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Biomass for energy in the EU – The support framework

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ABSTRACT

This paper aims to produce a quantitative approach on the overall measures and on public support framework for biomass for energy, based on the EU countries reports under RED and existing literature. The way in which the support for biomass is implemented in the EU energy sector is not similar across EU countries. Feed-in tariffs and feed-in-premiums are still the dominant support schemes for the deployment of bioelectricity, whereas subsidies remain the main support for bioheat. Furthermore, a vast number of EU countries apply mandatory blending quotas for biofuels for transport. The paper shows that biomass for energy has a key role within the EU policy support for RES, in which targets are the main drivers, together with overarching biomass guidelines to anticipate any environmental constraints. Stable support showed the highest effectiveness in the past and remains the key factor for biomass deployment beyond 2020. The renewed targets need to be accompanied by long-term support measures and a commonly shared policy vision. A further harmonization of public bioenergy support towards a single EU cleaner energy market is recommended. This implies four policy actions for all EU countries: in-depth efficiency review, integration with RED-2, compatible sustainability guidelines and local impact assessments.

1. Introduction

The transition to a low carbon economy, through a wide range of interacting policies and instruments, is consolidating in the European Union (EU). Increasing evidence of climate change and growing dependence on energy, has underlined the EU's determination to become a low-energy economy and to consume energy that is secure, safe, competitive, locally produced and sustainable. The first (1996/98) and second (2003) EU energy packages were focused primarily on liberalization and market structure. The third energy package (2009) also focuses on the development of market access, wholesale market integration and of effective retail markets, creating a regulatory framework to support a single, European energy market, by developing European-wide network codes (NCs) (EuropeanParliament, 2017a,b). Article 194 of the Lisbon Treaty on the "Functioning of the EU" introduces a specific legal basis for the field of energy, based on shared competences between the EU and its member countries stating that "*in the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between Member States (MS), to:* (i) *ensure the functioning of the energy market; (ii) ensure security of energy supply in the Union; (iii) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and* (iv) *promote the interconnection of energy networks"* (LisbonTreaty, 2009).

In April 2009, the Renewable Energy Directive (RED-1) was published. The RED-1 defines support schemes as "*means any instrument, scheme or mechanism applied by a Member State or a group of MS, that promotes the use of energy from renewable sources by reducing the cost of that energy, increasing the price at which it can be sold, or increasing, by means of a renewable energy obligation or otherwise, the volume of such energy purchased. This includes, but is not restricted to, investment aid, tax exemptions or reductions, tax refunds, renewable energy obligation* support *schemes including those using green certificates, and direct price* support *schemes including feed-in tariffs and premium payments*" (EC, Directive 2009/28/EC, 2009). The RED-1 commits the EU to achieving a 20% share of renewable energy in its gross final energy consumption (GFEC) by 2020 and a 10% share of renewable energy in transport energy consumption by the same year. The RED-1 lays down legally binding targets for each Member State for the share of renewable energy and requires them to include information on the measures taken or planned

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to promote the growth of renewable energy as well as the functioning of support schemes in their biennial progress reports.

In 2013, the EU adopted the guidance document for the designing and reforming renewable energy support schemes (SWD 439, 2013). The guidance document states that "financial support *for renewables should be limited to what is necessary and should aim to make renewables competitive in the market*". The document states also that "support *schemes should be flexible and respond to falling production costs. As technologies mature, schemes should be gradually removed. For instance, feed in tariffs should be replaced by feed in premiums and other* support *instruments that incentivise producers to respond to market developments*". In 2014 the EC's *Guidelines on State Aid for Environmental Protection and Energy* **(**EC, 2014**)** allow MS to support renewable energy sources, subject to certain conditions. The Guidelines aim to enable Europe to meet its ambitious energy and climate targets whilst minimizing distortions of competition in the Single Market and costs for taxpayers. MS are obliged to notify state aid measures to the Commission for approval ahead of implementation. Only after the Commission's approval can investors rely on the compliance of a measure with EU state aid rules. To maintain the global competitiveness of certain sectors, the Commission's 2014 Guidelines on State Aid for Environmental Protection and Energy allow MS to grant reductions from contributions levied on electricity consumption under certain conditions. This concerns energy-intensive users in sectors that are particularly energy-intensive and or exposed to international competition.

The EU focused on frameworks to guide MS in the process towards a single European energy market and cleaner energy markets overall. The cost-reductions in renewable energy technologies over the last couple of years are enabling consumers to increasingly produce their own energy and encouraging greater uptake (EC COM (2017)688). Our research questions are "what is the effectiveness of the EU support framework and (temporary) national policy measures, on the promotion and further deployment of affordable and sustainable agricultural biomass, forest biomass and renewable waste (together defined as 'bioenergy') sources"? The hypothesis is that the progress of bioenergy is larger and more efficient when country specific biomass support schemes are compatible with the different EU frameworks, flexible and respond to falling production costs on the country level. To answer these questions and asses this hypothesis, the paper focuses on policies and instruments in place in EU countries for bioenergy sector, as reported in the EU Member States' progress reports under the RED-1 and further highlighted with recent existing literature and sources as RES-Legal.[1] Several literatures exist on the role and effects of policies on the development of biomass for energy including the sustainability issues, but the main share of this literature is qualitative and descriptive. This paper aims to provide to the policy-makers, industry and regulators a quantitative approach on the (i) overall measures for enhanced biomass use for energy in the EU countries; (ii) the public support framework for biomass in electricity, heating/cooling and transport after 2014, and (iii) the effectiveness of these support frameworks in a country-specific condition. The paper is structured to provide a brief update of bioenergy progress in the EU; a description of the main support schemes to promote renewables; advantages and disadvantages of these schemes; a short overview of the existing literature on support schemes for biomass for energy; overall measures to support biomass for energy; sector specific support for biomass and an analysis of effectiveness indicator related to this support.

[1] RES LEGAL Europe is a professionally edited and free of charge online database on support schemes, grid issues and policies regarding renewable energy sources in the EU 28 Member States, the EFTA Countries and some EU Accession Countries. The database is updated on a regular basis.

2. Sustainability requirements for liquid, solid and gaseous biomass

In its resolution of the 2nd of July 2013 on "*Innovating for sustainable growth: a bio-economy for Europe",* the European Parliament (2016) called upon the Commission to propose a Biomass Framework Directive covering all applications of biomass (energy, fuels, materials and chemicals) and introducing a biomass hierarchy. It also called for a "*sustainable and efficient use of this resource to avoid adverse effects such as deforestation"* (EU Parliament Resolution, 2013). The existing RED-1 sets mandatory sustainability and greenhouse gas saving criteria for biofuels. For forest biomass, the Commission issued recommendations, but these are not uniformly implemented in the MS. In November 2016, the Commission proposed a revised RED-2)(Directive 2018/2001/EC) as part of the "Clean Energy for All Europeans" package, which includes mandatory sustainability criteria for both biofuels and biomass (EC, 2016). The European Parliament supports sustainability criteria for bioenergy and highlighted the sustainability issues of forest biomass in its June 2016 resolution on renewable energy. Stakeholder reactions to the Commission proposal have been mixed. While environmental NGOs called for stricter criteria, the bioenergy industries warned that tighter limits on conventional biofuels hinder the decarbonisation of the transport sector. Farmers and forest owners expressed concern about additional economic and administrative burden and stressed the principle of subsidiarity in forest policies (EuropeanParliament, 2017b). Only bioenergy sources that meet certain sustainability criteria, are eligible for financial support for bioenergy consumption and count towards the EU RES target, national RES shares and toward RES obligations (European Parliament, 2017b).

2.1. Sustainability requirements for biofuels

Biofuels and bioliquids are required to fulfill the sustainability criteria set in the RED-1, to count towards EU targets and to be eligible for national support (Directive, 2009/28/EC). Amongst others, biofuels and bioliquids should meet a minimum greenhouse gas (GHG) savings of 35% relative to fossil fuels. The Directive states "*those savings should increase to 50% in 2017 for existing plants and 60% in 2018 for new installations. Advanced, second-generation bio-fuels produced from residues, non-food cellulosic material and lignocellulosic material would be double credited towards the 10% target*". The ILUC (Indirect Land Use Change) (Directive, 2015/1513) of the European Parliament and of the Council of 9 September 2015 amended Directive 2009/28/EC and Directive 98/70/EC relating to the quality of petrol and diesel fuels. The ILUC Directive establishes a clear legislative framework for biofuels, while protecting existing investments in the transport sector. The EU Directive needed to be transposed into national law by the end of 2017, but it remains unclear whether all MS have done so. In July 2018 an ambitious political agreement on increasing renewable energy use in Europe was reached between negotiators from the Commission, the European Parliament and the Council. The new regulatory framework includes a binding renewable energy target for the EU for 2030 of 32% with an upward revision clause by 2023**.** A binding target of 14% is set for renewables in the transport sector (EC, 2018).

2.2. Sustainability schemes for solid and gaseous biomass

In the latest proposals by the European Commission, biomass fuels need to fulfil the sustainability and GHG savings criteria in 2020 and beyond only if used in installations producing electricity, heating and cooling. These requirements are applied for biomass fuels with a capacity of 20 MW and above in case of solid biomass fuels and 0.5 MW and above in case of gaseous biomass fuels. Currently, the European Commission recommends a threshold of 1 MW thermal of electrical capacity for applying sustainability criteria. Bioenergy from non-agricultural waste and residues only needs to fulfill GHG saving criteria

(European Parliament, 2017b). Up to now, only few EU countries have implemented national schemes related to the sustainability criteria of solid biomass use and rely instead on voluntary schemes (14 active from 20 voluntary schemes as in April 2018) that have been recognized by the European Commission (EC, Voluntary schemes - Biofuels, 2018). Anticipating possible obligatory sustainability criteria on the EU level, some EU countries have started to develop extensive sustainability schemes. The EU countries have derived their sustainability criteria from the (EC_COM(2010)11) on solid biomass from forests and agriculture for renewable energy purposes. Consecutively Belgium, Denmark, the UK and the Netherlands are the MS with the most specific criteria (Banja et al., 2017b), (Sikkema et al., 2017).

