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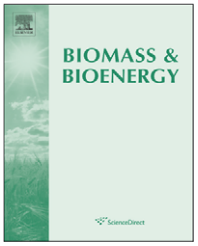

The effectiveness of policy instruments in promoting bioenergy

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ABSTRACT

Bioenergy could make a significant contribution in reducing greenhouse gas emissions in Europe and is unique in its potential to service all three of the major energy demand sectors for heat, electricity and transport fuels. Consequently during the last two decades many different initiatives have been launched and policy instruments employed in different countries to develop the bioenergy sector, some of which have been more successful than others.

This paper analyses the relationship between the growth of bioenergy in four European states and national energy policy. The policy instruments used are critically evaluated alongside the evidence base of bioenergy capacity and output achieved. The possible reasons for success or failure of different instruments and any unexpected impacts are discussed and some general conclusions drawn.

1. Background

Thermalnet is a closely integrated cluster of three networks on thermal processing of biomass for fuels and electricity, supported by the European Commission, which aims to address technical, non-technical and commercialisation issues. At a Thermalnet workshop in France in 2005 the participants (from a cross-section of European industrial and research institutes) identified energy policy as the single most important barrier preventing expansion of the bioenergy industry. Investigation of the role of energy policy in bioenergy development was therefore prioritised and a comparative evaluation of current and historic bioenergy policy in four European countries was carried out, analysing the policy instruments that had been used in each country, their success or otherwise, the reasons behind this and what implications this might have for future initiatives.

2. Methodology

The history of bioenergy development and policy context was examined in Germany, Italy, UK and Sweden. As shown in Table 1, these range from limited to significant biomass resources; include industrial waste wood, agricultural waste and energy crops; policy instruments incorporating green certificates, fixed-price tariffs and taxes; and they have diverse electricity markets ranging from renewables/nuclear dominated to coal dominated, with historically varying degrees of competition.

The time period chosen for study was 1990 to date, as this represented the period following the European Union ratification of the Kyoto protocol, during which all major European states have devised a renewable energy programme, with specific policy measures to support biomass and renewables.

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Table 1 – Key market characteristics for each country studied

	Key bioenergy resources	Bioenergy industry development	Main policy instruments utilised	Electricity market history
UK	Limited—agricultural wastes with support for energy crops	Limited development with electricity focus	Green certificates	Fossil and nuclear with small renewables element
Germany	Waste wood and residues	Growing sector, mainly focused on heat and CHP	Fixed-price tariffs	Predominantly coal, but strong renewables contribution
Italy	Significant wood residues and agricultural crops	Limited development, mainly for electricity	Feed-in tariffs, green certificates and taxes	Fossil and hydro; relatively recently privatised
Sweden	Very significant resources of forestry residues	Significant development, focused on CHP and district heating	Taxes	Nuclear, hydro and renewables

Data has been collated corresponding to the capacity of bioenergy electricity generation plant installed in each country and the actual annual energy output from bioenergy plants in each country during this period. These data have been critically analysed alongside a timeline of policy initiatives for each country during the period. Published information which details the development of policy during this period has been supplemented with interviews with experts with direct experience of the bioenergy industry within each of the countries.

The data and preliminary conclusions were presented to a Thermalnet workshop in Scotland in 2006, at which they were critically evaluated by those present and generally applicable conclusions discussed and subsequently incorporated into the current paper.

3. Biomass policy issues

In 2005 the European Commission noted that the effectiveness of support mechanisms for biomass in member states was less than that for wind and that biomass was lagging behind expectations at EU level. There are a number of ways in which biomass differs from other forms of renewable energy: it is a limited resource, usually with a cost attached to the feedstock (even if this is only the cost of delivery/provision); it has potential to be used for heat, electricity or transport fuels and there is a significant supply chain element to the provision of fuel, which means that the geographical and social implications of bioenergy can be much wider than for other forms of renewables, e.g., the impacts on wood processing industries, agriculture and employment implications for rural economies [3]. Each of these differences mean that it is not necessarily the case that policy structures which are effective for other forms of renewables will be appropriate for encouraging bioenergy development.

Table 2 – Timeline of key bioenergy policy initiatives in Germany

Year	Policy initiative
1991	Fixed prices
1992–2002	Investment subsidies
1998	Amendment to fixed prices
1999	Eco tax reform
2000	Fixed prices revised
2002	Fixed-prices regulation extended
2004	Fixed-prices regulation revised

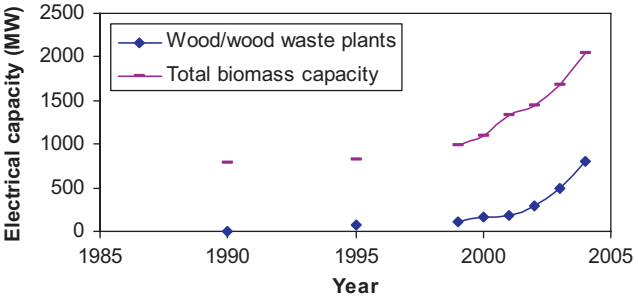

Fig. 1 – Growth in installed capacity of biomass plants in Germany (1990–2004). *Source of data*: Eurostat, 2006 data except for 2000 wood/wood-waste data—from "EUBIONET Biomass Survey in Europe, Country report of Germany, Nuse Lack, 2002".

