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RESEARCH ARTICLE

# Will biomass be used for bioenergy or transportation biofuels? What drivers will influence biomass allocation

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**Abstract** Potential competition for biomass for current and future bioenergy/biofuel uses in Brazil, Denmark, Sweden and the USA were compared. In each of these countries, bioenergy and biofuels are already important in their energy mix. However, there is limited competition for biomass between bioenergy (heat/power/residential/industrial) and transportation biofuel applications. This situation is likely to continue until advanced biofuel technology becomes much more commercially established. In each of these countries, biomass is predominantly used to produce bioenergy, even in those regions where biofuels are significant component of their transportation sector (Brazil, Sweden and USA). The vast majority of biofuel production continues to be based on sugar, starch and oil rich feedstocks, while bioenergyis produced almost exclusively from forest biomass with agricultural biomass having a small, but increasing, secondary role. Current and proposed commercial scale biomass-to-ethanol facilities almost exclusively use agriculture derived residues (corn stover/wheat straw/sugarcane bagasse). Competition for biomass feedstocks for bioenergy/biofuel applications, is most likely to occur for agricultural biomass with coproduct lignin and other residues used to concomitantly produce heat and electricity on site at biofuel production facilities.

**Keywords** bioenergy, biofuel, biomass, renewable energy policy

## 1 Introduction

Oil is currently the world's predominant source of energy, partly due to its flexibility of end use (energy and transportation) and it will likely remain the dominant global fuel source for several decades to come. Renewable energy has expanded in recent decades, primarily due to government support, currently constituting about 13% of the global energy mix and projected to increase to over 30% by 2050[1]. Biomass is one of the largest utilized source of the world's renewable energy and it is likely to remain so through to 2035[1]. Although biomass is predominantly used (60%) in heating and cooking applications in developing countries, its use in modern, high-efficiency bioenergy and transportation biofuel applications (40%) is increasing[1].

At a global level, there appears to be enough biomass available to meet projected increases in biomass-based energy demand[1]. However, biomass availability differs greatly by region and, in some countries, there is insufficient sustainable domestic supply to be able to meet increasing national demands. As a result, it is anticipated that a constrained local biomass supply will create competition for these limited resources. Although a wide range of end products (e.g., lumber, food, paper products, and chemicals) can be generated from forest derived biomass, this paper focuses on the possible competition for biomass between bioenergy and transportation biofuel production.

If net energy output is the primary goal, biomass will always be preferentially used for energy (heat and power) as opposed to biofuels as bioenergy allows for the recovery and use of more of the intrinsic energy (calorific value) within biomass than does its conversion to biofuels[2]. However, the decision about the most effective use of biomass is more complex. Unlike electricity generation (which can employ solar, hydro and wind power), renewable substitutes for transportation fuels are in practice limited to electric vehicles and biofuels. In some applications, such as long-distance transportation, biofuels are the most likely alternative to fossil fuels especially in long-haul trucking, marine and aviation applications.

Although a number of studies have looked at the various drives of low-carbon technologies[3–5], little work has considered the conditions that might influence the allocation of biomass to either bioenergy or biofuels

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applications. Of the various drivers that have motivated the quest for clean energy, energy security and climate change mitigation are recognized to be the most important general drivers that have promoted the use of biomass for modern applications at the global level[5,6]. However, most countries are influenced by other motivators such as prevailing economic interests, the cost-competitiveness of biomass based technologies and government policies that might encourage rural employment[1]. Thus, the collective influence of these various drivers will influence how biomass might be allocated.

In the work described here, the potential bioenergy/biofuel use of four major world biomass consumption countries namely Brazil, Denmark, Sweden and the USA was assessed. The findings for each country were compared with respect to the importance of biomass in the energy mix, the dominant biomass applications, the status of biomass competition and the relative influence of each of these four drivers on biomass allocation. In addition, the importance of each country's policies in biomass allocation is discussed.

## 2 Case studies

### 2.1 Bioenergy/biofuel uses of biomass in Brazil

As a developing country, Brazil has different demands on its energy market than do developed nations. It has to expand access to electricity and support a rapidly growing economy while maintaining affordable energy and fuel prices for a significant segment of the population that is relatively impoverished. Ensuring a stable, reliable and affordable energy supply is problematic for a rapidly expanding economy with burgeoning energy demands. This situation is further complicated as the energy mix, with strong hydropower and biomass components, is also influenced by policies which have a goal of preserving biodiversity and encouraging better land/water resource management. Additionally, the supply of many of these renewable energy sources is subject to climatic conditions. Droughts in 2001 and early 2014, impacted hydropower inflows, lowering energy levels while significant rainfall in 2011–2012 negatively affected sugarcane harvests and subsequent ethanol production[7,8]. To complicate matters further, government policies with respect to the control of gasoline prices, can often undermine national biofuel policies. These nationally specific circumstances all influence biomass allocation decisions in Brazil.

