Valentina Dinica

BIOELECTRICITY
renewables' Cinderella in Spain, New Zealand and worldwide

Ever since the oil crises of the 1970s, governments around the world have grappled with the challenge of increasing the security of energy systems. On the demand side, policy interventions have focused on the energy efficiency of technologies, products and buildings, and on energy conservation through behavioural changes. On the supply side, the deployment of domestic renewable energy sources emerged as a logical option; this was especially encouraged in the contexts where political leaders also agreed to address the environmental impacts of energy production based on fossil fuels (air, water and soil pollution, next to biodiversity and human health impacts). The 1980s and 1990s brought about wider global concerns regarding the sustainability of development, reflected in the adoption by most governments of the 1992 Rio de Janeiro Declaration on Environment and Development and numerous other international agreements. Key among such concerns have been the depletability of natural resources, especially fossil fuels (United Nations, 1987), and the impacts of greenhouse gases on climate change. In many countries these concerns have consolidated significant societal support towards the idea of publicly subsidising the use of renewable energy resources if this is a necessary condition for a transition towards sustainable energy systems.

The renewable resources that are currently offered subsidies are solar and wind energy, geothermal, small hydropower,[1] ocean energy, and biomass, which is a common name for a wide variety of organic materials such as wood, crop and forest residues, grasses, and organic wastes from farming. A quick worldwide overview of renewables' uptake shows that the use of such resources in the total

Valentina Dinica is Senior Lecturer in Public Policy at the School of Government. Her main research interests are in the areas of sustainable energy systems, sustainable tourism, environmental policy instruments and participatory policy processes. She teaches on methods and theories of policy analysis, and governance for sustainable development.

primary energy supply increased from 0.2% in 1973 to 1.4% in 2011 (IEA, 2012a, p.7). The total primary energy supply includes all three basic forms of societal energy consumption: heat, electricity and transportation fuels. A closer look reveals that the increase in renewables' uptake has mostly come in the form of electricity generation.

More interestingly, the best diffusion results have been obtained so far by onshore wind, based on technologies emerging in early 1970s. By 2011 the worldwide capacity of onshore wind energy was 240 gigawatts (GW) (IEA, 2012b, p.13). While this is good news, another statistic is quite worrying: that biomass, the oldest energy resource humankind has used since the discovery of fire, fuelled a power capacity of only 70 GW by 2011. Coincidentally, the very same power capacity was reached by a quite recent and very expensive technology producing electricity from solar energy: photovoltaic cells. This is an intriguing situation which is replicated across continents and countries (IEA, 2012b).

The low uptake of biomass is even more surprising because biomass resources are plentiful worldwide, and some technologies available for their conversion into electricity are technically mature or close to commercialisation (Johansson et al., 1993, pp.593-651). The uptake of biomass in New Zealand reflects this worldwide situation. While New Zealand has a particularly high potential for biomass resources by international standards, which could realistically cover at least twice its 2011 electricity consumption, by that year bioelectricity (or biomass-based electricity) accounted for only 1.3%.[2]

These statistics raise several questions worth exploring in some depth. Why does bioelectricity make such a meagre contribution to national energy systems? Can we explain this exclusively in terms of the extent of public financial support offered for renewables? Given that biomass resources have significantly greater advantages than any other renewables, why would governmental support be smaller? Are governments properly informed about these advantages? What other obstacles impede the diffusion of bioelectricity, and how can governments help to remove them, so that biomass can contribute to the sustainability of energy supply systems to their full potential?

This article tackles such questions by means of a longitudinal case study examining the diffusion challenges of bioelectricity in Spain between 1991 and 2011. This timeframe is relevant for New Zealand, because the extent of bioelectricity diffusion in New Zealand by 2011 was similar to that of Spain in 1991, with, in both cases, only 107 MW (megawatts) of capacity installed (Dinica, 2003, p.321; Ministry of Economic Development, 2012, p.113). Moreover, the same types of resources are now used in New Zealand as were used in Spain two decades ago: biogas (40 MW) and wood residues (67 MW). The Spanish case study offers the New Zealand government and energy stakeholders a look into a possible, bleak future for bioelectricity in this country, unless political and societal efforts are mobilised to tackle diffusion obstacles properly.

One can argue that the story of bioelectricity in Spain is a diffusion failure story because, after two decades of governmental financial and policy support, by 2010 the installed capacity was only 706 MW (Tena, 2012, p.36). By comparison, the intermittent wind technology reached 20,744 MW over the same timeframe. Solar photovoltaic technology accounted for 3,787 MW, its diffusion having started in 2004 (*Plan de Acción por las Energías Renovables*, 2010, pp.470-1). This diffusion result needs to be seen in the context that Spain has the third largest biomass potential in the European Union. In 2010 bioelectricity represented just 5.5% of Spain's electricity consumption, while its biomass potential could supply almost all annual electricity needs.[3] By exploring this case study, this article aims to improve the understanding of biomass resources and bioelectricity among the New Zealand public and decision-makers, and to generate policy lessons on the types of governmental interventions needed to avoid similar disappointing statistics in the decades ahead.