4. Germany

Table 2 shows the sequence of bioenergy-related policy measures that have been implemented in Germany since 1990 [1–3]. Fig. 1 shows the growth in capacity of bioenergy-based electricity-generating plants in Germany and Fig. 2 shows the actual annual electrical output from these plants since 1990.

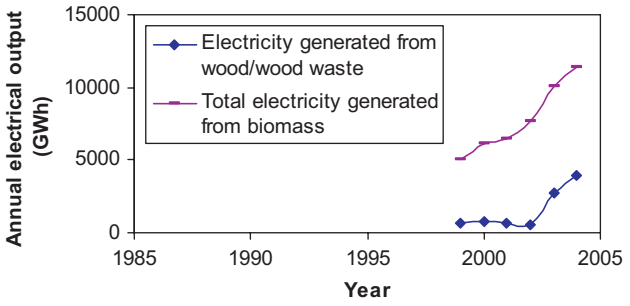

Fig. 2 – Annual electrical output from biomass plants in Germany (1999–2004). *Source of data*: Eurostat, 2006 data.

4.1. *Germany's electricity mix*

Coal and nuclear are the most significant fuels for electricity production in Germany, followed by gas [4]. The contribution of renewables has almost tripled since 1990, led by the installation of over 18 GW of wind capacity. Biomass makes a relatively small, but growing contribution, having shown annual average growth of 34% between 1997 and 2004 [5].

Biomass is used in Germany largely for heat production, and also for electricity and transport. Combined Heat and Power (CHP) plants in Germany tend to utilise waste wood, industrial wood and wood residues, while wood which exists as a result of Germany's extensive forestry industry tends to be used for heating. Anaerobic digestion is commonly used with manure and other biomaterial in the generation of electricity [3].

4.2. *Review of the impact of policy measures in Germany*

Germany introduced fixed prices or feed-in tariffs for renewable energy in 1991, which obliged utilities to buy electricity from producers of renewable energy at a premium price. Fig. 1 shows that this had only a very small impact on the capacity of wood-fired installations, which was almost completely negated by a reduction in the capacity of existing MSW plants; while biogas installations remained static, since the fixed prices did not extend to these technologies.

This mechanism remained in place until 2000 and during this period there is some growth in wood and overall biomass capacity, but not significant, especially compared to other sectors of Germany's renewables industry, which were growing much faster, e.g., wind capacity increased from almost nothing in 1990–2875 MW in 1998 [5].

It is worth noting that German energy policy was striving strongly for ambitious targets in the key growth sectors of wind (the 250 MW wind programme) and photovoltaics (the 100,000 roofs programme) during this period. Programmes for biomass were more modest and less high profile. It is possible that this lack of a strong vision and ambition for the biomass sector contributed to less momentum and slower growth. In addition, the fixed prices offered wind power 90% of the average utility rate for consumers, but biomass producers received only 80% and 65% for biogas, with no support at all for schemes above 5 MW installed capacity [6]. The fact that less financial support was available for biomass will undoubtedly have resulted in slower development relative to wind. An amendment to the feed-in law in 1998 was aimed at limiting costs to the utilities of having to purchase larger than anticipated quantities of renewable energy. As biomass had not developed significantly by this state, there was no impact on new plant capacity or output in Figs. 1 or 2.

From 1992 a Market Incentive Programme, run by the Ministry of Economics and Technology, allocated grants to renewable projects. From 1995 to 1997, 19 million DM (around 10 million euro) was allocated, roughly equivalent to 3 million euro per annum. Projects funded during this period would be expected to come on line by 2000, but Fig. 1 shows that even by then the impact on the installed biomass capacity has only been marginal and the investment subsidies have not had a significant impact.

In 1999 taxes on fossil fuels were increased and a tax on non-renewable electricity introduced, with annual increases for the following 4 years. Revenue generated by this initiative was allocated to investment subsidies via the Market Incentive Programme. This substantially increased the available funds so that by 2003 annual grants available amounted to 203 million euros per annum, focused on heat and CHP, and providing up to 30% of costs. This increased funding from 1999 onwards appears from Fig. 1 to directly result in an increase in wood- and wood-waste-generating capacity evident after a lag of about 2 years, consistent with the minimum possible development time for even quite small plant. However, Fig. 2 shows it does not translate into an increase in electrical output in the same timescale. This could be a result of the policy mechanism chosen: providing an investment subsidy encourages development of new capacity but not necessarily increased utilisation factors or efficiency. Secondly, the investment subsidy specifically targeted heat and CHP plants, which tend to have lower planned annual operation than electricity only plants and so the overall load factor of the new electricity generation mix that has been encouraged by the subsidy will be lower, resulting in a fall in annual output, simultaneous with an increase in capacity. Thirdly, new plants are more likely than established ones to have initial teething problems which will limit output, at least in the early years of operation.

The sustained nature of the increases in capacity in Fig. 1 seems to indicate a growing confidence within the German bioenergy industry. This is likely to reflect the fact that longer-term price commitments (20 years) were available under the amended fixed-prices legislation, facilitating new development commitments and the fact that the Market Incentive Programme was growing in terms of available funds and visible commitment.

