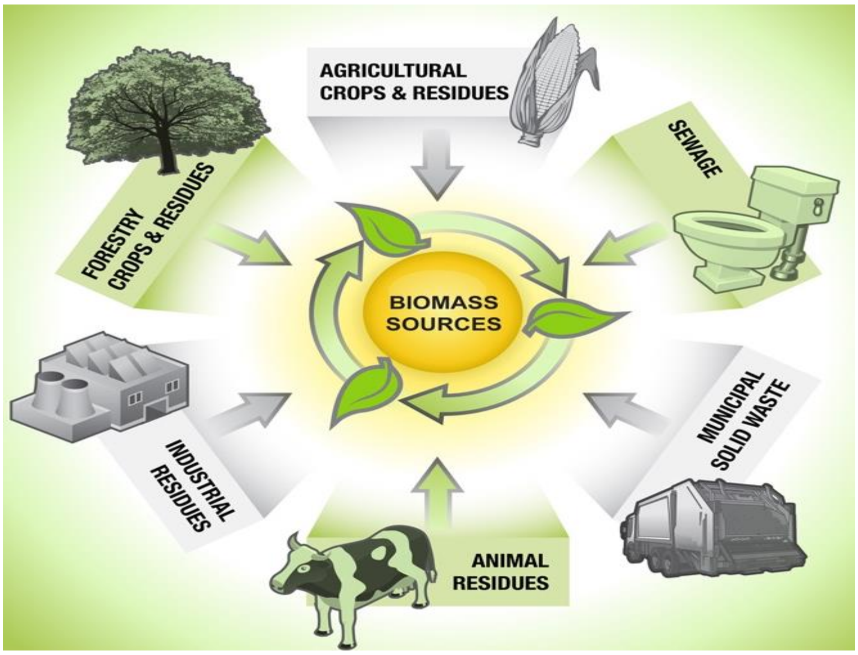
Biomass Sector Report



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Introduction

The world's population continues to grow at a high rate, such that today's population is twice that of 1960, and it is projected to increase further to 9 billion by 2050. Forecasting models suggest that developing countries will account for 99 per cent of this population increase, with population growth of 50 per cent in urban areas. This situation has brought about a situation in which the percentage of global energy used in cities is increasing considerably. In the early 1990s, cities consumed less than half of the total energy produced, while they currently use two-thirds of the worldwide energy. This means that the share of urban energy use in the global energy mix is growing at a higher rate than the global share of the urban population.

Although cities continue to use fossil fuels as the main source of energy, energy sustainability is becoming a key political solution to mitigate problems related to climate change. Indeed, cities represent 70% of the total emissions of CO_2 caused by humans , being one of the largest contributors to climate change. In addition, cities face devastating effects from climate change. Approximately 70% of cities are already coping with the effects of climate change. Since 90% of all urban areas are coastal, the damage caused by rising sea levels is expected to increase, with some cities in developing countries being particularly vulnerable. The increase in urban energy consumption has also led to an increase in urban air pollution. According to the World Health Organization (WHO), 90% of the inhabitants of urban areas are subject to environmental pollution levels that exceed the recommended limits. Biomass refers to all organic matter existing in the biosphere, whether of plant or animal origin, as well as those materials obtained through their natural or artificial transformation. Biofuels derived from biomass include firewood, wood shavings, pellets, some fruit stones such as olives and avocados, as well as nutshells. Of these, cut and chopped firewood is the least processed, and is usually burned directly in domestic appliances such as stoves and boilers. The chips come from the crushing of biomass both agricultural and forest, with their size being variable depending on the manufacturing process from which they are derived, or the transformation process that they have undergone. Finally, pellets are the most elaborate biofuel, and consist of small cylinders 6 to 12 mm in diameter and 10 to 30 mm in length that are obtained by pressing biofuels with binders. Pellets are used especially in fuels with a low energy/volume ratio. Fruit stones and seeds, as well as fruit husks, though used to a lesser extent than other standardized fuels such as fuelwood, wood chips and pellets, also represent an increasingly used solid biofuel. Indeed, it has been shown that mango stone, peanut shell and sunflower seed husk have a high energy potential, with a Higher Heating Value (HHV) similar to other commercialized biofuels. This fact, together with the increasing worldwide production of these by-products, makes them especially attractive for thermal energy generation, as well as to reduce CO_2 emissions. Biomass is present in a variety of different materials: wood, sawdust, straw, seed waste, manure, paper waste, household waste, wastewater, etc. Renewable energy for heating comes either from decentralized equipment in buildings or from centralized generation and its further distribution. Decentralized biomass boilers are an emerging technology in constant development. Biomass is a carbon-neutral energy source, since the biomass during its growth absorbs CO2 that is then released into the atmosphere during its combustion, with a zero-net balance of CO2 emissions . However, large amounts of thermal energy are wasted in power generation and in many manufacturing processes. Cogeneration is the most widely used technology to reuse lost heat, generating useful heat as well as electrical energy. Combined Heat and Power plants (CHP) simultaneously produce electricity and heat for use in industrial, trade or residential contexts. Industry consumes all the heat and electricity it needs, and the excess electricity is fed into the grid and is consumed mostly in the local environment.

