Renewable energies from the rural sector: the policy challenges

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1. Introduction

In June 2009, OECD member countries[1] agreed to adopt a mandate to develop a Green Growth Strategy, in which the relevant economic, environmental, social, technological, and development aspects would be coordinated in a comprehensive framework (OECD, 2009a).

Green growth involves an economic development path that is consistent with long-run environmental values, using natural resources less intensively than the current growth model, whilst nevertheless providing acceptable living standards and poverty reduction in both the developed and developing parts of the world.

In particular, green growth means 'promoting growth and development while reducing pollution and greenhouse gas emissions, minimising waste and inefficient use of natural resources, maintaining biodiversity, and strengthening energy security. It requires further "decoupling" of environmental impacts from economic growth' (OECD, 2009a, p.1). One of the key elements of the strategy as outlined is the shift to more sustainable and 'cleaner' energy sources − that is, energies that are both renewable and have a significantly smaller carbon footprint.

It was acknowledged that a greener growth strategy will require the elaboration and adoption of strong policy guidelines, embracing economic, social and environmental objectives that can shape and stimulate the shift to a sustainable global economy in an efficient and flexible way. These guidelines would serve as reference points for detailed country-specific policy initiatives. From this general starting point, more detailed policies will have to respect and adapt to the features of particular economies and different stages of current development, as well as being sector-specific.

This paper considers one sector, namely agriculture, which is not only characterised by strong specificities but also displays considerable heterogeneity across the OECD area between agro-climatic zones, institutional settings and basic factor endowments. The main focus of the paper is agriculture's potential as a source of clean renewable energy, in a context where wider criteria of environmental and social sustainability are also binding.

The following discussion examines the challenge of defining a basic policy framework for stimulating the renewable resource potential of agriculture in OECD countries, and ideally one that can, with sensible adaptation, also provide guidance to less developed countries with a very different agricultural profile.

As well as the objectives of sustainability, efficiency and coherence, which are relevant and applicable across virtually all sectors, other important key words in the general specification of a green growth strategy are job creation, technological innovation, appropriate restructuring, and the substitution of renewable human skills and appropriate man-made capital for scarce or fragile natural capital and dwindling non-renewable natural resources.

* The author is particularly grateful to Ronald Steenblik for comments on a previous draft, and also thanks Paul Dowling for his contribution. All opinions expressed and any remaining errors are the responsibility of the author.

[1] The 30 countries that were then OECD members plus the four countries that became members in 2010.

Inevitably, not all sectors have capacity to achieve high scores for all the items on this second list. This paper considers the scope for agriculture to deliver with respect to these objectives, and how policies might stimulate its contribution.

The elaboration of a green energy strategy for agriculture takes place in a wider context involving all sectors of the national economy and the links between national economies. Concerning agriculture's role in this wider debate, three highly pertinent questions are:

- What are the prospects for green growth in the agricultural sector itself? Given that agriculture will face increasing demands for food output as well as less traditional non-food demands, what is the scope for agriculture to respond to these potentially conflicting demands in a sustainable way? Can the substitution of renewable resources (in particular, human skills and renewable energies) help agriculture to expand its output in a greener way than has been observed over the last half century?

- What contribution can agriculture make to green growth in the economy as a whole?

- Might agriculture's provision of renewable energy sources actually become an engine *driving* greener growth in the rest of the economy?

Well-supported answers to these complex questions require a more comprehensive approach than can be attempted in this paper. Nevertheless, they are formulated here as a reminder of the context in which the more focused questions addressed below take on their full relevance. In particular, among the most important — and inter-related — trends driving the need for a greener economy are the ongoing process of climate change, the escalating pressures on finite natural resources and the unsustainable use of non-renewable energies (OECD, 2009a). We therefore break down the question of agriculture's role in the greening of the international economy into a set of narrower, more targeted questions. They are:

(i) What is the scope for clean, renewable energy provision by agriculture?

(ii) What are the appropriate policies for encouraging agriculture's ability to produce it?

(iii) Can renewable energy provision by agriculture contribute to other objectives of the Green Growth Strategy?