The annual output from biomass has also increased annually since 1999 and from wood/wood-waste plants from 2002. This is partly due to successful deployment of the new capacity being developed but also because the fixed-price legislation was extended to cover co-firing in 2002 and this is contributing to the annual output, without increasing annual capacity in Fig. 1.

The main lessons that can be drawn from Germany's experience appear to be that:

- Biomass is such a diverse resource and technology that it is important that national governments have a clear vision of

what they actually want to support. Germany had tailored programmes for PV and wind, but the lack of similarly specific initiatives for biomass meant that it did not enjoy similar success until later when, e.g., wood CHP and co-firing were specifically targeted.
- Investment subsidies have helped to initially stimulate the sector, but have only had long-term effectiveness when the available funding increased by several orders of magnitude and was combined with fixed-price tariffs.
- General energy taxes have been successfully used to provide the revenue for investment subsidies, avoiding overly burdensome central government costs.
- Fixed prices can be very effective, but only if set at an appropriate level vis a vis the technology costs and offering long-term security.
- Offering incentives to existing plant to convert to or use more of a renewable fuel can be a much quicker and more effective way of stimulating an industry than supporting new technology development.
- For relatively proven, short lead time technologies relatively modest price incentives alone can be effective, e.g., biogas systems.

5. Italy

Table 3 shows the sequence of bioenergy-related policy measures that have been implemented in Italy since 1990. Fig. 3 shows the growth in capacity of bioenergy-based electricity-generating plants since 1990 and Fig. 4 shows the actual annual electrical output from these plants since 1990.

5.1. *Italy's electricity mix*

Italy has traditionally relied on fossil fuels and hydropower for electricity generation. Gas and petroleum dominate, with coal and hydropower significant. Wind power, geothermal and biomass are increasing at a rapid rate and there is no nuclear contribution.

Competition reached the Italian electricity market somewhat later than much of the rest of Europe and has been relatively slow to develop, with ENEL, the former state-owned electricity monopoly still producing 80% of power in 2004 [7].

Table 3 – Timeline of key bioenergy policy initiatives in Italy

Year	Policy initiative
1991	De-regulation
1991	Investment subsidies
1992	Feed-in tariffs
1999	De-integration
1999	Carbon tax
2000	Investment subsidies
2000	Tax credits
2001	Green certificates

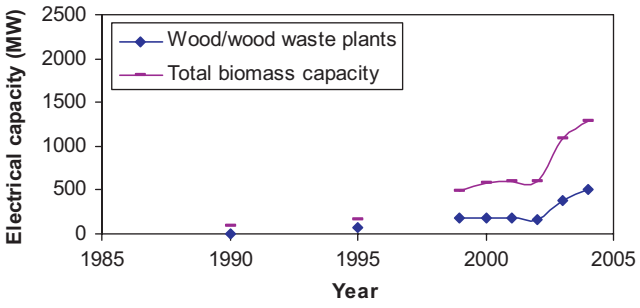

Fig. 3 – Growth in installed capacity of biomass plants in Italy (1990–2004).

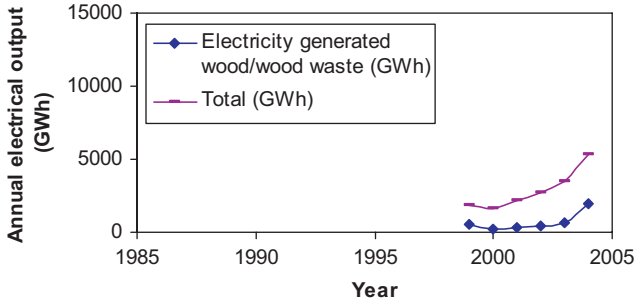

Fig. 4 – Annual electrical output from biomass plants in Italy (1999–2004).

5.2. *Review of the impact of policy measures in Italy*

Until 1990, the only substantial capacity in bioenergy in Italy was in waste and biogas, which was more aligned with the country's environmental/waste policy than its renewable energy policy. De-regulation of the Italian electricity market in 1991 included laws 9 and 10, which increased the maximum permitted renewable energy plant size and allowed renewable energy developers access to a previously monopolistic market. Then in 1991, investment subsidies were offered of up to 30–40% of the capital cost of renewables projects and fixed prices were then introduced in 1992. Under this legislation renewables projects would receive premium prices for an 8-year period, specific to the technology employed [8].

The lead time for bioenergy project development is typically at least 3 years so that development as a result of these policy initiatives should be manifest by 1994/95, but it would be impossible to distinguish whether growth was more due to the investment subsidies or fixed prices, as they were introduced so close together. Fig. 3 shows that there is an increase in biomass installations from 91 MWe before 1990 to 168 MWe in 1995. The vast majority of this is increase in wood-based capacity (4–68 MW). Therefore the investment subsidies and fixed prices were effective, but were withdrawn in 1996 (although support continued to be available for plants notified to ENEL by 1995 and so the capacity continues to increase to 489 MWe by 1999 on the basis of plants being completed that had been proposed within the time window). However, between 1999 and 2001, Fig. 3 shows that no more

installations of biomass from wood or wood wastes were implemented and output from the existing plant capacity actually declines, so that in 2002 there is then a reduction in capacity for wood-waste plants. Despite this the overall biomass sector continues to grow, based on increased numbers of waste and biogas plants.