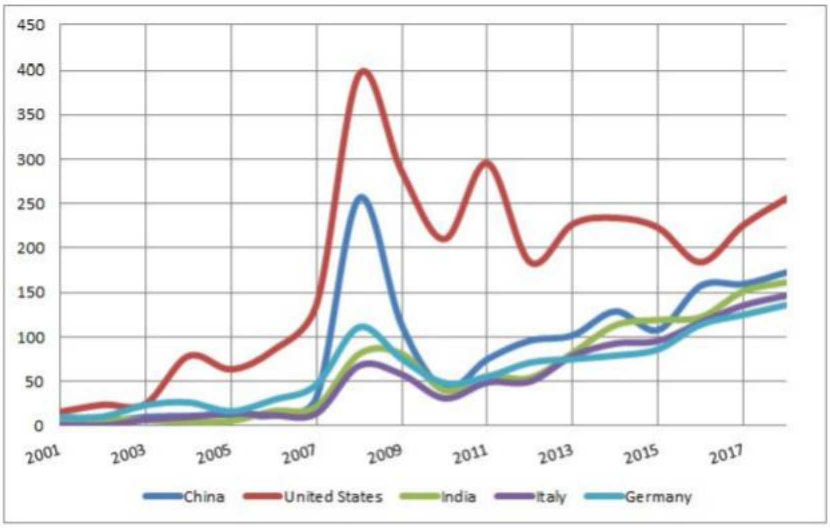
On the other hand, district heating and cooling networks are a highly effective way to integrate natural resources such as industrial and agricultural biomass, while increasing energy efficiency. Distributed energy systems consist of a network of underground insulated pipes, connected to a thermal or cold heat plant, through which hot or cold water is pumped to several buildings within a district. Due to the wide availability of biomass worldwide, mainly because it can be obtained as a by-product of many industrial and agricultural processes, biomass represents a growing renewable energy source with high growth potential. One of the main characteristics of biomass that makes it suitable as an energy source is that through direct combustion it can be burned in waste conversion plants to produce electricity or in boilers to produce heat at industrial and residential levels. However, it must be borne in mind that direct combustion of biomass is not always feasible in existing facilities, and that in many cases it is necessary to carry out physical-chemical or biological treatments to adapt it to the quality of conventional fuels. Biomass District Heating (BDH) is a very effective system for the integration of natural energy resources within urban environments, achieving on the one hand a 100% reduction in CO2 emissions compared to fossil fuels, and on the other hand an increase in energy efficiency due to the lower cost of biofuels. Biomass exists in a variety of different materials: wood, sawdust, straw, seed waste, manure, paper waste, household waste, wastewater, etc. The characteristics of some materials allow them to be used as fuels directly; however, others require a series of pre-treatments, which require different technologies before they can be used. Biomass has its flaws, but also its strengths. Among its great benefits is the forest use of the territory, which would also serve to clean the forest and thus prevent forest fires, and the ability to generate jobs. Biomass generates continuous employment such as the extraction of raw materials from the countryside and the bush. Nowadays, the use of biomass as biofuel represents a field of great interest to the scientific community. The table presents a synthesis of the ways of approach from the literature depending of the type of biomass.

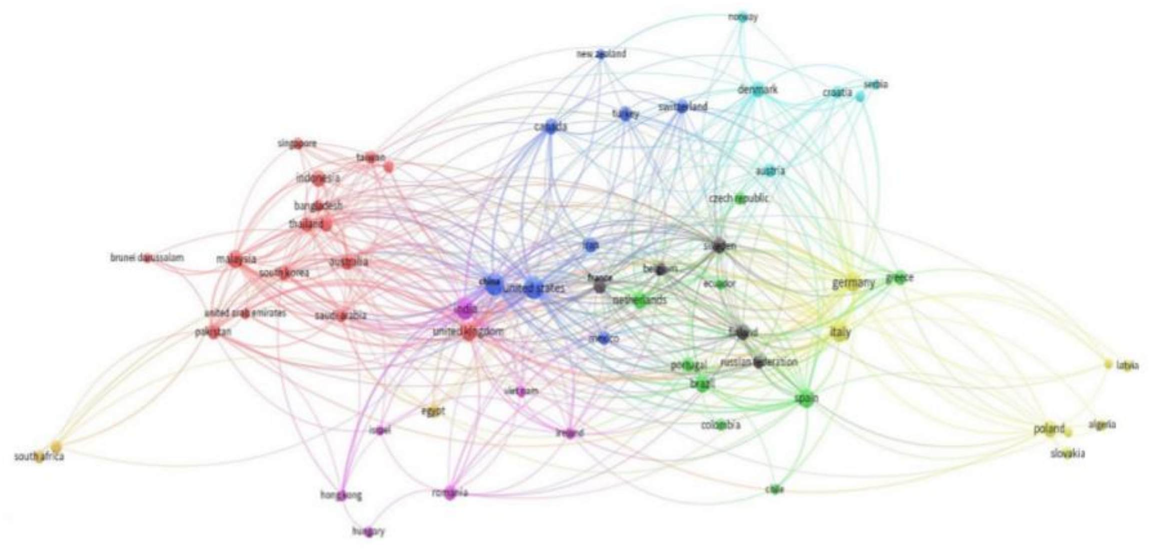
Table: Different types of Biomass and its Origins.