- In 2011 in Belgium, new regional provisions were adopted, transposing the requirements of Directive (2009)/28/EC regarding the sustainability of biofuels (Belgium Progress Report, 2015). The related trade of green certificates is subject to federal legislation, while the quota obligations are defined in regional regulations. Electricity suppliers need to show evidence that they have supplied a certain quota of renewable energy, which is determined by three regions Flanders, Wallonia, and Brussels-Capital (Mai-Moulin et.al., 2019).
- The Danish requirements are based on the UK sustainable biomass criteria but are non-mandatory via a voluntary Industry Agreement (IA). The IA attempts to comply with the Danish framework for sustainability, in terms of the environment, health, safety and the climate. The combined heat and power producers are responsible themselves (Mai-Moulin et.al., 2019).
- In the United Kingdom the measure for biomass sustainability is introduced to the Renewable Heat Incentive (RHI) from October 2015 and has become mandatory under the Renewable Obligation (RO) in the electricity sector from December 2015 (UK Progress Report, 2015). Amongst others, the UK has introduced specific sustainable land use criteria (e.g. no harvest of wood from carbon rich forests or from high biodiverse forests) and requires certification when sourcing woody biomass from forests.
- In the Netherlands, the use of biomass for energy is subject to stringent sustainability criteria (DutchGovernment, 2017). These sustainability criteria are the result of agreements between the government, energy companies and NGOs (Netherlands Progress Report, 2015). The latest Dutch legal requirements aim to prevent unwanted land use changes, to reckon with carbon debt, to safeguard a right nutrient balance in vulnerable soils and other sustainability criteria. Subsidy recipients from the energy sector need to demonstrate that their biomass supply is sustainable using either one of 2 methods: (i) certification schemes approved by the Minister of Economic Affairs and Climate Policy or a combination of certification and verification, or (ii) third-party verification (RVO, 2018).

Also, some EU countries have prohibited the use of certain biomass feedstocks for bioenergy, like Belgium, Finland, and the Netherlands. Belgium and Hungary explicitly aim to ensure that the use for energy is the last step in the use hierarchy of biomass feedstocks. This is being referred to as the ‘cascading principle’ and is derived from EU's waste framework directive (Directive, 2008/98/EC). Furthermore, several EU countries have followed the EC recommendations and accompanied their sustainability frameworks with GHG emission thresholds for emissions throughout the whole supply chain, from forest or agricultural land to the bioenergy production processes. Countries as Austria, Belgium (Flanders, Wallonia), the Netherlands and the United Kingdom have included in their support schemes regulations related to such bioenergy emissions. For example, in the United Kingdom the subsidy in the electricity and heating sectors is applied with a minimum GHG saving requirement when fossil fuels are substituted by bio-based fuels. The GHG emission saving must at least 60% compared to the EU grid average (based on an average fossil fuel comparator). The biomass boilers that do not have an RHI emission certificate will be ineligible for subsidies (UK Progress Report, 2015). Finally, the EC's recommended biomass sustainability requirements stipulate “to stimulate higher energy conversion efficiency, MS should in their support schemes for electricity, heating and cooling installations differentiate in favour of installations that achieve high energy conversion efficiencies” (EC COM (2010)11). This conversion efficiency will be relevant for the public support schemes beyond 2025. For heat production, specific energy conversion efficiency rates (η) are applied in some front running EU countries: Austria ($\eta \geq 60\%$), Germany ($\geq 70\%$) and France ($\geq 75\%$). For electricity production, so far only GHG reduction goals in the supply chain are implemented in Belgium, Denmark, the Netherlands and the United Kingdom.

3. Progress of bioenergy in the EU

EU's total gross energy consumption decreased from 1226 Mtoe in 2005, to 1162 Mtoe in 2017. The share of agricultural biomass, forest biomass and renewable waste (together defined as ‘bioenergy’) in EU's gross final energy consumption, increased from 5.9% in 2005 to 10.3% in 2017. For comparison, the bioenergy consumption in the EU was almost 120 Mtoe (58%) in 2017, while the other renewable energy sources like solar PV, wind and hydro power were about 86 Mtoe (42%). Germany, France, Sweden, Italy and Finland, were the leading countries in 2017 covering nearly 55% of the final bioenergy consumption in the EU. By 2017, biomass installed capacity in the EU almost three-folded in comparison with the 2005 figure, reaching 32 GW. This comprises a share of 7.7% in the total renewable electricity installed capacity. Bioenergy deployment saw a dip around 2011, affected mainly from the decrease in the consumption of solid biomass for the heating/cooling sector and the decrease of the biofuels in the transport

Table 1
Progress of bioenergy in the EU (2005–2017) and the 2020 plans (in ktoe).

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2020
Bioelectricity	6 000	10 669	11 471	12 812	13 571	14 417	15 353	15 612	15 985	20 052
- Solid biomass-el	4 743	7 476	7 891	8 456	8 570	9 014	9 609	9 713	10 041	13 462
- Biogas-el	1 105	2 766	3 295	4 045	4 633	4 986	5 270	5 443	5 515	5 497
- Bioliquids-el	152	428	285	312	368	417	474	456	429	1 096
Bioheat	**62 612**	**80 805**	**75 604**	**82 450**	**85 418**	**80 668**	**84 181**	**86 594**	**88 585**	**90 411**
Solid biomass-th	61 700	78 595	73 281	80 133	82 712	77 602	80 810	82 784	84 431	80 887
Biogas-th	743	1578	2122	2097	2490	2821	3124	3580	3909	4 526
Bioliquids-th	168	631	200	218	213	238	240	223	237	4 998
Biofuels	**3 277**	**13 184**	**10 890**	**11 163**	**11 418**	**12 453**	**13 093**	**14 081**	**15 192**	**29 054**
Bioethanol	594	2 809	2 493	2 314	2 250	2 155	2 535	2 727	2 859	7 324
Biodiesel	2 683	10 347	8 319	8 743	9 043	10 168	10 425	11 216	12 174	20 983
Total Bioenergy	**71 889**	**104 658**	**97 966**	**106 425**	**110 407**	**107 538**	**112 628**	**116 287**	**119763**	**139 516**

Source: (JRC NREAPs and progress reports data portal, 2018), (Eurostat SHARES Tool, 2019).

sector. Another distinction is that of solid biomass, gaseous biomass and liquid biomass. Bioenergy in the EU is projected to increase up to 139.5 Mtoe in 2020, although its share in final renewable energy will decrease to 57% due to faster increase of other renewable energy sources (Table 1).

4. Types of support schemes to promote renewable energy in the EU

Support schemes on the promotion of renewables are intended to cover the gap between costs of energy (electricity or heat) and revenues. Support schemes should be flexible enough to account for changes in the development of costs and technologies and so minimise the financial support granted. Support scheme design should also reflect the need to address longer term goals of fostering technological innovation, economies of scale, cost-reductions and spill-over effects that facilitate reaching the EU 2020 targets and reaching 2050 decarbonisation goals sustainably. General requirements for support schemes are set at the EU guidance document (SWD 439, 2013). Fig. 1 illustrates the main support schemes applied for the promotion of renewable energy.

Different approaches have been used to classify support schemes on the promotion of renewables. The support schemes can be: (i) regulatory (either focussed on investments or generation); (ii) direct (either focused on investment or generation); (iii) indirect (environmental taxes); and (iv) voluntary (green tariffs, agreements, contribution to shareholder programs). The most common categorization of support schemes is the one that distinguishes between (i) price-based and (ii) quantity-based. The main support schemes for the promotion of renewable energy are feed-in tariff (FIT), feed-in premium (FIP), Quota (tradable green certificates) and Tender/Auctions (Banja et al., 2017b).

This categorization may occur in an administrative procedure, which requires knowledge of the generation costs. This includes the calculation of a cost-based approach as the levelised costs of electricity (LCOE), which in turn is used to either administratively determine support levels (in a FIP or FIT), to set ceiling prices in the case of auctions/tenders or to determine multiplier for a technology-specific quota (Ecofys, 2013). Each support scheme is characterized by its advantages and disadvantages. FITs are simple, limiting the risk for investors, but they only support grid connected generation and can be costly for a country (Passey et al., 2014), (Laumanns, 2014). Moreover, they are less compatible with the principles of liberalised markets than other policy instruments (Ecofys, 2013). Quotas are highly compatible with market principles and the competitive price determination, but the uncertainty of electricity prices and certificates typically increases policy costs (Ecofys, 2013). Tenders guarantee a fixed purchase price and access to grid, but they have high administrative costs (Lucas et al., 2013), (Laumanns, 2014). Table 2shows a summary of these characteristics for main support schemes applied in EU countries to support the deployment of renewable energy.