Brazil has a long history of renewable energy development. The country invested heavily in renewable energy technology in the early 1970s, after the OPEC oil crisis sent their trade balance into a serious deficit. Today, Brazil is one of the largest proportional users of renewable energy in the world (46% in 2011)[9]. Biomass and hydroelectricity both have a prominent role in the country's renewable energy supply. With hydro/renewable electricity (such as solar) accounting for 33%, biomass for 58% and the remaining 9% denoted as "other" (with no clear definition provided)[9]. The relative breakdown of domestic renewable energy supply indicates that biomass is separated into sugarcane products and firewood/charcoal (Fig. 1).

Biomass is the largest source of renewable energy in Brazil (Fig. 1), accounting for nearly 60% [2.9 exajoules (EJ)] of total renewable energy production or ~30% of final energy production. Biomass is defined as sugarcane products, firewood, charcoal, alcohol and other renewable primary sources (it should be noted that it is unclear if black liquor and biodiesel are included within this definition)[9] Sugarcane is the predominant biomass feedstock, contributing ~17% to primary energy production. Firewood and charcoal use is declining in Brazil as access to electricity expands but still accounts for 9% of primary energy demand in 2011[9]. Figure 1b shows the use of biomass for both biofuels and bioenergy. It is apparent that bioenergy generation greatly exceeds biofuel production and that biomass is primarily allocated toward bioenergy generation rather than biofuel production.

As the main driver behind early biofuel development was concerns about energy security the government developed support mechanisms and policies that included, though were not limited to, ethanol mandates or subsidies, and the development of the flex-fuel vehicle industry. Compared to energy security, climate change mitigation desires have had a limited role in biomass allocation decisions in Brazil.

Historically, there has been no competition for biomass between bioenergy and biofuels in Brazil. Although this trend might change, as bioenergy and cellulosic ethanol can be produced from sugarcane bagasse (which is currently combusted for bioenergy generation at sugar mills), it is unlikely that competition will occur, due to ample domestic feedstock availability. It is more likely that bioenergy and biofuels will become coproducts with power contracts providing a more assured source of income for biofuels producers, helping offset the cost of making the biofuel and improving its cost-competitiveness with gasoline. For example, in GranBio's cellulosic ethanol plant in Brazil, surplus bioenergy generation amounts to 17 MWe per year[10].

Although woody biomass is currently used for bioenergy generation in Brazil and is of particular importance in industrial operations where black liquor, firewood and charcoal are combusted for heat and power generation, forest-derived biomass is not currently used to make biofuels in Brazil. Although pilot scale facilities to transform woody biomass to liquid biofuels exist, it is unlikely that wood-derived-biomass will be used for biofuel production in the near future in Brazil.