Year	Biomass Type	Biomass Origin	Analysis Type	Reference
2018	Walnut shell	Agriculture residue	Ultimate analysis	[17]
2013	Wood bark	Forests	Ultimate analysis	[26]
2017	Wheat straw	Agriculture residue	Ultimate analysis	[27]
2018	Peanut shell	Industrial residue	Ultimate analysis	[15]
2018	Mango stone	Industrial residue	Ultimate analysis	[13]
2016	Avocado Stone	Industrial residue	Ultimate analysis	[5]
2017	Wood	Forests	Ultimate analysis	[27]
2013	Olive stone	Industrial residue	Ultimate analysis	[28]
2005	Almond shell	Industrial residue	Ultimate analysis	[29]
2018	Sun flower seed husk	Industrial residue	Ultimate analysis	[24]
2015	Pine pellets	Forests	Ultimate analysis	[30]
2019	Palm oil Kernel Shell	Industrial residue	Proximate and elemental analysis	[31]
2018	Corn cob waste	Industrial residue	Ultimate analysis	[32]

Trend in publications of top five countries.

The figure below represents the evolution of the number of documents from the 5 countries with the highest scientific production related to biomass as renewable energy. It is possible to observe how in 2008 these 5 industrialized countries regain their scientific production on this subject due to the sustainability policies carried out by the different governments.





Above represents the collaborative work between countries.

From the collaboration between countries and biomass research, eight clusters are observed. All this is centralized around three countries belonging to different clusters: USA, India, and the UK. The red cluster is the most important, and is led by the UK; as can be seen, it is composed of its traditional area of political and economic influence, to which Japan joins. The green cluster is the second most important and consists mainly of Latin American countries. The blue cluster is led by the USA and is in close relationship with China and other North American countries such as Canada and Mexico. The yellow cluster is led by Germany and is mainly related to Eastern European countries. With less importance would be the Central European clusters (in the color Turquoise), Scandinavia-Russia (in the color Grey), and in Orange that of some African countries. It can therefore be deduced that there are two forms of grouping: the first is based on the influence or economic relations between groups of countries, which in this scenario would be the four most important clusters; and the second would be in terms of the type of biomass they may have, based on their geographical location or climatic conditions, which in this situation would be the last three clusters.

Cluster	Color	Countries	Geographic Areas	%
1	Red	Australia-Bangladesh-Brunei Darussalam-Indonesia-Japan-Malaysia-Pakistan-Philippines-Saudi Arabia-Singapore-South Korea-Taiwan-Thailand-United Arab Emirates-United Kingdom	Asia-Arabian Peninsula-UK	24.59
2	Green	Brazil-Chile-Colombia-Czech Republic-Ecuador-Greece-Netherlands-Portugal-Spain	Latin America-Spain and Portugal	14.75
3	Blue	Canada-China-Iran-Mexico-New Zealand-Switzerland-Turkey-United States	North America-China	13.11
4	Yellow	Algeria-Germany-Italy Latvia-Lithuania-Poland-Slovakia-Ukraine	Eastern Europe-Germany	13.11
5	Purple	Hungary-India-Ireland-Israel-Romania-Viet Nam	India	11.48
6	Turquoise	Austria-Croatia-Denmark-Norway-Serbia-Slovenia	Central Europe	9.84
7	Grey	Belgium-Finland-France-Russian Federation-Sweden	Scandinavia-Russia	8.20
8	Orange	Egypt-Nigeria-South Africa	Africa	4.92