It would appear that the investment subsidies and fixed prices were stimulating the wood/wood-waste sector. However, the 4/5 year period for which these lasted was insufficient to establish the industry and, so, in the absence of any new policy stimulant, development stagnated.

It can be concluded from this dip in activity that continuity of support is vital, especially for a country, like Italy, that does not have a long history of using biomass in heat and electricity plants. Ongoing support and incentives are required to sustain and develop its biomass industry.

In 1999, a carbon tax was introduced on electricity generators, which was highest for coal stations, then oil, much lower for natural gas and not levied on renewables. The revenues from the tax were used to finance energy efficiency and renewable projects. The tax was supposed to increase annually, but this did not happen [9]. After the introduction of the carbon tax in 1999, no new wood installations are built for 3 years and there is only modest growth in the biogas and waste sectors. The tax does not appear to be initiating new capacity other than the lowest cost and most proven technologies. This is partly because it specifically targeted district heating installations, which would already be in existence and we would expect to see the impact of the tax as an increase in annual electrical output. This is discernable in 2001 and 2002 from Fig. 3, but is more notable for waste installations than wood ones, showing that the cheaper waste fuel benefited more from this measure.

It is not until 2003 that we see any increase in wood-generating plant, when the capacity almost doubles in 1 year. Given the minimum 3 year lead time for development of bioenergy plants, this is likely to have been caused by measures implemented in 2000. This could therefore be attributed to the fact that, while some degree of investment subsidies were available throughout the 1990s they are reintroduced in 2000 and focused on the agricultural aspects of the industry as well as electricity production.

It appears that this very specific targeting of wood production has been successful in stimulating the industry in Italy, which does not have a long history of wood-based generation.

However, additionally Italy's policy on renewable electricity has incorporated the trading of green certificates since 2001—earlier than many of their European counterparts. The impact of this is first seen as an increase in output from existing plant capacity from 2001 onwards; then the increase in actual plant capacity follows in 2003 and 2004. This seems to suggest that the green certificates have initially resulted in additional generation from existing plant and then have helped lever investment into the bioenergy industry, with construction of new plant.

It is interesting to note that, as is usually the case, the green certificates are not technology specific and this is frequently cited as a reason why they are not appropriate for bioenergy systems, which currently tend to be one of the more expensive forms of renewables. In contrast to what one might expect, therefore, Fig. 3 shows that more expensive wood-waste plants are developing apace with the cheaper biogas and waste sectors. It is likely that this is because of the combination of the green certificates alongside investment subsidies.

There are a number of particular features of the Italian green certificate scheme that are frequently cited as contributing to its success. For example, generators have a period of 1 or 2 years in which to present their certificates before sanctions are applied and green certificates are allowed 1 or 2 years in advance for plants which are being built [8].

It is also notable that the green certificates scheme was run on a pilot basis until 2003 and, after this point, when the scheme is fully operational in 2004 there is a significant increase in output in Fig. 4. This is indicative of the increase in confidence of investors and generators once they perceive the scheme to be permanent and, given the construction lead time for bioenergy plants, we would expect to see this sustained in the following years.

The main lessons that can be drawn from Italy's experience are that

- Continuity of policy instruments is important and withdrawal is likely to impact negatively on the market, as was the case post 1996. Similarly confidence is engendered once a pilot scheme becomes permanent.
- Fixed Prices facilitated investment in bioenergy, but proved too expensive to maintain and so were ultimately more damaging to the industry, which contracted after their withdrawal.
- Specific targeting of the agricultural sector facilitated expansion of bioenergy in a country with limited history of bioenergy.
- Technology-blind trading certificates combined with substantial investment subsidies have been the most effective measures at encouraging the development of new capacity and utilisation of existing.

6. United Kingdom

Table 4 shows the sequence of bioenergy-related policy measures that have been implemented in the United Kingdom since 1990. Fig. 5 shows the growth in capacity of bioenergy-based electricity-generating plants since 1990 and Fig. 6 shows the actual annual electrical output from these plants since 1990.

6.1. *UK's electricity mix*

The main contributor to the UK's electricity market is electricity generated from the combustion of gas, with coal and nuclear also significant. Hydropower is responsible for a small portion of the UK's electricity, and renewables, most significantly wind, are small but increasing rapidly.

The United Kingdom does not have a particularly large wood or forestry industry base, although this is presently underused. There are significant quantities of agricultural residues potentially available, but one of the main focuses of

Table 4 – Timeline of key bioenergy policy initiatives in the United Kingdom

Year	Policy initiative
1989	Deregulation and NFFO
1998	Investment subsidies
2001	Carbon tax
2002	Green certificates
2002	Capital grants

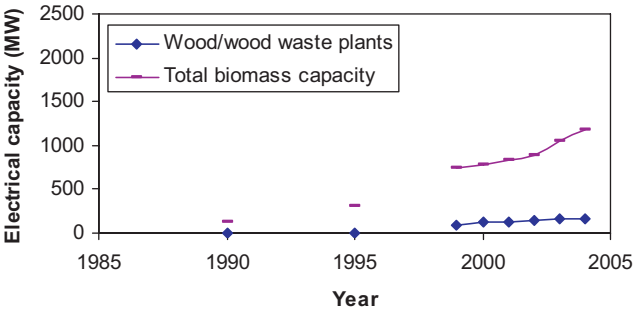

Fig. 5 – Growth in installed capacity of biomass plants in the United Kingdom (1990–2004).

