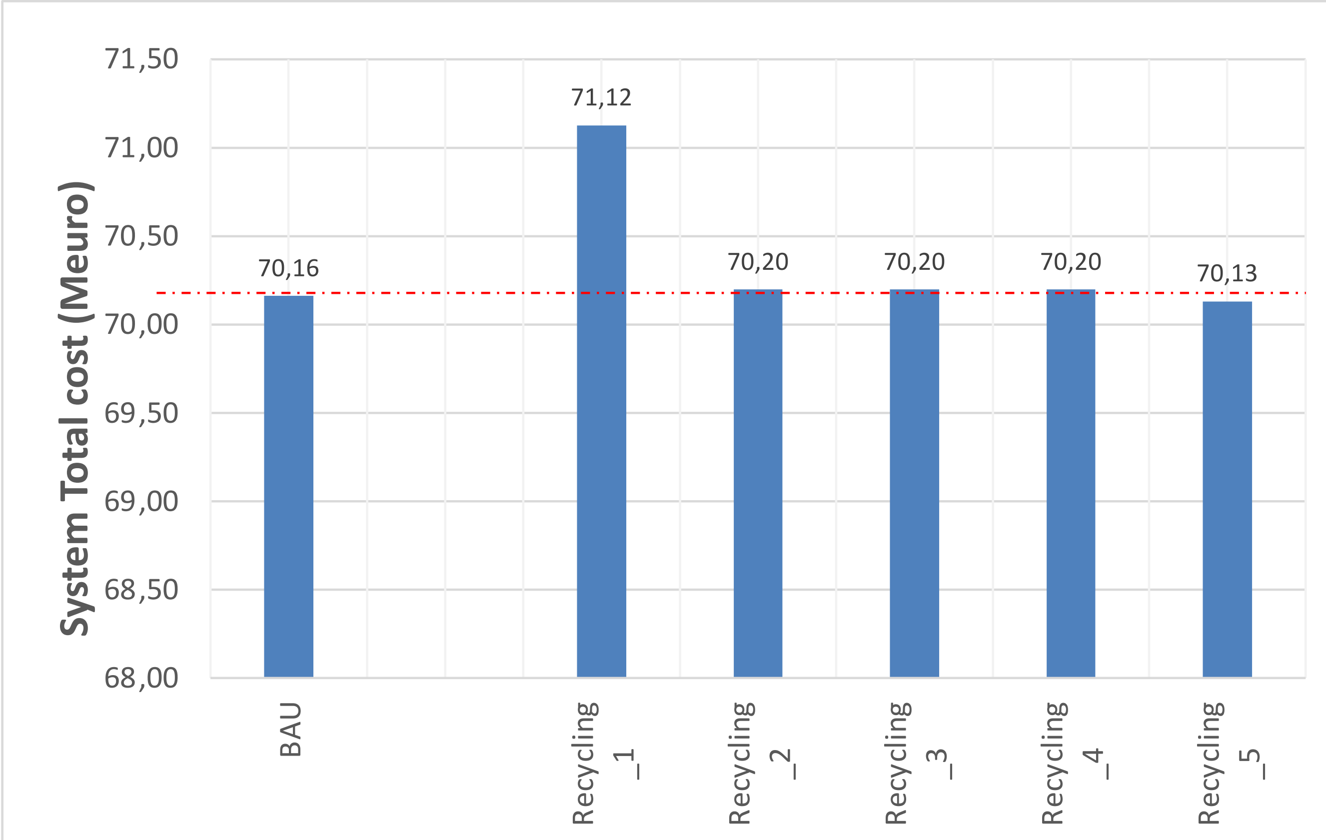
Results: scenarios related to Plastic materials (2/2)

Recycling scenario

In absence of constraints on the reuse of scraps from plastic components, the model suggests waste disposal of scraps as the optimal solution in terms of total system cost.

In the sensitivity analysis the investment costs of the recycling system are:

- 60 Euro/kg for the Recycling_1
- 30 Euro/kg for the Recycling_2
- 20 Euro/kg for the Recycling_3
- 15 Euro/kg for the Recycling_4
- 10 Euro/kg for the Recycling_5



Sensitivity analysis

Conclusions (1/2)

- This work was useful to validate the feasibility of modelling a specific industrial district for cars production using the TIMES energy modelling platform in order to evaluate the possible implementation of measures based on the principles of the circular economy.

- The results show that **steam turbines with bleed and cogeneration condenser** are introduced to replace the current systems of electricity and heat production for both the two industrial units analyzed

- **The installation of photovoltaic panels** for both industrial units leads to a reduction of natural gas consumption and consequently a reduction of CO_2 emissions causing an increase of the total cost of the system, due to the investments in new technologies.

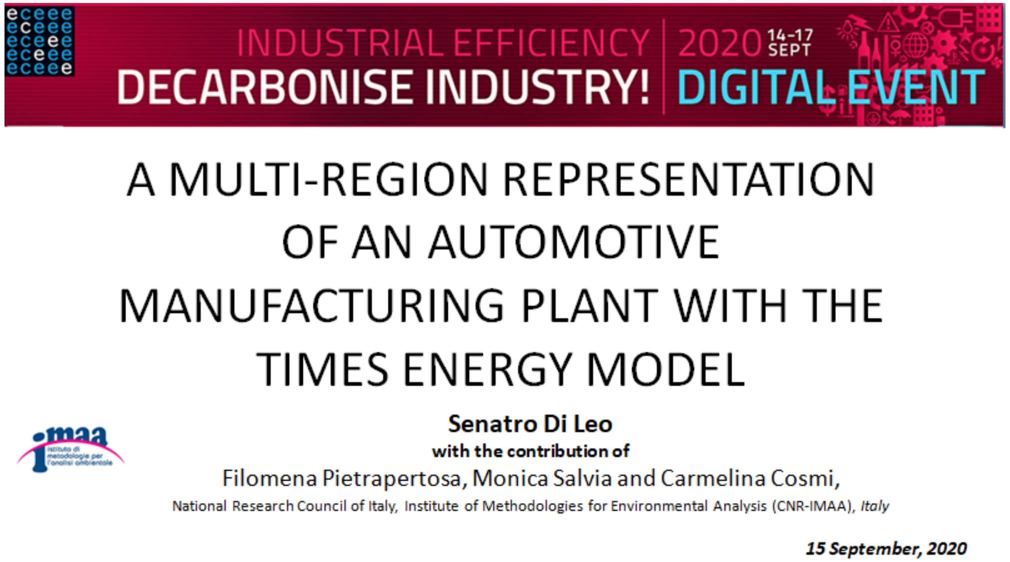
- **Introducing ORC technologies** into the molding process is not economically viable despite saving 30% of energy for electricity and cooling.

Conclusions (2/2)

- The **use of pyrogasification combined with an internal combustion engine for electricity production** is economically convenient for both production units even if a modest quantity of polypropylene waste is used and, consequently, the production of electricity is not much.

- **The use of pigmented polypropylene** supports a significant reduction in energy consumption and atmospheric CO_2 emissions from combustion processes, allowing also the elimination of emissions from the painting process.

- Recycling is economically sustainable if the investment cost of the shredding system is equal to or less than 10 Euro/kg.



Thank you for your kind attention

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