Comparative techno-economic assessment of gasification and combustion technologies in dealing with agroforestry biomass blends

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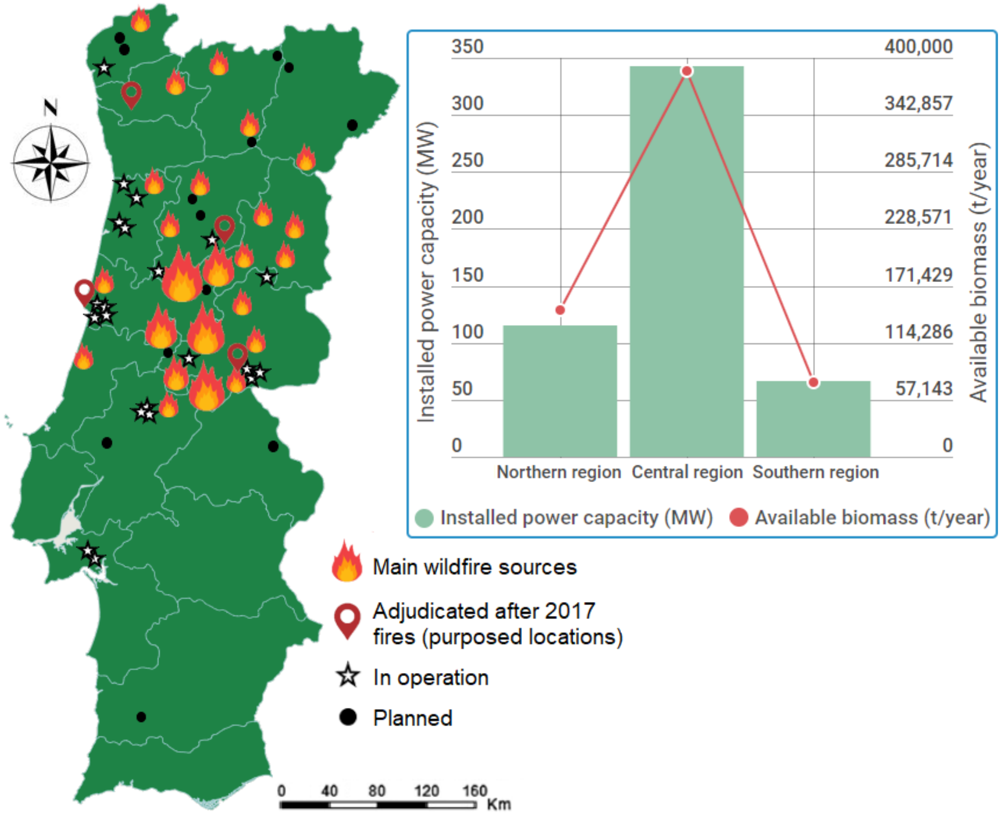
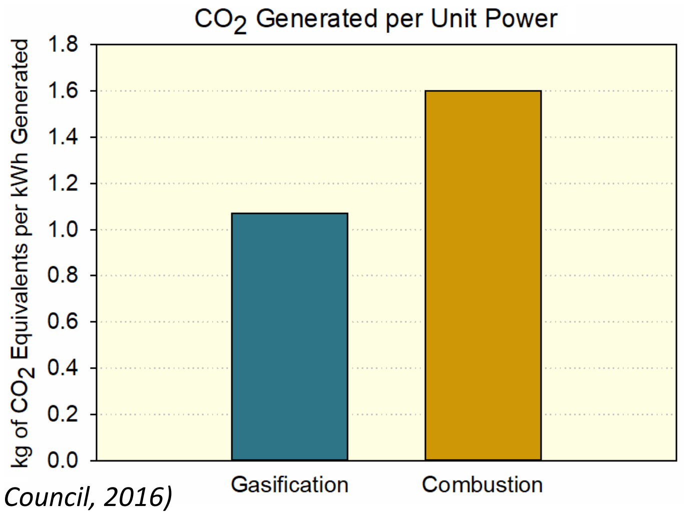
Biomass Power Generation in Portugal: Current Scenario