There have been many studies trying to assess the effects of support schemes on the deployment of renewable energy sources in the electricity, heating/cooling and transport sectors. Recently, Huntington et al. (2017) has suggested that among the core design of renewable energy policy support should be the separation between production and payment to reduce market distortions, being so in favour of quantity-based auctions. But this view has also been challenged by Winkler et al. (2018) in favour of market-based feed-in schemes, such as sliding and fixed FIPs, even if auctions are still seen as the most cost-effective policy solution (Del Rio, 2017). A specific sub-field of this literature has focused on the case of biomass energy sources. For instance, Hellsmark and Jacobsson (2012) disentangles the policy challenges to the development of gasified biomass and shows that the uncertainty of its long-term potential for substitution to oil should be reduced by a supportive regulatory framework. The authors point at quotas and feed-in-laws as being the best policies to ensure the long-term deployment of gasified biomass. Scarlat et al. (2015) also provides a review on the European landscape of support policies for biomass. The authors tackle the concern of the availability of biomass in the context of an enormous increase of the demand and estimate that domestic resources should be enough to answer the challenge. They also highlight the necessity to oversee the competition between traditional uses of biomass and new use in rising sectors, as well as the competition between food and non-food use of biomass. In this context, they underline the role of Europe sustainability criteria and the stability of support scheme. In Paiano and Lagioia (2016), the authors assess the potential of biomass for the decarbonisation of the Italian economy and the stabilization of its energy supply. They focus particularly on residual biomass and find that Italy's potential is consequent. More importantly, the authors appeal to common EU sustainability criteria, including solid biomass, to make the consumption of biomass in the electricity and heating/cooling sectors more flexible and efficient. Nicolini & Tavoni (2017) tested if policy support for renewable electricity has been efficient in its promotion of renewable energy sources. It focuses on the five largest EU countries from 2000 to 2010. The authors find a positive correlation between the amount of support and the production of the incentivized energy (1% increase in the tariff leads to 0.4%–1% increase on the renewable electricity generation). The results also point toward better performance of feed-in-tariffs than of green certificates system. A recent paper conducts an empirical evaluation of feed-in tariffs and renewable quotas systems for wind power deployment (in the EU over the period 2000 to 2014). Their results indicate that only feed-in tariffs had an impact on the installed capacity. The efficiency of quota systems appears to have been reduced by the lack of the risk-free framework that could ensure investor confidence (García-Alvarez, Cabeza-García and Soares, 2017). In Del Rio & Linares (2014) a comparison of the support

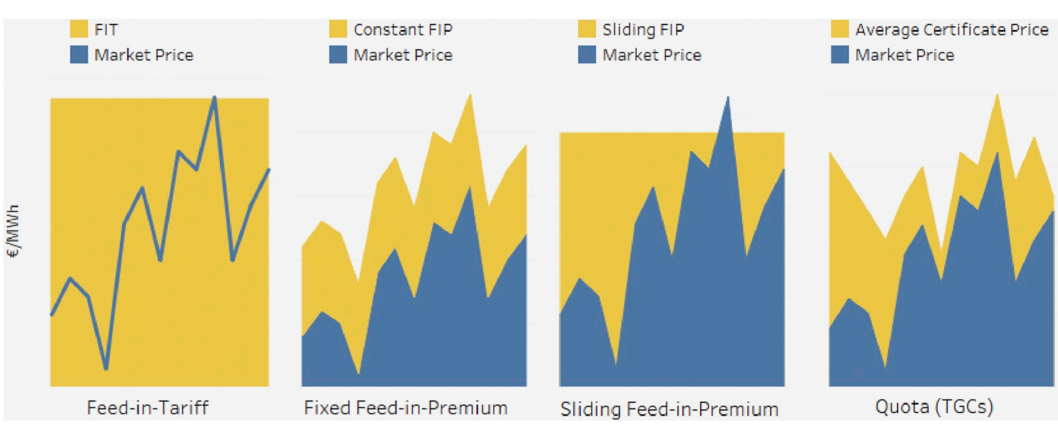

Fig. 1. Main types of support schemes to promote the deployment of renewable energy technologies.

Table 2
Advantages and disadvantages of main support schemes supporting the deployment of renewables.

Support scheme	Advantages	Disadvantages
Feed-in tariff	- Simple scheme that limits the risk for investors (fixed term support) - Provides an incentive to maximise production; - Drives technological development due to long terms support; - Create facilities for new players in the market - No burden to the public budget when founded by consumers - Can be adapted to impact on customer load patterns	- Difficult to find country-specific best FIT level and digression mechanism; - FIT can be very costly for a country; - Bad market integration since a fixed FIT does not respond to price signals; - Supports only grid connected generations - Badly design bring to high utility-costs for consumers - Less control over the installed capacity
Feed-in premium	- Incentive responds to the price signals of electricity market - Encourage investors to consider the engineering patters of a RES project (choice of site, type of wind turbines, orientation of PV panels etc.) - Efficient combination of electricity supply with demand - Reduce market price risks (minimum levels for FIP) - Provide security about minimum revenues (sliding FIP) - Possibility for higher revenues then FIT (when market price exceeds FIT level)	- Additional costs for the procurement of balancing services for wind and solar - A risk of over- and under compensation (the level of FIP is decided by an administrative decision) - Higher financing costs (related to evolution risks of market prices and corresponding revenues) - High complexity and costs for direct sale (prognosis systems, balancing services and electricity trading) especially for small-scale RES
Quota (TGC)	- Cost-efficient achievements because the TGC prices are determined by market price; - Penalty for not achieving the quota; - No risk for an uncontrolled growth of RES; - The scheme minimized the project costs - Possibility to introduce a "headroom" to prevent sudden drops in TGC prices	- Includes both electricity and TGC price risk increasing policy costs - Less suited for promoting a diversified energy mix while discouraging investments in expensive RES technologies; - Absence of incentive for beyond the upper limit create an oversupply of TGC which prices would sharply drop; - Tends to favour RES large-scale producers
Subsidy/Grants	- Allows for targeted development of renewable energy technologies especially when they are not sufficiently attractive to private markets; - Applicable for research and development into renewable energy innovations; - Facilitates renewable energy deployment especially in riskier environments	- Could be very difficult to remove when there is no longer needed - Long-term sustainability after grant is over may often be problematic - Payback and rate of return may be uncertain
Tenders	- Guaranteed purchase at fixed price; - Guaranteed access to the grid; - Long term guarantee leads to better financing options and potentially lower prices; - High competition results in cost efficiency and reveals the true market price of different technologies; - Limits can be set by the government for the capacity and the budget; - Due to the fixed schedule, electricity generation from RES becomes more predictable. - Bids can be selected according to specific criteria allowing for multiple country policies (ex: environment, employment)	- Can lead to discontinues (stop start) market development when regular action are not schedules - Difficult for small/medium biddings due to the high transaction costs (planning, feasibility study, risk assessments) and the risk of not getting a return on these investments in case they are not chosen. - High administrative costs. - High competition can lead to underbidding which results in low financial returns, contract failure or attempted post-auction price raises by successful bidders. - If there is not enough competition offers might be too high. - In open auctions there is a risk of collusive behaviour between bidders to drive up prices.

(Authors own compilation).
Tables and Figures in this paper contains information that are authors own processing sourced data.

schemes for renewable energies as feed-in tariff, tradable certificates and quotas with auctions as a third policy instrument has been analysed. The authors argue that pasts experiences have shown unsatisfactory outcomes linked to some factors such as too short support period, total costs not capped or absence of banding leading to too little technology diversity, etc. However, they note that some of the problems of auctions can be mitigated using appropriate design element. A recurrent criticism of renewable energy support schemes is that their interaction with other climate policies creates inefficiencies. In Del Rio (2017) the authors show that it is not really the case, using different criteria. They study some of the most relevant interactions between support granted to electricity generated from renewable sources and other policies, for instance the EU ETS, the Energy Taxation Directive and the Effort Sharing Directive in the EU, and manage to show that the results of the policies interactions are not always negative at all levels and that it is a function of the choice of the instruments and the design of the policy. A comparison of carbon tax and feed-in tariffs for supporting conversion of coal plants to co-fire with biomass is done by Johnston and van Kooten (2015). This comparison showed that there is an upper limit on a carbon tax beyond which the retrofitting of a coal plant is less efficient than increasing natural gas generating capacity. This is not the case when as support scheme is applied the feed-in tariff that specifically targets the biomass energy. The application of a carbon tax leads to lower aggregate emissions, compared with feed-in tariff support, due to the optimal generating mix. However, in this case the generation costs are higher than in the case of feed. in tariffs. A broad range of information can be found in the Council of European Energy Regulators 2017) Report, a document focusing on support schemes for 2014 and 2015. It shows that European countries are adapting their support schemes to allow for more market integration of renewable electricity. It also brings out the fact that basic features of the main support schemes in Europe have not been modified in recent years (funding remains mainly non-tax levies, renewable energy plants continue to be given priority in terms of network connection and electricity dispatching). Furthermore, plants using renewable energy have increasingly the same level of financial of financial responsibility as other plants concerning electricity balancing (CEER, 2017).

5. Overall measures to promote biomass for energy in the EU

Up to 2015, when the third set of renewable energy progress reports were submitted, more than 1300 support measures (economic, financial, regulatory, administrative, support) for the development of renewables were in place in the EU countries since 2005. More than

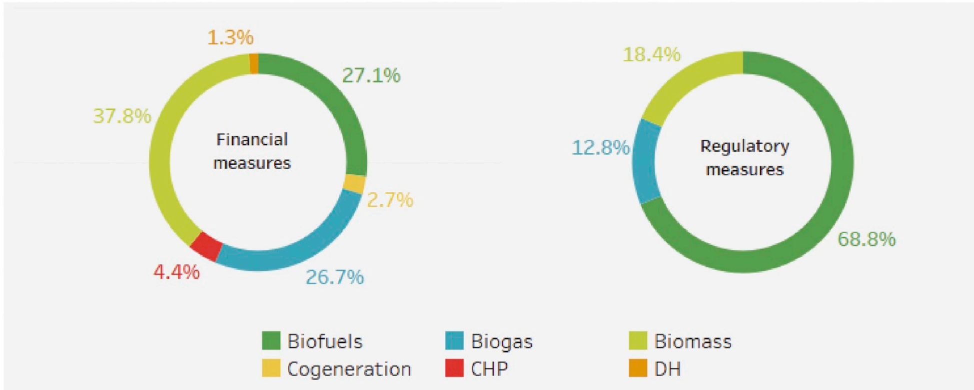

Fig. 2. Breakdown of financial and regulatory measures upon bioenergy sources (2005–2015).
Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

one-fourth of these measures were dedicated to biomass in three sectors (electricity, heating/cooling and transport). Financial measures accounted for more than 60% of these measures; the rest was regulatory and soft measures. Financial measures are implemented for all types of biomass. Biofuels have seen the implementation of all types of measures: financial, regulatory and soft. Over more than a decade nearly 20% of the measures to promote bioenergy were dedicated to biomass used for electricity production, mainly financial.