But what exactly are biomass resources, what is bioelectricity, and why are they important from a sustainability standpoint? These questions are addressed in the next section. Biomass is the most complex renewable energy resource, and its transformation into electricity can be achieved by means of a diversity of old and new technologies. The next section introduces the Spanish case study, focusing on the political aspects of the public support for bioelectricity. This ushers in a discussion of the diffusion obstacles on the demand side and on the supply side of bioelectricity production. In this context I examine the legal and policy interventions adopted so far, their effectiveness, and the extent to which the most recent policy commitments have actually been implemented. The article concludes with reflections on the need for policy innovations in New Zealand to support bioelectricity diffusion.

Biomass resources, bioelectricity and benefits of their use

Biomass is basically solar energy captured and stored by plants as chemical energy by means of photosynthesis. When we burn

While New Zealand has a particularly high potential for biomass resources by international standards, which could realistically cover at least twice its 2011 electricity consumption, by that year bioelectricity (or biomass-based electricity) accounted for only 1.3%

plants, we destroy their internal chemical connections, and this process generates heat. Fuelwood is the most widely known biomass resource, used for millennia for cooking and heating purposes. However, plants are consumed by animals and humans, which means that farming and other human activities also produce biomass resources.

In modern societies, biomass energy resources are often grouped into two categories according to their energy content: primary and secondary resources. Secondary resources are organic wastes from industrial or agricultural applications. They can be generated by, for example, the paper and furniture industries, the food and drink industries, farming companies (generating animal manure that can be transformed in biogas), sewage/wastewater treatment stations, and solid wastes disposal sites (generating landfill gas). These resources are called secondary because their organic content was already harnessed once in various non-energy applications. They still have a useful residual organic content which can be extracted for energy purposes, but it is generally inferior to that of primary resources. Primary biomass resources are considered to be forest and agricultural wastes, industrial organic wastes or residential wastes (mowed grass) that have not been used in any way previously (never been exposed to chemical/thermal treatment). They are also sometimes referred to as clean resources. This category also includes existing (commercial) forest stocks and dedicated energy crops: i.e. plants or trees grown for the purpose of harnessing their energy content. Thus, biomass is a heterogeneous resource which comes in a diversity of forms, costs and energy values.

But is biomass a sustainable energy resource, in terms of resource depletability? Secondary biomass is produced by human activities and so its exhaustablility is less of a concern. Primary biomass, however, is a renewable resource (and climate neutral) only insofar as its consumption rate is lower than its production rate. This is why biomass energy planners give priority to the use of certain crops and tree species which grow very fast. Given the importance of the consumption rate, societies should also strive to promote the use of energy technologies with a high efficiency of biomass conversion into energy services.

Bioelectricity can be produced using four different technological principles for electricity generation. Direct combustion and anaerobic fermentation are commercially mature technologies. The problem with direct combustion, however, is its low efficiency, typically between 5% and 28% (Johansson et al., 1993). Higher efficiencies can only be obtained for plants with a generating capacity larger than 50 MW. When combustion takes place in co-generation plants (which supply to consumers both electricity and heat) the combined efficiency increases to 50–80% (Carrasco, 2002). Anaerobic digestion results in a biogas which contains high levels of greenhouse gases like methane and carbon dioxide. That biogas can be burnt with energy conversion efficiencies varying between 27% and 60%.

A promising group of technologies, referred to as gasification technologies, are able to transform biomass into combustible gases. They emerged in the 1970s and can reach efficiencies of 40–50% when large-scale projects are possible (Hume, 2005, p.8; Carrasco, 2002). However, they are more expensive and are best used in combination with primary biomass resources, given their superior energy content, to make an investment economically worthwhile. Likewise for the fourth technological principle, pyrolysis, which involves the transformation of primary sources into bio-oil. This can be used either for electricity generation or as transportation fuel. While pyrolysis is the most promising technology, with efficiencies of bio-oil production expected of around 80%, it is still in the development stage and very few governments around the world are committed to financially supporting it (Carrasco, 2002). Gasification technologies are also in need of technical improvements, but their development is closer to commercialisation than pyrolysis.

Bioelectricity scores particularly high on the social and economic dimensions of sustainable development, compared to the other renewables, while having several unique environmental benefits

The above considerations on resource availability are embedded in the wider concept of sustainable development. Seen at the societal level, sustainable development has been defined as the type of development that meets the needs of current societies without compromising the ability of future generations to meet their own needs, social, economic and environmental (United Nations, 1987). The societal diffusion of any individual renewable energy technology has benefits along each of these mutually-influencing dimensions of need. Looking at renewable energy metaphorically as a 'family' of resources, one could argue that bioelectricity is the most generous of all renewable energy sisters in terms the societal and ecological benefits it offers. Bioelectricity scores particularly high on the social and economic dimensions compared to many other renewables, while having several unique environmental benefits. For example, bioelectricity production based on secondary resources avoids the emission of greenhouse gases from the organic wastes unwanted for any other economic applications. This has an economic value when markets for the trade of greenhouse gas emission rights exist, as in the EU. Moreover, bioelectricity reduces environmental pollution from industrial and agricultural activities, the contamination of soils, water and air. These benefits are additional to the benefits all renewable energy sources bring by avoiding the environmental impacts of the displaced fossil fuel technologies.[4] The use of primary resources combats soil erosion and can help restore degraded and abandoned lands.[5]