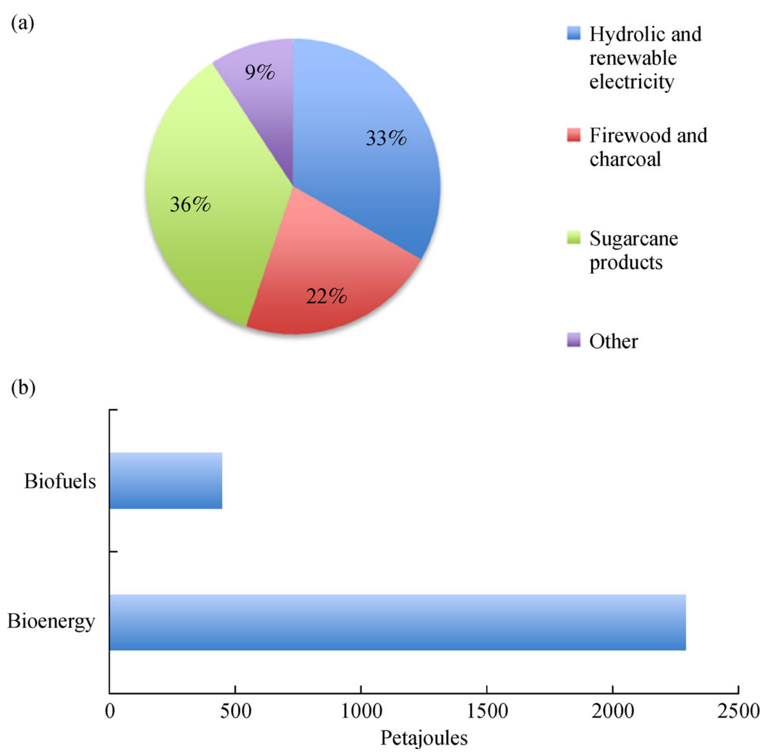


**Fig. 1** Domestic renewable energy supply (a) and the consumption of biofuels [450 petajoule (PJ)] and bioenergy (2292 PJ) (b) in 2011 by source in Brazil (original figure, data source MME, 2012[9])

## 2.2 Bioenergy/biofuel uses of biomass in Denmark

Denmark was reliant on fossil fuels for nearly 90% of its total energy needs in the 1980s. Since then Denmark has transitioned toward renewable energy, which now provide 22% of the country's energy demand with biomass being the predominant source[11,12]. Historically the country has predominantly combusted biomass (wheat straw and wood) in district heating (DH) and combined head and power (CHP) facilities. These technologies have been a focal point of Danish energy policy since the 1980s[13]. In contrast, the use of biomass for biofuels is insignificant compared with its use to generate bioenergy.

When the oil crisis of 1973 occurred, Denmark's economy experienced a significant downturn as no known domestic fossil fuel resources were available. This, combined with a strong stance against nuclear power, left the country in an energy shortage. Concerns about energy security arose out of the crisis, sparking a transformation of the Danish energy system, with an introduction of clear national energy policies spurring the move to renewable energy and energy efficient technologies[14]. These measures have facilitated the increased penetration of renewables, improved energy efficiency, shifted the balance of trade and decoupled economic growth from energy consumption[15]. Biomass is the largest source of renewable energy in Denmark, accounting for 68% of all renewables or 15% of the total energy supply in 2011. Wind power is the second largest renewable source and contributes to about 20% of the country's renewable energy generation. Biofuels were absent from the Danish energy mix until 2006. However, since then, biofuels have experienced significant growth, accounting for about 4% of renewables by 2011, with the vast majority of the biofuels imported. Solar and hydroelectric capacity in Denmark is negligible.

The Danish Energy Agency (DEA) defines biomass as solid biomass combusted for bioenergy generation. The DEA provides separate categories for biofuels (bioethanol and biodiesel), bio-oil and biogas[12]. Within the biomass category, wood is the principal feedstock (61% of biomass) although straw, and renewable waste provide significant contributions (16% and 17%, respectively). The wide array of feedstocks available in Denmark (Fig. 2) imparts flexibility in potential energy production from biomass.

Denmark is heavily reliant on imports to meet its national biomass demand. The country's dependence on imports and its strong bioenergy focus has limited competition for biomass between bioenergy and biofuels. The main drivers behind bioenergy development began as climate change and emissions concerns in the 1980s. In response to this concern, support schemes and policies supporting bioenergy generation expanded and, as a result, contribution of bioenergy to total energy grew.

Although targets for biofuels were introduced in 2006, the country continues to import nearly all of its biofuels.

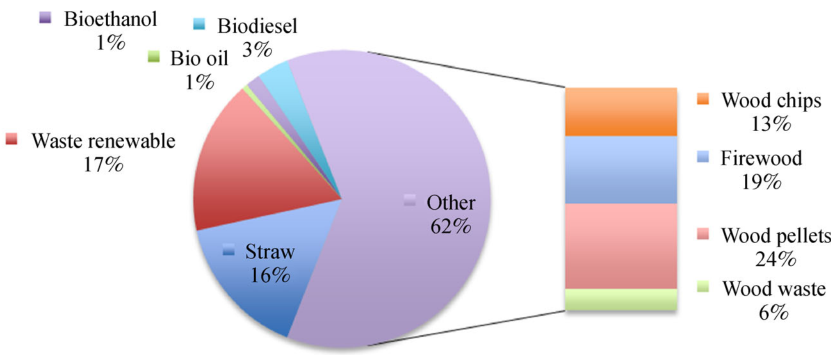


**Fig. 2** Danish 2011 biomass consumption by feedstock, wood (62%) is further categorized into chips, firewood, pellets and waste (original figure, data source DEA, 2012[12])

Major Danish companies such as Novozymes are involved in the research to commercialize and improve advanced biofuels derived from agriculture residues and wood. However, domestic production is very limited. If advanced biofuels are ever produced in significant volumes they will likely have to compete for biomass feedstocks that are already used to make bioenergy. As climate change mitigation is an important driver this reinforces the allocation of biomass to bioenergy based on the premise that greater greenhouse gas (GHG) emissions can be avoided by directing biomass to bioenergy rather than biofuels.