In the electricity sector regulatory measures are applied in countries such as France, Poland and Portugal in relation to biogas and new biomass plants. In the heating/cooling sector financial measures accounted for most measures applied. These financial measures were dedicated to subsidies, tax reliefs, bioenergy schemes for the use of non-food energy crops, support for district heating systems using woody biomass, eco-funds for promotion of woody biomass, investment grants for the production and sale of biogas, biogas market incentive program, creation of a guaranteed purchase price for biomethane injected into gas grids, zero-rated eco-loan for works to improve the overall energy performance of housing, support biogas production and supply into the gas network, energy tax on electricity and gas (offsetting for electricity, biomass heating), wood heating support actions, promote the installation in buildings of more efficient environmentally friendly energy systems run on biomass for heating/air conditioning, support for investments in the processing/marketing and/or development of agricultural products etc. The transport sector saw the largest number of measures applied, 172 or 48% of total measures related to bioenergy. The largest numbers of these measures in the transport sector were regulatory measures (biofuel quota, mandatory blending, sustainability) (Fig. 2). Financial measures in this sector were related to tax exemption, incentives programs, pollution taxes etc. Soft measures were related with the promotion mainly of the second-generation raw materials. Fig. 3 illustrates the financial measures applied for different sources of bioenergy in the EU countries over the period 2010–2014.

The largest share of financial measures implemented over the period 2005–2015 was dedicated to biomass for electricity and 36% was meant for heating/cooling purposes. Biogas and biofuels received nearly the same number of financial measures over this period, more precisely 27%. Among regulatory measures biofuels have received the largest share, at 69%. Biomass shared 18% of the regulatory measures and 12.8% was dedicated to biogas for electricity and heating/cooling. Biogas has seen the largest number of measures applied (financial and regulatory) for bioenergy in the electricity sector, almost 50% of the total. Nearly 40% of total measures implemented in this sector were dedicated to biomass (solid biomass, biogas, bioliquids). A share of 8.2% was dedicated to Combined Heat and Power (CHP) and a 4% share to cogeneration. In the heating/cooling sector, almost 45% of the total measures implemented over the period 2005–2015 were dedicated to biomass. The rest were dedicated to biogas (35.7%), solid biomass (10.4%), bioliquids (7.1%), cogeneration (0.9%) and district heating (2.6%). In the transport sector, more than 95% of the total measures implemented were dedicated to biofuels and the rest to biogas (mainly biomethane). France, Latvia, Austria, Finland, Sweden and UK were the EU countries that applied more financial measures related to bioenergy over the period 2005–2015.

6. Support schemes to enable biomass for energy

After 2014[2] the Czech Republic has the highest number of incentives for biomass in the electricity sector (42) followed by Greece (39), the Netherlands (36), Germany (30) and Poland (28). The Netherlands has the highest number of incentives in the heating/cooling sector (24) followed by Lithuania (14), United Kingdom (8), Luxembourg (7) and France (6). Overall, the Netherlands leads with 60 incentives for biomass in electricity and heating/cooling sectors followed by the Czech Republic (45), Greece (41), Germany (32) and Lithuania (32). According to a recent JRC report (Banja et al., 2017b) 10 EU countries (Belgium, Germany, Estonia, Greece, France, Croatia, Cyprus, Lithuania Poland and Romania) have specific support for the improvement of administrative procedures to remove regulatory and non-regulatory barriers for biomass deployment in the electricity sector. Only 4 EU countries (Belgium, Germany, Greece and Lithuania) have specific support for the transmission and distribution of renewable electricity from biomass, improving the rules for bearing and sharing costs in the grid connection process.

6.1. Support for biomass in the electricity sector

FIT and FIP are the main support schemes for biomass in the electricity sector. Eighteen EU countries (Bulgaria, Czech Republic, Germany, Ireland, Greece, France, Croatia, Italy, Cyprus, Latvia, Luxembourg, Hungary, Austria, Poland, Portugal, Slovenia, Slovakia and United Kingdom) are applying FIT as their main support schemes for biomass in this sector. Thirteen EU countries (Czech Republic, Denmark, Germany, Estonia, Greece, France, Croatia, Italy, Luxembourg, Hungary, Netherlands, Poland and Finland) apply a constant FIP scheme whereas three countries (Germany, Lithuania and Slovenia) apply a sliding FIP scheme. The quota system through tradable green certificates (TGC) is applied only in Belgium, Romania and Sweden. The tendering system is used already in ten EU countries (Germany, France, Italy, Lithuania, Croatia, Hungary, Poland, Portugal,

[2] For information on support schemes to promote biomass for energy over period 2010–2014 see the JRC Science for Policy report (Banja et al., 2017b).

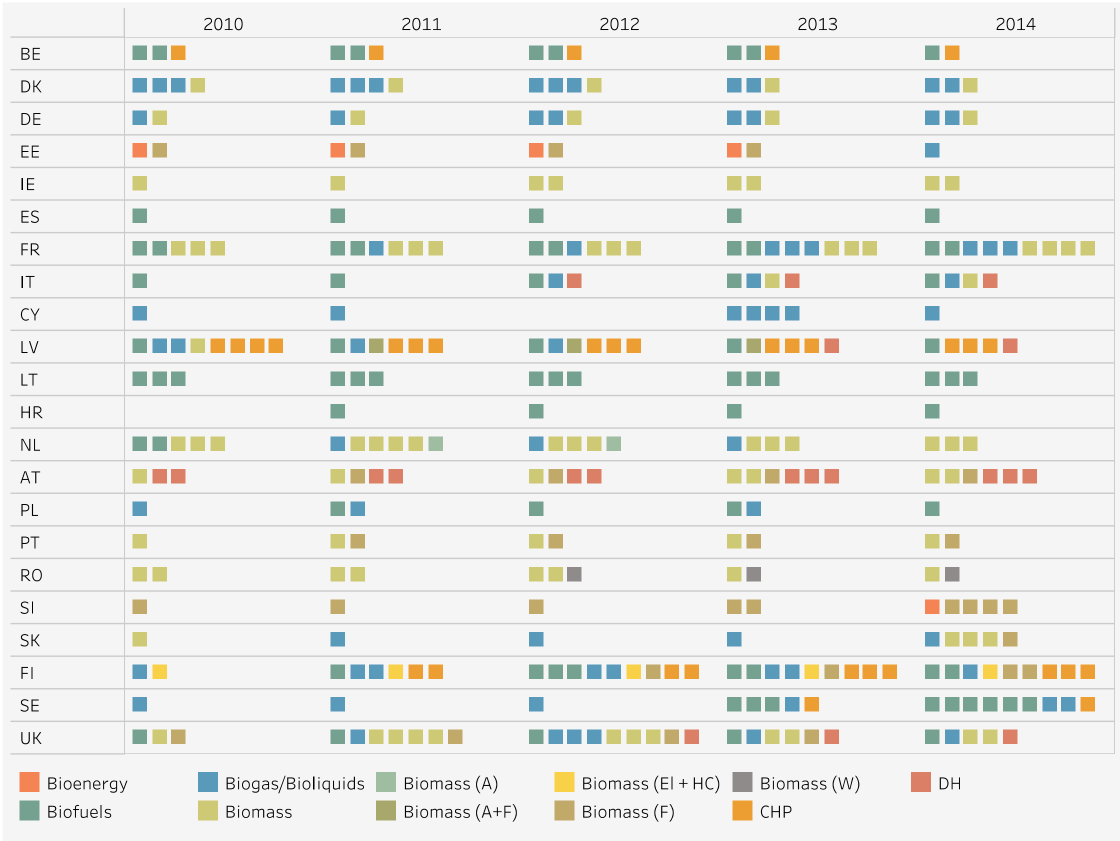

Fig. 3. Measures (financial) applied to promote bioenergy in the EU countries (2010–2014).
Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

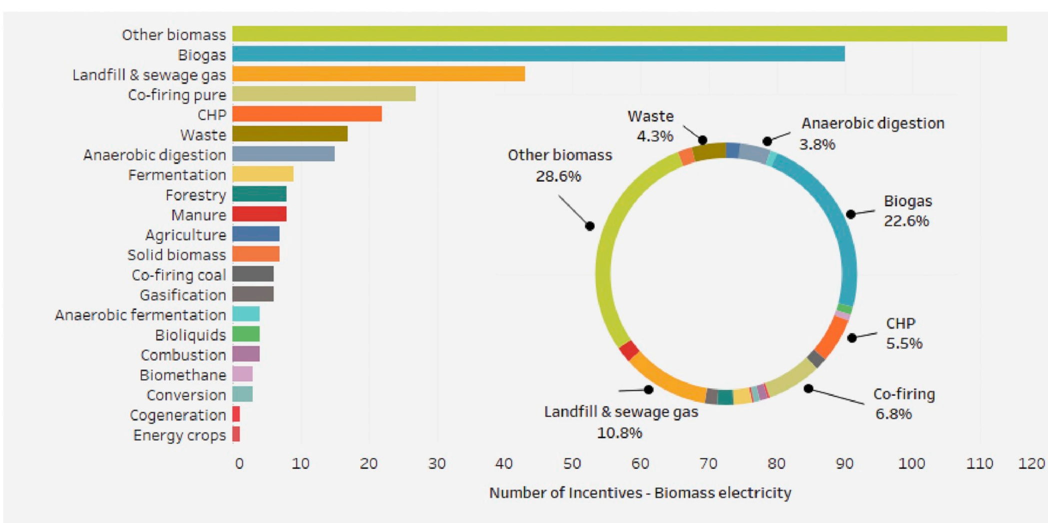

Fig. 4. Number of incentives to support the use of biomass in electricity sector.
Source (RES-Legal, 2018).

