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Review

Renewables exploitation for energy production and biomass use for electricity generation. A multi-parametric literature-based review

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Abstract: Nowadays, the provision of viable energy production and the energy autonomy are fundamental and utmost importance issues included in drawing the national strategic plan of both developing and developed countries. In parallel, the contentious role of fossil-based energy infrastructures, in the light of their high external costs of operation/use and the environmental depletion, have oriented current scientific research to find and exploit other energy sources that comply with increased pressure towards energy production, energy autonomy, and energy safety. Nevertheless, these preconditions of any energy mix introduced signify the importance of developing mature renewable energy technologies, which could enable sound and credible exploitation of any new-coming energy source, in the light of socio-economic acceptability and environmental sustainability. In parallel, the socio-economic traits, the know-how status, the technological maturity, the geo-morphologic conditions, and the well-being aspirations of each nation to its citizens consist also significant motives of energy-mix-schemes adaptation to a national level of analysis. According to the aforementioned statement, the present paper provides a four-fold overview upon: renewables' exploitation for energy production in the global and European contexts, as well as biomass exploitation for electricity generation in a global-oriented and technology overview of the relevant literature. Conclusively, the main limitations and challenges that are derived from this four-fold literature overview, were also outlined.

Keywords: renewable; energy production; electricity generation; literature overview

1. Introduction

Nowadays the technological advancements and the social acceptability of renewable energy technologies consist a controversial issue in a global level of analysis. This issue has also attracted the interest of scientific communities in the domains of social change processes, technological innovativeness, research and development (R&D), and electricity-oriented applicability. In line to this ongoing and active interest of renewable energy technologies' diffusion in the everyday life of people, the aim of the four-fold literature review was to explore the main socio-economic constrains and perspectives of renewables' exploitation in a wider context of energy production. Subsequently, the research interest of the paper was focused on biomass sources, due to the wide distribution of agricultural and energy crops worldwide. Particularly, a biomass-focused literature overview was conducted in order to reveal the potential supplementary contribution of biomass exploitation towards a more diversified energy mix that should be operated autonomously from the current carbon-based global energy production. The paper also outlined the key technological issues that are involved in biomass conversion and commercial distribution to the end-users of biofuels derived from agricultural and forestry biomass. At the end of the paper the main outcomes of the preceded analysis were gathered and presented in the light of both the literature and technology overview conducted.

In response to the renewable energy technologies to the "Not In My Back Yard" (NIMBY) social behaviour remains an argumentative issue, according to, firstly, the promotion of renewable energy production as a social change process in developed societies, and, secondly, the socio-psychological aspects involved in peoples' responses to social change. Furthermore, to perspectives of understanding the social role of renewable energy technologies are strongly associated with a better understanding of peoples', policy makers', industrialists', and media commentators' responses to such renewable energy technologies [1,2]. In these studies, the social acceptability or opposition to renewable energy technologies has been addressed in the light of Environmental Psychology on the concept of place attachment. Particularly, local opposition is reconceived as a form of place-protective action, which is arising whenever technology projects disrupt pre-existing place attachments and threaten place-related identity processes. Therefore, in a campaign in favour of/or against the installation of renewable energy technologies, residents who argued that these technologies would "industrialise" the area, they felt also strongly attached to their residential place and they:

- were most likely to interpret such renewable-based projects as producing negative local outcomes,
- felt negative emotions associated with these projects,
- indicated low levels of projects' support,
- had undertaken oppositional behaviours such as signing petitions or writing letters to the local authorities,

- expressed a significant positive correlation between place attachment and trust in the local opposition groups, and a significant negative correlation between place attachment and trust in the development company.

In parallel during the last decade of analysis, the technology transfer and the adoption of renewable energy innovation are still limited to qualitative analytical techniques and on empirically-based experiences of local scientific interest, such as (indicatively) in: Mexico [3], China [4,5,6], Netherlands [7], Europe [8,9], United States [10], and Spain [11].

Mallett [3] pointed out that active interest in social acceptance of renewable energy innovations should express a wide spectrum of stakeholders including technicians, industry representatives, local government officials. The author concluded that integral forms of technology cooperation are most effective in eliciting social acceptance of renewable energy innovations. Groba and Cao [4] investigated the roles of policy, technological innovation, and markets in exporting renewable energy technologies. These authors investigated the development of solar PV and wind energy technology component (WETC) exports from China in the light of the competitive position of the country‘s renewable energy industry. These authors stressed out that governmental energy policy, renewable energy innovation, and knowledge accumulation could drive exports. The authors concluded that high income countries, with large renewable energy markets and demand side policy supported schemes of incentive tariffs, were increasingly importing Chinese solar PV components, whereas trade costs showed a negative impact on solar PV exports, but not WETC. No evidence that bilateral knowledge transfer and indigenous innovation affected exports was proven.

Negro et al. [7] analyzed the dynamics of newly emerging innovation systems that stimulate renewable energy technologies. In parallel, the key-parameters of building up of such emerging innovation systems were identified while dynamic functional patterns of such a technology were identified in order to develop such a systemic innovative policy. A systemic-based analysis of renewable energy technologies was also the objective of the study of Tsoutsos and Stamboulis [9]. In this study the innovative and sustainable diffusion process of energy production and management was deployed. Particularly, Tsoutsos and Stamboulis [9] introduced and alternative approach which integrated the supply- and demand-side perspectives, pointing out that a successful policy for the speedy deployment of renewables should focus on the systemic innovation processes that characterized the development and sustainable diffusion of renewables. The proposed strategic plan aimed at the integration of the innovation dimension into a policy for renewables, contributing to the growth of successful applications and to the development of the affiliated industry of equipment production and services, fostering the deployment of a new technological regime.

In a global context of renewables' innovativeness, Buckley and Schwarz [10] explored the perspectives of the innovative technology of manure gasification in energy production. The environmental benefits of alternatives to land-spreading of traditional manure management, as well as the advantages of gasification versus traditional combustion techniques for high nitrogen fuels, were denoted. The environment overview of the technology introduced was implemented regarding sustainability, manure management, and renewable energy. In parallel, artificial, non-sustainable barriers to renewable energy, and the impact of wide jurisdictional variability are discussed.

In the European context Hervás Soriano and Mulatero [11] established the strategic energy technology plan (SET-Plan) as a strategy that can use research and innovation (R&I) to green EU energy sector. The initiatives of such a SET-Plan are outlined as follows:

- programming plans,
- takes stock of existing initiatives in the energy sector,
- fosters a cooperative approach to R&I,
- introduces a high-level SET-Plan steering group to monitor progress,
- creates a supportive information system (the SETIS) to fill the void in policy information, and
- produces estimates of financial needs over the programming period.

Hervás Soriano and Mulatero [11] argued that the SET-Plan could serve as a blueprint for R&I strategies to tackle other societal challenges. The effectiveness of the setting strategies were aligned to further clarifying the hierarchy of existing objectives and instruments, introducing specific instruments to pull the demand of new technologies, strengthening links with education and training policies, as well as formalizing links with the governmental structures.

Renewable energy technologies were also related to, both, the research and development (R&D) policies, as well as to the purposes of meeting governmental policy goals. These policies showed that environmental goals could be utmost importance factors for the development of various renewable energy technologies, followed by the economic, energy, and financial goals, since the development of sustained renewable energy projects could overcome high initial projects costs that, in turn, will result in increased renewable capacity and decreased costs [12,13,14].

In another study, Sung and Song [15] investigated a causality testing between public policies and exports of renewable energy technologies in the South Korean context. The authors revealed a positive relationship between, firstly, government expenditures on R&D and exports rate, and, secondly, between expenditures on R&D and the contribution of renewable energy to the total energy supply (CRES). In parallel, Garces and Daim [16] signified the importance of energy policies aiming to accomplish the energy security objectives, while the authors concluded that the US federal and state energy policies, R&D investment, knowledge stock, and knowledge accumulation were not entirely connected to electrical market variables.

Conclusively, in an earlier study, Anderson [17] outlined a wide spectrum of policies regarding the costs and the performance profiles of renewable energy technologies in developing countries in the grid and off-grid markets for electricity, including:

- investments in renewable energy that should be helped by competition and regulatory reforms in the energy industry, since such reforms should reduce the subsidies,
- further cost reductions should be appreciable in all key technologies, tax and regulatory policies, and in budgetary allocations for R&D, education, and training since there are positive externalities to investment, in the view of each generation of investments is acting to reduce the costs of future generations.
- environmental advantages of renewable energy are more apparent as developing countries begin to introduce their environmental policies on fossil fuels.

Finally, numerous studies have been devoted to investigate the perspectives of renewable energy technologies in electrification systems in a global level of analysis: Spain [18,19], Taiwan [20], Malaysia [21], United States [22], Italy [23], Portugal [24], Japan [25]. These studies manipulated the involvement of renewable energy technologies in the national energy production grids, in the light of projects' subsidizing, energy pricing, governmental initiatives to energy mix of production, feed-in tariff remuneration modeling and schemes.

2. Methodology Framework

In this paper a four-fold overview was conducted upon: renewables' exploitation for energy production in the global and European contexts, as well as biomass exploitation for electricity generation in a global-oriented and technology overview of the relevant literature. To this end, the paper firstly introduces an extended literature overview that holistically outlines a framework of renewable energy technologies in a global context of presentation, following by an extensive literature overview of European policies and challenges in applying renewables for energy production. Subsequently, the paper denoted the perspectives of biomass sources' exploitation in electricity generation. Moreover, the key-parameters and the technological advancements that apply to agricultural and forestry biomass sources towards biomass conversion and commercial exploitation in the form of biofuels, where also given. Conclusively, the main limitations and challenges –derived from this four-fold literature overview– as well as the proposed orientations for future studies were also outlined at the end of this paper. The main challenge of this paper is to fill the gap of theoretical and technological knowledge between the transition from biomass sources up to their large-scaled/in-field/marketable exploitation that all enable a stable, supplementary, cleaner, and autonomous energy production and electricity generation.

3. Literature Overview upon Renewables Exploitation for Energy Production in a Global Context

In the relevant literature there are plentiful studies pronouncing the advantages of the renewables (RES) use. These advantages are, indicatively, the: mitigation of environmental problems such as the deterioration of climate change, low operating costs of RES use –that is not affected by the prices of fossil fuels and by the status of the international economy, jobs' creation, improvement of the quality of life, reduction of health risks, incremental independence from fossil fuels, increased energy security and supply, increase in tourist activity, protection of the natural resources and the accommodated ecosystems, reduction of pollution incidents, as well as positive contribution to the local development [26–33].

On the other hand, apart from the advantages of using RES there are also disadvantages of RES exploitation—as these are stressed out in the relevant literature—including the: visual nuisance of RES infrastructure and the accompanying aesthetics distortion of the nearby landscape, desertification of the local flora and fauna species, acoustic nuisance emanating from wind power plants, as well as high installation costs [26,34,35].

Energy production from RES could support the strategic energy plan of each country to reduce its energy dependence from energy imports. However, this statement should not be considered as the only factor in reducing energy dependence on fossil-fuelled plants. In particular, the energy dependence of the EU countries is not determined solely by the pace of energy production from renewables, but it is mainly depended on other parameters, such as economic, social and political, as well as the: quantities of national energy consumption, energy efficiency, national policies for energy, the geo-strategic position of each country, as well as the foreign policies and the plans for energy security [36–43]. In parallel, electricity production from renewables is no merely a scientific endeavour, but it is an indispensable component in the production process, since numerous countries keep investing in green energy [44–50].

In a global context of analysis, renewable energy has been noted as an important factor in accomplishing low carbon emissions in the economic growth of China. Particularly, it was pointed out that there is a strong association between the electricity produced from RES and GDP per capita, with the opening of trade, foreign direct investment, financial development and the accelerated pace of fossil fuels in energy consumption. Nevertheless, it is also noteworthy that in a wider societal context there are published studies that addressed the commercial applicability of renewables in a modeled level of analysis [51,52].

Moreover RES infrastructure has been developed geographically in a dispersed manner thus contributing to regional development of energy infrastructure, satisfying the energy needs of small or larger areas, in the contexts of continental or insular, and, urban or agricultural, levels of analysis in a global overview [53–64]. Such a spatial expansion of RES exploitation:

- determines the RES contribution to national energy mix
- promotes the deployment of a more rational and wise use of renewables
- reveals that optimal spatial allocation of renewables is governed by conflicting criteria and strict constraints, such technical and geological constraints as well as by fostering projections where their applicability should cause low environmental burden
- visualizes and balances the relative opportunities and constraints on development arising from a wide range of environmental, industrial and socio-economic factors, such as emissions implications of altering policy constraints, technology and resource availability, modeling decisions, availability of biomass, and carbon capture and sequestration
- supports decision making in regional renewable energy planning by providing information on regional potentials and restrictions to different energy stakeholders, thus envisaging an energy developmental vision that can orient regional energy development towards sustainability
- prevents energy losses resulting from the energy transport over long distances, thus not burdening each national energy distribution system in order to produce excess energy that is partially lost, prior to end-users consumption. The properly designed of transmission and storage capacities for the power sector could foster the achievement of ambitious and long-term emission reduction targets, the lower possible storage requirements and curtailments and a non-escalation of temporal and spatial electricity prices, in case that emission reductions exceed a critical value.

4. Literature Overview upon Renewables Exploitation for Energy Production in a European Context

In the European context there exists an extensive research production upon the use of renewables for energy production. It is indicatively noted that in the Greek context the utilization of all forms renewables—that are abundant throughout the Greek territory—can be proven highly promising (mainly based on forestry, wind, or solar energy) entrepreneurial ventures. The main issues that are discussed in these studies are the socio-economic and environmental impact of materializing these ventures, involving the report of occasional delays in the start up phase and the concurring disappointments during the development processes of such ventures [65–96].

The European Union (EU) Directive 2009/28/EC set out the contribution of RES in final energy consumption to 20% by 2020. This targeted percentage is allocated among the factors of electricity, transport, heating and cooling. In order to achieve the participation of the RES 20% target by 2020, the EU should double the share of electricity from RES from 16% in 2006 to over 30%, while it should be ensured that the share of energy from RES in transport in 2020 is at least 10% of final consumption of energy in transport in each Member State. In this Directive a list of measures to reduce energy consumption and increase the use of RES is presented, while data on the main administrative structures to accelerate this penetration, are also outlined. Each Member State shall adopt a national action plan for RES support schemes and collaboration measures between them or with third countries, including statistical schemes of collaboration and joint projects [97]. In a literature overview, the collaboration concept under the renewables introduction to the current energy mix should be determined by the following key-issues [98–100].

- The rapid energy shift of the current energy mix, from fossil fuels to renewables, and the accompanying significant investments in infrastructure for electricity generation, transmission, and distribution.
- Renewables exploitation for climate change and sustainable economic growth. Thus, international research collaboration upon renewables requires a considerable amount of R&D expenditure and various core technologies, in order to achieve prompt and efficient development.
- In response to the socio-economic issues of food shortages, in combination with rising population and lack of access to electricity needed for development, tangible results have yet to materialize. Therefore, the use of environmentally-friendly renewable energy technologies in line to a strong rationale for political will, collaboration and transparent energy policies, will ensure the betterment of the human well-being.