2. Where we are we now and what might be possible in the future

2.1 *Previous work at the OECD*

The scope for producing and utilising agricultural biomass ('any organic material, of plant and animal origin, derived from agricultural and forestry production, … used as feedstocks for producing bioenergy and biomaterials'), and appropriate policy and market approaches for promoting its production and use, were the subject of an OECD Workshop held in Vienna in 2003 (OECD, 2004a).

Workshop participants identified six policy objectives as driving the growing interest in this area: climate change mitigation, improving energy security, environmental sustainability, rural development and economic efficiency, and greater market innovation. They acknowledged that a 'cross-cutting strategic approach is required to ensure that all these goals are achieved', although 'it may not be possible to achieve all these goals simultaneously' (p.19). For example, the potential trade-off was acknowledged between, on the one hand, improving efficiency by increasing the scale of bioenergy production and, on the other, securing greater benefits for local communities and rural development from small-scale bioenergy production.

Various other issues that were raised during the Vienna workshop (such as the key role played by the fossil fuel price in determining the profitability of bioenergies, the importance of horizontal and vertical coordination of activities in producing bioenergy and bringing it to the market, and possible policy-induced implications for other land uses) remain highly relevant today. The relatively long time horizon involved in the decision to invest in bioenergy production, the rapidity of technological developments in this field, the unnecessarily complicated administrative procedures often involved and the low level of public acceptance of some bioenergy initiatives were also identified as challenges for effective policy making on bioenergy.

A detailed model-based study undertaken in 2008 (OECD, 2008) analysed the effects on crop and oilseed prices, production and trade of current biofuel support policies, plus the new measures about to be implemented in the EU and US. The study noted the trend towards consolidation of biofuel companies and the internationalisation of the industry that followed the early years of rapid sectoral expansion, as well as the fact that 'the share of biofuel plants owned by farmers and other parts of the rural community is declining' (p.104). The implication of these trends is that, just as with various comparable developments in the past, the farming sector is falling back into its habitual role as supplier of raw materials for off-farm processing by larger business interests downstream that are able to provide the investment and scale economies necessary for adding value to these materials. This tendency was expected to continue in the future under the even heavier investment and technological demands of second-generation biofuels.

Another study (OECD, 2009b) examined the role of government support in the wider context of the emerging bioeconomy, considering the wide range of applications of biotechnological applications across the economy including industry and the healthcare sector. Renewable energy faces strong competition for scarce research money and development support within the expanding bioeconomy, whereas in the context of energy support the report warns that whilst IEA member countries spent over USD 250 million in 2006 on bioenergy R&D, their spending on R&D for nuclear fission and fusion, and for fossil fuels, was 13 and 4 times greater, respectively. Indeed, public spending on R&D for fossil fuels exceeded that on all renewable energy technologies taken together.