Slovenia and United Kingdom). Almost 70% (400) of all incentives in place to enable the use of biomass for energy, are applied in electricity sector. More than 40% of these incentives[3] are dedicated to biogas (22.6%) and landfill - sewage gas (10.8%). The share of incentives for other biomass[4] is 28.6%. Co-firing incentives have a share of 6.8%; CHP incentives account for 5.5%; waste incentives account for 4.3%; anaerobic digestion incentives account for 3.8% (Fig. 4).

Table 3 illustrates the average support levels under feed-in tariff,

[3] Shares reported here are related to the number of the incentives in place through FIT, FIP, tax mechanism and tenders in the EU electricity sector.

[4] The composition of other biomass is not specified in EU countries reporting. In this paper it is assumed to be solid biomass and bioliquids.

Table 3
Average support level for biogas in the EU electricity sector – FIT, FIP and CfD (€/MWh).
Source: (RES-Legal, 2018)

	FIT (avg. support)	FIP (avg. support)	CfD (avg. support)[a]
Sewage gas	63,5	60,8	85,5
Conversion	84,7		
Co-firing		86,3	
Gasification		108,2	
Landfill gas	94,9	100,8	62,7
Landfill & Sewage gas	103,2	67,5	
Anaerobic digestion	112,7	113,8	167,2
Biomethane	126,6		
Agriculture	127,6		
Waste	131,1	139,7	
Biogas	132,0	101,4	142,5
Anaerobic fermentation	149,0	109,5	
Other biomass	218,3	214,5	
Manure	221,5	231,4	

[a] Contract for difference scheme applies in the United Kingdom.

feed-in premium and contract for differences schemes currently in place in the EU, for biogas in the electricity sector. As shown in the table, manure that falls under different regulatory frameworks as FIT and FIP that complicates its use for biogas generation and leads to different interpretations on "what is manure",[5] receives the highest average support through both schemes. Biogas from other biomass has the second highest average support level in both these two schemes. The main support for manure under the feed-in tariff scheme comes mainly from Bulgaria, France, Germany, the Netherlands and Belgium. Bulgaria provides the highest incentive (248 €/MWh) for power plants working with indirect use of biomass from plant and animal substances, for which the total weight manure is more than 50%. France provides an incentive at maximum level of 225 €/MWh for biogas plants using 60% of livestock manure. The support in Germany for biogas plants with capacity up to 75 kW using manure, reaches a maximum of 231 €/MWh. The Netherlands applies a premium of 85 €/MWh for fermentation of manure in CHP (co-fermentation).

In Germany, the largest number of incentives through the feed-in tariff scheme is given to biogas, reaching almost 80%. In Austria, nearly 67% of incentives within the feed-in tariff scheme in the electricity sector, are dedicated to biogas applications. In France, the largest number of incentives through the feed-in premium scheme goes to biogas. Almost half of incentives within the Contract for Difference (CfD) scheme in the United Kingdom, are focused to biogas for electricity. Almost 72% of the incentives for biomass in the electricity sector under the feed-in premium in Denmark, are given to the applications related to biogas. In Lithuania, 67% of the incentives for bioenergy are related to biogas that receive support under the standard feed-in premium. In Italy, almost 42% of applications receiving support through the tendering system for biomass are related to biogas. Under the tax mechanism, half of incentives for biomass in the Netherlands are related to biogas. In the United Kingdom, under the same mechanism this share goes up to 67%. The main support scheme for other biomass is the feed-in tariff, more than 40% of incentives for biomass in place are dedicated to this type of biomass. More than 30% of the incentives for other biomass, are given through a combination of feed-in premium and tenders. Under this combination of support, the combined heat and power, cogeneration and co-firing incentives account for more than 40% of the total. Through the tendering process, Germany gives support

[5] Manure is a co-product of animal agriculture. Depending on the point of view, it is either a resource for crop production or it is a waste product (Livestock manure; Animal manure; Liquid manure; Bulky organic manure; Compost manure: Green manure).

Table 4
Support level (minimum, average, maximum) for biomass in electricity sector after 2014 (€/MWh)[a].
Source: (RES-Legal, 2018)

Country	Support schemes	Minimum	Average	Maximum
AT	FIT	47,5	129,4	220,0
BG	FIT	70,5	176,1	248,0
CY	FIT	67,23	68,4	69,7
CZ	FIP	18	84,5	147,0
CZ	FIT	48	116,0	178,0
DE	FIPs/Tender	148,8	158,9	169,0
DE	FIP	56,6	106,8	231,4
DE	FIT	54,6	105,8	231,4
DK	FIP	58	109,9	160,0
EE	FIP	3,2	36,9	53,7
EL	FIP	61	120,3	225,0
EL	FIT	80	158,3	230,0
FI	FIP	82,5	83,0	83,5
FR	FIT	150	187,5	225,0
HU	Tender	103,1	103,1	103,1
HU	FIP	103,1	103,1	103,1
HU	FIT	42	86,8	115,2
IE	FIT	85,6	118,0	157,0
IT	FIPs/Tender	85	102,0	119,0
IT	FIP	85	169,8	246,0
IT	FIT	85	178,5	246,0
LT	FIPs/Tender	51	95,7	122,0
LT	FIPs	46	84,3	114,0
LU	FIP	116,8	139,1	161,4
LU	FIT	117	156,4	191,0
NL	Tax mechanism	5	34,1	101,3
NL	FIP	31	75,7	111,0
PT	FIT	95	107,3	119,0
SE	Tax mechanism	34	43,7	63,0
SK	Tax mechanism	1,32	1,3	1,3
SK	FIT	58,66	85,1	102,0
UK	Tax mechanism	2,03	3,1	4,2
UK	FIT	19,7	42,8	55,8
UK	CfD/Tender	62,7	126,2	171,0
UK	CfD	62,7	116,3	171,0

[a] Countries that applies quota or subsidy support schemes to support biomass in electricity sector are not included in Table 4.

Table 5
Current average incentives in EU countries to support biogas and solid biomass in electricity sector.[a]
Source: (RES-Legal, 2018)

	Support scheme	Biogas-el		Support scheme	Solid biomass-el
FR	FIT	187,5	IT	FIT	198
LU	FIT	173,3	IT	FIP	180,5
EL	FIT	163,9	BG	FIT	176,1
IT	FIT	159	DE	FIPs/Tender	158,9
AT	FIT	148	EL	FIT	152,7
CZ	FIT	128,8	UK	CfD	142,5
UK	CfD/tender	124,3	LU	FIT	139,5
IE	FIT	120	LU	FIPs	139,1
PL	FIT/Tender	113,8	IT	FIPs/Tender	119
LT	FIPs/Tender	112,4	PT	FIT	119
DK	FIP	110,6	IE	FIT	115,5
DE	FIT	109	AT	FIT	113,9
PT	FIT	106,6	DK	FIP	108
UK	CfD	106,4	CZ	FIT	106,3
SK	FIT	88,4	EL	FIP	105,1
HU	FIT	86,8	HU	FIP	103,1
FI	FIP	83,5	DE	FIP	95,2
NL	FIP	75,7	DE	FIT	94,2
EE	FIP	53,7	HU	FIT	86,8
LT	FIT	51,7	FI	FIP	82,5
UK	FIT	42,8	SK	FIT	81,2
			NL	FIP	77,4
			CZ	FIP	75,6
			LT	FIPs/Tender	54
			EE	FIP	53,7

[a] Countries are ranked in descending mode.

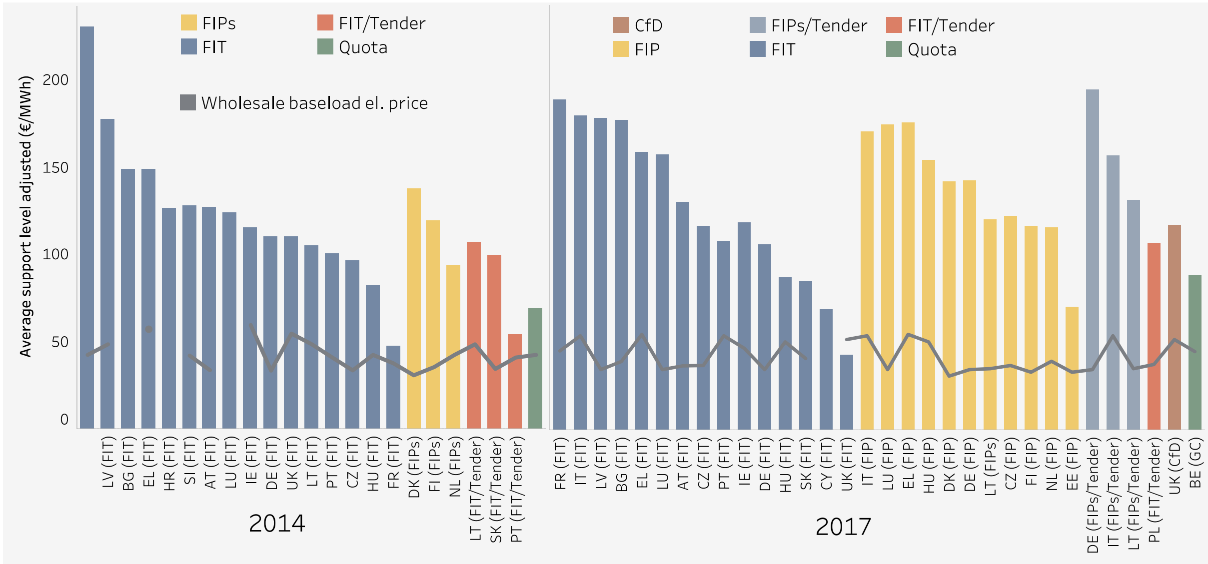

Fig. 5. Avg. incentives for biomass electricity in EU countries vs wholesale base load electricity price, (2014 & 2017).
Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

in the form of premium only to applications related to other biomass. Table 4 illustrates the support level (minimum, average and maximum) in each EU country, for biomass in the electricity sector after 2014 under feed-in tariff, feed-in premium, tender, tax mechanism and contract for difference schemes.