Forms Of Biofuels

Biofuels are used in all three states of matter, i.e., solid, liquid and gaseous. In solid state are basically wood and chips, charcoal and pellets. In liquid form, bioethanol and biodiesel stand out. In addition, in the gaseous state, there is biogas (methane, hydrogen and nitrogen, above all), normally obtained either by anaerobic fermentation of microbiological origin, or by gasification (partial oxidation of biomass at high temperature, about 1400 °C, without combustion). The two most important are focused on obtaining liquid fuels from biomass. The red cluster is mainly focused on the production of biodiesel, both in the classic ways of obtaining by transesterification of oils from seeds (especially rapeseed and sunflower) or from vegetable oil residue of industrial processes. This includes new sources of fat or raw materials such as microalgae or insects, and was found as a keyword for the country of Brazil. The second cluster, the green one, is more focused on bioethanol, produced either from sugars from crops such as sugar cane or beet, or from starches from crops such as potatoes, corn or other cereals. The other line of work in this cluster is the production of hydrogen or other hydrocarbons from biomass gasification. The third cluster is devoted to two fundamental issues, the generation of electricity from biomass and the production of biogas, the latter produced from livestock waste (slurry), sewage sludge, urban solid waste, agricultural waste and industrial organic waste. Given the diversity of origins in the production of biogas it is logical to find key words from countries as different in customs such as: Germany, Pakistan and Spain. The fourth yellow cluster focuses on China and the assessment of its resources for sustainable development. Finally, we find clusters 5 and 6, which are the smaller ones. The purple cluster 5 focuses on the Power Plant and the alternative to the Coal, as it has topics related to environmental impact. Cluster 6, turquoise in color, revolves around pyrolysis and India as a leading country.

Some Of The Key Challenges Faced By Countries In Biomass Manufacturing

There are a number of key barriers that exist in most regions that could have a large impact on supply if not addressed. The most fundamental are those related to market development.

- A key market barrier is the availability of finance on terms that enable producers to achieve an attractive rate of return. This is related to perceived risk and is likely to vary by region. Finance will be more readily available in regions where the market and price for biomass are clear and the institutional environment is stable. This means that raising finance may be difficult to support biomass supply in developing and emerging economies (such as Africa or South America), where political risks and/or currency risk/volatility may be higher.
- Energy crops could provide considerable biomass resource, but they present specific challenges: there are upfront costs in establishing the crop and returns are only achieved over the longer term. For this situation alternative financing models are required. For instance, finance could be provided by the end user of the fuel or by investors that are able to take a longer-term outlook, such as pension funds.
- A major barrier to development of biomass can be the financial burden to the farmer or landowner of initial investment in planting material or machinery. To address this, alternative approaches, such as contract farming approach will also be required. In the forestry sector, solutions used to mitigate risk and gain access to finance include encouraging inward investment from large international companies that can take on the risks in the biomass supply chain, and the use of joint ventures between biomass producers and energy plant developers. Joint ventures between biomass producers and biomass processers (e.g. pellet plants) are also being considered. In general terms, while price increases may help to diminish market barriers, stakeholders consider that this is only important where it leads to the development of a large-scale, stable market for biomass.
- A key market barrier that is very difficult to address is competition for biomass supply, for example from domestic demand in the supply region and competing markets for the

feedstock. Competing markets can include energy (such as the emerging low carbon energy markets in Asia), or demand for other products, such as the use of the feedstocks in biorefineries. Ironically, another potentially significant barrier in the future is reduced productivity due to climate change. This barrier may be hard to overcome, especially for energy crops. However, increased prices for biomass could provide the impetus needed for funding research and demonstration of varieties better adapted to changed climatic conditions.

- Secondary barriers that have been identified relate to understanding and introduc ing sustainability and technical standards, infrastructure necessary for the biomass supply chain (harvesting equipment, storage, pellet plants, etc.) and capacity building (development of skills etc.). These barriers can all be addressed in the short-to-medium term given adequate investment, good market opportunities and the will to introduce good practice. Progress in some aspects (e.g. sustainability certification) may be considerably more difficult in regions where governance is weak and the provision of robust evidence that meets international standards is less feasible.

Environmental impacts

A condition of Government support for biomass use in the UK is that the biomass, whether produced domestically or imported, must meet minimum sustainability standards. This requires uses to demonstrate that the use of the biomass achieves minimum greenhouse gas (GHG) savings, and for suppliers to demonstrate that it has been produced sustainably. This means that the harvesting rates are sustainable, biodiversity has been protected and land-use rights for indigenous populations are respected. Therefore, any expansion of biomass supply has to meet these criteria. For this reason, there must be examinations of the GHG emissions and other environmental impacts on soil, water and biodiversity caused by the supply of a variety of biomass resources from a number of regions. Impacts on air quality are not examined as these are mainly associated with the combustion of biomass at its point of use the higher GHG savings required. Compared to arable crops, cultivating energy crops can have beneficial effects on soil quality, including soil carbon and water quality. Deleterious effects can often be avoided or mitigated if best practice guidance on appropriate areas for planting, cultivating and harvesting are followed.