The social benefits are also considerable, as bioelectricity generates the highest employment per installed megawatt capacity of all renewable energy sources. For example, in Spain in 2011 bioelectricity plants created 22.3 new permanent jobs per megawatt installed (APPA, 2011a). The lowest employment is generated by wind energy and solar photovoltaics (Johansson et al., 1993). For bioelectricity, higher employment is generated not only in the construction phase but also (and especially) in the exploitation phase. The economic supply chain of biomass is very long and includes collection, processing, transport, transformation in feedstocks and storage. The supply chain of biomass can re-boost rural socio-economic development, offering jobs for people with lower qualifications. Another unique benefit is that the use of clean agricultural and forest residues reduces the risk of fires, which is significant in both Spain and New Zealand, and likely to increase with climate change.

In addition, biomass is the most hard-working of all the renewable energy sisters. A biomass power plant can operate for 8,000 hours per year, while most good sites for wind or solar power hardly enable operation for a third of this time. Biomass is also the most reliable of them because it can be generated continuously. It does not need expensive batteries for stand-alone applications, and it can even be used to cover peak demand. It is worth noting, finally, that biomass is the only resource that can serve all three basic forms of societal energy needs: heat, electricity and transport fuels. In the latter case, biomass is transformed into oils referred to as biofuels, such as bio-ethanol (from corn or sugar cane). Governments worldwide are very interested in biofuels, given the limited options for sustainable transport fuels. However, some scientists believe that the use of electric vehicles based on bioelectricity is a superior long-term solution. Campbell et al. (2009, p.1055) stated in the journal *Science* that:

> bioelectricity outperforms (bio-) ethanol across a range of feedstocks, conversion technologies, and vehicle classes. Bioelectricity produces an average of 81% more transportation kilometers and 108% more emissions offsets per unit area of cropland than does cellulosic ethanol. These results suggest that alternative bioenergy pathways have large differences in how efficiently they use the available land to achieve transportation and climate goals. (Campbell et al., 2009, p.1055)

Table 1: The increase in power capacity 1991–2010

Year	1991	1995	1998	2000	2005	2010
installed capacity (MW)	107	152	188	217	486	706

Source: IDAE, 2007; *Plan de Acción de Energías Renovables*, 2010

... taking a long-term view, bioelectricity is the most worthwhile of the three basic forms of societal energy needs that biomass resources could support: heat, electricity and transportation fuels

A significant factor in the superiority of bioelectricity is that electric vehicles are much more efficient than internal combustion engines. Biofuels could therefore be viewed as a transition pathway towards a future where the use of electric vehicles based on renewable electricity is dominant, and in which bioelectricity plays an important role.

Consequently, taking a long-term view, bioelectricity is the most worthwhile of the three basic forms of societal energy needs that biomass resources could support. This makes the examination of the obstacles to bioelectricity diffusion even more compelling.

The political dimensions of bioelectricity diffusion in Spain, 1991-2011

In contrast to New Zealand, which is rich in both renewable and non-renewable resources, Spain has the highest dependency on imported energy resources in the EU: about 80–82%. Having been severely hit by the oil crises of the 1970s, most governments pursued policies aiming to promote domestic energy resources for security of supply. The Spanish governments seem to have been aware, already in the 1980s, of many of the benefits of bioelectricity discussed above. This can be seen in the introduction of legal instruments to offer bioelectricity financial support, and in the national plans for renewable energy. The first ones, adopted up to the mid-1990s, mentioned the potential of bioelectricity to reinvigorate the struggling agricultural sector, and the employment benefits. Later, other benefits were acknowledged as justification for increasing the social tariffs paid to renewable electricity. The avoidance of soil erosion, fires, environmental pollution and greenhouse gases were considered particularly important (APPA, 2004).

The acknowledgement of these benefits was, however, not reflected in an attractive legal framework offering bioelectricity production sufficient and reliable financial support to make projects economically feasible. Table 1 gives a snapshot of installed capacity increases since 1991. The pace of diffusion has been very slow, reflecting, among other things, the very incremental improvements in the legal framework for economic support over the past two decades (discussed in the next section).

The governmental targets for bioelectricity have never been achieved, and have been continuously trimmed back. The target set in the 1999 government plan for the support of renewable energy was to develop 5,311 MW by 2010. This was later downgraded twice, to 1,695 MW by 2010. The latest plan of action for renewable energy aims for an installed capacity of only 1,350 MW by 2020. Of all renewable energy resources, biomass is the only one that was subjected to consistent and significant government cut-backs in targets. This suggests a limited political commitment on the part of the Spanish government to bioelectricity, which can also be seen in financial terms. The production subsidies offered during 2010 to all 'renewables sisters', totalled €5.1 million. Of this, only 5.2% went to bioelectricity. Solar photovoltaics received the highest support, with 48.5% of the budget, followed by wind energy with 36.5%; the late-comer, solar thermoelectric technology, was given 3.8% of the budget; the remaining 6% went to small hydropower plants (APPA, 2011a, p.100).