The period after 2014 saw a shift towards the combination of FIT, FIP and tenders (Germany, France, Italy, United Kingdom) and combination of FIT and FIP (Bulgaria, Ireland, Latvia, Croatia) to support biomass in this sector. This combination is being applied mainly for large-scale installations. Only Poland applies now a combination of feed-in tariff with tender. Over the period 2010–2014, Italy had the highest average support level for biomass at 230 €/MWh (FIT scheme). After 2014, France had the highest average support level for biomass at 187.5 €/MWh (FIT scheme). In maximum terms, it is Bulgaria with the highest support level under the FIT scheme. The average support level for biogas and other biomass is similar under almost all support schemes. Only in the feed-in premium[6] support scheme the average support level for biogas is double that of other biomass. Table 5 illustrates the average incentives currently in place in EU countries, to support the use of biogas and solid biomass in the electricity sector. France's average incentive for biogas is the highest amongst the EU countries followed by Luxembourg, Greece, Italy and Austria, all applying a feed-in tariff scheme. Italy has the highest average incentive to support the use of solid biomass through feed-in tariff and feed-in premium schemes, followed by Bulgaria (FIT) together with Germany (FIPs/Tender) and Greece (FIT).

The average support level for biomass in electricity in EU countries, resulted higher than the average base load price of electricity, being as such a "real support". As shown in Fig. 5[7] the France feed-in tariff average support in 2014 had the lowest level within this scheme, a situation that changed in 2017.

The average level of support for bioelectricity within the feed-in premium scheme was higher in 2017 compared with 2014. The current average support level for bioelectricity in the United Kingdom feed-in tariff scheme is lower compared with the average support in 2014. Comparing with the wholesale base load electricity price this average feed-in tariff support is lower in a time when the CfD scheme - even when combined with tender - provides a much higher average support level. The current average support level for bioelectricity in Germany through the combination of sliding feed-in premium and tendering system provides, a higher support compared with the support given within the feed-in tariff scheme, which is slightly lower than in 2014. In Italy, despite the average support level within feed-in tariff scheme decreased, this support remains higher than the average support from feed-in premium alone and in combination with the tendering system. Targets have been important for the deployment of biomass in the electricity sector. Some EU countries have already adopted long-term targets to phase out coal from the co-firing mechanism. The United Kingdom Government "*has announced the phasing out of all unabated coal fired power stations by 2025 and restricting its use from 2023*" (UK Progress Report, 2015). Denmark aims a total phase-out coal by 2030; Austria plans to be coal free by 2025; France had committed to a coal phase-out by 2023; Italy aims to phase out coal by 2025; In October 2017, the Netherlands announced that all coal-fired power plants would shut down by 2030; Portugal confirmed in November 2016 that power plants in the country will stop burning coal by 2030 (Beyond-coal.eu, 2018).

6.2. Support for biomass in the heating/cooling sector

Subsidy is the main type of support for biomass use in the heating/cooling sector. Eighteen EU countries (Belgium, Bulgaria, Czech Republic, Germany, Estonia, Ireland, Greece, France, Lithuania, Luxembourg, Hungary, Austria, Poland, Romania, Slovenia, Slovakia, Finland and United Kingdom) apply this type of support for biomass in this sector. Table 6 illustrates the average support level for some biomass feedstocks in the EU countries heating/cooling sectors.

Nine EU countries (Czech Republic, Denmark, Ireland, Greece, France, Latvia, Lithuania, Netherlands and Sweden), are applying tax mechanism (tax relief, tax reduction etc.) to support the use of biomass for heating purposes. FIP scheme is used only in Denmark and the Netherlands. Lithuania is the only country that applies a FIT scheme. Tendering system is used only in Hungary and Netherlands. A production-based incentive (Renewable Heat Incentive), similar to a FIT scheme is applied in the United Kingdom. France compensates the

[6] Sliding feed-in premium.

[7] In Fig. 3 the current average incentives are compared with the 2017 wholesale base load electricity price in EU countries. In the case of feed-in premium and contracts for difference the average incentive is adjusted (calculated as sum of the current feed-in tariff and base load electricity price).

Table 6
Incentives to support deployment of biomass in some EU countries heating/cooling sector.
Source: (RES-Legal, 2018)

Country	Support scheme	Sub-technology	Support level	Unit
DK	FIP	Biogas	1,34	€/GJ
LT	FIT	Landfill gas	34	€/MWhth
LT	FIT	Anaerobic digestion	72	€/MWhth
NL	FIP	Fermentation in CHP	125	€/MWhth
FI	Price mechanism	CHP	50	€/MWhth
FI	Price mechanism	CHP plants working on wood fuel	20	€/MWhth
DE	Loan	Solid biomass installations	20	€/kW
DE	Subsidy	Pellets installations	80	€/kW
NL	FIP	Other biomass	55	€/MWhth
NL	FIP	CHP	67	€/MWhth
NL	FIP	Boiler liquid biomass ≥0,5 MWth	70	€/MWhth
NL	FIP	Boiler liquid or solid biomass ≥0,5 MWth en < 5 MWth	55	€/MWhth
NL	FIP	Boiler on liquid or solid biomass ≥5 MWth	43	€/MWhth
NL	FIP	Boiler on wood pellets ≥5 MWth	62	€/MWhth
NL	FIP	Biomass ≤100 MWe	53	€/MWhth
NL	FIP	Extended lifetime ≤50 MWe	61	€/MWhth
NL	FIP	Waste water treatment/sewage treatment	84	€/MWhth
UK	DRHI	Biomass boilers and biomass stoves	72,6	€/MWhth
UK	NDRHI	Small commercial biomass < 200 kWth -first year	32,8	€/MWhth
UK	NDRHI	Small commercial biomass < 200 kWth –afterwards	23	€/MWhth
UK	NDRHI	Medium commercial biomass > 200 kWth < 1 MWth - first year	32,8	€/MWhth
UK	NDRHI	Medium commercial biomass > 200 kWth < 1 MWth – afterwards	23	€/MWhth
UK	NDRHI	Large commercial biomass (1 MWth and above) - first year	23	€/MWhth
UK	NDRHI	Large commercial biomass (1 MWth and above) – afterwards	32,8	€/MWhth
UK	NDRHI	Solid biomass CHP systems	47,6	€/MWhth

difference between the purchase price of methane and the wholesale market price of natural gas, to support biomethane injection.[8] More than 110 incentives are in place to support biomass deployment in this sector. Almost 60% (65) of these incentives are dedicated to biomass other than biogas. Almost 45% (21) of the incentives dedicated to biogas are supported through FIT and FIP schemes. The other biomass than biogas is mainly supported through quota, subsidy and loan schemes covering nearly 47% of total incentives for these feedstocks. Bulgaria applies loan scheme to support small cogeneration plants. At least 50% of a project's benefits must come from energy savings. Investment payback period is up to 7 years and range between EUR 15,000–1,500,000. Germany applies loans to support solid biomass installation exclusively for thermal usage. France also applies loans to support wood fueled heating plants whereas the biomass plants with a heat production over 1 ktoe per year are supported through subsidies. Luxembourg uses subsidies for straw, wood pellet and woodchips boilers amounts to 40% of the eligible costs, subject to a maximum of €5 000 in a single-family house. For multi-family houses, the subsidy amounts to 40% of the eligible costs, subject to a maximum of €4 000 without exceeding a maximum support of €20,000 per house. Subsidy is the main support for other biomass in Belgium, Poland, Romania, Slovenia, Slovakia, Finland, Estonia, Greece.

The highest average support level for biogas is given through FIP scheme, at 84/MWhth. Under the price mechanism scheme the average support level for biogas is more than double that for other biomass. The Netherlands provides a maximum premium at 125 €/MWhth for biogas through the fermentation process in CHP. The subsidy offered from Germany for pellet installations reaches 80€/kW. Lithuania offers a maximum FIT at 72€/MWhth for anaerobic process of biodegradable waste (< 1300 kWh/hour). Denmark applies a FIP of 1.34 €/GJ for biogas injected in the network for heating purposes. The Netherlands offers an incentive at 70 €/MWhth for the installation of a boiler with liquid biomass with a capacity ≥0,5 MWth.

Some EU countries have already adopted ambitious targets specifically for renewable heat or carbon reduction. Finland announced that it would phase out all coal by 2030, a significant step for the heat sector since coal currently accounts for 30% of heat consumption. Denmark aims at having an energy system free of fossil fuels by 2050, and heat will play a crucial role in achieving this goal (IRENA IEA REN21, 2018).

EU countries as Denmark, Estonia, Latvia, Lithuania, Finland and Sweden, have a very developed district-heating network (mainly based on biomass) in the conditions of the above-average climate-related demand. These countries have promoted renewable heat more broadly through a variety of policy instruments, often in combination with one another. In countries with low district heating penetration the financial incentives (grants, subsidy, loans) are applied. Germany launched a program in 2017 that offers grants of up to 60% of investment costs for new, innovative heating/cooling networks based on at least 50% renewable heat (IRENA IEA REN21, 2018). In France, lower-rate VAT for district heating networks using over 50% renewable or recovered energy has been in place since 2009. In 2014 the overall amount under the Heat Fund to support these heating networks has reached € 50 million (France Progress Report, 2015). Meanwhile the prices of gas are very competitive in countries such as the Netherland (17.1 €/MWh) and the United Kingdom (17.4 €/MWh) (BP Statistical Review of World Energy, 2018). In the United Kingdom, there are no specific supports for the renewable generators that are subject to the same charging mechanisms as non-renewable generators, by the transmission and distribution networks (UK Progress Report, 2015). To reduce the competition between fossil fuels and biomass in the heating/cooling sector, Sweden applies a combination of energy and CO_2 taxes. Since 2013 the heat production at combined heat and power (CHP) plants covered by the EU emissions trading scheme (EU ETS) has been completely exempt from CO_2 tax (Sweden Progress Report, 2015). In Denmark, the use of fossil fuels for heating/cooling attracts a substantial energy tax whereas there is no energy tax for renewable fuels (Denmark Progress Report, 2015).