National mandates for biofuel consumption lack punitive measures for noncompliance and have been largely unsuccessful at improving the adoption of biofuels. Only 0.3% of total transportation fuel demand is currently met despite a 5.75% mandate. To meet their mandate of emissions-free transportation by 2050, the Danish government has strong targets for penetration and promotion of electric vehicles that will likely dominate their renewable transportation portfolio beyond 2020. Thus, biomass allocation in Denmark will continue to favor bioenergy rather than seeing it used as a feedstock to produce transportation biofuels.

### 2.3 Bioenergy/biofuel uses of biomass in Sweden

Sweden is a global leader in renewable energy technologies as nearly half of the country's energy mix is derived from renewable energy sources. Biomass is the most important source of renewable energy in Sweden, accounting for ~34% of the country's total energy consumption (TEC) in 2013, the highest proportion of any OECD country. Similar to Denmark, bioenergy is the predominant use of biomass, accounting for 33% of Sweden's final energy mix (0.46 EJ in 2013)[16]. The strong forest sector and prevalence of DH and CHP infrastructure in Sweden have influenced the rapid development of bioenergy. Notably Sweden has been one of the most successful European countries in promoting the use of renewable transportation fuels. Biofuels accounted for 9.8% of total transportation energy demand in 2013[17]. Although bioethanol and biodiesel dominate the renewable fuels market, Sweden was the first country where biogas was commercially available for transport applications. Agriculture residues remain the principle biofuel feedstocks. However, the prominence of the Swedish forest sector has resulted in the country becoming a leader in research and development of technology to transform forest biomass into transportation fuels. Forest-derived biofuels have been on the market since 2011, and have an annual capacity of 1 ML[18].

Sweden's renewable energy mix is comprised primarily of biomass (65%) and hydroelectricity (27%) while wind (4.5%) and heat pumps in district heating (3.5%) account for the remainder[19]. Figure 3 shows renewable energy development by source in Sweden from 1990 to 2011. Biomass is the largest source of renewable energy in Sweden, and has experienced the fastest growth over the last two decades. Domestic biomass supply is largely forest-based, either in the form of wood chips, firewood, pellets or mill residues, while significant proportions of wood pellets and biofuels are imported. Currently, biomass is preferentially allocated to bioenergy as it accounted for ~95% of totally biomass based energy generated in Sweden in 2013. At 9.7%, the proportion of biofuels in transportation fuels in Sweden is one of the highest in the EU. However, compared to the country's bioenergy generation, this accounts for only 5% of total biomass based energy in 2013. Competition between bioenergy and biofuels for biomass is largely absent as both bioenergy feedstocks (e.g., pellets) and biofuels are imported to meet domestic demand.

The domestic production of forest-based biogas, biodiesel and biojet fuel are on the rise[18,20]. This positions Sweden as an ideal candidate for biomass competition. However, as advanced biofuel production is not yet at a commercial scale and current biofuels are largely imported, competition for biomass between bioenergy and biofuels is largely absent. Biomass imports are also needed to satisfy

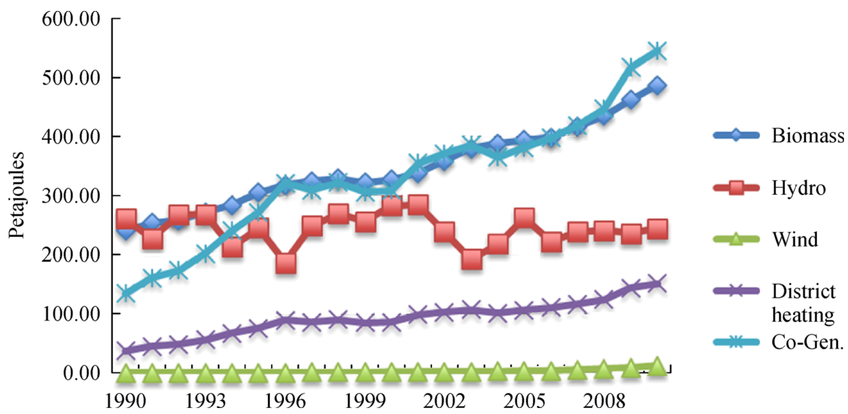


**Fig. 3** Renewable energy development by source in Sweden from 1990 to 2011 (original figure, data source Swedish Energy Agency, 2012[19]). Hydropower and wind were not reported separately until 1996.