Moreover, the "Energy Policy for Europe", as directed by the European Commission, established a future plan and actions' framework to achieve the main European Community energy objectives relating to sustainability, competitiveness and security of energy supply. Particularly, ten initiatives of this European Energy Action Plan—that compound a policy framework for renewable energy in the European Union, and could track to reach its future renewable energy targets-involve [101,102,103]:

- an optimized functioning of the internal energy market
- member States support towards developing solidarity at energy crises and ensuring the safe supply of oil, gas, and electricity energy
- enhancement of the operational responsibilities of the Community Emissions Trading Mechanism of Greenhouses towards achieving reduction of CO_2 emissions and attract investments in clean energy

- development of an energy-saving program at European (also national and international) level(s) of analysis
- extended use of RES
- development of a strategy for energy technology
- development of fuel conversion technologies with low CO_2 emissions
- development of safety and security issues regarding the use of nuclear energy
- common agreement on an international energy policy with unanimously agreed objectives, abiding from all Member States
- deep understanding of energy issues amongst European citizens/consumers/end-users
- The aforementioned initiatives should establish a coherent external energy policy to assure the achievement of the main goals of the EU policy, which are the security of supply and the adverted challenges of climate change. Conclusively, these initiatives aim at assuring a secure, competitive, and sustainable energy market in the EU [103].

The main EU policy—among the European policies for RES launched—can be summarized in the so-named 20-20-20 which refers in reducing greenhouse gas emissions by 20% compared to 1990, increased production of renewable energy to 20% and improving energy efficiency by 20% by 2020. To this end, the EU Action Plan sustains the core contribution of European energy policy in line to this goal and outlines specific measures that should be taken to achieve this goal. Specifically, the four key-objectives of the European Action Plan for Energy aim to [101,102,103]:

- save energy consumption by 20% compared to projections for 2020
- increase the participation rate of RES to 20%, compared to the gross final energy consumption by 2020
- increase the biofuels' share—that are directed in the transport mobility (gasoline and oil)—by 10% minimum, in order to achieve primary energy savings of 20%, and
- reduce gas emission by 20% by 2020, compared to 1990 gas emissions

The main objectives of European energy policies can be summarized in the following three areas: competitiveness, sustainability, and energy security. These goals' achievement necessitates the establishment of a new legislative and institutional framework that should: foster investments in energy infrastructure and set clear and predictable targets for electricity production from RES, while research is directed in new technologies that are energy efficient, and new rules are established for the internal market. Particularly, the EU has adopted the Climate and Energy Package (CEP) [104–108] through which it is planned to operate the emission permits trading mechanism of carbon dioxide emissions from large industrial and power plants, as well as from airline companies. Additionally, through the CEP, a wide spectrum of targets for each Member State was set in order them to, firstly, reduce greenhouse gas emissions within the regulated levels, secondly, outline objectives for the penetration of RES in energy production, and, thirdly, reinforce the statement of strong environmental leadership to achieve global climate deals, under a pressure of the European negotiations and significant changes in the social context [105,106,107].

Conclusively, and in line to the roadmap of Energy 2050 published in December 2011, greenhouse gases emissions should be reduced by 80% by 2050 compared to the reference year 1990. This goal should be achieved taking into consideration the energy security, the supply, and the competitiveness of the European market, as well as accomplishing low emissions of gases that affect the greenhouse effect. The roadmap for Energy 2050 has been structured in the light of scheduling a long-term European plan for the energy sector, in collaboration with the agents of the free market and of the Member States [109–121].

Finally, in the light of the aforementioned roadmap of Energy 2050 it is noteworthy that Pang et al. (2014) introduced the concept of strategic environmental assessment (SEA) that could provide a comprehensive framework for assessment of policies and plans upon contemporary environmental issues such as climate change, as well as resource and land use changes. Particularly, Pan et al. [122] revealed possibilities for comprehensive sustainability assessment among published energy-environment models and the alignment of renewable energy analysis to landscape and biodiversity issues through land use concerns. To this end, the available tools—including existing energy, research, environmental, and linking models; surveys on publication; as well as a case study on the aforementioned European roadmap of Energy 2050—all showed low concerns on land use, landscapes and biodiversity, and were proven ineffective to provide comprehensive decision support for assessing future energy scenarios. Subsequently, the development of overly new energy models could provide new orientations, developing them to involve renewable energy options with land use, landscape and biodiversity concerns, which could be advanced into powerful SEA tools for an integrated policy assessment. Subsequently the development of more comprehensive decision support tools will integrate main policy concerns while assessing renewable energy options.

5. Literature Overview upon Biomass Exploitation for Electricity Generation in a Global Context

The literature review at the *Scopus* database was implemented during the April of 2016 and its outcomes were collected and shown in the following Tables 1–5. The data mining was gathered and presented in a reverse chronological order of publicity following an alphabetical/chronological arrangement: per last name of the first author, and per year. All information presented in these Tables 1–5 was based on both the *Scopus* database, as well as, those full articles that are available from this web search platform. This search outcome upon RES sources utilization for electricity generation was further classified in the following five groupings: Table 1–Microbiological overview, Table 2–Economics and political initiates' overview, Table 3–Co-firing, forestry, and CO_2 sequestration overview, Table 4–Biomass gasification overview, and Table 5–Decentralized power overview.

Table 1. RES sources for electricity generation in a microbiological overview.

Ref #	Reference	Aim–Scope–Results
1	Miran et al. [123]	The potential of generation of cell voltage, installing Microbial fuel cells (MFCs), was examined. Particularly, the organic waste treatment and simultaneous bioelectricity generation was examined with the use of lemon peel waste for bioenergy generation. The authors pointed out that the carbon source present in lemon peel waste can be utilized by exoelectrogens present in the anodic chamber, releasing electrons and resulting in the generation of cell voltage.
2	He et al. [124]	An immobilized photosynthetic algal Chlorella vulgaris) into the cathode chamber of microbial fuel cells towards the simultaneous wastewater treatment, electricity generation and biomass production, was deployed. The study was developed in the Chinese context where the optimum influential roles of temperature (25^{o}C) and light intensity (5000 lux) on the performance, were also addressed.
3	Kondaveeti et al. [125]	The authors of this study investigated the possibility of electricity generation using renewable algae biomass in the South Korea context. The study revealed that total chemical oxygen demand (TCOD) reduction of 74% was obtained when initial TCOD concentration was 534 mg L^{-1} for 150 h of operation. The main organic compounds of algae for electricity generation were lactate and acetate.
4	Nishio et al. [126]	The study investigated the algal biomass use as a fuel for electricity generation in microbial fuel cells. The model consortium proposed was comprised of an alga-digesting Lactobacillus and an iron-reducing Geobacter for electricity generation from photo-grown Clamydomonas cells. The authors concluded that the total power-conversion efficiency: from light to electricity, was estimated to be 0.47%.
5	Rashid et al. [127]	The potential role of sustainable energy production from the wastes of activated sludge and algae biomass –as low-cost and sustainable means of energy production was the objective of this study. I particular, these wastes were used as substrates in microbial fuel cell (MFC) to produce electricity of high energy output. According to the study findings, the optimum experimental yields were the highest voltage of 0.89V and power density of 1.78W/m^2 under 1000Ω electric resistance.
6	Zhang et al. [128]	The method of microbial fuel cells (MFCs) for simultaneous sulphide removal and electricity generation by recovering power with corn biomass stover filtrate (CSF), as co-substrate, was outlined. The authors stressed out that their outcomes should be adopted in a wider environmental context of multiple contaminations' treatment –especially sulphide-based wastewaters– upon the MFC technology.
7	Cheng et al. [129]	A new application of enzymatic biofuel cells (BFCs) for direct production of electricity from carboxymethyl cellulose (CMC) biomass, was introduced in this study. For electricity production from CMC, cellulase was used as the biocatalyst in solution to catalyze the hydrolysis of CMC into glucose and glucose was then used as the biomass to produce electricity through biofuel cell technology. The authors concluded that an open circuit voltage of 0.75 V and a maximum power output of 128 μW cm^{-2} at 0.35 V under ambient air and room temperature were achieved. These values were comparable to those with other techniques employed to produce electricity from cellulose or cellulose derivates.
8	Toonssen et al. [130]	This study investigated the thermodynamic evaluation of different energy conversion chains based on centralized biomass gasification and decentralized heat and power production by a solid oxide fuel cell (SOFC). Various chains were evaluated, while the main difference between the chains was the secondary fuel produced via biomass gasification. The secondary fuels applied were hydrogen, synthetic natural gas (SNG) and syngas. The authors of this study concluded that the overall exergy efficiency from biomass to heat and power was for the hydrogen, SNG, and syngas routes 21.1%, 28.4%, and 30.4%, respectively.
9	Wang et al. [131]	This study explored the potential of directly generate electricity from corn stover in microbial fuel cells (MFCs) through the addition of microbial consortia specifically acclimated for biomass breakdown. The use of residual solids from the steam exploded corn stover produced 8% more power, at about 406 mW/m^2, than the raw corn stover. The study findings revealed that the high potential to directly generate electricity from waste corn stover in MFCs through bioaugmentation using naturally occurring bacteria.
10	Zhang et al. [132]	This study explored the potential functionality of wheat straw hydrolysate and the microbial ecology of electricity-producing microbial communities developed through two-chamber microbial fuel cells (MFCs). The suspended bacteria found were diversified from the bacteria immobilized in the biofilm – in the following sequence: Bacteroidetes, Alphaproteobacteria, Bacillus, Deltaproteobacteria, and Gammaproteobacteria – and they played different roles in electricity generation from the hydrolysate.

Table 2. RES sources for electricity generation in a economics and political initiates' overview.

Ref #	Reference	Aim–Scope–Results
1	Macedo et al. [133]	The study deployed the development stages of a micro-scale system for electricity generation from biomass with the power capacity of 500 W. This biomass-based system is composed by an open steam power cycle, aiming to meet the needs for energy supply in isolated communities in the Amazon region, since it sustains the advantageous biomass potential as an opportunity for the application of biomass energy to enhance the economic activity and to develop new technologies. The study outcomes concluded that the steam turbine is the critical component to the commercial-scale feasibility of the technology developed, particularly fitting at manufacturing of the system by small regional industries.
2	Cerón et al. [134]	Different scenarios were deployed in order to analyse how the energetic demand and subsidies from the Colombian government can contribute to properly integrate the variability of biomass plants of an economic viewpoint in three Colombian provinces. The authors investigated the economic efficiency of technologies for generating electricity from biomass energy sources using the energetic planning software, Homer Energy, and outlined potential solutions to supply the electricity deficit.
3	Umar et al. [135]	The authors of this study pointed out that the biomass wastes from the palm oil industry –reaching up to 85.5% of the total yield in biomass– offers great potential for large-scale power generation in Malaysia. In parallel, the introduction of the FiT (Feed-in Tariff) regime in 2011 was expected to catalyse and accelerate the development of the renewable energy industry, including biomass technology. The authors concluded that despite a major overhaul of the market structure under the new scheme, the sustainability of the grid-connected oil palm biomass renewable energy industry downstream components remains questionable, thus the threads and the opportunities of the existing policy system has to be reviewed.
4	Moore et al. [136]	The authors of this study deployed the methodological tools of on-site data collection, interviews, and financial models to determine the feed-in tariff (FIT) rate required to encourage investment in the generation of electricity from currently unused biomass from the Eastern Ontario, Canada, forest industry. The determining parameters of the financial model structured were the net present value, the internal rate of return, and the payback period associated with a 15MW biomass-to-electricity facility. The authors concluded that achieving a price of CDN\$ 0.013kW^{-1} of thermal output necessitate elevated FIT rates between CDN\$ 0.15-0.21$kW^{-1}h^{-1}$ to meet economic performance criteria. Without these changes, biomass could be significantly under-used and will not contribute to the renewable energy goals of Ontario.
5	Rodriguez et al. [137]	This paper explored the potential biomass resources available for energy generation from forestry and agriculture in the Green Triangle, one of the most promising Australian Regions for biomass production. The cost of electricity generation using direct firing of biomass and a required estimation upon tradable Renewable Energy Certificate (REC) prices to make it competitive with coal fired electricity generation, were deployed. More than 2.6 million tonnes of biomass are produced every year within 200 km of the regional hub of Mount Gambier and biomass fired electricity is feasible using feedstock with a plant gate cost of 46 Australian Dollars (AUD) per tonne under the current REC price of 34 AUD per MWh.
6	Wei et al. [138]	The authors investigated the perspectives biomass-derived synthetic gas (syngas) for electricity generation. The economic feasibility of using biomass gasification for generating electrical power is highly dependent on the power plant cost and the cost of its operation, thus a cost model was analyzed the Unit Cost (unit-cost) of electricity generation from micro-scale power facilities that used biomass gasification as its energy input. The capital and operating costs were also calculated. The authors indicated that operating cost was a major part of the total annual production cost of electricity generation, and the labour mainly contributed to the total annual production cost of operation, while operating at lower generation capacity levels.
7	Evans et al. [139]	In this study the feasibility of electricity generation from biomass has been investigated in line to the key indicators of price, efficiency, greenhouse gas emissions, availability, limitations, land use, water use and social impacts. The authors of noted that biomass produced electricity generally provides favourable price, efficiency, emissions, availability and limitations. On the other hand biomass produced electricity sustains unfavourably high land and water usage as well as social impacts. Critical issues of such biomass produced electricity schemes are the type and the growing location of the biomass source. Finally, hardy crops grown on unused or marginal land and waste products are proved sustainable than dedicated energy crops grown on food producing land using high rates of fertilisers.
8	Nasiri and Zaccour [140]	This study introduced a Nash equilibrium-based game-theoretic framework to analyze the process of utilizing biomass for power generation. This framework was compounded from the following three stakeholders: distributor, facility developer, and participating farmer. The analysis of the impact of incentives and initial target on the equilibrium, in which the biomass is part of electricity production, was also implemented.

Table 3. RES sources for electricity generation in a co-firing, forestry, and CO_2 sequestration overview.