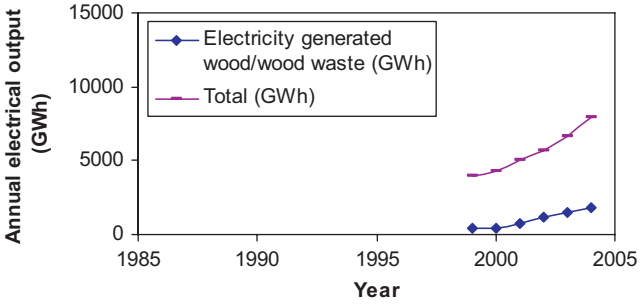

Fig. 6 – Annual electrical output from biomass plants in the United Kingdom (1999–2004).

bioenergy policy in the UK has been to attempt to develop cultivation of dedicated energy crops for the bioenergy industry.

6.2. *Review of the impact of policy measures in the UK*

The UK electricity market was the first in Europe to undergo privatisation and liberalisation in 1989. Since then there have been numerous changes to how the structure of the system works. Consumers purchase electricity from supply companies on an open, competitive market, while suppliers purchase electricity from generators in a wholesale market. A regulator ensures there is sufficient competition and consumers are protected. Transmission and distribution are undertaken separately from generation and supply activities [10].

Immediately after privatisation in 1989 the Non-Fossil Fuel Obligation (NFFO) was introduced to support the UK's existing nuclear industry and initiate growth in renewables. A fossil fuel levy was paid by generators who used fossil fuels, which was redistributed among contracted renewable electricity suppliers. These suppliers were paid a technology-specific premium price following a competitive bidding process. This programme kickstarted the development of renewables in the UK and the increase in capacity between 1995 and 2000 in Fig. 5 is almost entirely due to the NFFO. However, the competitive bidding element of the process meant that lower-cost biomass technologies tended to dominate, so biogas and waste fare better than wood plants. Also, the fact that direct contracts had been awarded with individuals allowed the government no room for manoeuvre when it became clear that certain contracted facilities were not going to be built in time to meet the target of 1500 MW installed of renewables capacity by 2000 [11].

Investment subsidies were introduced in 1998, which provided up to 40% of the cost of new biomass plant. Fig. 5 displays a small increase in electrical capacity in the following years, showing that these have had some impact, but only a small one because of the limited funding available being focused on specific projects, many of which have taken much longer than expected or failed to materialise. The investment subsidies have therefore had limited impact because other barriers, such as planning restrictions and fuel supply issues remained obstacles to development. Providing only financial assistance to large, complex wood projects has, in many cases, been insufficient to expedite them. By contrast, the technically and logistically more straightforward small biogas projects have proliferated with financial assistance only. Some attempts were made to address other aspects of bioenergy implementation, e.g., by providing grants for energy crop establishment, but these have not resulted in a significant increase in capacity in the time period under consideration.

In 2001 a tax on fossil-based energy consumption was introduced, which taxes non-domestic consumers at a rate of 6.39 euros/MWh, with renewable energy being exempt. Revenues from this are limited as the tax is set at a very low level and was offset by a reduction in other forms of taxation at the time; however, it funds some promotional and awareness campaigns [12].

The UK introduced a technology-blind green certificate scheme in 2002, called the Renewables Obligation. Supply companies must generate an annually increasing target amount of electricity from renewables. This is demonstrated by production of green certificates, which can be traded separately from the associated electricity. Suppliers must pay the "buy-out" price per MWh to the extent that they fail to reach their quota. For 2006/07 the buy-out price was approximately £33.24 or 48.86 euros/MWh, the funds from which are recycled to the ROC holder in proportion to the volume of ROCs that they possess [13]. Despite the substantial premium associated with the ROC, the RO has not been particularly successful at bringing forward more advanced or expensive renewable technologies and Fig. 5 shows that practically no new wood-based capacity has resulted from the RO. In recognition of this the UK authorities are currently examining the options for replacing the technology-blind RO with a banded system, to specifically support technologies such as biomass [14].

ROCs can also be earned from co-firing in existing coal-fired power stations and this practice has been extensively stimulated by the RO. In 2005, co-firing ROCs amounted to 9700 GWh [15]. This is clearly a significant success, compared to the much lower levels of generation in dedicated plants. The main reason for this is that, like the biogas systems, which have also been successful under the RO, the requirement for capital investment and the time and effort required to implement such a system are relatively less than for dedicated systems. Therefore offering a premium price per unit output is likely to be more successful for these plants which can achieve a quicker return on investment.

Further investment subsidies were introduced in 2002 via the BioEnergy Capital Grant Scheme. This scheme was established in 2002 in the aim of promoting development of the use of biomass for energy; in particular, the use of energy crops. To date it has resulted in establishment of some crops and production of some wood resource; but the contribution to capacity overall has been limited and slow to develop [16].