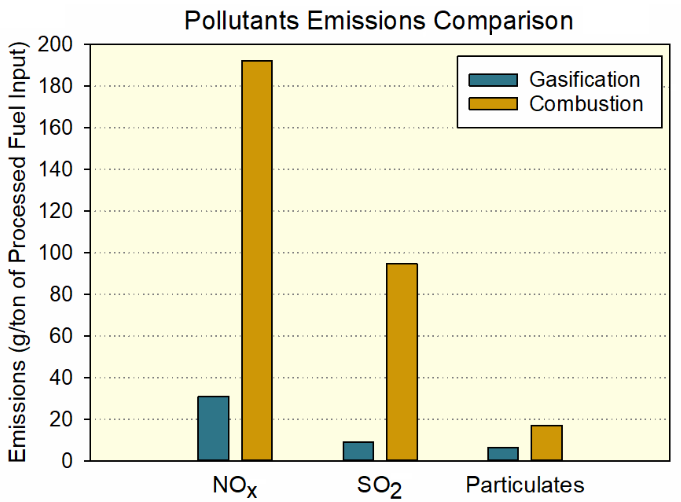
- In 2017, devastating wildfires swept central and northern regions of Portugal with great human life loss, burning a total area 442.418 ha.
- As a response, the Portuguese Government approved the establishment of new forest biomass combustion power plants.
- Most of the current installed power capacity is established mainly in the central region due to the higher quantities of biomass available.
- Presently, the national grid accounts a total of 12 dedicated thermal power plants and 9 cogeneration plants.



Combustion vs Gasification

Combustion	Gasification
• Lower initial capital investments;	• Higher initial capital investments;
• Lower efficiencies;	• Higher efficiencies allow reducing the biomass fuel input;
• Produces much higher concentration of noxious emissions;	• Cleaner production allowing to meet the current high pollutant emission standards;
• Well understood technology remains as one of the most widely used processes to supply heat and electricity to industrial processes.	• Still subject to increased risk due to the lack of standardization.





Adapted from (World Energy Council, 2016)

Key Ideas

i. Given the recent events, there is an urge to investigate the sustainability and feasibility of the installation and operation of new biomass power plants.

ii. Considering gasification's technical and environmental advantages, efforts should be made to assess the feasibility in deploying a biomass gasification system in Portugal instead of a traditional forest biomass combustion systems.

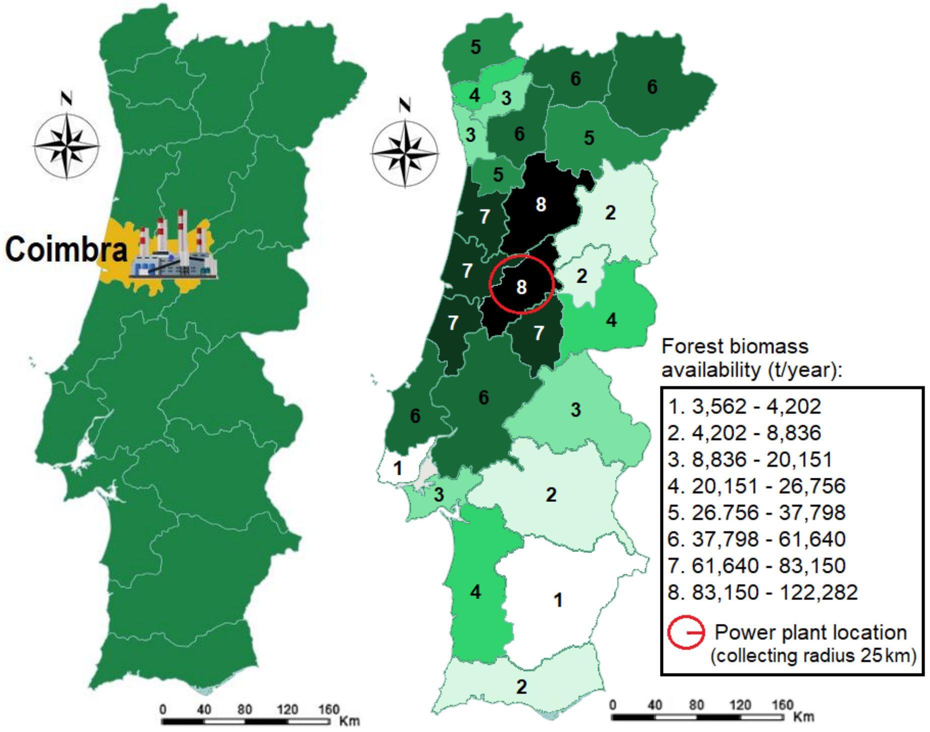
iii. With the biomass-to-energy quota increase, rational resources implementations must be considered in order to guarantee the biomass feedstock demands.