Ref #	Reference	Aim–Scope–Results
1	Akgul et al. [141]	In this study a mixed integer nonlinear programming (MINLP) supply chain optimisation framework was developed in the UK to examine the potential for existing power generation assets to act as a carbon sink as opposed to a carbon source. The profiles of price £30-50/tCO_2 up to £120-175/t CO_2 and carbon intensity of electricity 100kg/MWh up to 800kg/MWh were the key-factors of the power plants optimization. Conclusively, the power plants in question must operate at a high load factor and CO_2 capture rates. Finally, the policy maker should balance out the implications arising from such extended land use change.
2	Favero and Massetti [142]	In this study deployed climate mitigation policies that foster the incentive to trade biomass internationally. Alternative scenarios were developed by the integrated assessment model, in order to study trade of woody biomass from multiple perspectives. Trade of woody biomass substantially increased the efficiency of the mitigation policy, while in the tax scenarios, abatement increased by 120-323Gt CO_2 over the century.
3	O'Shaughness et al. [143]	In response to the substantial portion of global population (about 40%) reliance on the traditional use of biomass for cooking, the authors of this study developed a prototype electrical generator for portable stoves commonly in use in the developing world. This generator enabled the delivery of small amounts of off-grid electricity, while its power was generated using the thermoelectric effect. The technical specifications of this portable biomass cookstove are given, whereas the performance of the electricity generating cooking stove has subsequently been tested in in-field experimentations using locally sourced fuel and fire stoking methods.
4	Dwivedi et al. [144]	This study investigated the interactions between economic objectives of forest landowners and a power plant owner punctuated by forest growth and management characteristics. In parallel, these spatiotemporal impacts were assessed for four separate scenarios and four different power plant capacities using appropriate landscape-level indices. The study outcomes revealed that the age structure of surrounding forest plantations continuously fluctuates with respect to each year of power plant operation, whereas the age structure, once disturbed, never becomes comparable to the original age structure. Conclusively, the establishment of low capacity forest biomass-based power plants and the adoption of an integrated regional level planning approach could enable the maintenance of original age structure characteristics of surrounding forest plantations and the long run sustainability of various ecosystem services.
5	Perilhon et al. [145]	In this study, the life cycle assessment applied to electricity generation from renewable biomass was explored in respect to the two facilities: a 2-MW and 10-MW electricity power plants, accordingly. In particular, the production of electricity from renewable sources produced from biomass (wood waste) in cogeneration plants was investigated. The environmental impacts of this LCA methodology have been further compared to electricity production in a diesel engine cogeneration. The study concluded that under specific preconditions the 2-MW wood plant was proven the most favourable wood plant.
6	Shafie et al. [146]	In response to harnessing a large amount of biomass residues as a source of electricity generation, this study was conducted to analyze the potential of recovering energy from major source of biomass residues in Malaysia. To this end, the agricultural crop residues and the industrial crop waste were investigated, while the effective use of the waste could supply the required fuel for future electricity generation.
7	Basu et al. [147]	Co-firing is a considered a well-developed technology that is proven the most efficient means of power generation from biomass. In parallel, an incremental gain in carbon dioxide reduction can be achieved by immediate implementation of biomass co-firing in nearly all coal-fired power plants with minimum modifications and moderate investment, making co-firing a near-term solution for the issue of greenhouse gas emission. To this end this study examined several co-firing options including a novel option external (indirect) firing using combustion or gasification, along with the relevant capital and operating costs.
8	Hansson et al. [148]	The authors signified that the total technical potential for biomass co-firing amounts to approximately 50-90 TWh/yr, which requires a biomass supply of approximately 500-900 PJ/yr. Biomass co-firing sustains the potential to contribute substantially to the RES development in EU27 for electricity production. However, the co-firing potential among the EU27 countries varies substantially among the member states, since about 45% of the estimated biomass demand for co-firing comes from plants located close to the sea or near navigable rivers and indicates the possibility for biomass import by sea transport.
9	Berggren et al. [149]	This study investigated the potential for co-firing of biomass and coal in the Polish power-generation system. The study summarized that the co-firing was proven a low-cost option for near-term increase of RES use for electricity production, but this option has to be supplemented by other RES technologies required that must be developed to reach the 2010 target of 7.5% by 2010.

Table 4. RES sources for electricity generation in a biomass gasification overview.

Ref #	Reference	Aim–Scope–Results
1	Panklib et al. [150]	The authors of this study stressed out that the demand for energy in Thailand has been continually increasing, even though approximately 60% of Thailand's primary energy is imported, mostly petroleum products. In response to this situation, the Thailand's government plans to install small biomass gasification for electricity generation 200 kW for Sub-district Administrative Organization. Since the small biomass gasification for electricity generation can reduce the energy imports and support the jobs and the income for people in rural areas, the residue agricultural could be available for 8900 plants nationwide. The authors examined the following five main abundant and rural agricultural products of high residue energy potential towards electricity production, namely: sugarcane, paddy, oil palm, cassava, and maize, appropriate for small electricity production. The methods and the governmental policies in promoting small private power producers to supply electricity into the grid were also discussed.
2	Skorek-Osikowska et al. [151]	The authors investigated the possibility of biomass gasification in the production of electricity and generation of heat using a piston engine in which the power in the supplied biomass is no more than 50MW. While the input data of a gas generator and the process gas were collected, a mathematical model was deployed in order to structure the thermodynamic and economic analysis, accordingly. The key-parameters of the thermodynamic analysis were the electricity and heat production efficiencies, as well as the electric and heat power of the system. . The key-parameters of the economic analysis were the adaptation to various discount methods, the legal development towards such energy-based investment, as well as a sensitivity analysis of change of the selected characteristic quantities on the evaluation indices. In parallel, the key-factors of price of fuel and green certificates should play an influential role to the prosperity of such installations.
3	Ruiz et al. [152]	In this study, gasification techniques were systematically reviewed and the determining/critical parameters of such a designed gasification plant were outlined. Besides, having designed a plant according to certain specifications, there is a high probability that these diversified initial conditions could cause a malfunction of the plant.
4	Dasappa [153]	This study addressed the use of gasification technology – that is a thermo-chemical process for distributed power generation– either to replace fossil fuel in an existing diesel engine based power generation system or to generate electricity using a gas engine. The implementation of electrification programs in the rural sector was scheduled in line to two designed power generation plants of 5000 MW and 10000 MW, by using 30% of residues generated during agro processing and 10% of forest residues from the wood processing industry, respectively. The main techno-economics and key barriers to promotion of biomass energy were also outlined.
5	Liu et al. [154]	This study developed the economic feasibility of bio-energy generation from agricultural waste biomass in order to complement local nucleus business by meeting specific market demand for electricity. The methodological tool of the study was the formation of GIS maps combined with production location analysis, being based on the Bayesian Markov chain Monte Carlo method. Sensitivity and cost/benefit analyses were also conducted. Onsite gasification sustained positive profit margins for generating electricity to meet higher-valued peak power contracts, self consumption, and incidental sale, while pyrolysis towards bio-oil production and electricity generation may be too expensive.
6	Pihl et al. [155]	In response to the fact that integration/co-firing with existing fossil fuel plants could offer near-term highly efficient and low cost power production from biomass, the authors of this study developed a techno-economical analysis on options for integrating biomass thermal conversion (optimized for local resources 50 MWth) with existing CCGT (combined cycle gas turbine) power plants (800-1400 MWth). Hybrid combined cycles (HCC), indirect gasification of biomass and simple cycle biomass steam plants, were simulated using the software Ebsilon Professional and Aspen Plus. Moreover, gasification options showed even higher efficiency (46-50%). Conclusively, the authors argued that clear efficiency improvements and possible cost reductions can be reached by integration of biomass with CCGT power plants compared to stand-alone plants.

Table 5. RES sources for electricity generation in a decentralized power overview.

Ref #	Reference (in reverse chronology)	Aim–Scope–Results
1	Bazmi et al. [156]	The authors of this study signified the role of biomass sources as a means that offers the execution of decentralized electricity generation gaining importance in liberalized electricity markets. The decentralized power was further characterized by generation of electricity nearer to the demand residential areas, meeting the local energy needs. Therefore, scientists envisaged an increasing decentralization of power supply, expected to make a particular contribution to climate protection. In response to this issue, this study investigated the progress and challenges for decentralized electricity generation by palm oil biomass according to the overall concept of sustainable development.
2	Hiloidhari and Baruah [157]	The present study investigated the decentralized electricity generation potential from surplus rice straw residue in Lakhimpur district of Assam, India. Remote sensing images of Indian were used to map rice croplands of 1117 villages within nine development blocks of the district. The reasoning of this experimental procedure was rationalized from the fact that spatial availability of surplus rice straw residue and, hence, potential power could be mapped using a GIS integrated methodology taking cropland and associated data as inputs. This cropland illustrated prospective utility of straw fired electrical power in the locality. The biomass availability varied among the development blocks and villages mainly due to variations in cropped area. The outcomes of this study, in the form of spatial maps, indicated the prospect of decentralized generation of electricity. Subsequently, straw fired decentralized generation of electricity could be an attractive option considering both huge gaps between the demand and availability of electricity, as well as the remoteness of the locality.
3	Kumar et al. [158]	In this study it has been investigated the feasibility of electricity generation from biomass and the impact on decentralized power generation structure upon the following key indicators of: chemical compositions, ash fusion temperatures, and energy values of various components of four different types of surplus non-woody biomass species (Eupatorium, Anisomales, Sida, and Xanphium). Among these biomass species it was concluded the lowest ash contents and the highest energy values for their stumps, followed by branch, leaf, and bark, respectively. The authors concluded that the fusion temperature results and the land for energy plantations required per biomass species were calculated. Finally, the authors proposed the exploitation of Anisomales and Sida biomass species for energy plantations in wastelands and their utilization in power generation, either individually or in co-firing with locally available high ash coals.
4	Toonssen et al. [159]	The authors of this study investigated the decentralized generation of electricity from biomass with proton exchange membrane fuel cell. The authors signified that biomass can be applied as the primary source for the production of hydrogen in the future. Therefore, for the evaluation of alternative CHP technologies the whole chain of centralized hydrogen production from biomass up to and including decentralized electricity production in PEM fuel cells was considered. Two models for the production of hydrogen from biomass and three models for the combined production of electricity and heat with PEM fuel cells were developed using the program Cycle-Tempo. Two different levels of pure hydrogen, 60% and 99.99%, accordingly were considered. The electrical exergy efficiencies of the whole conversion chain reached at about 22% and 19%, respectively. The removal of the last impurities strongly increased the overall exergy losses of the conversion chain.

6. Biomass Exploitation in a Technological Overview

6.1. Processes of biomass conversion

In the relevant literature, the biochemical and thermochemical processes that are involved in biomass conversion are denoted in the following flowchart of Figure 1. The overall process is carbon neutral, since carbon dioxide is caught from the atmosphere by plants. In parallel, the processes shown convert plant biomass to energy, chemicals and materials. In the consumption path, carbon is turned to carbon dioxide and released to the atmosphere [160].

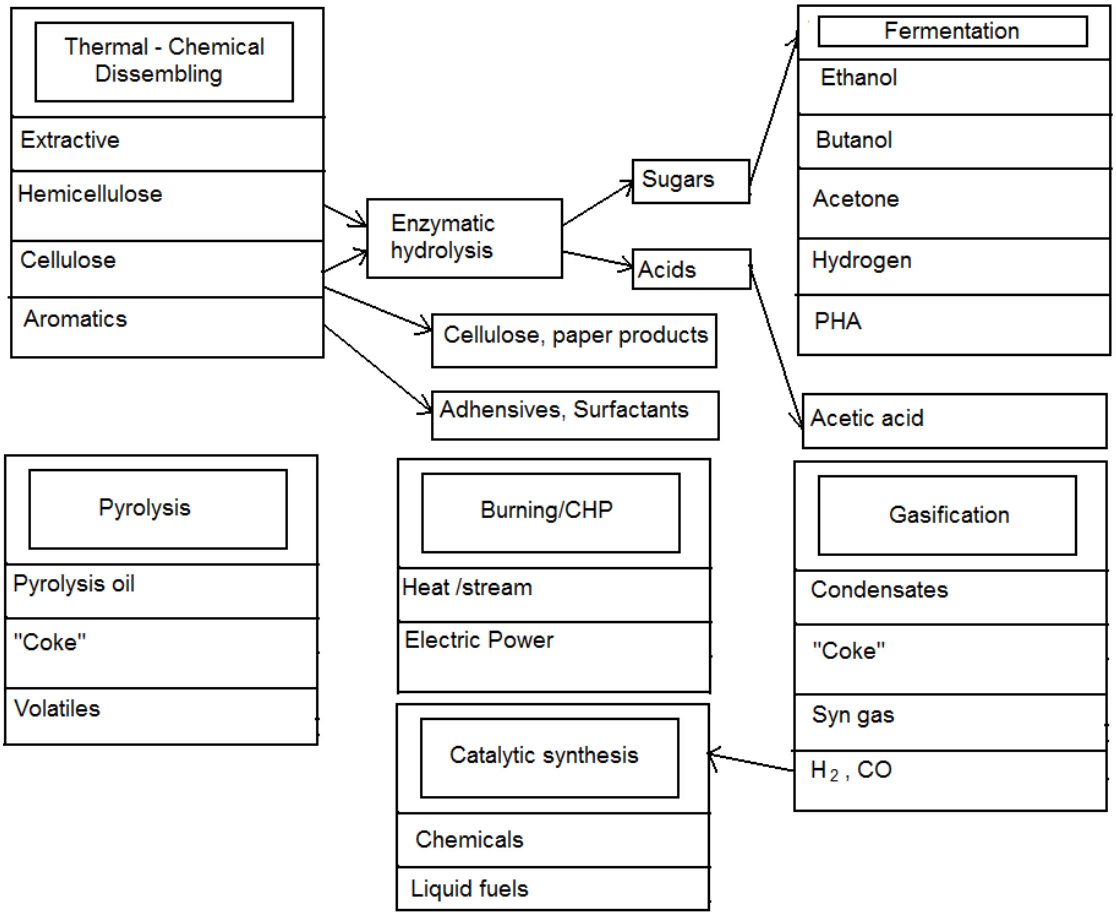

Figure 1. Processes of biomass conversion. Adapted from: Liu [160].

According to the aforementioned Figure 1, the basic four processes of lignocellulosic biomass conversion are the thermal-chemical dissembling, the pyrolysis, the burning/CHP, and the gasification. In parallel these processes can be classified/grouped as biochemical or systematic dissembling: that of thermal-chemical dissembling and pyrolysis, as well as thermochemical processes: that of burning/CHP and gasification. In the following sections of this review paper has been focused on those critical parameters that determine the technological adaptability of biomass sources towards energy production. The limitations and the challenges that are derived from this literature overview were also outlined.

6.2. Boiler of biomass heating

An initial assessment of biomass heating involves technical and economic considerations. Biomass heating systems sustain higher initial capital cost than fossil fuel systems of equivalent rated capacity. Nevertheless, this financial difference is commonly recouped through annual fuel cost savings. The technical considerations are utmost importance factors when considering the installation of a biomass boiler. An integrated flow chart that is necessary to follow, is outlined in the following Figure 2.

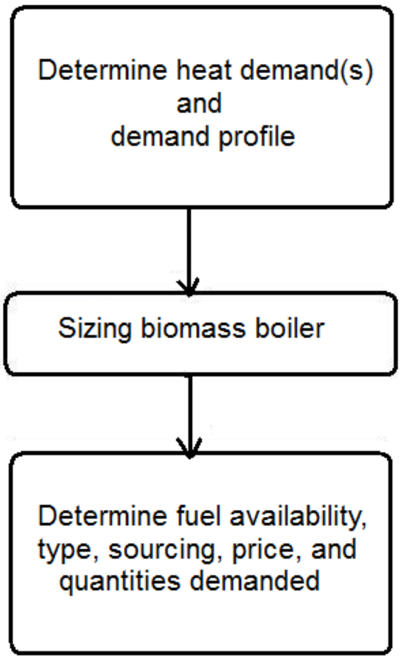

Figure 2. Flowchart of biomass heating: Technical consideration. Source: Anonymous [161].

In an economic considerations overview, in order to assess the economic feasibility of biomass heating, there are several important parameters that the investor needs to be aware of, such as:

- Site's annual energy consumption.
- Heat demand profile (including utilisation patterns).
- Costs associated with fossil fuel use.

A detailed economic evaluation should enable the final decision upon whether the biomass boiler is practical in the first instance. The concluded results consist of:

- Total capital investment required (€).
- Simple payback (years).
- Unit cost of heat from the project (€/kWh).
- Annual energy cost (€/year).

An initial assessment of economic feasibility can be estimated by using some online tools that are available on the internet. Such a tool is that of *CarbonTrust* [161].