The lessons that can be established from the UK's experience of developing bioenergy are:

- In a country where the existing bioenergy capacity is very small programmes that focus specifically on bioenergy are necessary to initiate development. The NFFO scheme had a sector specific to biomass, which is one reason why this was successful in introducing some new capacity.
- For a country with limited biomass fuel supply, investment subsidies are required to establish and maintain the growth of biomass. These must be long term to be successful.
- Rewarding competitive pricing results in the lower-cost (generally waste-based) bioenergy options being established.
- Investment subsidies can be effective in bringing forward capacity in a relatively new industry, but the extent of success will be determined by the funds available. If these are limited and short-term there will be some increase in capacity, but not enough to develop an industry long term. Providing investment subsidies for large, complex wood projects can frequently be inadequate to stimulate development. It is necessary to also attach other constraints such as the planning regime.
- For taxation to be effective, it needs to be set at a sufficiently high level. The level of the UK's climate change levy being inadequate to change behaviour.
- Trading Certificates do stimulate activity in bioenergy; however, the obligation may need to be weighted to promote bioenergy specifically in countries where bioenergy is not already established. In general, the price benefits of certificate systems tend to favour projects with shorter lead times and quicker returns.

7. Sweden

7.1. *Sweden's electricity mix*

Swedish electricity production is dominated by nuclear and hydropower, which together account for over 80% of Sweden's national electricity generation. Following this, Sweden relies on a strong range of renewables; bioenergy being the most significant after hydroelectricity, largely because of the significant natural resource (68% of the land is forested). The bioenergy industry is focused on CHP and district heating networks, fuelled mainly by agricultural residues and forestry byproducts.

7.2. *Review of the impact of policy measures in Sweden*

The history of energy policy in Sweden since the 1950s has been dominated by energy taxation. An energy tax has, for decades, been levied at differential levels on petrol, fuel oil, diesel oil, paraffin, liquefied petroleum gas, natural gas, coal and petroleum coke used for heating or as transport fuels, but not on electricity generators. A separate electricity tax applied to electricity consumers (Table 5). Over the years the tax levels have been increased and modified to protect the competitiveness of certain industries, but has remained sufficiently high to make the use of fossil fuels economically undesirable [17].

In 1991 a carbon tax was introduced in addition to the energy tax, which was levied on the tonnes of carbon produced by fuel consumption for heating and transport, with biofuels being exempt. Fig. 7 shows that, prior to 1991, there was already a high base level of bioenergy capacity in Sweden, based on the established wood industry, district heating infrastructure and efforts during the 1980s by the state-owned generating companies to reduce dependence on mineral oil. The introduction of a carbon tax in 1991 has no impact on bioenergy-generating capacity in the following 4 years (Fig. 7), but the overall use of biomass increased by 44% between 1990 and 1999 [18], primarily because the carbon tax was focused on heat, encouraging biomass heating applications.

It was not until 1996 that the Swedish electricity market was liberalised and a short-term subsidy programme was introduced from 1997 to 2002 to stimulate private investment in renewables capacity. This focused on wind, small-scale hydropower and biomass-based CHP, for which up to 25% of the total capital cost of the project was available. It is likely that these subsidies are responsible for the significant increase in wood and waste capacity in 2001, which can be seen in Fig. 7. However, the growth is not sustained, most

Table 5 – Timeline of key bioenergy policy initiatives in Sweden

Year	Policy initiative
1991	Carbon tax
1991	Energy tax
1997	Investment subsidies
2000	Tax increases
2003	Green certificates
2004	Tax for home and services
2004	Reduced CHP tax

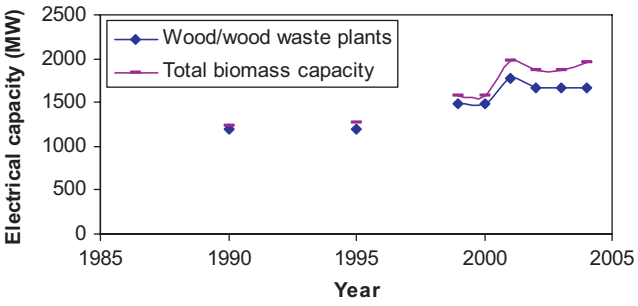

Fig. 7 – Growth in installed capacity of biomass plants in Sweden (1990–2004).

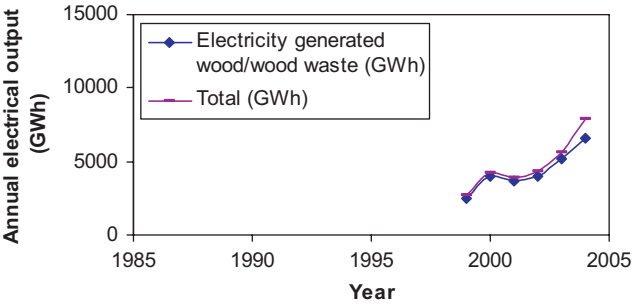

Fig. 8 – Annual electrical output from biomass plants in Sweden (1999–2004).

likely owing to the short period for which the subsidies applied. In fact from 2001 until 2004, the capacity of wood/wood-waste plants declines slightly, biogas remains stagnant and only MSW increases.