In the case of forestry resources, the impacts on soils from removing forest residues can vary widely and are dependent on the amount and type of residues removed, site characteristics, species and harvesting methods. Mitigation of any impacts is best achieved by understanding specific impacts for the national or sub-national level and creating specific sustainable forest management plans that prevent the removal of too many residues. Such plans can also ensure that removal of residues is not at a level that will reduce biodiversity. Therefore, in summary, providing long as appropriate governance is applied, a good guidance framework is in place, all socio-economic and environmental issues are considered, and the impacts are monitored, it should be possible to expand biomass supply in a sustainable way.

Example of government investment in bioenergy:

RenovaBio, Brazil In 2016, the Brazilian Government invested in a new initiative, RenovaBio, to develop a bio-based economy in Brazil. There is an ambition to increase the production of energy from biomass sources for use in Brazil, to provide 18% of national energy needs, as well as increasing its role as a significant international supplier. This is part of the Government's plan to meet its commitments under the Paris Agreement to decrease carbon emissions by 37% by 2025 (compared to 2005). One of the targets under RenovaBio is for fuel distributors to cut fuel emissions by gradually increasing low carbon biofuels volumes. To meet greenhouse gas reduction targets, distributors will have to purchase Emissions Reduction Certificates (CREs) from biofuels producers. It is anticipated that this will do two things – decrease fuel GHG emissions and increase the use of local biofuels8 . The major biomass crop in Brazil is sugar cane. A realistic conservative estimate for expansion of sugar cane production is that the area dedicated to sugar cane could at least double in the medium term. Principally, this could be achieved by extending sugar production to more land than is currently used for low intensity animal grazing and increasing livestock intensity in other areas to maintain current levels of production, in accordance with Brazil's agro-ecological zoning practice. This would need to be driven by a strategy designed to increase the overall supply of sugar (for food or as an ethanol feedstock) in-line with the RenovaBio strategy.

Overcoming Barriers?

Apart from the barrier posed by lack of availability of finance, the most important barriers relate to market development, production of biomass (planting energy crops and harvesting forest residues), transport infrastructure and long-distance logistics because they are fundamental to the success of a supply chain. These barriers are relatively hard to overcome and require considerable investment of funds (e.g. in new or improved infrastructure) and the development of policy that will help to create a stable market. It is likely that overcoming them will take some time (i.e. they will only be fully resolved in the medium term). Second-tier barriers relate to the understanding and introduction of sustainability and technical standards; infrastructure necessary for the biomass supply chain (harvesting equipment, storage, pellet plants, etc.); and capacity building (development of skills, provision of data/information or tools to understand the resource etc.). These barriers can all be addressed but require significant investment of funds and time to be overcome.

Most of these barriers can be addressed in the short to medium term. However, the impacts of regional markets that are closer to the biomass resource – particularly the emerging renewable energy markets in Asia and the influence of other, higher value, markets on biomass production – are likely to be long term.

Physical barriers

- The cost of transport for land and sea freight can be significant, particularly for resources from the Southern Hemisphere that are exported to Europe.
- High logistics costs – many forestry regions are remote (even in developed nations, such as Canada), so there may be a need to invest in roads or rail links to enable efficiencies in logistics. Distance from the UK can also be an issue for some regions.
- A lack of necessary infrastructure, such as roads, bridges or rail and lack of suitable handling and storage systems at the port. The potential risk of fire during pellet storage means that storage should be correctly designed to minimise the likelihood of fire and include detection and control systems.
- There may be a lack of planting and harvesting infrastructure, particularly for energy crops, but harvesting equipment and infrastructure are also important for forest residues.
- Climate change and other issues that may result in decreased growth and yield or increased mortality from pests, diseases and fire16 .

How easy is it to overcome these physical barriers?

These physical barriers can have large impacts on supply. Cost of transport is a good example of this, particularly for resources that are a distance from the pellet plant. However, in developing countries, lack of infrastructure is an important barrier as well. A lack of infrastructure at the port has an impact on cost efficiency, rather than being a barrier to participation in the market. A lack of planting material has a large impact in the near term but can be addressed in a relatively short time. Likewise, a lack of harvesting equipment can have a significant impact in the short term, but can be resolved, given time and a stable market. All these barriers can be addressed more quickly if the price increases. Climate change issues are intransigent, and the biomass supply chain will have problems addressing them. However, suppliers may adopt different cultivation strategies to adapt and choose more resilient species, where information is available. Price increases for biomass pellets from forestry residues would not change this as adaptation will be driven by higher value forest products markets. Price increases for energy crops would make a difference as they would provide some funding for demonstrating different varieties.