6.3. Schematic processes of biofuels production from biomass sources

Biomass sources have recently attracted a wide interest among countries and scientists, due to their high energy content, while being converted in biofuels. It is indicatively noted that sugarcane is one of the fundamental agricultural crops towards ethanol production, especially in tropical countries [162]. In Brazil, sugarcane occupies 8.4 million hectares that corresponds to 2.4% of farmable lands in the country. The gross revenue of this market is about US$ 20 billion (being allocated as: 54% ethanol, 44% sugar, and 2% bioelectricity). Additionally, up to 50% of all vehicles in Brazil are flex fuel cars that is approximately 15 million cars [162]. Therefore, Brazil will play a dominant role upon extending the biomass sources towards energy production, whereas sugarcane bagasse and straw are proven promising feed stocks for biomass ethanol. In 2008 Brazil produced 415 million tons of sugar cane residues, 195 million tons of sugarcane bagasse, and 220 million tons of sugarcane straw, whereas for the year 2012 sugarcane production accounted of 590 million tons, which correspond to 178 million tons of bagasse, and 200 million tons of straw [162].

The first generation biofuels are currently produced from sugars, starches and vegetable oils, but these products have shown several disadvantages, such as their limited availability by soil fertility and per-hectare yield, while their contribution to savings of CO_2 emissions and fossil energy consumption is restricted by high energy input for their cultivations and conversions [163]. In parallel, although current R&D has been focused on agricultural residues such as sugarcane residual biomass, woody biomass (mainly in the forms of hardwoods and softwoods) remains an important feedstock for cellulosic ethanol production. It is estimated that 370 million dry tons of woody biomass can be sustainably produced per year in the US. Woody biomass is also sustainably abundant in many other regions worldwide such as Scandinavia, New Zealand, Canada, Japan, and South America. Besides, short-rotation intensive culture or tree farming offers an almost unlimited opportunity for woody biomass production [162]. Moreover, variable other biomass sources that are appropriate sources of energy, as energy crops, contain diversified quantities of cellulose, hemicellulose, lignin, and ash. The following Table 6 presents a typical composition of the aforementioned compounds for various biomass sources [164].

Table 6. Typical composition of indicative energy crops. Source: Chuan-Chao Dai et al. [164].

Biomass source	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
Corn stover	38-40	28	7-21	3.6-7.0
Coir	36-43	0.15-0.25	41-45	2.7-10.2
Bagasse	32-48	19-24	23-32	1.5-5
Wheat straw	33-38	26-32	17-19	6-8
Rice straw	28-36	23-28	12-14	14-20
Sorghum stalks	27	25	11	-
Barley straw	31-35	27-38	14-19	2-7
Leaves	15-20	80-85	0	-

As it is presented in Table 2, lignocellulosic biomass is chiefly composed of cellulose, hemicellulose, and lignin. Nowadays, lignocellulosic biomass has been recognized as a source of energy, fuels, and chemicals. In the relevant literature [162] during the last four decades of research and development (R&D), it was signified the use of lignocellulosic materials for energy generation via ethanol production. However, the technology required for industrial conversion of lignocellulosic materials into ethanol, has been not fully developed. To this end, a technical solution for efficient use of lignocellulosic materials to ethanol production is the applicability of a biomass pretreatment step. Under the biomass pretreatment, the production of sugar syrups with high concentrations and yields via enzymatic hydrolysis of biomass requires the pretreatment to be efficient to render the material accessible to the relevant enzyme pool [162].

Indeed, lignocellulosic biomass seems to be an attractive choice to ethanol production because, firstly, it is the most widespread renewable source available on earth since the overall chemical energy stored in biomass by plants is approximately 6–7 times of total human energy consumption annually, secondly, it is locally available in many countries and, thirdly, it does not compete with food or food industries. However, woody biomass conversion to fermentable sugars is more difficult than that of agro-based biomass because of the presence of more hemicelluloses (being not easily fermentable) and lignin, as well as due to a more condensed and crystallized structure of cellulose in woody biomass [163]. Figures 3 and 4 represent the flowchart for bioethanol production from biomass, and the flowchart for biodiesel production from lignocellulosic biomass, respectively [164].

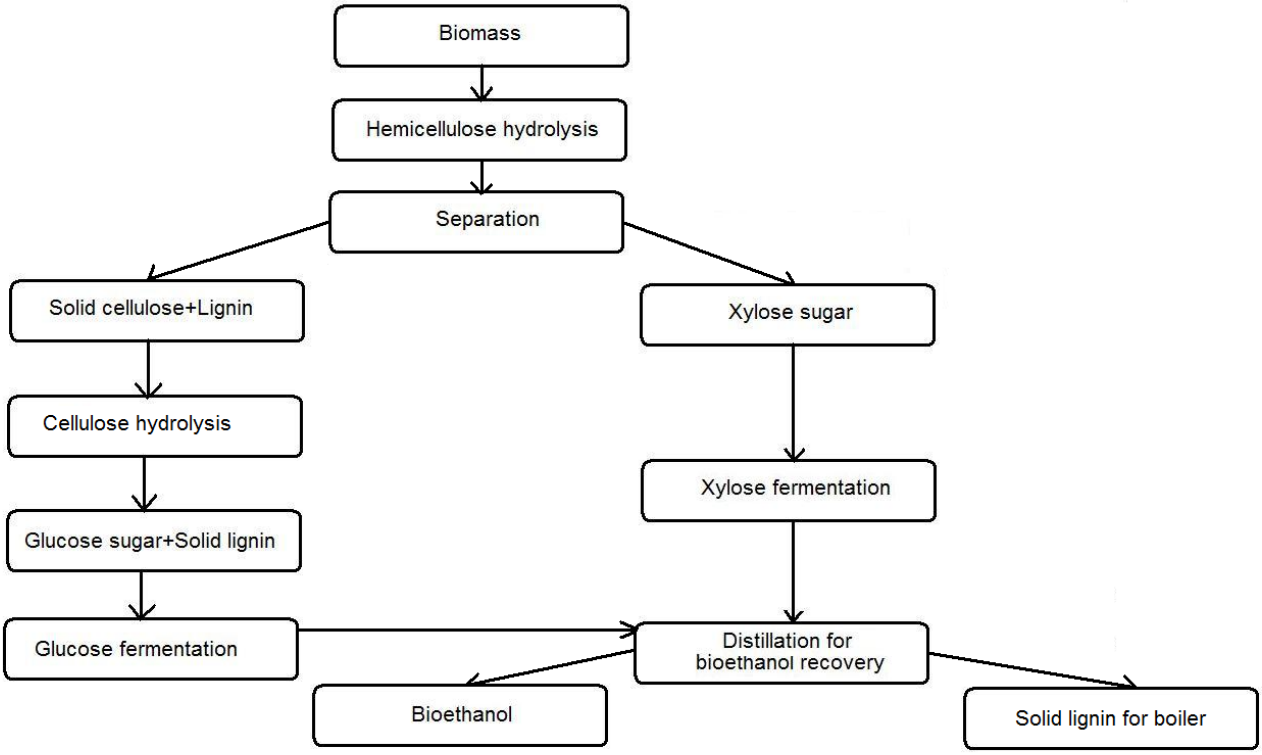

Figure 3. Flowchart for bioethanol production from biomass. Source: Chuan-Chao Dai et al. [164].

According to these Figures 3 and 4, it can be noted that the production of biofuel from cellulose of biomass necessitates that the lignocellulosic biomass should be first dissembled to facilitate the isolation of cellulose from other constituents, such as lignin and hemicelluloses. Subsequently, cellulose macromolecules should be depolymerized, since depolymerization significantly advances the chemical and biological conversions of cellulose to biofuel. Then, the depolymerized cellulose, such as glucose, can be converted to biofuel via biological treatments, and finally the biofuel can be purified. Additionally, biomass can be deoxygenated, since the presence of oxygen reduces the heat content of molecules and creates high polarity, which impairs its blending with existing fossil fuels [163].

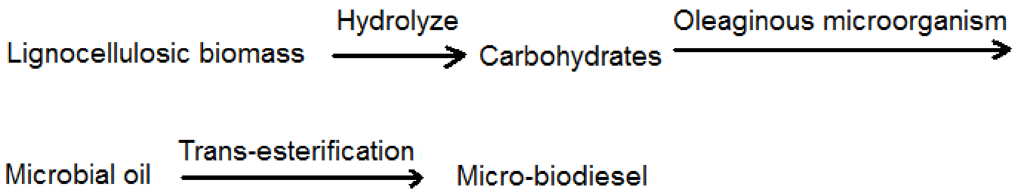

Figure 4. Flowchart for biodiesel production from lignocellulosic biomass. Source: Chuan-Chao Dai et al., 2010.

At the end of this section that outlined the main processes of biofuels production from biomass sources it is noteworthy to refer the hydrogen production processes from biomass sources. To this end in the Table 7, below, various pathways to produce hydrogen from glucose are gathered and presented.

Table 7. Methods for converting glucose to hydrogen as biofuel. Source: Fatehi Pedram [163].

Method	Theoretical yield (%)	Practical yield (%)	Energy efficiency (%)
Dark fermentation (DF)	4	1–3.2	10–30
DF+ electricity-assisted microbial fuel cell	12	9	75
Ethanol fermentation/partial oxidation reforming	10	9	60
Gasification	12	2–8	35–50
Pyrolysis	12	2.5–8	30–50
Hydrolysis+ aqueous reforming	12	6–8	30–50
Synthetic pathway biotransformation	12	12	122

According to this Table 7, the theoretical and practical yields of hydrogen production through chemical catalytic reactions, such as gasification, pyrolysis and hydrolysis—accompanied by aqueous phase reforming (APR)—of glucose are in similar range [163]. Particularly, the gasification is conducted at a high temperature of 1000 K in the presence of oxygen and water, while pyrolysis is accomplished at a high temperature but in the absence of oxygen. The main advantage of APR over gasification is the lower extent of undesirable decomposition reaction. Moreover, the APR is carried out at a lower temperature, 400–550 K, and at a medium pressure, 50–70 bar. The water medium of this process enables the occurrence of the hydrogen production reaction. In an industrial applicability viewpoint, although the chemical catalytic reaction seems to have considerably higher hydrogen production yields, the prerequisite of high energy input and poor selectivity toward hydrogen production are limited its advantageous yields of hydrogen [163].

However, the biological conversion of cellulose to hydrogen is developed at much lower temperatures, thus the energy input of this process is much lower than that of chemical catalytic processes. Contrarily, the theoretical and practical yields of hydrogen production through this method are considered low (such as in the dark anaerobic fermentation of Table 7). In order to increase the hydrogen yield, a bioelectrochemically-assisted microbial fuel reactor was reported, but this process also needs electricity input and it has not been studied in large scale/in-field applications [163]. The next section is further addressing the technological specifications involved in the process of biomass pretreatment.

6.4. Biomass pretreatment

The complex structure of lignocellulosic biomass makes its utilization in biofuel production a complex process. According to the Table 6, above, the lignocellulosic raw materials are generally composed of 40–50% cellulose, 25–35% hemicelluloses and 15–20% lignin. A pretreatment stage enables the dissociation of the plant cell wall in order to improve the accessibility of chemicals and/or microorganisms to cellulose for possible conversions. The pretreatment processes target at the removal of lignin, which improves the digestibility of cellulose in the subsequent process of hydrolysis. Table 8, below, lists various pretreatment processes of woody biomass in order to improve the performance of fermentation processes in biofuels' production [162].

Table 8. Profile of pretreatment processes of lignocellulosic feedstock. Source: Ayla Sant'Ana da Silva et al. [162].

Pretreatment type	Example
Physical pretreatment	Ball milling, Irradiation
Physicochemical pretreatment	Steam explosion, hot water pretreatment
Chemical pretreatment	Acid, alkali, solvent
Biological	Fungi
Enzyme	Cellulase

Another classification of biomass pretreatment that was given from the same authors contained the following processes [162]:

- Hydrothermal pretreatments, including liquid hot water (LHW) and steam.
- Steam-explosion pretreatment.
- Mechanical pretreatments, including ball milling, wet disk milling, and extrusion processes.
- Ionic liquid pretreatment.
- Other pretreatment processes, including alkaline-; ammonia-; and biological- pretreaments.

In the text follows, the paper has been focused on a more detailed presentation of the physical, chemical, and biological pretreatments.

6.4.1. Physical pretreatment

Physical pretreatment consists of the environmentally friendly process of mechanical disruption of lignocelluloses. The functionality of this process is to increase the surface area of biomass and to decrease the crystallinity of cellulose, without causing an expensive mass loss. Other physical methods that break the structure of lignocelluloses are the irradiation using gamma rays, the electron rays and the microwaves. Microwave irradiation has been also applied in food drying chemical synthesis and extraction [162].

Another approach to separate the lignocelluloses of woody materials is the physicochemical pretreatment. Hydrothermal treatment, such as hot water pretreatment and steam explosion, is also a suitable method, particularly prior to enzyme hydrolysis. In the hot water pretreatment process water is maintained under pressure at an elevated temperature of 230–240 °C for 15 min in liquid form, thus less inhibitory compounds (such as furfural) are produced in comparison to steam explosion method. However, the viscosity of the spent liquor produced in this method is rather high, which makes its handling process complex. The steam explosion is practically applied in industry via steaming biomass at an elevated temperature of 170 °C. The limitation of the production of inhibitors involves the precise adjustment of the process conditions. Steam explosion has been further classified in variable subcategories, such as ammonia fiber explosion and acid-explosion, in which acid or ammonia is also added to the system during the steaming process [162].

In a modelled example of physical pretreatment of biomass, the case of a pellet plant process was comprehensively studied and selected for further analysis in this section [165]. The relevant data have been extensively presented from Huang Jack [165], whereas a succinct framework of this process is also given below. Pellet plant process consists of a flowchart that enables the end user to be affiliated with the processes involved in the industry of wood pellet production. The projection of such flowchart should be also depicted in a 3D format and it can be a customized pellet plant design. A typical flowchart of a pellet plant process is given in the following Figure 5.

In this Figure 5, a typical wood pellet plant consists of the following list of pellet plant process [165]:

Raw materials storage, in which the raw materials of a pellet plant—such as saw dust, wood chips, corn stalks, rice husk, and sugarcane bagasse—will be stored. A typical warehouse of such a raw material has to be moisture-resistant.