While solar energy has indeed a large potential in Spain, it is still much more expensive than bioelectricity, even when primary resources are used. It also generates the lowest employment per unit of capacity installed (APPA, 2011a), and it is intermittent. Wind energy is also intermittent and experts estimate that, given technical features of the grid infrastructure, Spain can only accommodate about 30% of wind energy in the electricity system (Menendez, 1998). This is equivalent to around 33,600 MW of wind power, of which two-thirds have already been installed. Returning to the metaphor of the renewable energy sisters, in the light of the relative benefits discussed earlier, one cannot help but see bioelectricity as the family's Cinderella.

Having studied the situation of renewable energy sources in Spain extensively since late 1990s, it appears that three main reasons underpin this limited political commitment. First, of all benefits the Spanish government prioritised security of supply, and later the reduction of greenhouse gases, meaning that the overall target for renewal energy was more important than the targets per renewable energy type. Besides, the EU targets on renewable electricity per country have always been aggregated for all renewable energy sources. As wind turbines and solar technologies do not have a supply side that needs government intervention for development, and are technically easy to install, they have been seen as easier options to increase the share of renewable energy in the electricity system in short–medium term.

Decision-makers have been very slow to learn about the diversity and costs of biomass resources, ... which have consequences for the economic feasibility of bioelectricity projects.

Second, decision-makers were interested in helping Spain become a world leader in the manufacturing of at least one renewable energy technology that was most likely to be of interest to governments worldwide (Dinica, 2003). It was considered in the early 1990s that wind technology was the closest to commercialisation, and that it was worth trying to stimulate the emergence of a strong Spanish industry for the manufacturing of wind turbines and all necessary equipment. By subsidising the production of wind power quite heavily, and requiring all foreign manufacturers to establish joint ventures with Spanish companies with production facilities in Spain if they wished to qualify for production subsidies, the Spanish government was very successful towards this goal (Dinica, 2003). Hence, the preference so far was to create employment by developing new manufacturing industries, as many industrial corporations (active in the areas of ammunition, aviation, mechanical equipment, etc) were facing dwindling demands and close-downs. The same industrial strategy can now be seen in the extensive production subsidies for solar technologies.

The third reason has to do with learning processes in the public sector. Decision makers have been slow to learn about the diversity and costs of biomass resources, the development needs of the more efficient resources and technologies, and the complex interactions between resource types, electricity technologies and project sizes, which have consequences for the economic feasibility of bioelectricity projects. This learning is illustrated below. While policy learning has been much faster among governmental officials, the electoral cycle typically makes learning among politically-elected decision-makers more time-consuming. This is a general problem for sustainable development challenges which are particularly complex, requiring political leadership for a whole-of-government approach.

Thus, when put in perspective the Cinderella treatment of bioelectricity in Spain can be rationalised to some extent. The following section explains the main features of the legal frameworks for price support adopted over the past two decades. This helps to understand the magnitude of (and changes in) the economic and financing obstacles.

Diffusion obstacles on the demand side of bioelectricity production in Spain

An energy conservation law was put in place in 1980 which guaranteed grid connection, along with some undisclosed financial support per kilowatt hour (kWh) supplied to the grid as excess by independent power producers. This was perceived by potential commercial investors as highly unreliable, as they prefer to see in legislation the price per kWh offered – referred to as social tariff or premium – and a specified contract length, ideally as long as the plant's economic life (Dinica, 2006). It took stakeholders a very long time to persuade decision-makers that only such legislative specifications would raise enough investment interest among commercial and financing agents to achieve the objectives for installed capacity increase for bioelectricity. Up to 2011 there were many improvements in the legal framework in these two respects. However, in contrast to all other renewable energy sources, the improvement on the social tariff/premium offered for bioelectricity has been very slow.

In 1994 the Spanish authorities took the first steps towards liberalising the electricity industry, adopting a new electricity law and a special royal decree for renewable energy sources. Addressing the concerns of interested commercial agents, the law stated that contracts with independent power producers would be guaranteed for a minimum of five years. In addition, it removed the reference to excess electricity, which meant that only self-generators would be eligible for economic support. The decree introduced clearly specified feed-in tariffs per kWh, differentiated per renewable energy type, but failed to differentiate between secondary and primary resources. The price support offered in 1994 was hardly relevant for bioelectricity production (about a third to a half of the costs of production based on primary resources at that time). By 1998, three-quarters of the installed capacity used secondary resources. The dominant resources were biogas and industry wastes, which helped project owners avoid environmental charges (Dinica, 2003, pp.317-62).

The industry liberalisation project was completed with the 1997 electricity law, followed by another special decree for renewable energy sources in 1998. This new legal framework introduced market spot prices at generation level, giving renewable electricity producers two options: stay with contractually-guaranteed feed-in tariffs, or trade electricity in the spot market and receive a social premium on top of the spot price. Given that social premiums were higher than tariffs (to reflect the higher risk taken by investors), most large investors have opted for social premiums. Another change was the differentiation between primary and secondary biomass in the new decree. The price support offered per kWh increased for the tariff option, but insignificantly. The government preferred to make use, complementarily, of investment subsidies, targeting projects based on gasification and/or primary resources (offering maximum 30% of investment costs).