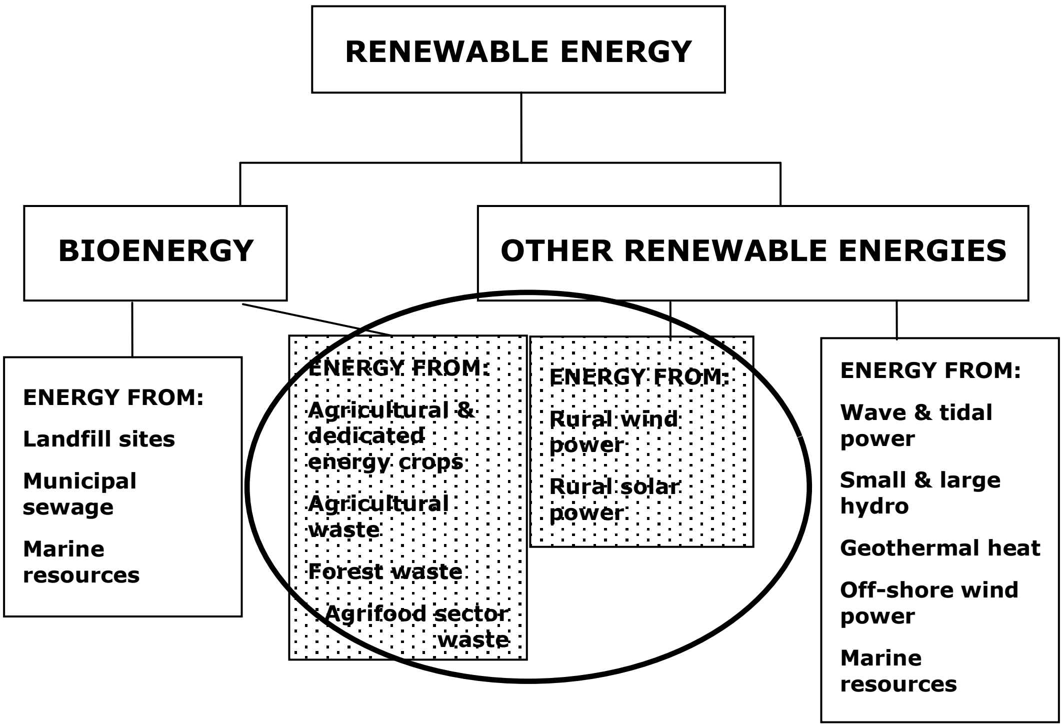
A detailed inventory of measures for promoting renewable power generation from biomass is provided in OECD (2010a). Although the greater part of biopower and bioheat output is still directly or indirectly based on forest products, this study noted the major potential for expanding output of biomass and bioenergy from agriculture and the role agricultural biomass could play in meeting future energy needs.

Agriculture's traditional role is that of managing land- or livestock-based biological processes to produce commodities for final food consumption, with or without further transformation, or for use as intermediate inputs into industrial processes. This paper looks at a wider range of farm-based activities that also includes any renewable energy produced or captured by farmers, *either* directly derived from their fixed on-farm land- and livestock-based resources, *or* from the by-products and residues of on-farm processes using these on-farm resources. These sources or their outputs need not be primary 'agricultural commodities' in the conventional sense, and need not rely on the use of biological transformation processes.

These wider boundaries allow non-biological renewable energy forms, notably electricity and gas generated on-farm, to be included among farming's supply of renewable energy resources. Extending the boundaries of the 'agricultural sector' in this way can be defended on the grounds that the renewable energy outputs are also under the decision-making control of the farmer and they all compete, at least potentially, for the same bundle of fixed resources – land, farm labour and farm capital. Moreover, they all contribute to farm incomes.

For completeness, the picture is further enlarged to include, albeit peripherally, two more sources of bioenergy: the forestry sector and the agrifood chain downstream from farming. Although these sources of renewable energy are not under the control of agricultural producers, do not compete with other productive uses of on-farm resources and do not contribute to farm income, they nevertheless derive directly or indirectly from land-based bioenergy resources and are complementary to farm-generated renewable energy outputs.[2]

Figure 1: Types of renewable energy



The circled area in Figure 1 encloses the renewable energy resources in the rural and agrifood sectors that are the focus of this paper. The next sub-section gives a brief summary of how energy is derived from the resources identified in this circled area.

2 Other renewable, land-based energy sources, such as small- and large-scale hydropower, and geothermal power, are not discussed in this paper as they lie beyond both farming and biological processes. However, this does not imply that their potential for reducing GHG emissions, achieving cleaner and greener growth, and promoting rural development is without interest.

2.2 Renewable energy resources originating in the rural and agrifood sectors

Agricultural biomass yields not only food and energy, but also a wide range of biomaterials (renewable industrial inputs). These include fibres, industrial oils used to make paints and inks, starch used for producing polymers and detergents, and a variety of high-value, low-volume products used in the production of cosmetics, flavourings and healthcare products (OECD, 2004a, p.28). In fact, '…all products that currently result from the processing of petrochemicals can, in theory, be produced from biomass feedstocks'(OECD, 2004a, p. 41). With higher prices for fossil fuels and, and the eventual adoption of carbon pricing, there is likely to be more pressure to switch to biomass for producing a very wide range of non-energy industrial products.