In 2001 there were significant increases to the energy, carbon and electricity taxes: the carbon tax from 370 to 530 SEK per tonne; the tax on diesel by 0.117 SEK (0.013 euros) per litre, and taxes on electricity by 0.019 SEK (0.002 euros) per kWh. The impact of this can be seen in Fig. 8, as the electrical output from wood/wood-waste plants increases at a time when actual plant capacity decreases. Increasing taxes has encouraged greater utilisation of the existing bioenergy capacity (see also Figs. 7 and 8).

In 2003, investment subsidies were replaced by a green certificate scheme to mobilise investment in renewable energy. It requires certain users of electricity to ensure a specified proportion (increasing annually until 2010) is from a renewable source by producing sufficient green certificates. Photovoltaics, wind power, biomass, geothermal energy, wave energy, peat and small-scale hydro are all eligible; but waste and large scale hydropower could potentially saturate the certificate market and so are not eligible [17]. In order to maintain liquidity there is a minimum or buy-out price at which the government will buy certificates from producers, which was 0.66 ct per kWh in 2003. If the obligation is not met however, there is a penalty of 1.9 ct per kWh (2003 level) or 2.22 ct per KWh in 2004. One major distinction from other countries' certificate trading systems is that some users are not included in the scheme. Exemptions have included energy-intensive industries, steel-making, metal processing, paper and pulp, wood board, basic chemical industry, mining, cement and mineral oil refineries.

Since the introduction of the certificate scheme in 2003, there has been no growth in the capacity of wood-fired electricity plant, but a significant increase in the output from those plants. It has already been noted that a similar trend from 2001 is likely to have been caused by tax increases that year and it seems likely that the continued increases through to 2004 have been contributed to by the tax increases. It is possible that the green trading certificates are also having an impact, but it will only be possible to confirm this as more data become available for subsequent years.

Continuous review and amendment of energy taxes continued in 2004 with a substantial new electricity tax for households and the service sector followed by a more limited one for the manufacturing industry, agriculture, forestry and fishing. Amendments reduced the impact for fuels used in CHP and renewables.

The conclusions that can be drawn from Sweden's bioenergy experience are as follows:

- The high levels of available forestry resources and established network of district heating have doubtless been instrumental in Sweden's high level of bioenergy implementation. However, even in this context, policy instruments are required to support and guide sector development.
- Investment subsidies have been effective at initiating development of new wood/wood-waste capacity, but the limited time period for which these were available limited their impact.
- Taxation has been very effective at supporting bioenergy, particularly the heat sector, but needs to be set at a suitably high level and periodically reviewed, as has been the case in Sweden. The taxes introduced have been more effective at maximising bioenergy output from existing plant than instigating new capacity.

Trading Certificates are expected to have a positive impact on the sector but there has been insufficient experience so far to verify this.

Given Sweden's forestry background and its tradition of combusting wood for heat and power, it is not surprising that it should have a strong bioenergy contribution in its electricity mix. However, even then, policy instruments play an important role in steadily growing the industry.

8. Conclusions

There are a number of policy instruments that are commonly used by governments in promoting renewable energy technologies, including biomass. These frequently include fixed prices, taxation, investment subsidies and green certificates, each of which are evaluated separately below based on the experience cited above.

8.1. *The effectiveness of fixed prices in developing bioenergy*

Fixed prices were successful in Germany at initiating growth in the renewables sector (particularly wind), but were much less successful in relation to biomass. One possible reason for this is that the bioenergy element of the German programme was much less high profile than the PV and wind sectors and the failure to specifically target bioenergy (in which Germany had no previous capacity) meant it was unlikely to succeed. Also, the payments made under the scheme were less generous than for other technologies. This appears to have been insufficient to attract interest from developers to move to a new, unfamiliar sector.

Fixed prices combined with investment subsidies were used in Italy to stimulate renewables capacity. They initiated limited growth in the sector, but after a few years were withdrawn, as they had become unaffordable. This damaged confidence in the long-term future of the industry.

Fixed prices have never been implemented in the UK, but the NFFO scheme effectively offered a fixed-price electricity purchase contract to a limited number of biomass generators who had made the most cost effective offers in a competitive bidding process. This was effective in bringing some new biomass-based capacity into the system, but the success rate of projects was very low, partly because the other issues preventing the establishment of bioenergy were not addressed simultaneously.

Fixed prices have never been used in Sweden, which uses mainly taxation-based measures to maintain a high bioenergy contribution.

Fixed prices have been very successful in growing wind, PV and other renewables in Europe. However, these examples show that they have been less successful with regard to biomass. In each case there are apparently "special" circumstances that might explain this lack of success, e.g., in Germany the prices were too low, in Italy they were available for too short a period, in the UK the pool of contractors awarded fixed prices was too small to be effective and many failed for other reasons. Overall, bioenergy seems to benefit when fixed prices are set at a sufficiently high level, for at least 8 years (to accommodate the typically longer development lead time for bioenergy plants) and attached to a programme specifically aimed at encouraging bioenergy. Nevertheless it seems likely that on many occasions fixed prices will be inadequate on their own to grow the bioenergy industry. They will work best when supported by the confidence that is engendered by a national programme and/or government commitment specifically tailored to bioenergy and put alongside other measures to address other barriers such as planning issues or fuel supply.