Technical barriers

There are a number of technical barriers that need to be addressed for new supply chains. These include:

- Standards: UK/EU standards for domestic and industrial pellets may prove to be a significant hurdle in inexperienced markets in Africa and South America. These standards concern the production of biomass to fuel-quality standards; and complying with health and safety requirements for storing and handling.
- Energy crops: the novel nature of the crops and relatively low quantities grown globally mean that the crop is unfamiliar to growers. This creates capacity barriers – a lack of skills and understanding of what is required to grow the crop (including how to establish it), how to avoid disease or yield issues and how to harvest the crop.
- Energy crops: there is a need to decrease establishment costs and increase yields, including developing and demonstrating new varieties with promising yields. Potential growers will need to be confident that substantial yield increases can be achieved for long periods, and that they can be confident in the techniques for growing and harvesting these varieties .
- Forestry residues: it is known that extensive whole-tree harvesting, and removal can result in nutrient depletion on site, so it is necessary to understand the optimal level of residue removal for each site and to develop guidance on how residues can be used without harming the forest structure, biodiversity and productivity. This guidance is needed at the national or sub-national level as it needs to be related to specific local conditions.
- Degradation of raw material: this can occur in the supply chain pre-pelletisation and will lead to dry matter loss and potentially health issues. While stemwood and residues are relatively stable, some degradation due to microbial and fungal action will occur over time. If the material is harvested as chips, bacterial action on the liberated sap can cause heating and loss of dry matter. As a consequence of this, microbial spores can form that present health issues if the material is being stored in a confined space. Similar issues will also affect biomass crops. All of these can be overcome by pelletising the material quickly after harvest.

- Lack of experience of pelletisation of biomass and of the capacity needed to develop the market in some regions.
- Pelletisation: there is a need to demonstrate efficient and economic performance of the pre-processing and pelletisation process. This must be done for the full range of biomass materials proposed and at a large scale. The performance of the pelletising plants can be sensitive to the nature of the raw materials involved and, for example, to their moisture content17 .
- Demonstrating performance of energy crop pellets in designated end uses: energy crops can have a high mineral content that can affect the combustion performance and may also impact biochemical and microbial processes. For example, anaerobic digestion processes need to take mineral contents into account because of potential residue issues. This will be overcome with the use of specially designed systems, but research is required in their development.
- Pellet handling and storage: degradation of the pellets during transport and consequent handling or health and safety problems.

Overcoming barriers:

The example of South African wood pellet supply Development of biomass export supply chains in South Africa will be influenced by:

- Availability of biomass in the country and the state of development of the supply chain.
- Existence of infrastructure.
- Institutional factors.
- General trading conditions.
- Moves to develop internal bioenergy markets. Initially, it is likely that a sustainable pellet production industry would be based on thinning from forest plantations and primary wood processing residues. In the future, this may be able to be augmented by agricultural residues and energy crops.
- The barriers to unlocking this potential are the need for investment in equipment, skills and capacity to turn the available feedstocks into pellets for export.
- Logistics, especially in port storage and loading for biomass, need to be improved. Sea freight costs need to be reduced to make the export of pellets more competitive. Institutional barriers will also need to be addressed, particularly for environmental and social sustainability to be demonstrated.
- Finally, protocols for quality/standards specific to pellet production from plantation residues need to be developed.

- To overcome these barriers requires good governance and legislative structure; and finance to achieve the necessary investments. Infrastructure and mechanisms for large-scale bioenergy export South Africa's general port and cargo handling infrastructure is well developed and could provide a good platform to develop the required port biomass pellet storage and loading infrastructure.
- A number of ports are able to handle all categories of dry bulk cargo and are ideally situated. They are already handling substantial cargo for the wood products industry. However, there are no facilities at ports to store pellets to support cost-effective, large-scale export activities. The required investment will only come once a sustained large-scale pellet export market is in place. Institutional factors South Africa ranks 'fair' in terms of governance, ease of doing business and political risk indices.
- This makes it capable of becoming a long-term supplier of exported bioenergy.
- Legislation designed to support renewable energy use is already in place through the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP).
- Carbon taxes will soon be introduced (South African Carbon Tax Bill due to be passed in 2018). Taken together, these pieces of legislation have the potential to stimulate interest in bioenergy production.
- Measures to ensure good forest governance have been implemented.
- Around 82% of South African plantations are Forest Stewardship Council (FSC) certified. This means that any biomass supplied can be within the required sustainability standards.
- The REIPPPP and forthcoming carbon taxation means that any new interest in the production of bioenergy may be focused on its use in South Africa. This will be further stimulated by substantial increases in the price of electricity, diesel and fuel oil over the past decade in South Africa, which make bioenergy more attractive from a cost point of view.
- Taken together, it is clear that South Africa has good bioenergy potential and the capacity to turn this potential into a stable supply of exported bioenergy given the availability of appropriate investment. The issue will be if the drivers to create bioenergy markets in South Africa will stimulate the development of a home market for biomass (so reducing the capacity to export) or if the need to earn foreign income will drive biomass export.
- This uncertainty represents a risk in terms of potential supply to the UK unless it is based on firm supply contracts through credible South African partners. Other African countries also have similar potential to develop biomass supply chains, but without the same degree of institutional background and infrastructure. In these cases, more investment in infrastructure, skills and capacity would be required.