Thus, stimulating bioenergy production will heighten competition with other market demands and societal goals, and may risk distorting or disrupting a number of other markets. These competing claims on potential energy resources, and on the land used to produce them, have to be kept in view when reviewing agriculture's potential for producing green energy.

Table 1 summarises the various routes by which agriculture, forestry and the agrifood sector contribute renewable energy to final energy markets. The first route is by transforming conventional agricultural crops (grains, sugar beet and sugar cane, oilseeds) into biofuels (by fermentation and distillation to ethanol, or via oil extraction and refining to biodiesel or jet-kerosene substitutes), or into biogas (via anaerobic digestion). At the starting point of this route, bioenergy demand competes for the raw material with food demand and to a lesser extent with demand from other non-food uses. Moreover, on the supply side, the raw material competes with all other alternative potential uses for the land used to grow the bioenergy feedstock.

The second route starts with the production of dedicated (non-food) energy crops (any ligno-cellulosic crop, although currently grasses like switchgrass and miscanthus, and short-rotation woody perennials like willow, poplar and eucalyptus, are of prime interest) and can potentially yield a wider range of hydrocarbon substitutes. Generally, more complex and costly production facilities are required to transform such biomass materials into fuels.

Ligno-cellulosic feedstocks can be processed into biofuels along two very different technological pathways. The *biochemical pathway* uses enzymes and other micro-organisms to convert the cellulosic components of the feedstocks into sugars that are then fermented into alcohol, which is distilled to produce ethanol. The *thermo-chemical pathway* adopts pyrolysis or gasification techniques to produce a synthesis gas containing carbon monoxide and hydrogen, from which various biofuels including synthetic diesel may be obtained (IEA, 2008a, p.4). The most promising second-generation biofuels are considered to be BtL-diesel, BtL jet kerosene, and lignocellulosic ethanol, which can be substituted for or blended with, respectively, fossil-fuel-based diesel, jet fuel and gasoline (EEA, 2007, p.23). A more energy-rich second-generation biofuel is bio-SNG (synthetic natural gas), which can be compressed or liquefied for use as transport fuel in modified vehicles (EEA, 2007, p.23).

Large-scale commercial production of second-generation biofuels is not expected for a decade or so, and although various pilot and demonstration plants using different processes and feedstocks are underway, currently no particular technology or type of feedstock appears to dominate.

Dedicated energy crops can produce more biofuel per hectare than first-generation biofuel technologies if the entire plant is used as a fuel feedstock. Typically, there is no food demand for these feedstocks to compete with demand for them as an energy resource; on the supply side, however, second-generation feedstocks compete with food crops for land unless they can be grown on marginal land that would normally not be used for food production.

Table 1: Renewable energy outputs of the rural and agrifood sectors

Energy resource originating in agriculture, forestry or the agrifood sector	**Type of resource used**	**Competing non-energy demands same resource**	**Type of energy produced**	**Final energy market**
Agricultural crops	Grains, sugar crops, edible part of other starchy commodities Vegetable oils	Food Other non-food non-energy industrial uses	Biofuels (1^{st} generation) ▪ Ethanol ▪ Biodiesel	Transport fuel
	Grains		Biogas	Electricity, heat, natural gas
Dedicated energy crops	Grasses, short rotation coppice (willow, poplar etc) Any other ligno-cellulosic biomass	No competing food demand, but other industrial demand and possible competition for land	Biofuels (2^{nd} generation)	Transport fuel
			(Direct combustion of primary solid biomass)	Electricity Heat
			Biogas	Natural gas
Agricultural residues and wastes	Straw, any kind of ligno-cellulosic waste Animal manure	Direct use as fertiliser on-farm	Biofuel (2^{nd} generation)	Transport fuel
			Biogas	Natural gas
			Direct combustion of primary solid biomass	Heat Electricity
Forest residues	Forest thinnings, wood chips, sawdust	Timber Fuel wood Habitat	Biofuels (2^{nd} generation)	Transport fuel
			Direct combustion of primary solid biomass	Heat, electricity
Wind energy	Wind power	None	Electricity	Electricity
Solar energy	Photovoltaic power			
Waste from the agrifood sector	Used cooking oil, animal fats	Other non-food non-energy industrial uses	Biofuels ($1^{st}/2^{nd}$ generation)	Transport fuel
	Non-edible parts of starchy commodities (shells, husks, bagasse)		Direct combustion of primary solid biomass	Heat Electricity
			Biogas	Natural gas