iv. Agroforestry biomass blends allows to maintain a stable biomass supply avoiding disruption by providing supplementary resource options.

Techno-Economic Assessment

Technical and operational baselines:

Location	Coimbra District
Installed Power	11 MW
Project Lifetime	25 years
Biomass Average Consumption	115,500 t/year
Biomass Cost	35 €/t
Area of Influence (radius)	25 km
Annual Electricity Production	78,436.72 MWh
Sales of Electricity	121.34 €/MWh
Number of Workers	16
Gasification power plant main components	Biomass storage and treatment park Biomass bubbling fluidized bed gasifier Gas cooling and cleaning system Gas turbine and generator Electrical substation Control room



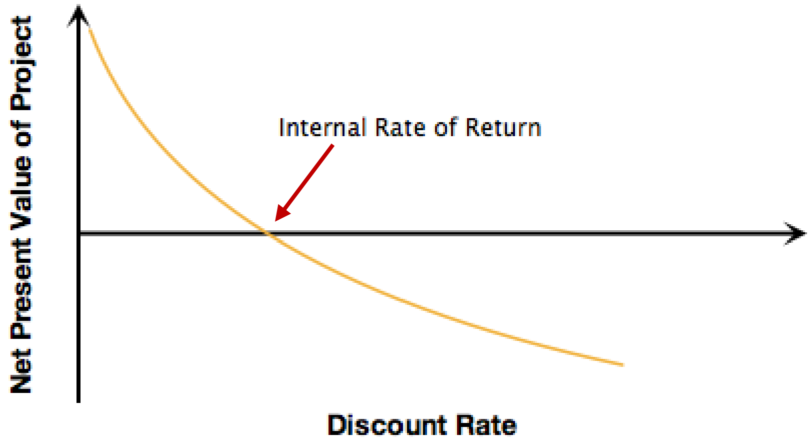
Economic Model Development

- **NPV** (Net Present Value) indicates the profitability of investment projects by summing all inflows and outflows of cash over the project lifetime.

$$NPV(i, N) = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

- **IRR** (Internal Rate of Return) is the discount rate at which the NPV of all cash flows equal to zero.