demand of bioenergy demand[19]. The predominant drivers in Sweden are climate and emissions concerns that, when combined with the effective policy mechanisms, such as carbon, emissions and energy taxes make bioenergy and biofuels cost-competitive with alternative energy products. Sweden currently relies on imports for the vast majority of the country's biofuels. Despite ongoing innovation surrounding advanced biofuels in Sweden, it is unlikely that biomass will be more valuable as a feedstock for biofuels rather than bioenergy. Despite some of the highest carbon taxes in the world, the cost-competitiveness of advanced biofuels remains is challenging.

The reliance of the Swedish forest sector on the industrial integration of bioenergy generation (~45% of bioenergy generation occurs within industrial operations) makes the transition away from these technologies very difficult. However, it is possible that Sweden's advanced biofuel facilities could piggyback on existing manufacturing facilities, similar to what has occurred in corn and sugarcane facilities in Brazil and the USA.

## 2.4 Bioenergy/biofuel uses of biomass in the USA

The USA is a global leader in energy, consuming 102.6 EJ in 2011, with fossil fuels dominating the energy mix, representing 82% of total energy consumption (TEC)[21]. Since the mid 2000s, the USA has been the largest biofuels producer in the world, dominated by bioethanol from corn. This strategy has received significant government support over several decades[22]. However, recently, biofuels production in the USA has stagnated due to several factors including declining gasoline consumption, the creating of the blend wall (the maximum proportion of ethanol permitted in petroleum-based fuel), slower than expected development of advanced biofuels, the expiration of the biodiesel tax credit in December 2013 and uncertainty surrounding government support policies, principally the Renewable Fuel Standard (RFS).

Fossil fuels dominate energy mix in the USA, representing 82% of TEC in 2011 (Fig. 4a). However, the relative importance of the various fossil fuel energy sources is changing with the consumption of petroleum and coal declining while natural gas use is increasing. Petroleum consumption has fallen as vehicle efficiencies have increased. The slow economic recovery has also altered consumer behavior, decreasing individual gasoline use. Since 1990, 77% of newly installed electricity generation capacity has been natural gas fired, as opposed to coal. The recent increase in production of domestic, unconventional, oil and gas since 2009 has driven the price of natural gas down, reaching historic lows in 2012. Low gas prices, combined with the benefits of higher electricity generation efficiency in gas power plants, have also prompted a transition from coal to natural gas in existing electricity generation facilities nationwide[23].

The USA has a diverse renewable energy portfolio which includes hydro, solar (photovoltaic and thermal), wind, geothermal and biomass. In 2011, renewables generated 9638 PJ or 9% of TEC[21]. When the renewable energy mix is considered (Fig. 4b), the diversity of energy options is noticeable compared to the countries discussed above. The greater diversity of renewable energy technology results in competition between the various renewable energy sources for government policy support and funding. Biomass was the largest renewable energy source, accounting for 48% of consumed renewables or 4.5% of TEC[23].

Despite being the world's largest producer and user of both bioenergy and biofuels on an energy basis, there has not been any competition for biomass between bioenergy or biofuel production. Biomass is the largest source of renewable energy in the USA, primarily due to its integration within the forest sector. As pulp and paper production has declined in the USA since the 2004, in-mill bioenergy generation has also decreased. Coincidentally, domestic biofuel production, primarily ethanol, has increased significantly over this time.