Biomass for cooling purposes is mainly used in centralized systems, for example in combination with a district heating plant, whereas the decentralized cooling systems are currently driven by electricity, solar power or heat pumps. A biomass boiler for cooling purposes can have a

[8] The amount of this cost shared among natural gas customers, was 0.74M€ in 2013, 3.29M€ in 2014 and 57M€ in 2015 and 22.96M €; in 2016.

higher efficiency compared with efficiency of an oil boiler. However, the considerable costs of biomass for cooling systems make the competitiveness to compression heat pumps difficult. The cooling demand account still for a small part of heating/cooling demand and differs among countries i. e in Germany the cooling demand reach less than 4% of the heating demand (Aalborg Universitet, 2018) whereas In Italy this share ranges between 10 and 15% (Connolly et al., 2015). The use of biomass for cooling purposes benefits from the same support given for biomass for energy and as well as from the innovations in increasing the efficiency of the technologies applied for this purpose.

6.3. Support for biofuels in the transport sector

In 2017, the blending of bioethanol and biodiesel in the EU transport fuels, was respectively 3.3% and 5.8% (energy basis) below the 10% target. The blending of conventional biofuels in transport fuels is estimated at 4.1%, still well below the 7% cap. The blending of advanced biofuels in transport fuels is about 1.2%, thus already surpassing the non-binding 2020 target of 0.5% (USDA GAIN, 2018). The main support for biofuels in the transport sector is quota, applied in 24 EU countries (Belgium, Bulgaria, Czech Republic, Denmark, Ireland, Greece, Spain, France, Italy, Latvia, Lithuania, Luxembourg, Croatia, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland and United Kingdom). Fourteen EU countries (Belgium, Czech Republic, Denmark, Greece, Latvia, Lithuania, Hungary, the Netherlands, Austria, Portugal, Slovenia, Slovakia, Finland and Sweden) apply a tax mechanism (tax exemption, tax relief, pollution tax) to support the use of biofuels in their transport sector. Six EU countries (Estonia, Greece, Lithuania, Hungary, Austria and Slovenia) apply the subsidy scheme. In Germany, the biofuel quota has been replaced as of January 2015 by a greenhouse gas reduction quota. The support is given to biofuels exclusively produced from biomass. Beginning from 2015, the GHG emissions must be reduced by 3.5%, from 2017 by 4% and beyond 2020 by 6%. Accordingly, the allowed share of greenhouse gases discharged from diesel and gasoline is being reduced in form of a quota, meaning that the usage of biofuel is only indirectly stimulated. In Denmark, petrol or diesel fuels must ensure that biofuels make up at least 5.8% and advanced biofuels at least 0.9%, measured by energy. The support for biogas uses in the transport sector is given in the form of a premium with a range from 1.34 €/GJ to 5.23 €/GJ. In Estonia biomethane receives a subsidy of 100 €/MWh to which the average market price of natural gas of the current month is deducted.

Table 7 summarizes the average blending quotas for biofuels applied in EU countries over the period 2010–2017. Austria applies double counting for biofuels; Croatia applies double counting for second generation and waste based biofuels; France applies double counting for cellulosic biofuels and waste biofuels up to the maximum values stated on the left; in Germany double counting expired at the end of 2014 with the transition to a GHG reduction mandate; the United Kingdom applies double counting for biofuels made from wastes, residues, non-food cellulosic material, and ligno-cellulosic material; Hungary applies double counting for waste materials and residual products from agricultural and forestry production, including biofuels from non-food cellulosic and ligno-cellulosic materials; Ireland started applying in 2017 double counting for biofuels; Italy applies double counting for advanced biofuels necessary for reaching the targets (at 0.6% in 2018); in the Netherlands biofuels produced from waste, residues, non-food cellulosic material and ligno-cellulosic material may be double-counted under specific conditions if the annual obligation is fulfilled; Double counting of biofuels is also applied in Poland, Portugal and Slovenia (USDA GAIN, 2017), (MS Progress Reports, 2015).

7. Effectiveness indicator

Quantitative indicators provide a means of evaluating policy effectiveness in a systematic and reliable manner. Policy effectiveness can be measured in several different ways. Possible parameters or indicators include consumption, production, installed production capacity, energy access (in the case of developing countries), employment and added value in manufacturing (direct and indirect). The appropriate parameter(s) will depend on the predefined objectives of the policy in question (Puig and Morgan, 2013). The Effectiveness Indicator (EI) is expressed as a percentage of the remaining production potential that can be realized by the end of the pre-defined medium-term period as measured at the start of that period.

$$EI = \frac{G_n - G_{n-1}}{G_{2020} - G_{n-1}}$$

G_n – Energy generation from technology “i” in year “n".

The advantage of the effectiveness indicator is that it considers the country-specific factors whereas the disadvantage is that it is difficult to identify additional mid-term potential. It is important to know that the EI measures only the effectiveness of *overall renewables policy* in increasing the production or consumption of renewables. It *does not measure the impact of individual policies or measures, nor does* it provide any insights into why a particular national policy is effective or in effective relative to the potential or to performance in other sectors or countries (Puig and Morgan, 2013). The following section is focused on (i) the effectiveness indicator for biomass use in the EU, and EU

Table 7
Mandatory blending quota for biofuels in EU countries (2010–2016). Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

	2010	2011	2012	2013	2014	2015	2016	2017
AT	4,4%	5,8%	5,8%	5,8%	5,8%	5,8%	5,8%	5.8%
BE	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7%
BG	3,0%	3,0%	5,5%	5,5%	6,0%	7,5%	9,0%	9.0%
CZ[a]	6,0%	6,0%	6,0%	6,0%	6,0%	6,0%	6,0%	6.0%
DE[b]	6,3%	6,3%	6,3%	6,3%	6,3%			
DK	0,8%	3,0%	5,8%	5,8%	5,8%	5,8%	5,8%	5.8%
EL	6,5%	7,0%	7,0%	7,0%	7,0%	7,0%	7,0%	7%
ES	5,8%	6,3%	6,5%	6,5%	6,5%	6,5%	4,3%	5%
FI	6,0%	6,0%	6,0%	6,0%	6,0%	8,0%	10,0%	12%
FR	7,0%	7,0%	7,0%	7,0%	7,7%	7,7%	8,0%	8%
HR		1,5%	1,5%	1,5%	1,5%	3,3%	5.2%	6.5%
HU	4,9%	4,9%	4,9%	4,9%	4,9%	4,9%	4,9%	4.9%
IE	4,0%	4,0%	4,0%	6,0%	6,0%	6,0%	6,4%	8.7%
IT	3,5%	4,0%	4,5%	4,5%	4,5%	5,0%	5,5%	6.5%
LT	5,8%	5,8%	5,8%	5,8%	5,8%	5,8%	5,8%	7.0%
LU	2,0%	2,0%	3,8%	4,8%	4,8%	4,8%	4,8%	5.85%
LV	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5.0%
MT		1,5%	2,5%	3,5%	4,5%	5,5%	6,5%	7.5%
NL	4,0%	4,3%	4,5%	5,0%	5,5%	6,3%	7,0%	7.75%
PL	5,7%	6,2%	6,6%	7,1%	7,1%	7,1%	7,1%	7.1%
PT	5,0%	5,0%	5,0%	5,5%	5,5%	7,5%	7,5%	7.5%
RO[c]	5,0%	5,0%	5,0%	6,0%	6,0%	6,0%	6,5%	6.5%
SI	5,0%	5,5%	6,0%	6,5%	7,0%	7,5%	7,5%	7.5%
SK	3,4%	3,8%	3,9%	4,0%	4,5%	5,8%	5,8%	5.8%
UK	3,9%	4,2%	4,7%	5,3%	5,0%	5,0%	5,0%	5.0%

[a] The mandatory blending quota for Czech Republic in this table refers to biodiesel. The mandatory blending quota for petrol in 2017 was 4.1% (by volume).
[b] In 2015–2016 the GHG reduction quotas in Germany were 3,75%. In 2017 the GHG reduction quota was 4%.
[c] The mandatory blending quota for Romania in this table refers to biodiesel. The mandatory blending quota for bioethanol in 2017 was 4.5%.

Table 8
Effectiveness Indicator for electricity from biomass in the EU (2010–2016) – calculated vs 2020.