$$NPV(IRR, N) = \sum_{t=0}^{N} \frac{C_t}{(1+IRR)^t} = 0$$

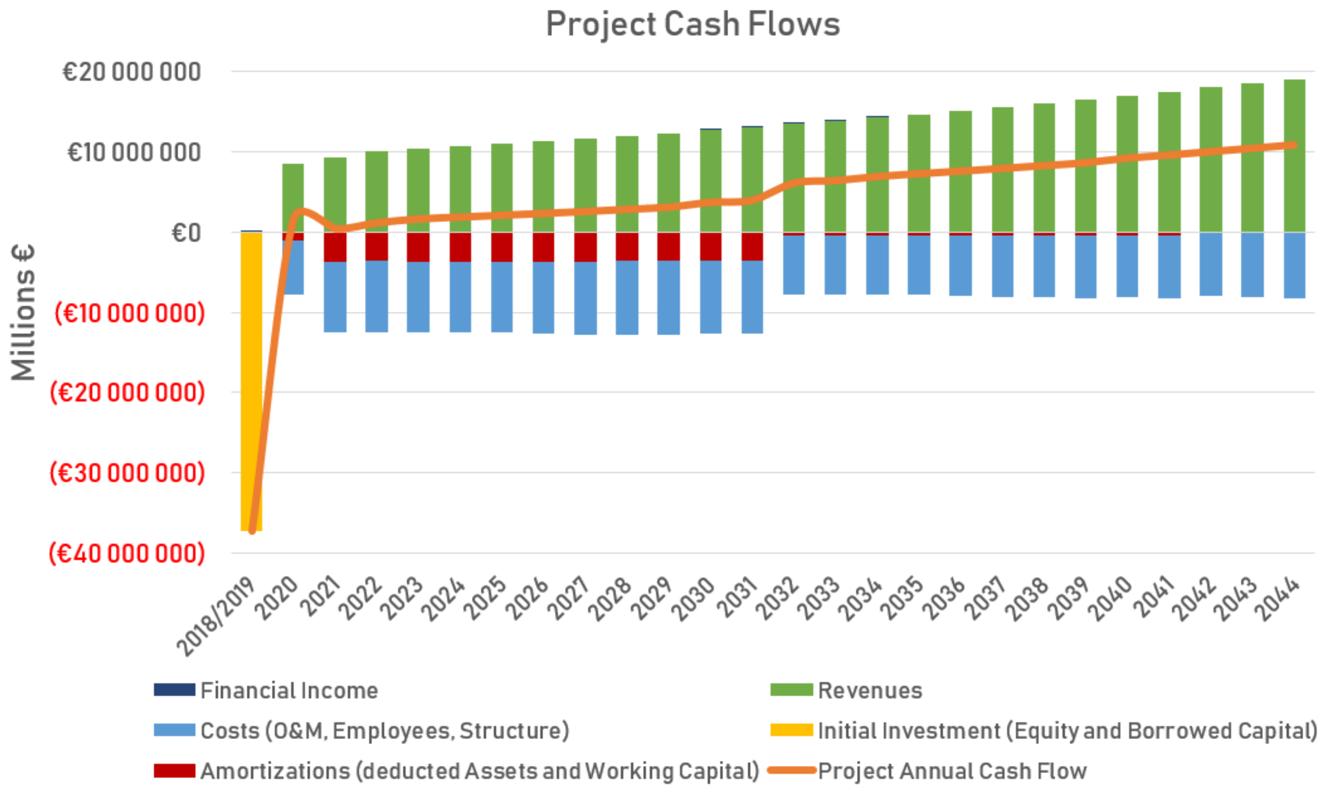


- **PBP** (Payback Period) is the time required to reclaim the initial capital investments, shorter the PBP, stronger the financial feasibility will be.

$$PBP = Years\ before\ full\ recovery + \frac{Cumulative\ NPV\ at\ the\ end\ of\ the\ year}{Total\ annual\ cash\ flow\ during\ the\ year}$$