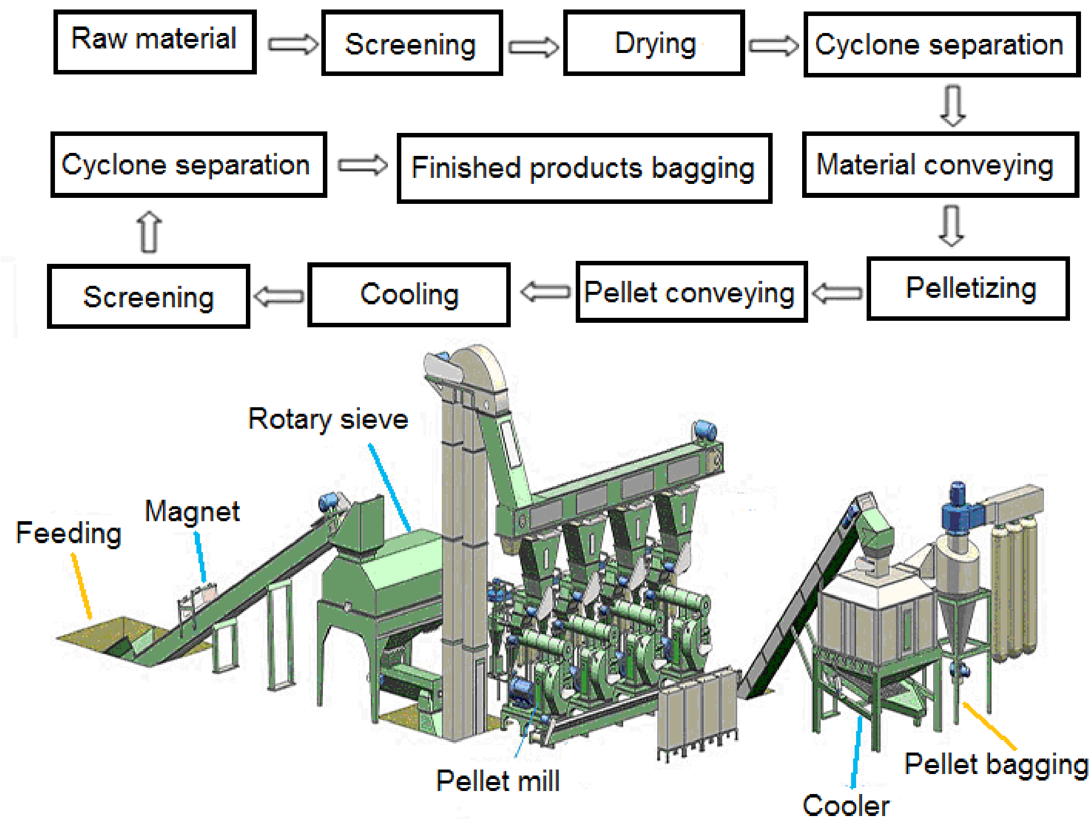

Figure 5. Flowchart upon a typical pellet plant process. Source: Huang Jack [165].

Initial size reduction, since the pellet plant process is commonly involving the size reduction of the bigger raw materials such as logs. As the pellet plant process advances, a wood chipper is used in order to cut further the big raw materials into smaller pieces with a diameter no more than 20 mm towards the processes followed.

Drying, is an important process of the pelletizing technology, since strict **moisture content** of the raw materials is needed. In the drying process, the **rotary pellet dryer** is used to complete the process.

Grinding, in which the raw materials undergone the second **size reduction process** in a pellet plant. Grinding is implemented by the use of a hammer mill in order to grind the raw materials into small particles of less than 5mm, in order to improve the **wood pellet quality and output,** and to lower the energy consumption of the pellet mill. The smaller the raw materials are, the better wood pellets are formulated.

Pelletization, in which the raw materials are pelletized into wood pellet. In a **large pellet plant** a ring die pellet mill is the appropriate choice to make wood pellets. A larger capacity—than that of one ring die pellet—of the pellet plant can be handled by connecting several ring die pellet mills together.

Cooling, that is the **temperature reduction** process of a pellet plant needed since the wood pellets remain at an extremely high temperature when they are discharged from the pellet mill. To this end the **counter flow pellet cooler** can be operated in order to cool down the wood pellet and to make it regain the proper rigidity.

Sieving, in which a separation of the fines from the well-made wood pellet is applied. To this end a pellet screener can the fines from wood pellet products, thus a high quality of fine particles of wood pellet has accomplished.

Packaging, which is the last process in a pellet plant process. Packaging ensures the proper package and storage of the wood pellet products. This process is especially needed for commercial use of the final production.

6.4.2. Chemical pretreatment

The chemical pretreatment of cellulosic biomass includes oxidizing hydrolysis, acid or alkaline hydrolysis and solvent extraction. In this process, a lime treatment (including treatment of woody biomass at 180°C with lime solutions) has been considered as an effective chemical pretreatment method, due to its low cost and wide use in agro- and wood-based processes. Pretreatment with dilute acid at intermediate temperatures (such as in 160 °C) is usually considered the most cost-effective method to loosen the cell wall matrix via degrading the hemicelluloses of biomass [162].

In a modelled example of chemical pretreatment of biomass, the case of an acid pretreatment process was comprehensively studied and selected for further analysis in this section [162]. The main issues associated with acid hydrolysis are related to the formation of toxic compounds from biomass degradation and from equipment corrosion. Such toxic products foster inhibition in cell metabolism, when biomass hydrolysis's is used for bioconversion. Therefore, in the relevant literature appropriate steps that remove these inhibitory compounds and improve the yields in bioconversion processes, have been employed [162]. Such a typical mechanism of the acid hydrolysis reaction of lignocellulosic materials sustains the following steps [162]:

1. *The diffusion of protons through the wet lignocellulosic matrix;*
2. *The protonation of the ether–oxygen link between the sugar monomers;*
3. *The breakage of the ether bond and the generation of a carbocation as an intermediate;*
4. *The solvation of the carbocation with water;*
5. *The regeneration of protons and the cogeneration of sugar monomers, oligomers, or polymers, depending on the ether connection that is broken;*
6. *The distribution of products in the liquid phase (if permitted by their shape and size); and*
7. *The restart of the process from step 2.*

Particular specifications of the material to be treated include the sample phase, the structure and physical accessibility (in the case of heterogeneous hydrolysis), the conformation effects, as well as the structure and the substituents of the sugar ring [162].

The following Table 9 presents different conditions of acid pretreatment for variable lignocellulosic materials for enzymatic hydrolysis, as well as the cellulose conversion efficiency for hardwood, softwood, sugarcane bagasse and straw. Historically and conventionally, acid pretreatment is proven the main choice for wood pretreatment [162].

Table 9. Examples of sugarcane and woody biomass pretreated with diluted acid. Source: Ayla Sant'Ana da Silva et al. [162]. Notations: [1]Softwood; [2]Hardwood.

Feedstock	T (°C)	Time (min)	H_2SO_4 (wt %)	Enzyme loading (FPU/BGU)	Enzymatic digestibility (%)
Athel pine[1]	165	8	1.4	15FPU/52.5BGU	60 (160 h)
Spruce[1]	180	30	5.0	15FPU/g solid	55 (24 h)
Eucalyptus camaldulensis[2]	165	8	1.4	15FPU/52.5BGU	38 (160 h)
Mixed wood (10% birch and 90% maple)[2]	230	0.12	1.17	---	95
Sugarcane bagasse	130	15	0.5	7FPU/3.5BGU	41.5 (72 h)
Sugarcane straw	195	10	1.0	15FPU/10BGU	72.4

6.4.3. Biological pretreatment

Biological pretreatment, such as fungal, is considered a pretreatment of milder operational conditions in comparison to the aforementioned physical or chemical pretreatment. The fungal petreatment of oxidative biodegradation of lignin by white-rot fungi is an indicative process of biological petreatment. The main advantages of biological pretreatment are its low energy input, no chemicals requirement, mild environmental conditions, and environmentally friendly operability. However, the biological pretreatment processes usually necessitate a long retention time, sustain low yield, and are also sensitive to the process conditions of temperature and pH.

In a modelled example of biological pretreatment of biomass, the case of enzymatic pretreatment of biomass was comprehensively studied and selected for further analysis in this section [162]. The biological processes of ethanol production are commonly involving hydrolysis—which breaks cellulose to glucose—and fermentation to convert glucose to ethanol. Ethanol can be produced through the processes of separate hydrolysis and fermentation (SHF) or simultaneous saccharification and fermentation (SSF) [162].

In the relevant literature, Mingjie etal. [166] introduced a novel biological process for cellulosic ethanol production, following the specifications of the SHF and the simultaneous saccharification and co-fermentation (SSCF) processes. These methodological approaches are outlined in the following Figure 6.

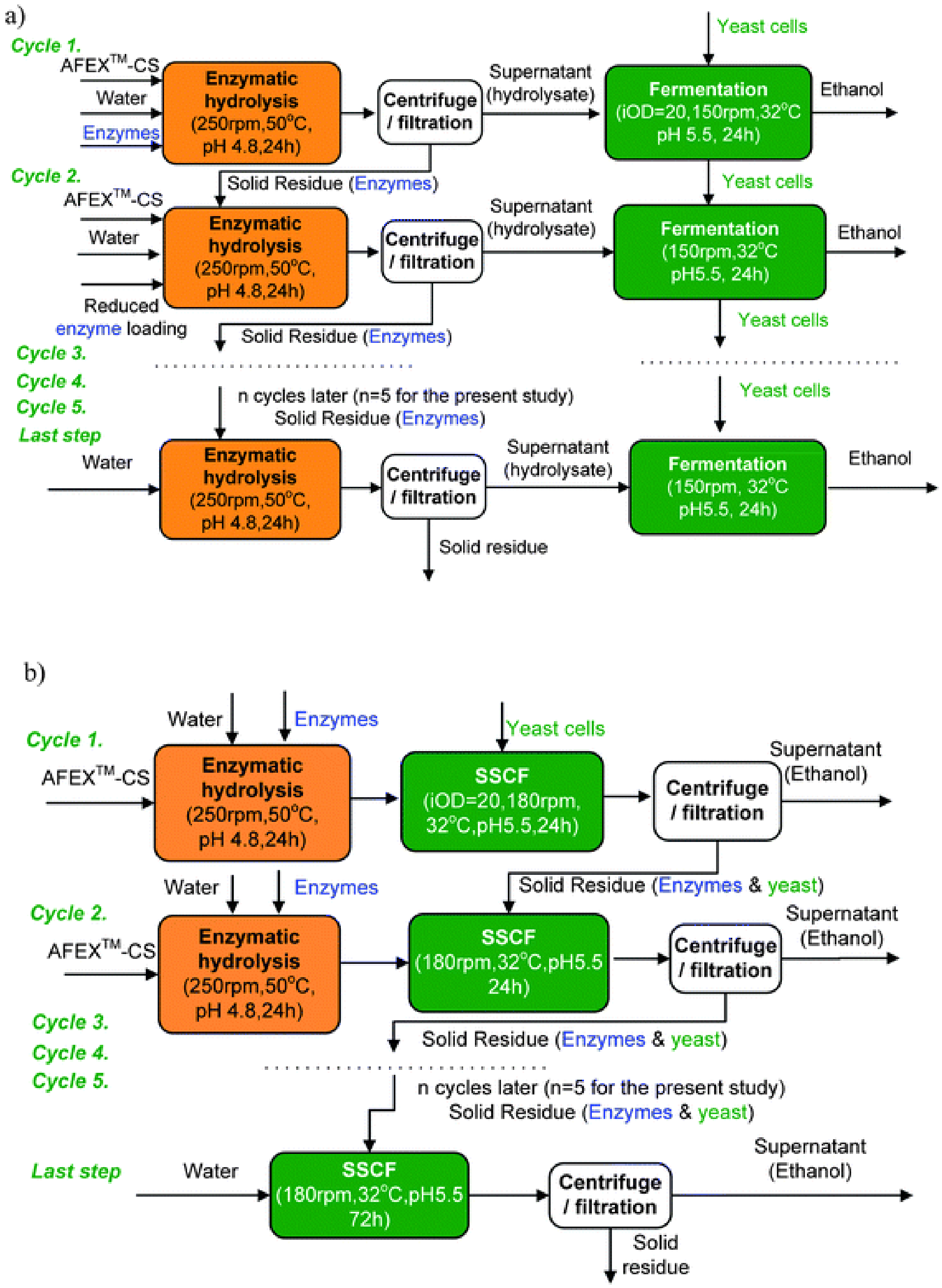

Figure 6. Flowchart of the biomass conversion research laboratory (BCRL) shown the: (a) SHF process and (b) SSCF process for ethanol production from wheat straw. Source: Mingjie Jin et al. [166].

The SSCF process was designed for bioethanol production from lignocellulosic substrates by co-fermentation of xylose and glucose. Indeed, SSCF is proven a suitable process design for simultaneous saccharification and co-fermentation for sufficient xylose utilization. According to the suitable biomass sources used, spruce sustains low ratio between xylose and glucose makes total xylose conversion challenging, whereas wheat straw sustains a relatively good ratio between xylose and glucose. However, large amounts of xylose make total xylose conversion challenging [166].

The SHF process facilitates the operation of hydrolysis and fermentation processes under separate optimized conditions. It has been reported that pre-steamed agro-based raw materials (such as corn stover) revealed that the ethanol yield (that is ethanol produced per unit mass of dried feedstock g/g) of SHF was higher than that of SSF [166]. Moreover, SHF supported a faster hydrolysis rate than SSF under optimized conditions. In the SSF process cellulose was hydrolyzed to glucose by cellulase, while yeast spontaneously fermented glucose to ethanol. The SSF advantages over the SHF process are, firstly, its commonly higher productivity (that is ethanol produced per unit mass of dried feedstock per unit time, g/g.h) than does SHF, since SSF has a shorter operating time and, secondly, the fact that SHF includes less inhibition of enzymes and a longer time of enzymatic hydrolysis. Usually, fermentation temperature and the presence of ethanol are not at optimized conditions for cellulase activities in the SSF process, leading to poor enzyme performance. This difficulty has been approached by the following two processes [162]:

- Enzyme immobilization onto a solid support was proposed to improve the enzyme activity at non-optimal conditions (that is for SSF). The higher ethanol yield of the immobilized enzyme process can be attributed due to higher glucose yields as a result of increased enzymatic stability at the non-optimal enzyme conditions required for the SSF. However, this process results in a higher ethanol yield under the optimum conditions of fermentation rather than that of enzyme hydrolysis, due to the facts that, first, the optimum conditions for the immobilized enzyme reaction may not coincide with those for the enzyme in solutions, second, although the same mass of enzyme can be used in the solution and immobilized systems, there is no the same amount of enzyme available to participate in the hydrolysis reactions and, three, enzyme immobilization results in a random orientation of adsorbed enzyme on the silica substrates, inactivation some enzyme due to buried or inaccessible active sites [162].
- Semi-simultaneous saccharification and fermentation (SSSF) are also applied to ethanol production. According to this method the hydrolysis process is applied under optimized conditions and it breaks down cellulose to glucose, and subsequently fermentation is conducted on the product of hydrolysis without removing the hydrolystate. Therefore, the SSSF process is an operating mode between the SHF and SSF that sustains the advantages of both SHF and SSF in terms of higher productivity and yield [162].

Conclusively, the following Figure 7 depicts an integrated flowchart for ethanol production from biomass, showing different pretreatments options and the composition of the solid pretreated material [162]:

Figure 7 shows various pretreatments options that involve the composition of the solid pretreated material under the SSF process. As the pretreatment choice will also be affected by the type of biomass, the envisaged biorefinery model will need to consider the main types of biomass that will be used for the biorefinery operation so as to select an appropriate, and versatile pretreatment method. Nowadays and in different geographic areas, sugarcane and woody biomass are commonly exploited as the main renewable resources to be fed into a biorefinery. However, due to a wide diversification of physical properties and chemical composition, the relevant pretreatments are proven selective and customized. Another conditioning step—that is the wood size reduction prior to the pretreatment—may not be necessary for sugarcane bagasse, therefore the energy consumption and the costs incurred in diversified pretreatment processes are diversified, too [162].

