The role of biomass in the process of ecological transition: characterization and comparison of traditional and renewable energy sources

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This doctoral research intends to highlight modern trends and approaches in replacing fossil fuels for global energy needs. The project aims to examine the potential of renewable energy and the current situation of renewable energy-related industries through an overview of production processes and control strategies in renewable energy production technology, thus contributing to the acquisition of essential information that goes in the direction of improving and optimizing these energy sources. In particular, it will focus on the potential achievement of defined goals and targets for sustainable development to meet environmental, social and economic needs. The environmental impacts generated by renewable energy, compared to traditional fuels, will also be characterized and compared.

Il ruolo delle biomasse nel processo di transizione ecologica: caratterizzazione e confronto tra fonti energetiche tradizionali e rinnovabili

Questo progetto di dottorato mira a mettere in risalto tendenze e approcci moderni nella sostituzione dei combustibili fossili per il fabbisogno energetico globale. Il progetto si propone di esaminare il potenziale delle energie rinnovabili e la situazione attuale delle industrie legate alle energie rinnovabili, attraverso una panoramica dei processi di produzione e delle strategie di controllo nella tecnologia di produzione delle fonti energetiche rinnovabili, contribuendo così all’acquisizione di informazioni essenziali che vanno in direzione del miglioramento e dell'ottimizzazione di queste fonti energetiche. In particolare, si concentrerà sul potenziale raggiungimento di obiettivi e traguardi definiti per lo sviluppo sostenibile per soddisfare le esigenze ambientali, sociali ed economiche. Verranno inoltre caratterizzati e confrontati gli impatti ambientali generati dall’energia rinnovabile, rispetto ai combustibili tradizionali.

# **1. State-of-the-Art**

In recent years, human population growth and overall industrial development have led to an exponential increase in global energy demand (Kang et al., 2020). The European economy still heavily relies on fossil fuels for its energy needs, but these will be depleted in the coming decades. An economy based on renewable and low-cost energy sources, a clean environment, and energy independence are characteristics of responsible societies, and all of these have become the global challenge of our time. Commitments related to climate policy and the energy crisis have led to a search for alternative ways to obtain energy. One element of this vision is to replace traditional fossil fuels with biofuels. European Union energy policy reform and subsequent legislation and regulation at the national level have provided a strong incentive for the development of increasingly competitive renewable energy generation technologies. Europe, with its European Green Deal strategy, aims to become the first climate-neutral continent by 2050 (Cambini et al., 2020).

Bioenergy is considered the most consistent renewable energy source because of its economic advantages and its great potential to replace non-renewable fuel sources. In the current scenario, renewable technologies produce electrical, thermal or mechanical energy using biomass (energy crops, agricultural or forest residues, urban waste, etc.), wind, solar (thermal and photovoltaic), hydroelectric (river flow, tide, wave motion) and geothermal energy are considered the best alternative sources (Kasinath et al., 2021). The production of energy from biomass has shown significant growth and an increasing weight among renewable energies (Magazzino et al., 2022); biomass is the most abundant renewable resource on earth (Schen et al., 2020) and it is considered the leading emerging alternative to fossil fuel resources. Moreover, it can provide energy and multiple products (Awasthi et al., 2020). In fact, it will play an increasingly important role in the future global energy infrastructure, for the generation of electricity and heat, but also for the production of gaseous and liquid fuel products (Kasinath et al. 2021; Speight et al., 2020). Efficient conversion of biomass into energy requires investment in research and development of innovative technologies. The knowledge of the biological and technical mechanisms is essential to favor the introduction of more advanced and efficient techniques/methods in terms of energy, economic and environmental sustainability. Many are the processes that can be used to convert biomass into energy: it can be burned, transformed into fuel gas by partial combustion, biogas by fermentation, alcohol by biochemical processes, biodiesel, bio-oil, or syngas from which chemicals and fuels can be synthesized.

Circular economy and bioeconomy are the approaches to address the challenges and achieve global environmental and socio-economic goals (Stark et al., 2022; Biber-Freudenberger et al., 2018). Therefore, the generation of energy from alternative sources will contribute to the mitigation of climate change and to minimizing the alarms posed to the environment.

# **2. Ph.D. Thesis Objectives and Milestones**

Within the overall objective mentioned above this PhD thesis project can be subdivided into the following activities according to the Gantt diagram given in Table 1:

A1) **Bibliographic research and evaluation of the state of the art**.

A2) **Study of use of biomass as a renewable resource:** to identify the common biomass sources (A2.1) and methods of converting biomass into energy (A2.2). The opportunities and challenges of the obtained products will also be established (A2.3).

A3) **Evolution and current regulation of global European policies:** decarbonisation policies (A3.1) and adoption of sustainable and reliable energy systems(A3.2).

A4) **Characterization and comparison of the environmental impacts of the use of biomass with respect to traditional energy sources**, through the inventory of the use of traditional and renewable energies (A4.1) and the energy and environmental comparison between traditional and alternative sources (A4.2).

A5) **Writing and Editing** of the PhD thesis, scientific papers and oral and/or poster communications.

***Table 1***Gantt diagram for this PhD thesis project.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity Months | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| A1) | ***Bibliographic research and evaluation of the state of the art*** |   |   |   |  |  |  |  |   |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A2) | ***Study of use of biomass as a renewable resource*** |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |   |  |   |   |   |  |  |  |  |
|  | 1) Common biomass sources  |   |   |   |  |  |  |  |   |   |  |  |  |  |   |   |  |  |  |   |   |  |  |  |  |
|  | 2) Methods of converting biomass into energy |   |  |   |  |  |  |  |   |   |  |  |  |  |   |  |   |  |   |   |   |  |  |  |  |
|  | 3) Opportunities and challenges of the products obtained |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A3) | ***Evolution and current regulation of global European policies*** |   |  |   |   |   |   |  |   |   |   |   |   |  |   |  |  |  |  |   |   |   |   |   |  |
|  | 1) Decarbonisation policies |   |  |   |   |   |  |  |   |   |   |   |  |  |   |  |  |  |  |   |   |   |   |  |  |
|  | 2) Adoption of sustainable and reliable energy systems |   |  |   |  |  |   |  |   |   |  |  |   |  |   |  |  |  |  |   |   |  |  |   |  |
| A4) | ***Characterization and comparison of the environmental impacts of the use of biomass with respect to traditional energy sources*** |   |  |   |  |  |   |   |   |   |  |  |   |   |   |  |  |  |  |   |   |  |  |   |   |
|  | 1) Inventory of the use of traditional and renewable energies |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2) Energy and environmental comparison between traditional and alternative sources |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A5) | ***Thesis and Paper Preparation*** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |

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