However, competition between bioenergy and biofuels

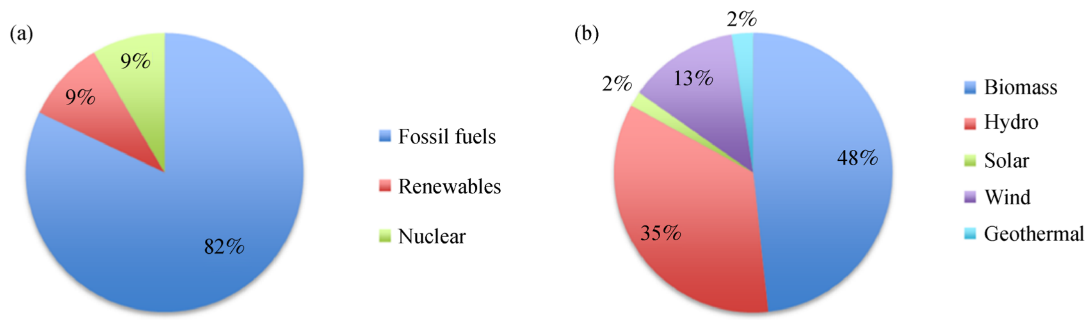


**Fig. 4** Energy mix (a), and the proportional contribution of renewable technologies (b) in the 2011 renewable energy mix of the USA (original figure, data source US EIA, 2012[15])

for biomass feedstock in the USA is unlikely to occur in the near future. The Departments of Energy and Agriculture have both indicated that the country has the potential to access over 1 Gt of biomass for bioenergy or biofuel production annually by 2030[24]. Despite a lack of current competition for biomass feedstocks, it has been suggested that competition for forest-based feedstocks between bioenergy and biofuels might occur as both domestic advanced biofuel demand and international pellet/biofuel markets develop.

However, currently, the blend wall is limiting bioethanol growth and has sparked a growing interest in other biofuels. The expansion of biofuels in the USA is largely due to government policies based on improving domestic energy security, as evident from the government support schemes implemented over the past 40 years.

Without clear, long-term support for bioenergy or biofuels within the USA, exports of these products might develop as international markets develop. A situation could possibly arise in which the US becomes a global supplier for bioenergy and biofuel products, due to the possible availability of low-cost biomass, with high global market prices for bioenergy and biofuel products outcompeting the domestic market for these products.

## 3 Country comparisons

### 3.1 Importance of biomass in current energy mix

Biomass is the largest source of renewable energy in the world. This is also the case for the four countries being compared. When consumption of biomass for energy and fuels is compared as a proportion of total energy (Fig. 5), it is important to consider both biomass consumption as a proportion of total energy and the total energy generated from biomass when considering the importance of biomass in each country.

Despite the USA being the global leader in biofuel production (2053 PJ in 2011) and bioenergy generation (2600 PJ in 2011) the contribution of biomass to total

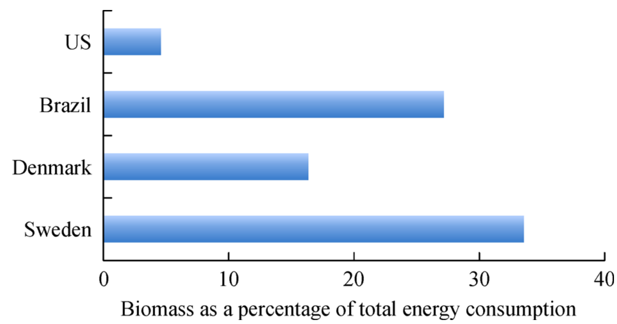


**Fig. 5** Consumption of biomass as a proportion of total energy demand for the country profiles (original figure, data source[9,12,15,16])

energy demand is the second lowest, at 4.5%. This is the result of its comparatively high-energy demand (~103 EJ in 2011) compared to the other countries. In contrast, in 2013, Sweden's biomass consumption accounted for 469 PJ, which is an order of magnitude smaller than the USA. However, it was the largest energy source in the country, accounting for 34%. For Brazil, the high penetration of biomass within the industrial energy mix (over 50% of total bioenergy is within industry) largely explains why biomass forms 27% of the country's final energy mix. Industrial operations in Brazil account for the majority of the country's energy demand as private energy demand for heating and transportation is low when compared to Denmark, Sweden or the USA.

It was apparent that bioenergy is, by far, the most dominant use of biomass in most countries' energy mixes (Fig. 6). It should also be noted that biofuels utilize a very small proportion of biomass, even in Brazil, the second largest biofuel producer in the world. However, in the case of the USA, biofuel consumption is rapidly approaching that of bioenergy and may surpass it in the future with further development of advanced biofuels.