Direct combustion of primary solid biomass to obtain electricity or heat, which appears alongside several resource categories in Table 1, is a relatively mature technology for converting biomass to energy. This conversion can be carried out in industrial-scale boilers and burners, combined heat and power plants, or in much smaller-scale installations suited to small enterprises or household use.

Agricultural wastes and residues, whether of crop or animal origin, are currently under-exploited, relative to their enormous potential, as a source of renewable energy. There are three main types of process for converting these waste products to energy. First, any kind of ligno-cellulosic wastes can be used as feedstock for a variety of second-generation biofuels (for the processes involved, see above). In this case, agriculture supplies the raw feedstock to commercial-scale downstream processors.

The second process is via conversion to biogas. This involves the biological breakdown of biomass in the absence of oxygen (anaerobic digestion), during which the feedstock is separated into an energy-rich gas, and a solid fraction, digestate, which has a variety of uses.[3] Although anaerobic digesters were originally designed for manure and sewage sludge, a higher biogas yield is obtained in on-farm applications when animal manure is mixed with a second feedstock (co-digestion), typically some kind of crop biomass or even slaughterhouse waste (see, for example, Braun *et al.,* 2010). Virtually any waste organic material[4] can be broken down by anaerobic digestion.

The biogas obtained from anaerobic digestion of biomass is composed primarily of methane and carbon dioxide, with the ratio depending on the feedstock used. Agricultural biogas is considered to be of high quality (relative to biogas from landfill or municipal sewage) as it is richer in methane and contains fewer pollutants (EurObserver'ER, 2007).

Small-scale on-farm digesters are an increasingly attractive option for biogas production in both developed and developing countries. Biogas generated on the farm can be used to produce both heat and electricity, with both the electricity and heat used on-farm, or the electricity sold into the local grid. Methanisation (upgrading of biogas to natural gas quality) for injection into the natural gas grid, or for compression as a transport fuel, is becoming economically feasible for small-scale operators, although it is a more common option for large-scale centralised plants

The liquid obtained from the digestate, when used as a fertiliser on-farm, has various advantages for the farmer, including improved balance and delivery of nutrients to the soil, greater ease of handling, storage and transport, and absence of pathogen and seed contamination (Birkmose, 2010; Crolla, 2010).

Other on-farm techniques for the fractionalisation of farm waste are also available for separating out the energy content from other constituents. One option is the mechanical separation of manure into the fibre and liquid fractions, with the former being delivered to centralised biogas plants and the latter being retained on-farm for soil fertilisation. As with anaerobic digestion, this process also helps the farmer to obtain a market value for part of the energy content of his farm waste, whilst improving the nutrient value of his liquid manure and reducing on-farm environmental problems associated with storing and spreading it (see, for example, Gilkinson, 2008; Birkmose, 2010).

A third channel for converting agricultural and forest waste to energy involves direct combustion of primary solid biomass to obtain electricity or heat (see above). In Europe, this conversion channel was initially developed by the timber processing industry as a way of disposing of timber waste material (EurObserver'ER, 2010a). The timber and paper industries generate large volumes of waste materials that can be exploited for energy generation if feedstock supply chains can be efficiently organised. More recently, arable farming and the agrifood sector have also been responding to government incentives to invest in these processes or supply the solid primary biomass feedstocks required by the large energy companies, by district heating plants and so on.