8.2. *The effectiveness of taxation in developing bioenergy*

In Germany hypothecated taxes appear to have been successful in increasing levels of bioenergy capacity in the years following 1999. The taxes applied were relatively high and increased annually for 4 years, giving adequate time to build confidence in the measure and resulted in a huge increase in the funds available for investment subsidies via the Market Incentive Programme.

A hypothecated tax was also introduced in Italy in 1999; but, in this case, the intended annual increases did not actually materialise and the level of the tax was relatively low, so that significant funding for new projects did not materialise from the measure and the impact on generating capacity was minimal.

Sweden has used taxation very effectively to increase levels of bioenergy and renewable generation. However, Sweden has significant renewable energy resources (especially biomass) and has a long history of high levels of energy taxation. The taxes employed there have been consistently high and frequently revised, but consistently supportive of biofuels at the expense of fossil fuels.

The UK has used the climate change levy to encourage energy efficiency and investment in renewables. Its impact has been very small because it is set at a low level, which does not make it particularly attractive for customers to switch fuel. Only a small proportion of the nominal tax is hypothecated, as most is offset by a saving in other taxes and the revenue only makes a limited contribution to energy efficiency awareness campaigns.

It seems that taxation can be an effective means of growing a bioenergy industry, even in the early stages, if it is set at a high enough level to make consumers actually switch fuel (this has been achieved with the consistently high taxes in Sweden, but not in the other countries considered), provides adequate funds for investment in the industry (achieved in Germany, but not in Italy or in the UK) and applied as a long-term measure. The last point is particularly important where capital investment in new plant is required, as it reduces the investment risk. Even in Sweden with its high base level of bioenergy, it requires many years of gradually increasing taxes before the output from bioenergy plants increases substantially as a result.

8.3. *The effectiveness of investment subsidies in developing bioenergy*

All the countries considered have run some form of investment subsidy programme.

In Germany, investment subsidies initially appeared to not have any impact on new plant capacity. However, when the levels of investment were markedly increased new capacity was brought on line by investment subsidies. It was interesting to note, though, that this increase in capacity did not immediately result in an increase in plant output, so that investment subsidies may not be the most efficient way to maximise productivity of plant.

In Italy, investment subsidies combined with fixed prices appeared to be reasonably effective at encouraging growth in the bioenergy sector, but this ceased when the subsidies were removed, so they were not present for long enough to allow the sector to support itself. When reintroduced Italian investment subsidies focused specifically on bioenergy and the agricultural components. In a country without a high level of biomass resource this sort of specific targeting is important.

In the UK, investment subsidy programmes for biomass have had limited success because of the limited funds available, time period for which these were run and focus on developments that have been obstructed by other barriers, such as planning difficulties, grid access or public opposition.

In Sweden, investment subsidies have had less of a role to play because there was an already established biomass sector, with associated infrastructure. Where these subsidies were applied their impact was limited.

Overall investment subsidies in these countries do not appear to have been a particularly effective way of developing the bioenergy industry and even less effective at sustaining them. When dealing with countries with little or no history of bioenergy deployment, conventional wisdom is that investment subsidies are required to support the first generation of plants, which can then move on to requiring a lower level of support in another form [19]. However, these examples do not really seem to support this and, where they do lead to increased capacity, e.g., in Germany, output does not seem to be equivalently enhanced.

It may be the case that because bioenergy is so diverse and each new plant is so unique that providing investment subsidies does relatively little to reduce the costs of future plants. There may therefore be a case for focusing investment subsidies on other aspects of bioenergy, e.g., fuel supply, logistics and other enabling measures rather than the actual plants, which may be better supported by an output-based measure. Or perhaps there could be gains in attempting to impose a "one-size-fits-all" approach by making a generation of bioenergy plants as generic as possible, replicating the design and strategy of a first plant as far as possible in subsequent ones to maximise the learning effect. This approach is currently being trialled with respect to biomass heat facilities in the UK [20].

8.4. *The effectiveness of green certificates in developing bioenergy*

Germany has not used green certificates to stimulate renewables, working, instead, with fixed-price tariffs.

In Italy green certificates appear to have been successful first in maximising output from existing bioenergy plant and then in instigating additional new capacity, when operated in tandem with investment subsidies. The Italian certificates were not technology specific, but it appears that the simultaneous availability of investment subsidies has been helpful in ensuring that bioenergy development keeps pace with other renewables.

Experience of green certificates is longest in the UK, where it has been very successful in increasing renewables generation, but significantly less so for bioenergy. A policy of maintaining a technology-blind certificate scheme alongside investment subsidies was maintained for many years, but this is now under review and the UK is now considering introducing a banded certificate scheme.

There has been insufficient experience of certificate schemes in Sweden to determine their impact alongside the extensive energy taxes employed there.

It seems that a technology-blind certificate scheme is, on its own, insufficient to support bioenergy because of the cost relative to other renewables. The major element of this cost is the recurring fuel cost for bioenergy systems and the Italian scheme appears to have counteracted this by aiming investment subsidies at the fuel production end of the bioenergy chain. There has been less success in the UK at combining investment subsidies and green certificates to support bioenergy and it remains to be seen whether or not banding the certificates will prove successful.

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