### 3.2 The state of biomass competition

When the relative consumption of bioenergy and biofuels

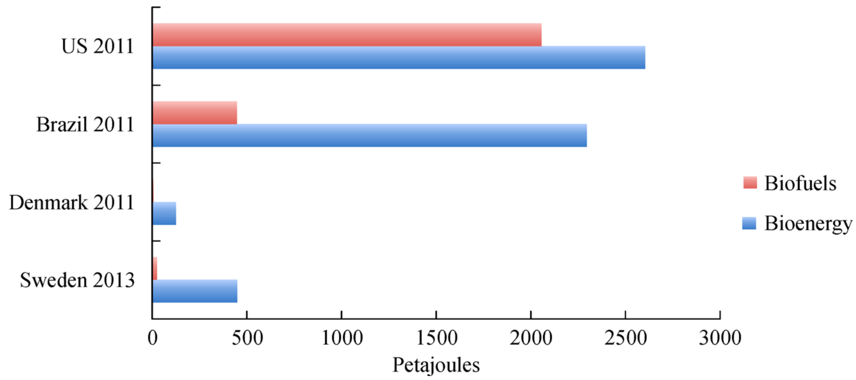


**Fig. 6** Comparison of bioenergy and biofuel consumption for all case countries (original figure, data source [9,12,15,16])

are compared for each country (Fig. 6) it is apparent that limited competition for biomass occurs between biofuel production and bioenergy generation as different feedstocks are used for these applications. Agricultural products, mainly sugar, starch and oil-rich biomass crops, are the predominant biofuel feedstocks, thus competition is unlikely to occur.

However, increased targets for biofuel blending, heightened sustainability concerns and realized commercial scale cellulosic ethanol facilities might result in the growth of advanced biofuels in the future. Under these circumstances it might be anticipated that competition for biomass between biofuels and bioenergy might increase. However, when several of the current commercial biofuel plants are examined, it seems apparent that competition is unlikely to occur, even under circumstances where widespread commercialization of advanced biofuel occurs. All currently commercial cellulosic ethanol plants rely on the cogeneration of biofuels and bioenergy to make the processes economically viable. Since the October 2013 opening of Beta Renewable's cellulosic ethanol operation in Crescentino, Italy (83 ML biofuel and 13 MWe bioenergy), the GranBio (82 ML biofuel and 17 MWe) facility has begun the coproduction of cellulosic biofuels and bioenergy. The major benefits from coproduction are twofold: bioenergy contracts improve cost-competitiveness of fuel production and energy generation utilizes waste lignin. The long-term price guarantee of an electricity contract makes bioenergy an attractive coproduct as it ensures a fixed income for the facility, helping to improve cost-competitiveness of the biofuel products. Combustion of the energy dense lignin helps to minimize processing waste. However, this fraction is only considered a waste stream when enzymatic hydrolysis is employed. Thermochemical conversion of biomass to biofuels will use the lignin fraction, thus bioenergy cogeneration would be limited. At the time of writing no commercial scale thermochemical advanced biofuel plants are in continuous operation.

### 3.3 The drivers for biomass allocation

Identifying the factors that have influenced biomass distribution in the past, assessing their present contribution to allocation decisions and how they might influence possible competition in the future was one of the objectives of this work. Although energy security and climate change were two major drivers, strong regional variation exists in both the cost-competitiveness of biomass based energy and fuels and the prevailing economic interests of each country. The relative importance of these country-specific drivers and their influence on biomass employment for bioenergy or biofuel applications are discussed below.

Energy security concerns have been an important driver for the emergence of bioenergy and biofuels in many of the country profiles. Recently, increased access to alternative oil and gas sources has changed the energy landscape, lessening the impact of energy security concerns as a driver. Although energy security has had a key role in the development of biofuels in both Brazil and the USA, it has also been crucial in the development of bioenergy technology in Denmark and Sweden over the same time period. Energy security concerns change over time with shifting energy markets, technology, supply and demand, but this does not necessarily change biomass apportionment decisions. Despite varying levels of energy security, and bioenergy and biofuel consumption in each of the four countries over the last few decades, currently neither application appears to be correlated to energy security. However, transportation fuels are primarily produced from oil, while stationary energy has multiple alternatives; thus, in the absence of domestic oil resources, energy security could act as a driver for biofuel development.

As an additional driver, climate change mitigation has historically been important in spurring the development of bioenergy and biofuels. Apportionment decisions for biomass are largely dependent upon the perceived sustainability of biomass and the ability of bioenergy or biofuels to achieve GHG emission reduction targets.