	2011	2012	2013	2014	2015	2016
Effectiveness Indicator	8.2%	22.3%	30.4%	39.4%	49.3%	52%

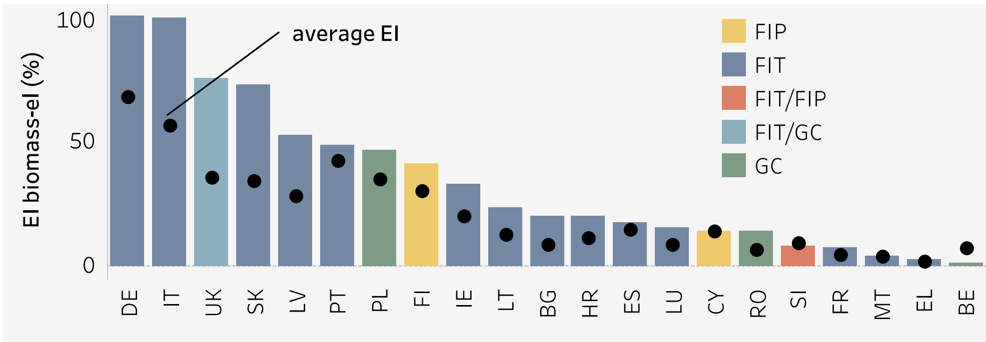

Fig. 6. Effectiveness indicator for biomass electricity in EU countries, 2010–2014.
Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

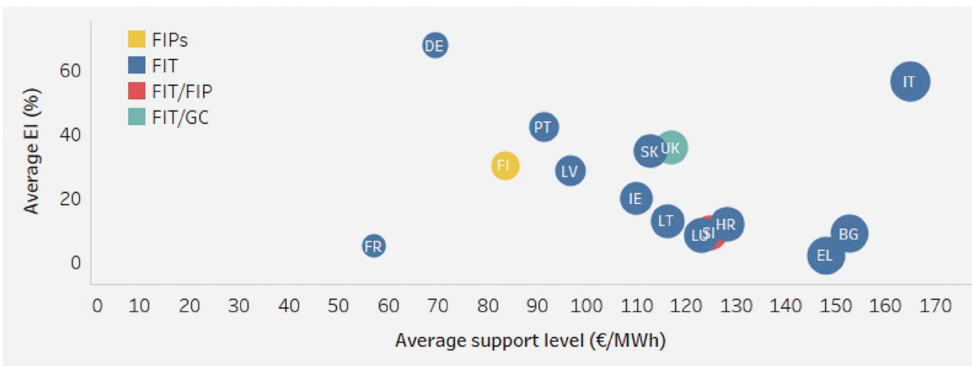

Fig. 7. Biomass electricity: average Effectiveness Indicator vs average Support Level in EU countries (2010–2014).
Source: EU MS NREAPs (2010), EU MS Progress Reports (2011–2017).

countries electricity sectors and (ii) the relation of this indicator with the average support for biomass electricity under feed-in tariff, feed-in premium and tendering system. The effectiveness indicator is assessed for biomass electricity deployment over the period 2010–2016 towards 2020 projections based on actual rates of deployment and the expected plans as they are reported in the EU countries NREAPs. Calculated for the EU over the period 2010–2016 (year 2010 as the baseline) the EI increased from 8.2% in 2011 to 52% in 2016 (Table 8).

With the current deployment rhythm, the planned 2020 figures for biomass use in electricity sector are now out-dated for some countries such as Germany, Italy, United Kingdom, Czech Republic and Estonia (Banja et al., 2017a). Germany has already reached its mid-term projections regarding the use of biomass in electricity sector (EUCO3030 scenario, 2016). Fig. 6 illustrates an example of the effectiveness indicator (cumulative %) for biomass electricity over the period 2010–2014 (including the average effectiveness indicator calculated for each year of this period) towards 2020 plans. As shown in this figure there has been a clear pattern in the relationship "support schemes – deployment", for the electricity produced from biomass over this period. The effectiveness indicator is higher for applied support in the form of feed-in tariff over the period 2010–2014.

Fig. 7[9] illustrates in indicative way the relation "average support – average effectiveness indicator" for biomass electricity over the period 2010–2014 under feed-in tariff, feed-in premium and green certificates schemes. The average effectiveness indicator, as well as the average support level, shows a broad spectrum in quantitative terms for the EU countries under consideration. As shown in this figure Germany, a country with feed-in-tariff scheme for bioelectricity, reached a level of average effectiveness indicator in 2014 slightly higher (67.4%) than that of Italy (56.4%), despite a significantly lower average support level. In Germany, the support framework has been based on a stable scheme that has seen regular updates keeping feed-in tariff as the main support scheme. In Italy, the support for bioelectricity has been mainly based on the quota system. After 2013, Italy switched the support towards feed-in tariff scheme. Moreover, the period 2008–2011 has seen a higher frequency of the system adaptation.

The applications of a support in the form of feed-in tariff in Slovakia and the combination of feed-in tariff with green certificates in the United Kingdom have resulted to produce almost the same average effectiveness indicator (at 35%) for biomass electricity in these countries. Even if Greece has applied an average feed-in tariff three times higher than France, it has a lower average effectiveness indicator over the same period, 2% compared with 4%. Greece has adapted its feed-in tariff scheme only once -in 2006- until 2015. In France, the support through feed-in tariff has seen the adaptation process in 2006 and in 2010. The application of feed-in premium[10] in Finland, similar in absolute terms with feed-in tariff applied in France, has seen a higher effectiveness indicator (30%). In Finland, the feed-in tariff system applied since 2011 has been functioning in combination with tax mechanism. Both Portugal's and Latvia's support framework has seen many system adaptations and a combination with tendering system. The feed-in tariff scheme in Ireland and Lithuania, has been a successor of a tendering system for the support of renewables. Bulgaria has not applied any change or adaptation in its support system over years. It reached a comparable effectiveness indicator (nearly 9%) with Croatia, Luxembourg or Slovenia that applied a lower average support level for each MWh.

[9] The average FIT for Greece in period 2012–2014 is calculated based on the overall amount of support for biomass electricity and the electricity generation reported in Greece's 2nd and 3rd progress reports (author's work).

[10] The average feed-in premium for Finland includes the market price over period 2010–2014.

8. Conclusions and policy implications

The EU is guiding its MS in a process towards a single European energy market and cleaner energy markets overall. The support schemes based on administrative procedures have been very successful in scaling up renewable energy deployment in the EU. Bioenergy has remained still high on the EU policy agenda. Bioenergy is the main contributor in the EU's renewable energy markets and has a large contribution potential for a low carbon economy due to the lower carbon footprint of bio-based products. In this EU policy agenda, the targets have played an important role, especially under the push of environmental constraints (phasing out coal in co-firing process), which needs to be kept as such even in post 2020 period. However, the support schemes are affected by climate conditions in a country and the physical facilities in a sector (i.e. presence of pipeline infrastructures for district heating). Also, the competition with low prices of gas used for heating or coal for power production is evident in some countries, influencing the slow deployment of biomass. The use of biomass for cooling purposes is still a small part of the bioenergy market in the EU countries and differs among countries.

All kind of measures for biomass for energy in the EU countries over the decade 2005–2015 are assessed in this paper, with a focus on the main support schemes currently in place for transport, heating/cooling and power production. Transport saw the largest number of measures applied to bioenergy, (almost 50%), followed by the heating/cooling sector (over 30%). Less than 20% were dedicated to bioelectricity, mainly to biogas and new biomass plants. The main support in the transport sector is given through biofuel obligation (mandates) and fiscal incentives (tax mechanism). The support for the heating sector is highly diverse with subsidies, tax reliefs, bioenergy schemes for the use of non-food energy crops, support for district heating systems using woody biomass, eco-funds for promotion of woody biomass, Investment grants for the production and sale of biogas, biogas market incentive program, simplification of the granting of approvals for biogas plants, etcetera. The policy support for bioelectricity is largely driven by FIT and FIP support schemes; the manure for biogas is the biomass feedstock that receives the highest average incentives in the electricity sector.

Overall, the effectiveness is found higher for applied support for biomass in the electricity sector. A stable support framework with regularly adaptations has produced the largest effectiveness with relatively low financial support per MWh German case with feed-in tariff, followed by a regularly changing support system with relative high support (Italian case). The lowest effectiveness is shown by Greece (relatively high financial support) and France (relatively low financial support). Recent developments show that shifting towards a combination of feed-in tariffs and premiums with tenders, has turned out to be faster and more flexible in adjusting support levels of costs reduction. The support shows to be most effective for the market-based mechanism, which are almost fully destined for the large-scale installations. Providing long-term contracts leads to more stability and reduces the risk in investments. Despite of these advantages, the shift towards large-scale installations carries out the risk of neglecting the small-scale options in the tendering procedures. Also, the application of fiscal incentives (energy tax and carbon tax) has been effective in some selected countries (Sweden, Finland), where the level of these taxes and the selectivity of application procedures played an important role. The use of production-based incentives has not been successful at the desired scale, for example the Renewable Heat Initiative in the UK, even though they provide support for a long period of time.

The existing RED-1 sets mandatory sustainability and GHG greenhouse gas saving criteria for liquid biofuels. For solid (mostly forest) and gaseous (mostly agricultural) biomass, the Commission issued recommendations, but these are not uniformly implemented in the EU countries. All sectors should be treated in the same way: the sustainability criteria in the EU should cover the electricity, heat and transport sectors. Notably the phasing out of coal for electricity production is one of the uncertainties. This shall impact on the use of wood and agricultural resources in medium term. The fast growth of biogas for electricity demonstrates the need to explicitly cover the environmental constraints of using agricultural feedstock in national biomass frameworks.

The analysis presented in this paper has faced limitations, predominantly related to the information that was used to compile the supported amount for each EU countries and each category of biomass for energy. These limitations are linked with the different way the EU countries reports on the quantitative support for renewables, including bioenergy, that is linked also with the diversity of support frameworks they are implementing.

A further harmonization of public support schemes for bioenergy towards a single EU cleaner energy market is recommended for near future. This harmonization has four policy implications for all EU countries. *First*, an overall comparative analysis of the efficiency of renewable energy support schemes across different EU countries is needed to streamline future harmonization, especially those for bioheat and bioelectricity (in-depth efficiency review). *Second*, those harmonized biomass schemes and measures should be formulated and funded within the framework of a new RED-2 (RED-2 integration) and could benefit additional funding via the Common Agriculture Policy (CAP), the EU's Rural Development Programs or any other related initiatives. *Third* there is need for national sustainability frameworks that are compatible with each other and with the EU overarching RED (compatible sustainability guidelines). Such schemes can be developed also in cooperation with the private sector. All three involved sectors should use local resources as much as possible, preferably forest or agricultural residues and by products for which there is no or limited competition from other users. The cascading approach is optional and could be linked to certified forest or agricultural feedstocks. *Fourth*, EU-broad research should guide the use of bioenergy at the local level, i.e. the social and economic impacts of local bioenergy compared to other energy options, as well as on the impact on the ecosystem services of related forest and agricultural sectors (local impact assessments).

Disclaimer

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Appendix A. Supplementary data

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