Although the greater part of the woody waste used as solid fuel is an industrial waste product, farmers may also be able to provide forest thinnings and boost their incomes by doing so if their farms include wooded areas or if they practice some form of agro-forestry. In rural areas with large commercial plantations, the management, collection and transport of forest waste

[3] For example, digester liquor is used as a fertiliser, while the solid, fibrous fraction of the digestate may be used as a soil conditioner to increase the organic content of depleted soils, or to make low-grade building materials.
[4] Except for woody materials, which cannot be broken down by most anaerobic organisms.

could contribute to rural employment. In some ecosystems, the removal of fallen timber or more intensive forest management practices can have negative consequences for the forest as habitat. Elsewhere, however, these activities can yield significant public good benefits by reducing fire risks and improving amenity value. Where this is the case, obtaining a market value for the resulting forest trimmings and waste products as a renewable energy feedstock provides income to support the provision of the related public goods. Obviously, the more decentralised the production of the waste, the greater the logistic challenge in organising regular feedstock supplies.

Two further on-farm sources of renewable energy are wind and solar power used for electricity generation.[5] Although these outputs do not rely on any biological transformation process, they fall within the decision-making sphere of the farmer, contribute to farm income and may have implications for the farm's fixed resources. Hence, they are included among the options considered in this paper.

Electricity generation from these two sources in an agricultural setting requires either a long-term investment by the farmer, or a long-term contractual agreement whereby the farmer allows the siting and operation of wind turbines or photovoltaic installations owned by others somewhere on his farm. Once these installations are in place, the operating costs are relatively low. Whether the electricity generated is used on-farm, thereby displacing electricity sourced off the farm, or whether it is fed into the commercial grid, it represents a net increase in the energy supply. There is considerable scope for smaller-scale, community-based wind farms[6], whilst solar photovoltaic capacity is even more flexible in terms of scale and location.

The capture and conversion of these 'free' energy sources may cause relatively little disruption to the farm operation, but there could be some competition for the farm's resources. If the farm owns and operates the installations, there are demands on farm capital and management, and to a small extent on farm labour. Furthermore, regardless of who owns the installations, there may be competition with other potential uses for land, depending on the topography of the farm. When wind turbines can be sited on ridges or other exposed terrain that is marginal for farming purposes, then competition with other land uses is small. Roof-mounted photovoltaic panels on large surface-area farm buildings, or more extensive ground-based photovoltaic systems sited on salt-contaminated or badly eroded land, have minimal opportunity cost in terms of alternative productive land use. Clearly, there is no competition with any use other than electricity on the demand side.

Organic waste produced in the agrifood chain downstream from farming is also a source of renewable energy, including first- and second-generation biofuels, heat and electricity from primary solid biomass conversion, and biogas, using conversion technologies already described above. Clearly, downstream food processing that takes place in large-scale plants can provide wastes as feedstock in the volume and consistency needed to feed large-scale bioenergy plants, thereby offering the possibility of economies of scale that are not available with smaller-scale on-farm generation. On the other hand, when farm wastes are processed into bioenergy on the farm, with only the pure energy having to move off the farm, the cost of transporting the bulkier primary agricultural commodities to more centralised processing locations is avoided.

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[5] Solar power can also be harnessed by solar thermal technologies, with applications that include water heating, space heating, space cooling and process heat generation. This technology is not discussed here, since it has no particular link with the rural or agrifood sectors, although some on-farm applications (e.g. solar hot water systems for dairy stables) are available.

[6] According to CanWEA (2008), an average 50 MW wind farm with 20 turbines needs about 500 hectares of land, of which 95% remain available for grazing or crops.

The competition between food and energy crops for land, and between food and energy use for food crops, raises the spectre of higher food prices and deepening global food scarcity. In fact, land diverted from food production will have to be replaced by net additions to cropped land elsewhere unless recently abandoned agricultural land can be reclaimed for cropping and crop yields can grow at a faster rate than observed in recent years. However, when land lost from food crop production is replaced by bringing new areas under cultivation (so-called indirect land use change), there may be damaging consequences in terms of greenhouse gas emissions if this land formerly stocked more carbon than is typically stocked by an annual food crop.[7] By contrast, the other five raw sources of energy identified in Table 1 involve 'free' energy resources (wind and solar) or waste products, which do not compete for productive land.