Table 2: Primary biomass resource potentials and costs, assuming 45% humidity

Resources types		Potential MTOE/year[6]	Average cost €/ton
Existing forest stocks	Woody wastes	0.6	26.6
	Harvest of existing trees commercially available	3.4	43.2
Agricultural wastes	Plant wastes	6.4	20
	Woody wastes		
Energy-dedicated agricultural plant-crops		3.6	45.6
Energy-dedicated forests on agricultural lands		1.5	34.7
Energy-dedicated new forests on 'forestry lands' (hills, mountains)		1.8	42
Primary biomass potential in Spain		17.3	–

Source: *Plan de Acción de Energías Renovables*, 2010, p.165

A follow-up decree, adopted in 2004, finally differentiated more meaningfully among ten types of biomass resources, three primary and seven secondary. A small price increase was given to investors choosing the premium option. The price difference between primary and secondary resources for the tariff option remained insignificant. Only very small increases in the tariff levels were allocated. The second important change in the 2004 decree was the introduction of long-term contracts for power purchase, set at 20 years. This was applicable only for primary and biogas resources.

The most recent change in the legal framework happened in 2007, when the level of price support became more realistic, given the expense of primary biomass resources (see Table 2). Secondary biomass was given between 7 and 11.3 euro cents/kWh, and primary biomass between 11.3 and 15.5 euro cents/kWh (*Plan de Acción de Energías Renovables,* 2010). The contractual guarantee lowered to 15 years for any new project. This is a setback, but still better than what was offered in the past. Overall, the legal frameworks of the 2000s have slowly increased the price support levels, which can be seen in a transition towards the use of primary biomass. By 2011, half of the installed capacity mixed secondary with primary resources, and 20% was exclusively based on primary resources (APPA, 2011b).

Nevertheless, the 2007 price increases are still not high enough. The estimates of the government energy agency IDAE show that many resource/technology/size combinations of projects are still uneconomical (*Plan de Acción de Energías Renovables,* 2010, pp.169-73). Finally, the low levels of price support have resulted in investments that overwhelmingly use the two older technological principles described earlier: anaerobic digestion and direct combustion. By 2011, four small experimental projects were using the gasification technology (APPA, 2011b),

biomass is the only renewable energy source that has a supply side. ... Its development requires policy innovation within, and coordination across, many institutional, legal and policy frameworks in policy domains that have so far evolved outside the scope of energy policies.

Table 3: Size of bioelectricity projects

Size of project	2002	2011
<1 MW	23%	24%
< 10 MW	49%	47%
< 30 MW	26%	24%
> 30 MW	2%	5%

Source: based on Dinica, 2003 and APPA, 2011b.

but there were no projects based on pyrolysis for electricity (only for biofuels, which receive much higher subsidies). Overall, the legal frameworks applicable for bioelectricity since 1990 aiming to address the economic obstacle have improved in the two main aspects of interest for commercial agents, banks and insurers: length of contractual guarantee and extent of price support. However, the pace of improvements has been too slow and they have enabled only a small number of projects to be profitable.

In addition, bioelectricity developers also encountered serious financing obstacles, given the policy-related risks to the economic feasibility of projects. These were especially high during the 1990s, before the long-term contractual guarantee was introduced. About three-quarters of the projects developed in that decade used internal financing schemes: either the financial resources of developers or corporate loans (with loans given against various assets, such as buildings, not related to the energy project). In the early 2000s banks started to approve project finance loans, whereby the loan is given against the energy project itself. Nevertheless, the financing terms offered by banks for project finance loans are much harsher than for other renewables. Banks offer less money for bioelectricity, often only a third of the investment, and often require the loan to be paid back much faster. This suggests that the financial reserves on which bioelectricity plants could draw over the past two decades has been very limited, contributing to the explanation for the small capacity increase by 2010. The availability of project finance loans is crucial for a significant and sustained diffusion of any renewable energy technology (Dinica, 2003). By comparison, the diffusion of wind energy in Spain could only catch speed when the improvements in the legal framework for price support made project finance loans possible for most investors at attractive financing terms.

Bioelectricity has not experienced such a success story so far. The improvements in price support and contractual guarantee came late. In 2009 the European financial and sovereign debt crises began. In January 2012 the government took the radical decision to stop guaranteeing any new contracts and production premiums/tariffs to renewable energy generators. This led the industry into a sudden hibernation stage, while the government works on a new strategy for the electricity sector.

It was mentioned earlier that biomass is the only renewable energy source that has a supply side. This side is more complex, in terms of policy interventions and public sector coordination needs, than the demand side. Its development requires innovation within, and coordination across, many institutional, legal and policy frameworks in policy domains that have so far evolved outside the scope of energy policies. One useful indicator of diffusion patterns which enables analysts to gauge the magnitude of supply-side obstacles is that of project sizes. This is a useful indicator because biomass projects have large economies of scale. Their production costs only start to decrease significantly for projects larger than 30 MW capacity (Carrasco, 2002). Whenever we observe predominantly small projects, this may indicate financing obstacles (banks do not lend too much money because of various risk perceptions), resource market obstacles or both.