The impact of the global market expansion on biomass prices

It is difficult to know how the global market expansion will impact biomass prices, but from the above trends and analysis, it is expected that:

• Market dynamics are likely to change over the next decade or so, with increased use in Asia and potentially elsewhere (Australia? Africa?).

• The market will be influenced by freight cost and distances; and currency exchange rates. These will be particularly important for trade from developing and emerging economies .

• Transport distances keep European and Asian markets generally separate, except in areas where supply might overlap, such as Africa.

• Prices tend to stabilise as the market itself stabilises. This is because increased demand will allow for increased investment as the market grows more confident resulting in lower investment risk premiums.

Long-term price trends to 2050 are likely to result from two opposing pressures. As the cheaper sources of biomass feedstock are used up and more expensive feedstock (such as forest residues and energy crops) come onto the market, it is expected that prices will increase. Conversely, as the market stabilises, it is expected that investment will be made in areas where costs can be saved, resulting in a downward pressure on prices.

Pellet producers have been demonstrated to be good at strategies to minimise cost increases by mixing feedstock where possible (such as sawmill co-products with forest residues to allow increase in volume at minimal cost).

It may be possible to mix in woody energy crops in this way, although this would be limited by bark content. However, it will not be feasible to mix grassy energy crops into wood pellets, as this is likely to impact pellet specification too much. Danish modelling of biomass prices to 2050 (Bang et al 2013) indicated that low prices are likely to remain stable, but that the range in prices is likely to increase, meaning that high prices will increase in time.

• Prices may be hit by occasional spikes, related to weather and factors that prevent harvest, and lower prices, related to mild winters that result in a decrease in demand.

State of South Africa's Biomass Developments

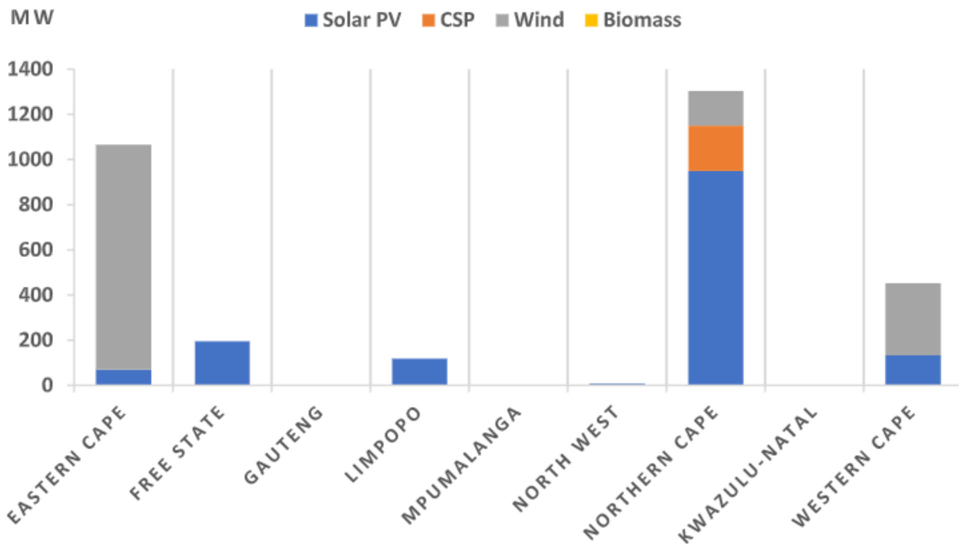


Fig. 2 South Africa's electricity generation in TWh by different technologies.

However, according to the latest publication issued by South Africa's Department of Statistics, coal energy accounts for over 85% of all electricity generated in 2016vand this is followed by nuclear and natural gas-derived energy[36]. ESKOM is presently South Africa's largest power entity generating about 96% of all South Africa's electricity while the municipalities and independent power producers makeup the rest. A map detailing all the locations and types of power plants managed by ESKOM are shown below. ESKOM's generating plant mix consists of 14 coal-fired power stations which are mostly clustered in Mpumalanga province largely due to coal accessibility while Africa's only nuclear power plant, operated by ESKOM is located in the Western Cape region. The nation's owned entity also runs some hydro-powered electricity plants alongside few gas-fired stations. Renewable energy sources as an alternative energy source in South Africa can seriously reduce the over-reliance on coal which is a finite and environmentally unfriendly resource. Furthermore, the development of the renewable energy sector in the country has the potential of creating more job opportunities thus improving the South African economy. Due to the geographical location and human population of South Africa, several renewable energy sources have significant potential in the country.