Diverging perspectives are evident when examining the different approaches to biomass utilization that occurred in Denmark and Sweden in the early 2000s. Swedish adoption of biofuels starkly contrasts with the rejection of EU blend mandates in Denmark and illustrates that the presence of climate change mitigation desires is insufficient for discerning how biomass is allocated in a given region. Sustainably harvested lignocellulosic biomass will experience greater climate benefits than current agriculture-based biofuel feedstocks (such as corn). It is possible that increased climate change concerns could increase competition for lignocellulosic biomass. Specific targeting of transportation-derived emissions will encourage biofuels to be featured prominently in this debate. Confusion surrounding actual climate benefits of bioenergy and biofuels, combined with loosened climate targets in the wake of the economic recession, has contributed to slower biofuel and bioenergy growth in the EU.

## 4 Policy and biomass allocation

A number of drivers are involved in the development of bioenergy and biofuels. Despite the importance of energy security, climate change mitigation desires, prevailing economic interests, and cost-competitiveness, it appears that government policy mechanisms override all other drivers and provide a foundation for bioenergy and biofuel development. Thus, policies will be necessary to support both the advancement of bioenergy and biofuel technology.

Policy support mechanisms, such as subsidies, research funding and blend mandates, are necessary to support pioneer facilities and allow for process optimization at the commercial scale, eventually driving down production costs. Unfortunately, policies are not always sufficient to promote and maintain production, particularly for biofuels, as described in the country profiles.

In both Brazil and the USA, binding blend mandates were introduced (in 2005 and 1993, respectively) to create a guaranteed demand for the fuel. The introduction of a 22% blend mandate in Brazil was an effective way to combat cheap oil prices and the presence of mandates concurrently with bioethanol subsidies in the USA saw bioethanol consumption increase from ~354 PJ in 2005 to ~1120 PJ in 2010[21]. In the US, unlike Brazil, mandates are not pegged as a percentage of gasoline consumption. Rather, the RFS outlines clear volumetric targets to be met by all fossil fuel providers.

In the EU, the 2003 Biofuel Directive introduced blending targets of 2.0% and 5.75% for 2005 and 2010, respectively, although the quota was non binding[13]. By 2010 biofuels accounted for only 4.4% of transportation fuel demand, falling short of the mandate. Despite the shortfall the EU Commission endorsed a minimum binding target of 10% for biofuels in transport by 2020. In 2012 biofuels reached 5% of transportation fuel demand. However, uncertainties regarding the future of EU biofuel policies and slow economic recovery in many of the member states is limiting expansion of biofuels in Europe[25,26].

Unfortunately, blend mandates are also subject to unforeseen complications limiting their efficiency. In the US, the blend wall is limiting bioethanol consumption while undermining the RFS mandates, while a flexible bioethanol mandate was introduced in Brazil in an attempt to cope with the fluctuating bioethanol supply due to variability in the annual sugar harvest. Sustainability concerns have changed the EU biofuels climate; especially considering the region relies on imports to meet their current biofuel mandates[26]. It is also worth noting that the majority of member countries have failed to meet their targets since the mandates were first introduced in 2003.

## 5 Conclusions

A review of current and projected global energy trends, with a focus on biomass-based energy, indicated that there was no competition for biomass between bioenergy or biofuels applications. This is likely to remain the case for the foreseeable future. It is apparent that bioenergy generation is, and will likely remain, the major use for biomass even in jurisdictions such as Brazil and the US where biofuels are produced and used extensively.

This limited competition is primarily due to the differing feedstocks employed to make bioenergy and biofuels. The vast majority of biofuel production uses conventional, sugar, starch and oil rich feedstocks, while bioenergy production is derived predominantly from woody biomass. Brazil is likely to be the only country where biomass competition might occur in the near future as sugarcane bagasse is increasingly used to generated heat and power at the mill site (sometimes exporting excess electricity into the grid), while companies such as Granbio and Raizen are assessing the potential of using bagasse as a feedstock for cellulosic ethanol production. However, rather than creating competition for lignocellulosic feedstocks, these facilities are more likely to coproduce biofuels and bioenergy from these residues to achieve improved economic viability.

It is evident that, although there are a number of drivers involved in the development of bioenergy and biofuels, good government policies are essential as these provide a more stable structure for bioenergy and biofuel development. For the cases of Brazil and the USA, although the energy security threats that originally catalyzed biofuel development have somewhat dissipated, the development of strong biofuel policies (e.g., RFS) enhanced the expansion of the industry in each country. For Sweden and Denmark, policies such as those initially used to better use their forest and agriculture-derived residues to produce bioenergy and, more recently, to reduce their fossil fuel derived carbon emission, will continue to motivate ongoing development of bioenergy and, to a lesser extent, biofuels.

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