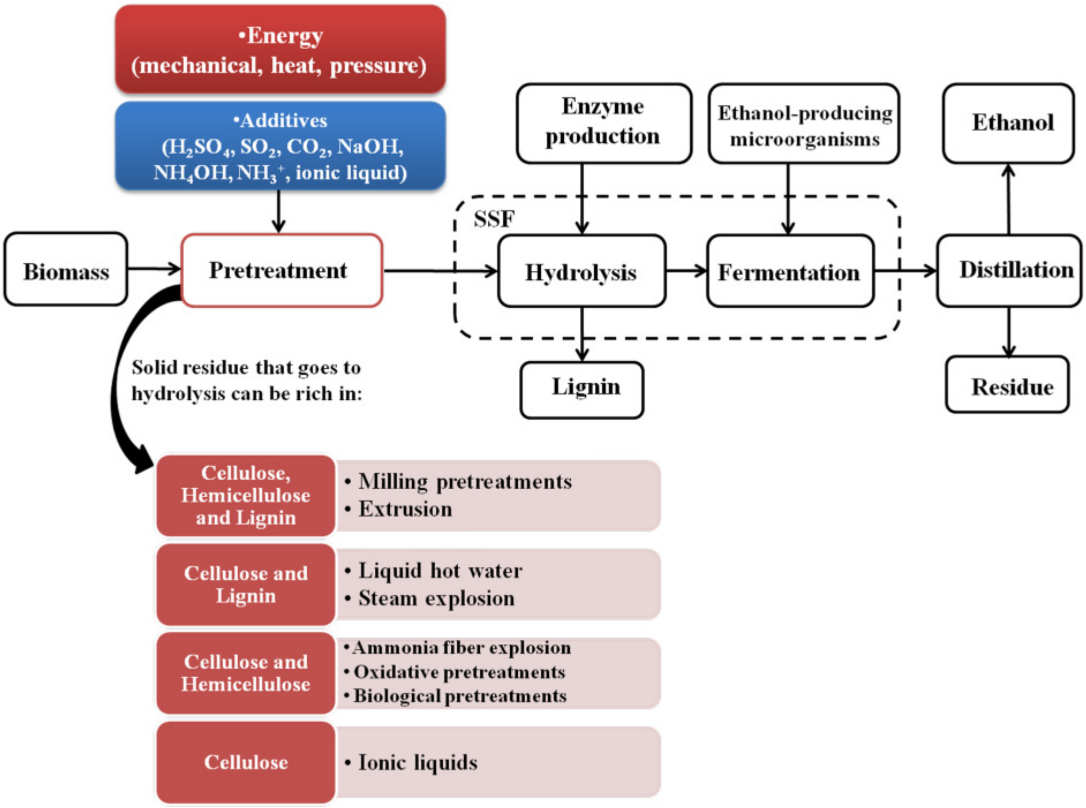

Figure 7. Flowchart for ethanol production from biomass. Source: Ayla Sant'Ana da Silva et al. [162].

7. Results and Discussion

7.1. Results and Discussion upon the literature-based overview

According to the aforementioned analysis, the main issues that can be integrated from this literature overview are outlined as follows:

Small-scale socio-economic and environmental contexts of biomass exploitation

- Active interest and social acceptance of renewable energy innovations in the view of a wide spectrum of stakeholders including technicians, industry representatives, local government officials, community representatives, end-users.
- Regional/Municipalities-scaled strategic plans aimed at the integration of the innovation dimension into a policy for renewables.
- Integrated assessment that enables the development of comprehensive decision support tools at both in-grid and off-grid electricity markets.
- Environmental benefits of alternative-to-land-spreading manure management.

Technological and projections' context of biomass exploitation

- Technology transfer and adoption of renewable energy innovation in the light of social acceptance of renewable energy technologies.
- Roles of technological innovation in exporting renewable energy technologies at both developed and developing countries.
- Dynamics of newly emerging innovation systems that stimulate renewable energy technologies.
- Development of sustained renewable energy projects to overcome high initial projects costs that result in increased renewable capacity and decreased costs.

Large-scale policies context of biomass exploitation

- Subsidizing energy costs and governmental initiatives to energy mix of production, whereas evaluating feed-in tariff remuneration modeling and patterns.
- Governmental expenditures on R&D and exports rates, towards the contribution of renewable energy to a national energy supply.
- Assessment of energy-based and environment-based models, in the light of renewables, landscape, and biodiversity issues.
- Effective of the setting strategies –being aligned to further clarify the hierarchy of existing objectives and instruments– enabling local economies to take advantage of efficient management and access to financial capital.

The main challenges and the future research orientations that are derived from the aforementioned literature review can be outlined in the following issues:

Firstly, future studies could provide an integrated planning that will overcome the socio-economic, environmental, and technical risks involved from uncertain inland energy distribution, towards the smooth energy autonomy from regional energy units using regional/endemic biomass sources.

Secondly, detailed data profiles upon economics costing, fiscal policies, and governmental initiatives, should be all ideally coordinated in the light of the aforementioned literature outcomes, towards formulating an integrated long-term strategic plan.

Thirdly, the perspectives of such an integrated long-term strategic plan –parallel to the aforementioned literature-based research and qualitative and quantitative data profiles– are further determined by the environmental, socio-economic, and technical specifications applied in the remote, island or mountainous, areas of applicability. Specifically:

- Environmental specifications should be the climatic conditions of the accommodated plant species' breeding and the geo-morphologic profile of these agricultural plantations. To this end, the grouping and the typology features of power production from RES in different regional territories can be conducted in the light of geographic information systems (GIS), while observing and analyzing these visualized maps of RES allocation can be implemented in those territories where the majority of RES have been located.
- Socio-economic specifications should be the competitive land uses (such as the so named *food-to*-energy debate) as well the social acceptability of biomass plantation to energy purposes, including the citizens' involvement and the support to their family profitability/income from such energy-oriented initiatives.

- Technological specifications should be oriented towards technological advancements' spur in biological breeding methods, agricultural yields' maximization, as well as the optimization of installed capacity and machinery of these power plants' infrastructure, which are also aligned to the aforementioned agricultural yields at each remote territory.

7.2. Results and Discussion upon the technology-based overview

The final decision upon the appropriate selection of a biomass pretreatment should be made by considering the parameters of high yields for multiple crops, harvesting times, highly digestible pretreated solid, high biomass concentration, no significant sugar degradation, formation of a minimum level of toxic compounds, high yields of sugars after subsequent hydrolysis, fermentation compatibility, operation in reasonably sized and moderately priced reactors, lignin recovery, and minimum heat and power requirements [162].

Although the technological advancements' spur upon the relevant biomass pretreatment processes is an ongoing and dynamic process itself, it in noteworthy that diversified pretreatment methods produce various effects on the biomass in terms of its structure and composition. Indeed, the hydrothermal and acidic pretreatments conceptually remove mainly the biomass hemicellulose fraction and alkaline pretreatments remove lignin, whereas the product of a milling-based pretreatment retains its initial biomass composition. In parallel, the choice of pretreatment as well as its operational conditions determines the composition of the resulting biomass hexose and pentose syrups. Furthermore, cellulose crystallinity is not significantly reduced by pretreatments based on steam, or hydrothermal, or acidic procedures, whereas ionic liquid (IL)-based techniques can shift crystalline cellulose into amorphous cellulose, substantially increasing the enzymatic hydrolysis rates and yields. Moreover, the activity profile of the enzyme blend and the enzyme load for an effective saccharification may be also varied according to the pretreatment. Finally, a low hemicellulase load can be used for a xylan-free biomass and a lower cellulase load is commonly needed for the hydrolysis of a low crystalline and highly amorphous pretreated biomass material [162].

Table 10, below, lists the pretreatment options presented in this review paper and its general effects in the biomass composition and structure. All pretreatments support an increase in the surface area, which responds for the increased enzymatic digestibility of the treated materials. However, the substantial decrease in cellulose crystallinity is only observed for the treatments using ball milling and ion liquid (IL). This is an effect of utmost importance for the increased rates and yields of cellulose enzymatic hydrolysis. The acid, LHW, and steam explosion pretreatments are more effective on hemicelluloses and on the modification of the lignin structure, which also cause a higher formation of inhibitors in comparison to milling, extrusion and IL pretreatments [162].

Table 10. General effects of different pretreatments on the composition and structure of the biomass. Source: Ayla Sant'Ana da Silva et al. [162].

[i]: +++ expressive effect; ++ moderate effect; + low effect; - no effect; nd: not determined
[ii]: SSA: Specific surface area; [iii]: CrI: Crystallinity index; [iv]: LHW: Liquid hot water;
[v]: WDM: Wet-disk milling

Pretreatment	Increase of SSA	Reduction of CrI	Removal of hemicellulose	Removal of lignin	Modification of lignin	Formation of toxic compounds
Acid	++	-	+++	++	+++	+++
Alkali	-	-	+	+++	++	++
LHW	++	-	+++	+	++	++
Steam explosion	++	-	+++	+	+++	++
Ball milling	++	+++	-	-	-	-
WDM	+++	+	-	-	-	-
Extrusion	++	+	-	-	-	-
Ionic liquid	+++	+++	+	++	+	nd

8. Conclusions

The authors of this review paper presented a systematic literature review, offering a fundamental theoretical background of the existing methodologies involved in the exploitation of renewable energy sources in general, and in biomass sources in particular. In parallel, this review paper was focused their research expertise on providing the limitations and the challenges derived from the biofuels production in a large-scale applicability. In the light of the aforementioned sections, in this concluding section the outcomes of the relevant research are classified in four main contexts of reference: technological, economics, societal, and political.

In a technological context it can be signified that biomass sources can be directly used for heat and electricity production. However, this direct utilization of biomass is limited from the uneven geographical distribution of biomass, since a viable transportation grid has to be developed, the bulky nature of biomass (especially that of low heat value) and its accompanying costly and complicated transportation systems, the poor efficiency and the high environmental pollution of engines that utilize biomass sources (including excessive CO_2 emissions). In parallel, a portion of the energy stored in biomass is inevitably lost during the conversion process, thus the biofuel product contains ultimately lower energy, than biomass as raw material. Therefore, special provision has to be made in biofuels' production. In particular, biofuels' production should sustain a high energy density on a mass, while energy crops have to produce high yields of biomass production, of low carbon footprint throughout the life cycle assessment of the biofuels' derived.

In an economics context the allocation of RES is actually an economics issue. Indeed, it is not possible to fully consider the exploitation of any energy resource without considering the economy. Subsequently, to a large extent it is economics that determines the future RES-based technologies that will come to dominate the energy sector and where these technologies will be located. In a societal context this is the case in the liberalised energy markets that are now emerging around the world. Moreover, it is the economic forces of demand and supply that determine which RES are exploited by what technology and where this happens. While technology plays an important role in discovering new RES that could be adapted in a specific country, however, when, where and to what extent RES are exploited is almost entirely a question of economics.

In a societal context it is noteworthy that there is a strong ethical dimension to how citizens try to resolve this energy-oriented economic problem. Indeed, how we produce and consume energy has a strong bearing on socio-economics relations. To this end, energy production units are also social units. The act of energy production and electricity generation can form and destroy communities and profoundly affect the quality of life, as well as the freedoms and rights if individuals, especially while considering the limitations upon an excessive use of production resources of land (see also the food-to-fuel debate upon energy crops cultivation), land (see also the optical nuisance and the spatial occupation of spacious agricultural areas in wind farms against pasture agricultural zones), and capital (that is utmost importance resource of production in epochs of economic recession).

In a political context, it is important governmental policies to understand and to be drawn in accordance with the political dimension to the market allocation of resources. To this end the central governmental policies have to be aligned to the principles of the free market efficiency and to adopt into their political regulations in energy concepts such as the opportunity cost, the cost-benefit scenarios, and the marginal analysis in the energy sector. Additionally, in a strategic energy planning overview, there are especially critical factors, such as the understanding of the use, the different forms, the challenging issues, and the inherent limitations of the relevant economic models.

In an environmental context, the economic system of energy production and electricity generation is not a closed system. Contrarily, this economic system requires land, wind, solar irradiation (that is natural raw materials) which it cannot itself produce and it generates waste. Wastes –in the form of pollution that it is created by producers and consumers– are costs of production and consumption that are not reflected in the tariff pricing of energy produced and they leak from the system. These leakages are cost external to the energy pricing process and they are known as externalities. The externalities cost is borne by the whole society and not by the individual energy consumer or energy producer that creates them. Besides, the externalities cost is commonly accompanied by a reduction in environmental quality.

Finally, it is apparent that not only are the answers themselves to the aforementioned issues are complex, but also how these decisions upon energy production and electricity generation from RES are made is itself a critical issue. Conclusively, the authors of this review paper expect that the results of their study would have some theoretical and methodical importance, being especially supportive to all stakeholders (including, customers, end-users, managers, manufacturers) as well as to those companies that are involved in the energy marketplace.

Conflict of Interest

All authors declare no conflict of interest in this paper.

References

1. Batel S, Devine-Wright P (2015) Towards a better understanding of people's responses to renewable energy technologies: Insights from Social Representations Theory. *Public Und Sci* 24: 311-325.
2. Devine-Wright P (2010) Place attachment and the social acceptance of renewable energy technologies. Chapter 17 In: *Psychological Approaches to Sustainability: Current Trends in Theory, Research and Applications*. Edited by Victor Corral-Verdugo and Cirilo H. Garcia-Cadena. Nova Science Publishers Eds., 317-336.
3. Mallett A (2007) Social acceptance of renewable energy innovations: The role of technology cooperation in urban Mexico. *Energ Policy* 35: 2790-2798.
4. Groba F, Cao J (2014) Chinese Renewable Energy Technology Exports: The Role of Policy, Innovation and Markets. *Environ Resour Econ* 60: 243-283.
5. Sung B, Song WY (2014) How government policies affect the export dynamics of renewable energy technologies: A subsectoral analysis. *Energy* 69: 843-859.
6. Zhang X, Chang S, Eric M (2012) Renewable energy in China: An integrated technology and policy perspective. *Energ Policy* 51: 1-6.
7. Negro SO, Hekkert MP, Smits REHM (2008) Stimulating renewable energy technologies by innovation policy. *Sci Public Policy* 35: 403-416.
8. Jacobsson S, Lauber V (2006) The politics and policy of energy system transformation - Explaining the German diffusion of renewable energy technology. *Energ Policy* 34: 256-276.
9. Tsoutsos TD, Stamboulis YA (2005) The sustainable diffusion of renewable energy technologies as an example of an innovation-focused policy. *Technovation* 25: 753-761.
10. Buckley JC, Schwarz PM (2003) Renewable energy from gasification of manure: An innovative technology in search of fertile policy. *Environ Monit Assess* 84: 111-127.
11. Hervás Soriano F, Mulatero F (2011) EU Research and Innovation (R&I) in renewable energies: The role of the Strategic Energy Technology Plan (SET-Plan). *Energ Policy* 39: 3582-3590.
12. Shen YC, Lin GTR, Li KP, et al. (2010) An assessment of exploiting renewable energy sources with concerns of policy and technology. *Energ Policy* 38: 4604-4616.
13. Van Alphen K, Kunz HS, Hekkert MP (2008) Policy measures to promote the widespread utilization of renewable energy technologies for electricity generation in the Maldives. *Renew Sust Energ Rev* 12: 1959-1973.
14. Gan J, Smith CT (2006) A comparative analysis of woody biomass and coal for electricity generation under various CO_2 emission reductions and taxes. *Biomass Bioenerg* 30: 296-303.
15. Sung B, Song WY (2013) Causality between public policies and exports of renewable energy technologies. *Energ Policy* 55: 95-104.