Biomass Development in South Africa

South Africa is Africa's largest sugarcane producer with a production capacity of over 18 million tons annually, where sugarcane leaves and bagasse account for over 21% of the entire biomass. However, this sugarcane residue reaching over 1 metric ton is often set ablaze on-field while about 2.5metric tons of other generated bagasse are also inefficiently combusted in the country, this underutilized biomass has the potential to generate about 1 metric ton of bioethanol or over400 MW of electricity if processed efficiently. Aside from sugarcane, South Africa is also among the major producers of corn in the world with annual production exceeding 12million metric tons where the Free state and Mpumalanga provinces are the largest contributors. Corncobs which are agricultural residues from corn are among the country's largest agricultural waste with over 5 million metric tons generated annually. The corncob's energy profile is similar to the low-grade South African coal with the added advantage of having a lower content of nitrogen and sulphur when com-pared to coal. Therefore, corncob is a potential substitute for coal or can be co-fired in coal plants for power generation. While a majority of the derived corncobs have been used for cooking and heating in rural areas, the industrial utilization of this agricultural waste for energy generation in South Africa is yet to be fully maximized.

To further investigate the bio energy potential in the country, the Department of Science and Tech-nology (DST) funded the Bioenergy Atlas for South Africa. This resource is aimed at supporting the bioenergy development in the country. Summarily, the bioenergy atlas revealed that the potential of biomass as an energy source in South Africa is limited due to restrictions caused by cultivable land, rainfall and food security challenges. However, the bio energy atlas also revealed that despite the aforementioned constraints, the use of all accessible domestic organic wastes coupled with the development of communal digesters in rural areas will con-tribute about 1600 megawatt electric (MWe) capacity. Many countries have adopted policies to stimulate the production of biofuels. South Africa has also adopted one of such policies which is the Biofuel Industrial Strategy (BIS) which is a policy designed to promote the use of biofuels while creating jobs in rural areas. The overall development of bioenergy in South Africa is affected by some challenges. In terms of South Africa policies regarding biomass is delayed in the implementation of the BIS due to government inaction coupled with the setting of a modest 2% for biofuel integration into the energy mix is among the challenges facing the development of South Africa's biofuel industry. Also, working committees or task force to monitor and drive the industry to the set targets are often absent. Subsidies and other governmental supports are seriously unavailable to stimulate the growth of this renewable energy resource. Land use and water scarcity The generation of biofuels especially first-generation biofuels hurts food security. The recent drive towards biofuel utilization has led to competition between food availability and biofuel production where it was estimated that the crops used for biofuel production in 2013 could sufficiently feed 280 mil-lion people. Due to the water scarcity issues in South Africa, diverting this limited resource for growing fresh crops for biofuel production can further intensify drought or affect The state of renewable energy development in South Africa.

Conclusion and Recommendations:

South Africa is endowed with enormous biomass, wind and solar energy potential however, its primary fuel source is coal which is cheap but deleterious to the environment. The over-reliance on coal is also stressing the existing coal power stations therefore the development of renewable energy sources is of utmost importance in the country. While DNI, windspeed and amount of biomass generated annually are sufficient to make solar, wind and biomass energies feasible in the country, there are however some challenges to renewable energy development in the country. Such challenges include; technical, financial, policy and environmental challenges. Going forward some recommendations are presented to help mitigate these challenges and consequently improve the integration of renew-able energy into the South African energy mix. This includes the following:

- An efficient waste management scheme should be provided especially in rural areas or previously unserved areas, so more household wastes and agricultural residues can be efficiently collected and utilized. Presently, over 30% of all generated wastes in the country are either dumped in private dumpsites or inefficiently combusted in rural areas[51]. Such wastes are potentially useful for biomass energy production especially through co-firing with coal in the existing coal power plants. A favourable ambience for investors should be provided. This can be in the form of subsidies, loans and even policies designed to stimulate the growth of the RE industry. The introduction of policies should also be followed by the execution of such policies. Some existing policies have failed to address the issues they were designed for largely because there is no implementation of such policies. Awareness should also be created about the benefits of renewable energy to the society, especially in rural areas. Township meetings and demonstrations can be organized to show the different types of renewable energy technologies that can be adopted in rural communities. This would help pre-pare a positive mindset towards RE technologies adoption in such regions and would potentially reduce the conflicts relating to land use between investors and landowners. Tedious bureaucracy should also be curbed to give international investors a favourable atmosphere for investing. Further utilization of the solar energy resource in the country. Presently, the major applications of solar energy in South Africa are in solar photovoltaics, solar CSP and solar water heating. However, there are other possible applications of solar radiation which are relatively underutilized but can be beneficial to South Africa. One of such is solar cooking.

Solar cooking is the process of using a device (so-lar cooker) which harnesses sunlight to bake, warm, cook and fry food materials. With the South African residential sector consuming over 23% of annually generated electricity, the utilization of such technology would seriously help reduce the overdependence on coal which will consequently lead to CO2mitigation. Solar driers, solar green-houses and even solar chimneys are interesting technologies that can be integrated into the renewable sector.

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