Economic Model

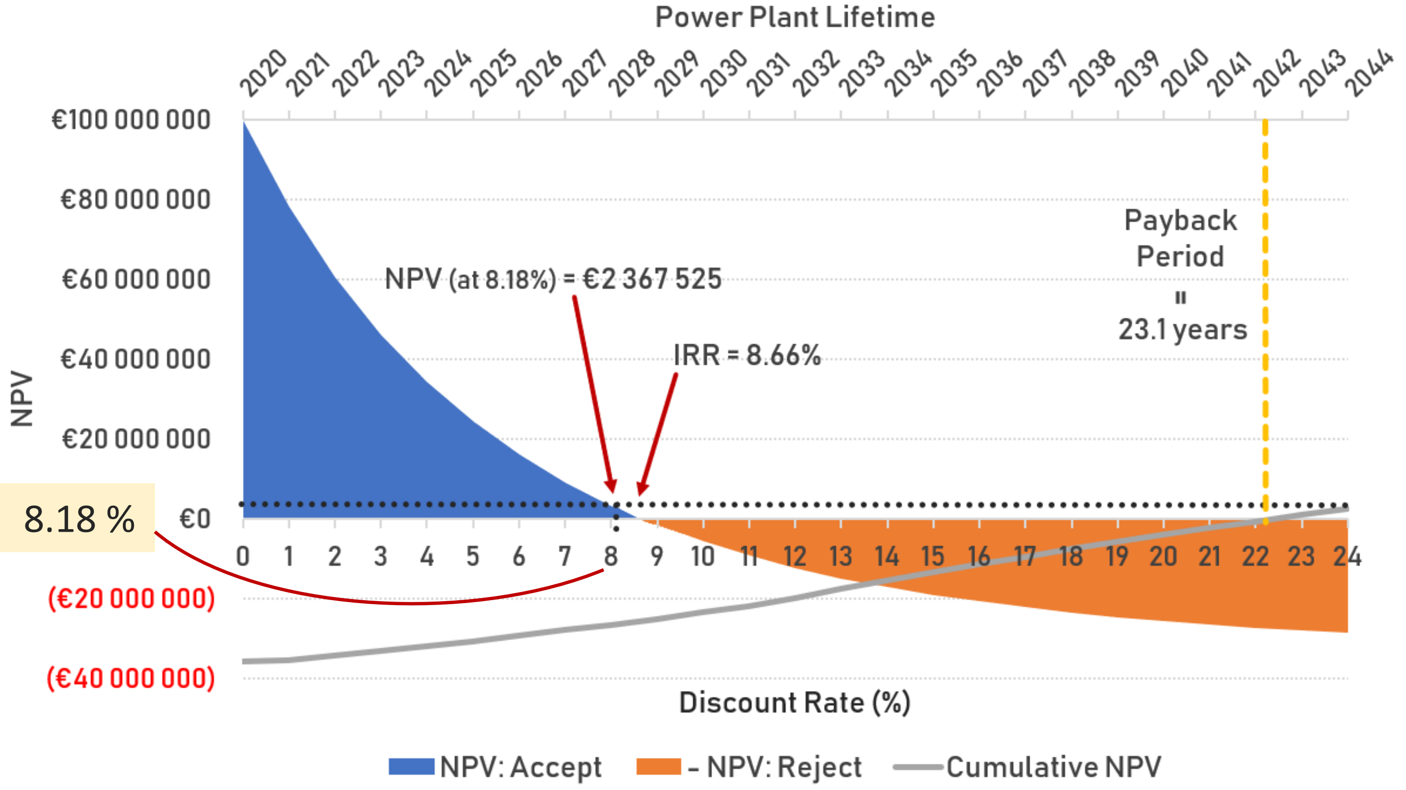
Project Cash Flows



- The initial outlay of about 37 M€, indeed reflects the dimension of cost expenses needed to start the project.
- Only by 2022, the power plant is assumed to operate at cruising speed, maintaining its production output of 78,436.72 MWh/year.
- At the end of 22 years of exploration, the power plant will be debt free with no more amortizations expenses to consider.