In 2011 a review was carried out of all bioelectricity plants owned by members of the Spanish Association of Renewable Electricity Producers (APPA, 2011b).[7] Almost three-quarters of the APPA projects operating in 2011 were small, as shown in Table 3. An earlier study found very similar project sizes in 2002 (Dinica, 2003, p.336). This suggests that there has been no meaningful alleviation of resource market obstacles, since it is known that some improvements in the financing opportunities did emerge over the past seven–eight years. The next section reviews some key obstacles to the emergence of biomass resource markets, the policy interventions needed, and the latest government commitments.

Diffusion obstacles at the supply side of bioelectricity production in Spain

Lack of awareness and/or confidence in the energy business among potential resource suppliers

Most potential suppliers of biomass (as raw resources, or in their processed form as feedstocks) are unaware or distrustful of the new business opportunity because this is very different from their established operational niche. This holds for farmers, public agencies managing public lands, industrial companies and other private actors (*Plan de las Energías Renovables*, 2005). For example, farmers are hardly willing to switch to dedicated energy crops when they do not understand the costs involved or the growing requirements, and there are no reference or average prices in the market. All farmers are producers of primary agricultural residues. However, they are typically reluctant even to respond to offers of contacts from interested power producers (Dinica, 2003).

Building new business relations among completely different commercial actors in a short to medium term may require a combination of direct regulations and communication instruments. The latter should focus on awareness-raising, but also capacity-building (e.g. through workshops and guidelines) towards an understanding of the economics and technicalities of supplying clean residues and (plant/woody) energy crops. They could also focus on the options to become involved in processing mechanically/thermally such resources and storing and transporting them (as, in such cases, vertical integration comes with better profits); likewise for industrial/forestry residue owners, and for equipment/technology companies looking for new business opportunities.

The three renewable energy policy plans adopted in the 2000s envisaged this, but implementation has been limited, as the allocated budgets were small (*Plan de Acción de Energías Renovables,* 2010; *Plan del Fomento de las Energías Renovables,* 1999; *Plan de las Energías Renovables,* 2005).

Examples of direct regulations are those proposed by APPA, but not yet adopted or implemented (e.g. APPA, 2004; Garcia, 2010). First, given the fire risk and the diffused environmental pollution they cause (air, soil and water), any generator of primary residues (agricultural/forest) could be obliged (and possibly subsidised, unless bioelectricity remuneration increases) to collect all or a quota of such residues from their lands and offer a minimum quota for electricity generation within Spain. More than 25 million tons of agricultural residues ends up in landfills annually (*Plan de Acción de Energías Renovables,* 2010). This intervention would also address the problem that most such residues that do not end up in landfills are sold for thermal applications or industrial applications (paper, furniture), domestically and in the EU (*Plan de Acción de Energías Renovables,* 2010). The direct regulations would apply for all forests (as 70% are in private ownership), unless there are ecological considerations from the Environment Ministry. Given the high fragmentation of private forest ownership, there is a role for public authorities to facilitate the emergence of associations/cooperatives for the energy management of biomass resources (Tena, 2012, p.56). It is estimated that a significant use of clean residues would avoid 50–70% of the annual fires (Garcia, 2010, p.19). APPA also suggests a drastic increase in the charges for environmental pollution through residues.

Such instruments require planning and policy integration efforts from several ministries, with competences on agriculture, trade, industries, forestry, land management, energy and environmental management. But they also require the involvement of sub-national authorities and integration into their legal/policy frameworks. Acknowledging the importance of policy coordination across a wide range of ministries, in 2005 the government set up an Inter-ministerial Committee for Biomass (*Plan de Acción de Energías Renovables,* 2010). This would be a suitable institution to consider such instruments. So far the committee's work has been limited, due to low budgets, but the 2010 plan aims to reinvigorate its activities and competences.

The legal framework for the location and extraction of forest residues already exists through the 2003 law of mountains, but implementation is needed to support the above-suggested direct regulation instruments. The reason for this implementation delay is that public authorities for forest management are uncomfortable with the expectation to extend their legal/policy frameworks to the area of energy policy to facilitate biomass supply. They are unaccustomed to planning and acting based on energy-use criteria (*Plan de las Energías Renovables,* 2005). As regards the emergence of dedicated energy crops, APPA suggested their introduction as compulsory crops in the national programme for crops rotation, aiming to address soil quality issues (Garcia, 2010, p.19). Additionally, the industry suggested the exemption of all biomass products from product taxes, which are the highest in Europe at 18% (Tena, 2012, p.58).

Bioelectricity could be deployed to help New Zealand shift to 100% renewable electricity generation within several decades, and ... facilitate a shift to electric vehicles in the longer term.

Uncertainties about the contractual arrangements for resource supply

Numerous electricity investors have been concerned with the risks associated with biomass resources, given their large spatial distribution, quality variability and the need to contract with many suppliers and storage companies offering resources at various times of the year (*Plan de las Energías Renovables,* 2005). In 2004, the Ministry for Agriculture and the Ministry for Industry responded by developing a standard contract suitable for contracting with large numbers of resource suppliers. Such contracts are meant to ensure power producers a long-term, low-risk supply of sufficient biomass resources at predictable prices.