16. Garces E, Daim T (2013) An assessment of the impacts of government energy policy on energy technology, innovation, and security: The case of renewable technologies in the US electricity sector. *Lect Notes Energ* 16: 257-276.
17. Anderson D (1997) Renewable energy technology and policy for development. *Annu Rev Energ Env* 22: 187-215.
18. Nisar A, Ruiz F, Palacios M (2013) Organisational learning, strategic rigidity and technology adoption: Implications for electric utilities and renewable energy firms. *Renew Sust Energ Rev* 22: 438-445.
19. García VG, Bartolomé MM (2010) Rural electrification systems based on renewable energy: The social dimensions of an innovative technology. *Technol Soc* 32: 303-311.
20. Tsai WT (2005) Current status and development policies on renewable energy technology research in Taiwan. *Renew Sust Energ Rev* 9: 237-253.
21. Abidin NZZ, Ibrahim JB (2015) Embracing renewables - Overcoming integration challenges from Malaysia's utility perspective. 2015 IEEE Eindhoven PowerTech, PowerTech, 2015: art. no. 7232373.
22. Loiter JM, Norberg-Bohm V (1999) Technology policy and renewable energy: Public roles in the development of new energy technologies. *Energ Policy* 27: 85-97.
23. Franco A, Salza P (2011) Perspectives for the long-term penetration of new renewables in complex energy systems: The Italian scenario. *Environ Dev Sustainability* 13: 309-330.
24. Amorim F, Martins MVM, Pereira Da Silva P (2010) A new perspective to account for renewables impacts in Portugal. 7th International Conference on the European Energy Market 2010, EEM 2010: art. no. 5558695.
25. Suwa A, Jupesta J (2012) Policy innovation for technology diffusion: A case-study of Japanese renewable energy public support programs. *Sustainability Sci* 7: 185-197.
26. Vassilev SV, Vassileva CG, Vassilev VS (2015) Advantages and disadvantages of composition and properties of biomass in comparison with coal: An overview. *Fuel* 158: 330-350.
27. Zandler H, Brenning A, Samimi C (2015) Potential of space-borne hyperspectral data for biomass quantification in an arid environment: Advantages and limitations. *Remote Sens* 7: 4565-4580.
28. Costa C, Rotsios K, Moshonas G, et al. (2014) Use of multivariate approaches in biomass energy plantation harvesting: Logistics advantages. *Agr Eng Int: CIGR Journal* May 2014: 71-80.
29. Bick S (2013) Skidding options for biomass operations: From big to small, each alternative has advantages and drawbacks. *Northern Logger Timber Processor* 62: 30-35.
30. Vassilev SV, Baxter D, Andersen LK, et al. (2013) An overview of the composition and application of biomass ash.: Part 2. Potential utilisation, technological and ecological advantages and challenges. *Fuel* 105: 19-39.
31. Talluri S, Subramanian MR, Christopher LP (2012) Advantages of thermophilic hydrogen production from lignocellulosic biomass. 2012 AIChE Annual Meeting Conference Proceedings: 1p.

32. Lanning CJ, Fridley JL (2012) Advances in woody biomass drying by taking advantage of surface properties. American Society of Agricultural and Biological Engineers Annual International Meeting 2012, ASABE 2012, 1: 715-723.
33. Santos CA, Ferreira ME, Lopes Da Silva T, et al. (2011) A symbiotic gas exchange between bioreactors enhances microalgal biomass and lipid productivities: Taking advantage of complementary nutritional modes. *J Ind Microbiol Biotechn* 38: 909-917.
34. Hotchkiss R, Matts D, Riley G (2003) Co-combustion of Biomass with Coal - The Advantages and Disadvantages Compared to Purpose-built Biomass to Energy Plants. *VGB PowerTech* 83: 80-86.
35. Fransen B, De Kroon H (2001) Long-term disadvantages of selective root placement: Root proliferation and shoot biomass of two perennial grass species in a 2-year experiment. *J Ecol* 89: 711-722.
36. Nishiguchi S, Tabata T (2016) Assessment of social, economic, and environmental aspects of woody biomass energy utilization: Direct burning and wood pellets. *Renew Sust Energ Rev* 57: 1279-1286.
37. Miret C, Chazara P, Montastruc L, et al. (2016) Design of bioethanol green supply chain: Comparison between first and second generation biomass concerning economic, environmental and social criteria. *Comput Chem Eng* 85: 16-35.
38. Singh J (2015) Overview of electric power potential of surplus agricultural biomass from economic, social, environmental and technical perspective - A case study of Punjab. *Renew Sust Energ Rev* 42: 286-297.
39. Cambero C, Sowlati T (2014) Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives - A review of literature. *Renew Sust Energ Rev* 36: 62-73.
40. Aylott MJ, Casella E, Farrall K, et al. (2010) Estimating the supply of biomass from short-rotation coppice in England, given social, economic and environmental constraints to land availability. *Biofuels* 1: 719-727.
41. Haughton AJ, Bond AJ, Lovett AA, et al. (2009) A novel, integrated approach to assessing social, economic and environmental implications of changing rural land-use: A case study of perennial biomass crops. *J Appl Ecol* 46: 315-322.
42. Fischer SL, Koshland CP, Young JA (2005) Social, economic, and environmental impacts assessment of a village-scale modern biomass energy project in Jilin province, China: local outcomes and lessons learned. *Energ Sust Dev* 9: 50-59.
43. Felker P (1984) Economic, environmental, and social advantages of intensively managed short rotation mesquite (Prosopis spp) biomass energy farms. *Biomass* 5: 65-77.
44. Yilmaz Balaman T, Selim H (2015) A decision model for cost effective design of biomass based green energy supply chains. *Bioresource Technol* 191: 97-109.
45. Dillibabu V, Natarajan E (2015) Green energy from biomass gasification. *J Chem Pharm Sci* 7: 182-185.
46. Hamzeh Y, Ashori A, Mirzaei B, et al. (2011) Current and potential capabilities of biomass for green energy in Iran. *Renew Sust Energ Rev* 15: 4934-4938.

47. Bhutto AW, Bazmi AA, Zahedi G (2011) Greener energy: Issues and challenges for Pakistan - Biomass energy prospective. *Renew Sust Energ Rev* 15: 3207-3219.
48. Demirbas T, Demirbas AH (2010) Bioenergy, green energy. biomass and biofuels. *Energ Sources* 32: 1067-1075.
49. Kaltschmitt M, Thrän D (2009) Biomass-based green energy generation. Chapter 7 In: *Sustainable Solutions for Modern Economies*. Edited by Martin Kaltschmitt and Daniela Thrän. Royal Society of Chemistry (RSC) Green Chemistry Eds., 86-124.
50. Jenner M (2008) Biomass energy outlook: How green is your carbon? *BioCycle* 49: 41.
51. Alfonsin V, Suarez A, Urrejola S, Miguez J, Sanchez A (2015) Integration of several renewable energies for internal combustion engine substitution in a commercial sailboat. *Int J Hydrogen Energ* 40: 6689-6701.
52. Iniyan S, Suganthi L, Samuel AA (2006) Energy models for commercial energy prediction and substitution of renewable energy sources. *Energ Policy* 34: 2640-2653.
53. Lombard A, Ferreira SLA (2015) The spatial distribution of renewable energy infrastructure in three particular provinces of South Africa. *Bull Geogr* 30: 71-85.
54. Palmas C, Siewert A, von Haaren C (2015) Exploring the decision-space for renewable energy generation to enhance spatial efficiency. *Environ Impact Assess Rev* 52: 9-17.
55. Young M (2015) Building the blue economy: The role of marine spatial planning in facilitating offshore renewable energy development. *Int J Marine Coastal Law* 30: 148-173.
56. Güngör-Demirci G (2015) Spatial analysis of renewable energy potential and use in Turkey. J Renew Sust Energ 2015, 7: art. no. 013126.
57. Campbell MS, Stehfest KM, Votier SC, Hall-Spencer JM (2014) Mapping fisheries for marine spatial planning: Gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy. *Marine Policy* 45: 293-300.
58. Karakostas S, Economou D (2014) Enhanced multi-objective optimization algorithm for renewable energy sources: Optimal spatial development of wind farms. *Int J Geogr Inform Sci* 28: 83-103.
59. Wang Q, M'Ikiugu MM, Kinoshita I (2014) A GIS-based approach in support of spatial planning for renewable energy: A case study of Fukushima, Japan. *Sustainability* 6: 2087-2117.
60. Behringer S, Upmann T (2014) Optimal harvesting of a spatial renewable resource. *J Econ Dyn Control* 42: 105-120.
61. Davies IM, Watret R, Gubbins M (2014) Spatial planning for sustainable marine renewable energy developments in Scotland. *Ocean Coastal Manage* 99: 72-81.
62. Yang C, Ogden JM (2013) Renewable and low carbon hydrogen for California-Modeling the long term evolution of fuel infrastructure using a quasi-spatial TIMES model. *Int J Hydrogen Energ* 38: 4250-4265.
63. Baltas AE, Dervos AN (2012) Special framework for the spatial planning & the sustainable development of renewable energy sources. *Renew Energ* 48: 358-363.
64. Haller M, Ludig S, Bauer N (2012) Decarbonization scenarios for the EU and MENA power system: Considering spatial distribution and short term dynamics of renewable generation. *Energ Policy* 47: 282-290.

65. Katsaprakakis DA, Christakis DG (2016) The exploitation of electricity production projects from Renewable Energy Sources for the social and economic development of remote communities. the case of Greece: An example to avoid. *Renew Sust Energ Rev* 54:341-349.
66. Kyriakopoulos GL, Arabatzis G (2016) Electrical energy storage systems in electricity generation: Energy policies, innovative technologies, and regulatory regimes. *Renew Sust Energ Rev* 56:1044-1067.
67. Zografidou E, Petridis K, Arabatzis G, et al. (2016) Optimal design of the renewable energy map of Greece using weighted goal-programming and data envelopment analysis. *Comput Oper Res* 66: 313-326.
68. Ntona E, Arabatzis G, Kyriakopoulos GL (2015) Energy saving: Views and attitudes of students in secondary education. *Renew Sust Energ Rev* 46: 1-15.
69. Arabatzis G, Petridis K, Galatsidas S, et al. (2013) A demand scenario based fuelwood supply chain: A conceptual model. *Renew Sust Energ Rev* 25: 687-697.
70. Arabatzis G, Malesios Ch (2013) Pro-Environmental attitudes of users and not users of fuelwood in a rural area of Greece. *Renew Sust Energ Rev* 22: 621-630.
71. Balaras CA, Dascalaki EG, Droutsa P, et al. (2013) Hellenic renewable energy policies and energy performance of residential buildings using solar collectors for domestic hot water production in Greece. *J Renew Sust Energ* 5: art. no. 041813.
72. Kyriakopoulos G, Chalikias M (2013) The Investigation of Woodfuels' Involvement in Green Energy Supply Schemes at Northern Greece: The Model Case of the Thrace Prefecture. *Procedia Technol* 8: 445-452.
73. Menegaki AN, Gurluk S (2013) Greece & Turkey; assessment and comparison of their renewable energy performance. *Int J Energ Econ Policy* 3: 367-383.
74. Metaxas A, Tsinisizelis M (2013) The development of renewable energy governance in Greece. Examples of a failed (?) policy. *Lecture Notes Energy* 23: 155-168.
75. Mondol JD, Koumpetsos N (2013) Overview of challenges, prospects, environmental impacts and policies for renewable energy and sustainable development in Greece. *Renew Sust Energ Rev* 23: 431-442.
76. Zafirakis D, Chalvatzis K, Kaldellis JK (2013) Socially just support mechanisms for the promotion of renewable energy sources in Greece. *Renew Sust Energ Rev* 21: 478-493.
77. Arabatzis G, Kitikidou K, Tampakis S, et al. (2012) The fuelwood consumption in a rural area of Greece. *Renew Sust Energ Rev* 16: 6489-6496.
78. Chalikias M, Kyriakopoulos G, Goulionis J, et al. (2012). Investigation of the parameters affecting fuelwoods' consumption in the Southern Greece region. *J Food Agr Environ* 10: 885-889.
79. Kaldellis JK, Kapsali M, Katsanou E (2012) Renewable energy applications in Greece-What is the public attitude? *Energ Policy* 42: 37-48.
80. Markatou M (2012) Renewable energy technologies in greece: A patent based approach. *Int J Renew Energ Res* 2: 718-722.
81. Mourmouris JC, Potolias C, Jacob FG (2012) Evaluation of renewable energy sources exploitation at remote regions, using computing model and multi-criteria analysis: A case-study in samothrace, Greece. *Int J Renew Energ Res* 2: 307-316.

82. Tegou LI, Polatidis H, Haralambopoulos DA (2012) A multi-criteria framework for an isolated electricity system design with renewable energy sources in the context of distributed generation: The case study of Lesvos Island, Greece. *Int J Green Energ* 9: 256-279.
83. Kolovos K, Kyriakopoulos G, Chalikias M (2011). Co-evaluation of basic woodfuel types used as alternative heating sources to existing energy network. *J Environ Protect Ecol* 12: 733-742.
84. Tourkolias C, Mirasgedis S (2011) Quantification and monetization of employment benefits associated with renewable energy technologies in Greece. *Renew Sust Energ Rev* 15: 2876-2886.
85. Boemi SN, Papadopoulos AM, Karagiannidis A, et al. (2010) Barriers on the propagation of renewable energy sources and sustainable solid waste management practices in Greece. *Waste Manage Res* 28: 967-976.
86. Chalikias M, Kyriakopoulos G, Kolovos K (2010). Environmental sustainability and financial feasibility evaluation of woodfuel biomass used for a potential replacement of conventional space heating sources. Part I: A Greek Case Study. *Oper Res* 10: 43-56.
87. Kyriakopoulos G (2010) European and international policy interventions of implementing the use of woodfuels in bioenergy sector. A trend analysis and a specific woodfuels' energy application. *Int J Knowl Learn* 6: 43-54.
88. Kyriakopoulos G, Kolovos K, Chalikias M (2010) Environmental sustainability and financial feasibility evaluation of woodfuel biomass used for a potential replacement of conventional space heating sources. Part II: A Combined Greek and the nearby Balkan Countries Case Study. *Oper Res* 10: 57-69.
89. Kyriakopoulos G (2009) Biomass utilization for energy infrastructure and applications. *Int J Soc Humanistic Comput* 1: 163-174.
90. Tsiblostefanakis EC, Mantouka KA (2009) Economy efficiency for renewable energy sources in Greece. *WSEAS T Bus Econ* 6: 42-51.
91. Zafeiriou E, Arabatzis G, Koutroumanidis T (2011) The fuelwood market in Greece: An empirical approach. *Renew Sust Energ Rev* 15: 3008-3018.
92. Xydis G, Koroneos C (2009) Alternative scenarios of the utilisation of renewable energy sources in small prefectures: A case study in lasithi prefecture, Greece. *Int J Glob Energ Issues* 31: 61-87.
93. Angelis-Dimakis A, Trogadas P, Arampatzis G, et al. (2008) Cost Effectiveness Analysis for Renewable Energy Sources integration in the island of Lemnos, Greece. Proceedings iEMSs 4th Biennial Meeting - International Congress on Environmental Modelling and Software: Integrating Sciences and Information Technology for Environmental Assessment and Decision Making - iEMSs 2008: 1215-1222.
94. Lazarou S, Noou K, Siassiakos K, et al. (2008) The impact of renewable energy sources penetration in achieving the energy and environmental policy goals in Greece. *WSEAS T Environ Dev* 4: 1161-1170.
95. Tsoutsos T, Papadopoulou E, Katsiri A, et al. (2008) Supporting schemes for renewable energy sources and their impact on reducing the emissions of greenhouse gases in Greece. *Renew Sust Energ Rev* 12: 1767-1788.