Economic Model Results

Financial Indicators

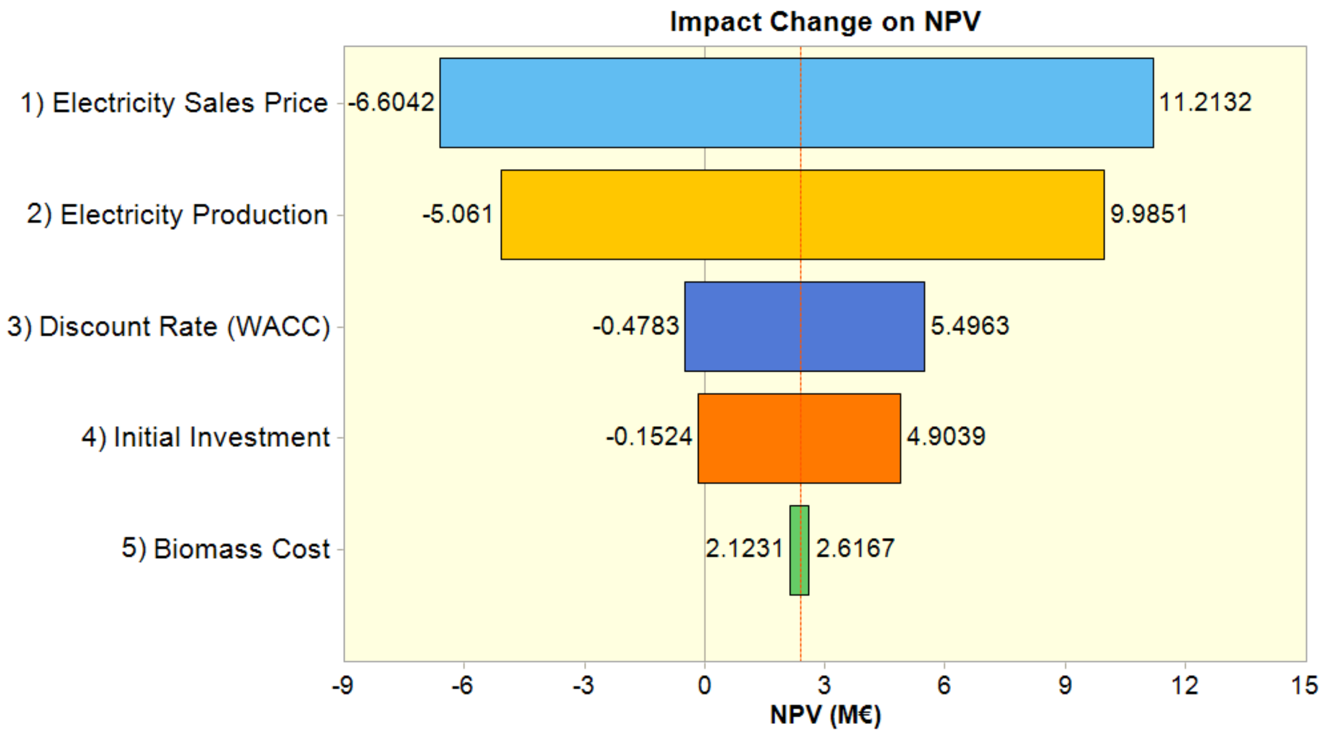


Input Discount rate 8.18 %

- *What makes the project feasible?*
  - A positive NPV, an IRR greater than the discount rate, and a PBP inferior to the power plant lifetime. ✓
- *World Bank Group* typical benchmarks for biomass projects: positive NPV, IRR greater than 10%, and PBP inferior to 10 years. ✗

Economic Model Results

Monte Carlo Sensitivity Analysis



Monte Carlo allows performing the risk analysis of the project by simulating a range of possible outcomes for a number of scenarios, assessing decision-making over uncertainty.

- Electricity sales price and electricity production showed considerable impact change on NPV.
- Biomass cost is the least impactful, and even in a worsening price scenario it still manages to achieve a positive NPV revenue.

Environmental Impact Assessment

Estimated annual emissions in (t/year)

	CO_2	CO	NO_x	SO_2
Projected 11 MW biomass gasification power plant	202,799.80	467.84	382.62	19.82

- The estimated emissions results for the projected biomass power plant go in hand with the estimations in the literature.
- Emissions control is simpler in gasification since the syngas comes at higher temperatures and pressures as compared to the combustion's exhaust gases, promoting the easier removal of pollutants and traces of contaminants.
- The gasification's higher efficiencies allows saving on operation costs while decreasing the greenhouse gas emissions, helping the Portuguese Government to meet ever stricter EU pollution standards.

Main Conclusions

i. Overall, the economic model presents a positive prospect of admitting the feasibility of setting the project in the region under current market conditions.

ii. Despite the viability of the project and affordable risk provided by the economic model calculations, the attractiveness of the venture may not convince investors less willing to take risks.

iii. Gasification provides competing advantages as compared to combustion systems, particularly in what comes to greenhouse gas emissions control.

iv. However, disadvantages as high initial costs and lack of standardization have been delaying gasification to stand as a highly commercial technology.

Thank you for your attention!