Expensive foreign technologies are needed to collect and process biomass into feedstocks

Many mechanical and thermal processes are involved in the production of feedstocks for power plants. Improvements are still needed in many aspects of resource collection, transport, storage and processing (Tena, 2012). Storage without loss of energy value is a significant challenge, given the seasonality of biomass production and its vulnerability to decay. These factors affect both the size and reliability of resource markets. In 2005 the government promised financial support for investors in relevant equipment, companies and infrastructures (*Plan de las Energías Renovables,* 2005). Due to budgetary constraints, this policy programme was hardly implemented, and was reintroduced in the 2011–20 plan.

In addition to logistical obstacles, there are administrative obstacles here too. Sub-national authorities are still to design special permitting procedures for the new types of economic activities and agents involved in the supply and processing of biomass resources. In addition, permitting bioelectricity projects currently requires the involvement of numerous national and sub-national authorities, as the entire biomass supply chain needs to be considered and bioelectricity production cuts across many policy domains. The new Inter-ministerial Committee for

Biomass could draft a special permitting process, to be implemented either by itself or by a dedicated national bioelectricity committee, until sub-national authorities are able to set up their own integrated procedures and legal frameworks.

With the freezing of the legal framework for price support in January 2012, the policy gap for bioelectricity diffusion has widened. The renewable energy industry is now holding its breath to see how the Spanish government is planning to rescue the country from the financial crisis, and which roles renewable energy resources could play in Spain's economic recovery, security of energy supply and environmental quality.

... the Spanish experience suggests that in order to address the economic obstacle, independent power producers should be offered feed-in tariffs guaranteed for a minimum of 15 years. ... The levels of feed-in tariffs have to reflect the real production costs of the biomass resources

The New Zealand energy system and policy context surrounding bioelectricity production

New Zealand is blessed with many types of renewable energy source, each having significant energy potential. Currently more than three-quarters of the country's electricity production comes from renewable resources, primarily large hydropower, geothermal power and small levels of wind energy. The government energy strategy aims to lift renewables' contribution to 90% of electricity consumption by 2025. Of all renewable electricity technologies, over the past years the government supported financially only the emergence of marine energy technologies. This article has made the case for bioelectricity, which has so far not received any (consistent) form of financial support in New Zealand. The experiences with biomass diffusion in Spain offer decision-makers and stakeholders in this country significant policy lessons. These deserve special consideration when designing legal and policy frameworks for the support of bioelectricity, once the necessary societal and political support is mobilised towards this promising technological option.

A large research project under the leadership of Scion[8] carried out an assessment of New Zealand's resource potential for biomass. It elaborated various scenarios, assuming several options for the percentages of biomass with energy applications (25%; 50%; 100%, relative to other industries), and the land possibly available (for both primary and secondary resources). Estimates show that for a minimum land use of 830,000 ha and a 25% use of biomass for energy, the potential would be 1.4 MTOE (million tons of oil equivalent) per year; for a maximum use of the available land considered, 5,100,000 ha, and a 100% deployment of biomass for energy purposes a potential of 34.46 MTOE/year emerges (Hall and Gifford, 2007, p.68). The maximum potential is seven times larger than the country's electricity consumption in 2011 (of 4.81 MTOE: Ministry of Economic Development, 2012).

Currently New Zealand uses large amounts of biomass, but mainly for heat applications in industries and households (Scion, 2009). While policy plans and commercial interests envisage a high future use of biomass for biofuels and thermal energy, clearly there is also potential for a significant production of bioelectricity in New Zealand. Bioelectricity could be deployed to:

- help New Zealand shift to 100% renewable electricity generation within several decades;
- meet future increases in electricity demand;
- help households and industries (whenever possible) to switch away from the current energy-inefficient and air-polluting heat generation systems (whenever their conversion efficiencies are lower than what could be obtained through commercially mature technologies); and
- facilitate a shift to electric vehicles in the longer term.

The Spanish experience shows that the organisation of biomass resource markets is a long-term nationwide project, requiring significant policy integration, alongside adequate legal/policy frameworks targeting the most fundamental of obstacles: economic and financial. New Zealand's policy framework for bioelectricity is currently limited to information supply and some technical guidelines. The 2011 national policy statement in renewable electricity generation focuses on the planning and permitting of renewable energy projects. However, looking at the diffusion obstacles for bioelectricity, this framework is unlikely to lead to anything but some niche projects, mostly for self-generation purposes, as long as resource markets are not in place and projects are not economically feasible.

If the New Zealand government decides that bioelectricity is a worthwhile technology which merits being supported with public funds, the Spanish experience suggests that in order to address the economic obstacle, independent power producers should be offered feed-in tariffs guaranteed for a minimum of 15 years, and ideally 20 years. This approach is more desirable than using premiums/kWh on top of spot prices, because the social costs of diffusion are lower (Dinica, 2003).[9] The levels of feed-in tariffs ought to reflect the real production costs of the biomass resources the government aims to support, and this has to be investigated before any legal price support system is put in place.

Additionally, it would be highly desirable to engage the finance and insurance communities in diffusion processes: for example, by regularly organising workshops to explore the particularities and opportunities of bioelectricity, in relation to all possible risks, including political. Innovative and efficient technologies like gasification and pyrolysis are worthy of development and demonstration subsidies. When all this is properly done, the demand-side legal/policy framework needs to be matched by a comprehensive supply-side framework, capable of mobilising the human, entrepreneurial, administrative and physical resources needed for the development of reliable, high-quality biomass energy products and markets.