96. Mirasgedis S, Sarafidis Y, Georgopoulou E, et al. (2002) The role of renewable energy sources within the framework of the Kyoto Protocol: The case of Greece. *Renew Sust Energ Rev* 6: 249-272.
97. Jäger-Waldau A, Szabó M, Monforti-Ferrario F, et al. (2011) Renewable energy snapshots 2011. JRC Scientific and Technical Reports of European Commission – Joint Research Centre Institute for Energy and Transport. Available from: http://iet.jrc.ec.europa.eu/remea/renewable-energy-snapshots-2011.
98. Schenk T, Stokes LC (2013) The power of collaboration: Engaging all parties in renewable energy infrastructure development. *IEEE Power Energ Mag* 11: 56-65.
99. Sasaki H, Kajikawa Y, Fujisue K, et al. (2010) Detecting the valley of international academic collaboration in renewable energy. IEEM2010 - IEEE International Conference on Industrial Engineering and Engineering Management 2010; art. no. 5674434: 99-103.
100. Chineke TC, Ezike FM (2010) Political will and collaboration for electric power reform through renewable energy in Africa. *Energ Policy* 38: 678-684.
101. Scarlat N, Dallemand JF, Monforti-Ferrario F, et al. (2015) Renewable Energ Policy framework and bioenergy contribution in the European Union - An overview from National Renewable Energy Action Plans and Progress Reports. *Renew Sust Energ Rev* 51: 969-985.
102. Scarlat N, Dallemand JF, Banja M (2013) Possible impact of 2020 bioenergy targets on European Union land use. A scenario-based assessment from national renewable energy action plans proposals. *Renew Sust Energ Rev* 18: 595-606.
103. Pozeb V, Goričanec D, Krope J (2011) European Energ Policy - Directives and action plans. Recent Researches in Geography, Geology, Energy, Environment and Biomedicine. Proceedings of the 4th WSEAS International Conference on EMESEG 2011:107-110.
104. McKillop A (2012) Europe's climate energy package must be reformed or abandoned. *Energ Environ* 23: 837-848.
105. Kulovesi K, Morgera E, Muñoz M (2011) Environmental integration and multi-faceted international dimensions of EU law: Unpacking the EU's 2009 climate and energy package. *Common Market Law Rev* 48: 829-891.
106. Uusi-Rauva C, Tienari J (2010) On the relative nature of adequate measures: Media representations of the EU energy and climate package. *Glob Environ Change* 20: 492-501.
107. Uusi-Rauva C (2010) The EU energy and climate package: A showcase for European environmental leadership? *Environ Policy Governance* 20: 73-88.
108. Vielle M, Moulinier JM, Bernard A (2009) Evaluation of the energy-climate package with the help of gemini-e3 model. *Revue de l'Energie* 589: 153-173.
109. Connolly D, Lund H, Mathiesen BV, et al. (2014) Heat roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system. *Energ Policy* 65: 475-489.
110. Alonso PM, Hewitt R, Pacheco JD, et al. (2016) Losing the roadmap: Renewable energy paralysis in Spain and its implications for the EU low carbon economy. *Renew Energ* 89: 680-694.
111. Babonneau F, Haurie A, Vielle M (2014) Assessment of balanced burden-sharing in the 2050 EU climate/energy roadmap: a metamodeling approach. *Climatic Change* 134: 505-519.

112. Jonsson DK, Johansson B, Månsson A, et al. (2015) Energy security matters in the EU Energy Roadmap. *Energ Strategy Rev* 6: 48-56.
113. Turnyanskiy M, Neu R, Albanese R, et al. (2015) European roadmap to the realization of fusion energy: Mission for solution on heat-exhaust systems. *Fusion Eng Des* 96-97: 361-64.
114. Xiong W, Wang Y, Mathiesen BV, et al. (2015) Heat roadmap china: New heat strategy to reduce energy consumption towards 2030. *Energy* 81: 274-285.
115. Odenberger M, Kjärstad J, Johnsson F (2013) Prospects for CCS in the EU energy roadmap to 2050. *Energ Procedia* 37: 7573-7581.
116. Jeffrey H, Sedgwick J, Robinson C (2013) Technology roadmaps: An evaluation of their success in the renewable energy sector. *Technol Forecast Soc Change* 80: 1015-1027.
117. Hey C (2012) Low-carbon and energy strategies for the EU. The European commission's roadmaps: A sound agenda for green economy? *GAIA* 21: 43-47.
118. McDowall W (2012) Technology roadmaps for transition management: The case of hydrogen energy. *Technol Forecast Soc Change* 79: 530-542.
119. Wang YD, Chen WM, Park YK (2011) Integrated regional Energ Policy and planning framework: Its application to the evaluation of the renewable roadmap of carbon free Jeju Island in South Korea. Chapter 13 In: *Sustainable Systems and Energy Management at the Regional Level: Comparative Approaches.* IGI Global Eds.: 236-260.
120. Gómez A, Zubizarreta J, Dopazo C, et al. (2011) Spanish energy roadmap to 2020: Socioeconomic implications of renewable targets. *Energy* 36: 1973-1985.
121. Amer M, Daim TU (2010) Application of technology roadmaps for renewable energy sector. *Technol Forecast Soc Change* 77: 1355-1370.
122. Pang X, Mörtberg U, Brown N (2014) Energy models from a strategic environmental assessment perspective in an EU context - What is missing concerning renewables? *Renew Sust Energ Rev* 33: 353-362.
123. Miran W, Nawaz M, Jang J, et al. (2016) Sustainable electricity generation by biodegradation of low-cost lemon peel biomass in a dual chamber microbial fuel cell. *Int Biodeter Biodegr* 106: 75-79.
124. He H, Zhou M, Yang J, et al. (2014).Simultaneous wastewater treatment, electricity generation and biomass production by an immobilized photosynthetic algal microbial fuel cell. *Bioproc Biosyst Eng* 37: 873-880.
125. Kondaveeti S, Choi KS, Kakarla R, et al. (2014) Microalgae Scenedesmus obliquus as renewable biomass feedstock for electricity generation in microbial fuel cells (MFCs). *Front Environ Sci Eng* 8: 784-791.
126. Nishio K, Hashimoto K, Watanabe K (2013) Digestion of algal biomass for electricity generation in microbial fuel cells. *Biosci Biotech Bioch* 77: 670-672.
127. Rashid N, Cui YF, Muhammad SUR, et al. (2013) Enhanced electricity generation by using algae biomass and activated sludge in microbial fuel cell. *Sci Total Environ* 456-457: 91-94.
128. Zhang J, Zhang B, Tian C, et al. (2013) Simultaneous sulfide removal and electricity generation with corn stover biomass as co-substrate in microbial fuel cells. *Bioresource Technol* 138: 198-203.

129. Cheng H, Qian Q, Wang X, et al. (2012) Electricity generation from carboxymethyl cellulose biomass: A new application of enzymatic biofuel cells. *Electrochim Acta* 82: 203-207.
130. Toonssen R, Woudstra N, Verkooijen AHM (2010) Decentralized generation of electricity with solid oxide fuel cells from centrally converted biomass. *Int J Hydrogen Energ* 35: 7594-7607.
131. Wang X, Feng Y, Wang H, et al. (2009) Bioaugmentation for electricity generation from corn stover biomass using microbial fuel cells. *Environ Sci Technol* 43: 6088-6093.
132. Zhang Y, Min B, Huang L, et al. (2009) Generation of electricity and analysis of microbial communities in wheat straw biomass-powered microbial fuel cells. *Appl Environ Microbiol* 75: 3389-3395.
133. Macedo WN, Monteiro LG, Corgozinho IM, et al. (2016) Biomass based microturbine system for electricity generation for isolated communities in Amazon region. *Renew Energ* 91: 323-333.
134. Cerón AMR, Weingärtner S, Kafarov V (2015) Generation of electricity by plant biomass in villages of the Colombian provinces: Chocó, Meta and Putumayo. *Chem Eng T* 43: 577-582.
135. Umar MS, Jennings P, Urmee T (2014) Sustainable electricity generation from oil palm biomass wastes in Malaysia: An industry survey. *Energy* 67: 496-505.
136. Moore S, Durant V, Mabee WE (2013) Determining appropriate feed-in tariff rates to promote biomass-to-electricity generation in Eastern Ontario, Canada. *Energ Policy* 63: 607-613.
137. Rodriguez LC, May B, Herr A, et al. (2011) Biomass assessment and small scale biomass fired electricity generation in the Green Triangle, Australia. *Biomass Bioenerg* 35: 2589-2599.
138. Wei L, To SDF, Pordesimo L, et al. (2011) Evaluation of micro-scale electricity generation cost using biomass-derived synthetic gas through modelling. *Int J Energ Res* 35: 989-1003.
139. Evans A, Strezov V, Evans TJ (2010) Sustainability considerations for electricity generation from biomass. *Renew Sust Energ Rev* 14: 1419-1427.
140. Nasiri F, Zaccour G (2009) An exploratory game-theoretic analysis of biomass electricity generation supply chain. *Energ Policy* 37: 4514-4522.
141. Akgul O, Mac Dowell N, Papageorgiou LG, et al. (2014) A mixed integer nonlinear programming (MINLP) supply chain optimisation framework for carbon negative electricity generation using biomass to energy with CCS (BECCS) in the UK. *Int J Greenhouse Gas Control* 28: 189-202.
142. Favero A, Massetti E (2014) Trade of woody biomass for electricity generation under climate mitigation policy. *Resource Energ Econ* 36: 166-190.
143. O'Shaughnessy SM, Deasy MJ, Kinsella CE, et al. (2013) Small scale electricity generation from a portable biomass cookstove: Prototype design and preliminary results. *Appl Energ* 102: 374-385.
144. Dwivedi P, Bailis R, Carter DR, et al. (2012) A landscape-based approach for assessing spatiotemporal impacts of forest biomass-based electricity generation on the age structure of surrounding forest plantations in the Southern United States. *GCB Bioenergy* 4: 342-357.
145. Perilhon C, Alkadee D, Descombes G, et al. (2012) Life cycle assessment applied to electricity generation from renewable biomass. *Energy Procedia* 18: 165-176.
146. Shafie SM, Mahlia TMI, Masjuki HH, et al. (2012) A review on electricity generation based on biomass residue in Malaysia. *Renew Sust Energ Rev* 16: 5879-5889.

147. Basu P, Butler J, Leon MA (2011). Biomass co-firing options on the emission reduction and electricity generation costs in coal-fired power plants. *Renew Energy* 36: 282-288.
148. Hansson J, Berndes G, Johnsson F, et al. (2009) Co-firing biomass with coal for electricity generation-An assessment of the potential in EU27. *Energ Policy* 37: 1444-1455.
149. Berggren M, Ljunggren, E, Johnsson F (2008) Biomass co-firing potentials for electricity generation in Poland-Matching supply and co-firing opportunities. *Biomass Bioenerg* 32: 865-879.
150. Panklib T, Prakasvudhisarn C, Khummongkol D (2014) The potential of biomass energy from agricultural residues for small electricity generation in Thailand. *Energ Source* 36: 803-814.
151. Skorek-Osikowska A, Bartela T, Kotowicz J, et al. (2014) The influence of the size of the CHP (combined heat and power) system integrated with a biomass fueled gas generator and piston engine on the thermodynamic and economic effectiveness of electricity and heat generation. *Energy* 67: 328-340.
152. Ruiz JA, Juárez MC, Morales MP, et al. (2013) Biomass gasification for electricity generation: Review of current technology barriers. *Renew Sust Energ Rev* 18: 174-183.
153. Dasappa S (2011) Potential of biomass energy for electricity generation in sub-Saharan Africa. *Energ Sust Dev* 15: 203-213.
154. Liu X, Farmer M, Capareda S (2011) The Economic Feasibility of Electricity Generation from Biomass on the South Plains of Texas. In: *The Economics of Alternative Energy Sources and Globalization*. Edited by Andrew Schmitz, Norbert L. Wilson, Charles B. Moss, David Zilberman. Bentham Eds., 158-169.
155. Pihl Erik E, Heyne S, Thunman H, et al. (2010) Highly efficient electricity generation from biomass by integration and hybridization with combined cycle gas turbine (CCGT) plants for natural gas. *Energy* 35: 4042-4052.
156. Bazmi AA, Zahedi G, Hashim H (2011) Progress and challenges in utilization of palm oil biomass as fuel for decentralized electricity generation. *Renew Sust Energ Rev* 15: 574-583.
157. Hiloidhari M, Baruah DC (2011) Rice straw residue biomass potential for decentralized electricity generation: A GIS based study in Lakhimpur district of Assam, India. *Energ Sust Dev* 15: 214-222.
158. Kumar M, Patel SK, Mishra S (2010) Studies on characteristics of some shrubaceous non-woody biomass species and their electricity generation potentials. *Energ Source* 32: 786-795.
159. Toonssen R, Woudstra N, Verkooijen AHM (2009) Decentralized generation of electricity from biomass with proton exchange membrane fuel cell. *J Power Source* 194: 456-466.
160. Liu J, Deng Y (2008) The Biorefinery: Employing Biomass to Relieve Our Dependence on Fossil Sources. *Biorefinery J Biobased Mater Bioenerg* 2: 97-99. Available from: http://www.biorefineryresearchinstitute.com/biorefinery.php.
161. Anonymous (2010) Biomass – Assessing the Potential in Rural Areas. From: “Assessing Biomass Feasibility” project, which was undertaken as part of the University of Strathclyde’s Sustainable Engineering, MSc in “Energy Systems and the Environment”. Available from: http://www.esru.strath.ac.uk/EandE/Web_sites/09-10/Rural_renewables/Methodology_Specific Consideration_ Biomass_BiomassBoiler.html.

162. Silva AS, Teixeira RSS, Moutta RO, et al. (2013) Sugarcane and Woody Biomass Pretreatments for Ethanol Production. Chapter 3 In: *Sustainable Degradation of Lignocellulosic Biomass - Techniques, Applications and Commercialization*. Edited by Anuj K. Chandel and Silvio Silvério da Silva. InTech Eds. 42pp.
163. Fatehi Pedram (2013) Production of Biofuels from Cellulose of Woody Biomass. Chapter 3 In: *Cellulose - Biomass Conversion*. Edited by Theo van de Ven and John Kadla, InTech Eds. Available from: http://www.intechopen.com/books/cellulose-biomass-conversion/production-of-biofuels-from-cellulose-of-woody-biomass.
164. Dai CC, Tao J, Wang Y, et al. (2010) Research advance and superiority of microdiesel production with biowastes. *Afr J Microbiol Res* 4: 977-983.
165. Huang J (2015) Pellet Plant Process Flow Chart: Gemco Energy. Available from: http://www.biomass-energy.org/blog/pellet-plant-process-flow-chart.html.
166. Jin M, Gunawan C, Uppugundla N, et al. (2012) A novel integrated biological process for cellulosic ethanol production featuring high ethanol productivity, enzyme recycling and yeast cells reuse. *Energ Environ Sci* 5: 7168-7175.