1 Large hydropower plants are typically excluded from public financial support as they are already competitive with fossil fuels.
2 These are estimates based on Hall and Gifford (2007, p.68) and Ministry of Economic Development (2012).
3 These are estimates based on IDAE (2010) data.
4 Bioelectricity plants do have some air emissions, while the cultivation of certain energy crops leads to environmental and greenhouse gas impacts that are of some concern. However, scientists are working on minimising these impacts and new crops are already under testing, such as the fast-growing switchgrass which demands less fertilizer. In long term, the agricultural, mechanical and transport equipment could be switched to bio-fuels and even bioelectricity (see below).
5 The application of biomass resources for energy purposes has often been criticised for reducing the potential for food crops. While this is a challenge in some developing countries where the cultivation of energy crops for biofuels was attempted, the reality in most OECD countries is that significant land areas are uneconomic for the current food prices and lay abandoned. For worldwide land potentials see Johansson et al., 1993, pp.593-651; for New Zealand see Hall and Gifford, 2007, p.68).
6 MTOE stands for million tons of oil equivalent. To put the potential of primary resources into perspective, in 2010 Spain's electricity consumption was 21.7 MTOE (*Plan de Acción de las Energías Renovables,* 2010).
7 Their investments total 510 MW, while by 2010 there were 706 MW operating.
8 The Crown research institute with expertise in forestry: http://www.scionresearch.com/general/about-us.
9 When contractual/delivery risks are high, this is reflected in higher interest rates on loans (because of higher financing risks). To make projects economically feasible, this needs to be reflected in high premiums, which will be passed on to consumers anyway.

References

APPA (2004) *Plan de Accion para la Biomasa*, Madrid: Association of Renewable Energy Producers

APPA (2011a) *Estudio del Impacto Macroeconomico de las Energías Renovables en España*, Barcelona: Association of Renewable Energy Producers

APPA (2011b) *Biomass: inventorio de plantas* 2011, Barcelona: Association of Renewable Energy Producers

Campbell, J.E., D.B. Lobbel and C.B. Field (2009) 'Greater transportation energy and GHG offsets from bioelectricity than ethanol', *Science* (5), pp.1055-7

Carrasco, J. (2002) Personal communication with biomass expert at the Center for Energy, Technology and Environmental Research, Madrid, 12 April

Dinica, V. (2003) *The Sustained Diffusion of Renewable Energy: politically defined investment contexts for the diffusion of renewable electricity technologies in Spain, the Netherlands and United Kingdom,* Enschede: Twente University Press

Dinica, V. (2006) 'Support systems for the diffusion of renewable energy technologies – an investor perspective', *Energy Policy*, 34 (4), pp.461-80

Garcia, M. (2010) 'APPA pide al govierno una mayor implicacion en el dessarollo de la biomassa', in *APPA Info, March*, pp-18-20

Hall, P. and J. Gifford (2007) *Bioenergy Options for New Zealand: a situation analysis of biomass resources and conversion technologies*, Rotorua: Scion

Hume, D. (2005) *The Uptake and Cost of Alternative Generation in the Auckland Region: a report to the Electricity Commission*, Auckland

IDAE (1997) 'Energía de la biomasa en España', *Era Solar,* 87, pp.20-8

IDAE (2007) *Biomasa: producción eléctrica y cogeneración*, Madrid: Instituto de Diversificacion y Ahorro de Energía

IEA (2012a) *Key World Energy Statistics*, Paris: International Energy Agency

IEA (2012b) *Medium-Term Renewable Energy Market Report,* Paris: IEA

Johansson, T.B., H. Kelly, A.K.N. Reddy and R. Williams (eds) (1993) *Renewable Energy Sources for Fuels and Electricity,* Washington: Island Press

Menendez, E. (1998) *Las Energías Renovables: un enfoque politico-economico,* Madrid: Los Libros de la Catarata

Ministry of Economic Development (2012) *Energy Data File,* Wellington: Ministry of Economic Development

Plan de Acción de Energías Renovables 2011-2020 (2010), Madrid

Plan del Fomento de las Energías Renovables 1999–2010 (1999), Madrid

Plan de las Energías Renovables 2005–2010 (2005) Madrid

Stevenson, T. (2010) *Analysis of Barriers to Distributed Generation (DG): a report prepared for the Energy Efficiency and Conservation Authority,* Wellington: EECA

Scion (2009) *Bioenergy Options for New Zealand: transitions analysis – the role of woody biomass from existing plantation forests, species options and drivers for change in energy supply,* Wellington: Scion

Tena, E.C. (2012) *La biomasa en España: una fuente de energía renovable con gran future,* Madrid: Fundacion Ideas

United Nations (1987) *Our Common Future: report of the World Commission on Environment and Development,* New York: United Nations

Waste Solutions Ltd (2007) *Bioenergy Resource Assessment: municipal bio-solids and effluent and dairy factory, meat processing and wool processing waste,* Wellington: Waste Solutions