Nevertheless, many of the renewable energy options in Table 1 face competition from non-energy market demands or societal demands for the same resource (third column of Table 1), indicating that whilst greener energy is available in a technical sense, it will generally have an opportunity cost and choices will have to be made. To what extent markets can, and should be allowed to, make these choices without government intervention is inevitably a policy issue.

The last column of Table 1 shows that all major energy markets (transport fuel, electricity, heat and gaseous fuels) can be supplied by renewable energies originating in agriculture, forestry and the agrifood chain. Renewable energies compete with energy from all sources on these final markets, since specialised markets restricted to renewable energies as such do not exist unless created artificially by policy measures. This means that renewable energies have to be accepted by final consumers as equivalent to their non-renewable substitutes, and that there has to be demand for these energies at their supply price on final markets. Any efforts further back up the chain to incentivise their production will fail if sufficient final demand is not present. Indeed, the scope for switching from fossil fuels to cleaner energies will ultimately be limited by the extent of their penetration of end-use markets. A key issue for policy makers concerns the relative merits of stimulating final demand by, on the one hand, assisting renewable energy to compete in price with non-renewables on final energy markets, and on the other, of imposing mandatory targets for their use by final consumers.

A successful strategy for rebasing economic growth on green energy requires policy makers to be aware of the entire supply chain for each form of green energy, from the supply of the raw energy resources by primary sectors right through to the supply of usable energy onto markets for final energy consumption, and to the interactions – competitive or complementary – between these supply chains. This paper's focus on energies from renewable resources originating in the rural and agrifood sectors is not intended to suggest that the policies for stimulating green energy should necessarily be targeted on these upstream sectors. On the contrary, at *which* point(s) in the various renewable energy supply chains policy intervention can be most effective remains an open and highly pertinent question, which is addressed in following sections. Assisting or encouraging suppliers of the raw energy resources is neither a necessary or sufficient condition for a successful strategy.

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[7] If previously uncropped land (especially carbon-rich rainforest, peatland or permanent pasture) is used to make up for land lost to these dedicated energy crops, the immediate impact on GHG emissions is significant and likely to outweigh any emission-saving from the renewable energy for a number of years (see, for example, Searchinger *et al*., 2008; Searchinger, 2010).

2.3 Current production of renewable energies

Table 2 shows that in 2008, about 3.85 million GWh of electricity was generated worldwide from renewable energy sources, of which about 48% within the OECD area. In addition, about 633 petajoules of heat came from renewable sources, three quarters being generated in the OECD area. OECD countries used a greater variety of renewable sources for energy generation, with just three quarters coming from hydroelectric power and over 10% coming from wind power. In non-OECD countries, nearly all renewable energy was generated from hydroelectric power.

The breakdown of renewable energy sources used for heat generation differs between OECD and non-OECD countries (Table 2). For both country blocks, primary solid biomass accounts for about half of the energy from renewable sources. However, OECD countries are relatively advanced in exploiting municipal waste for heat generation, and in diversifying their energy sources to include industrial waste and geothermal sources, whereas in non-OECD countries the only other significant renewable source for heating tends to be industrial waste[8].

Table 3 summarises the balance sheets for renewables in OECD and non-OECD countries. Production of nearly all the renewable energies shown is greater in the OECD region, with the exception of energy from solar thermal power and from primary solid biomass. The latter source is over six times more important in the non-OECD area. It is striking that the lion's share of energy from this source outside the OECD area is used in the residential sector, whereas industry takes over half of the OECD area's much smaller production. The difference is even more marked for biogas, with residential use predominating in non-OECD countries, while the greater part goes to industrial uses within the OECD area. Nearly two thirds of the energy from geothermal sources is taken by the residential sector in the OECD, and by the commercial and public sectors outside the OECD area. Finally, whereas the residential sector uses most of the OECD's solar thermal energy, outside the OECD this source mainly supplies other non-specified sectors.

Table 3 shows that currently only primary solid biomass and liquid biofuels are traded to any significant extent.

It is beyond the scope of this paper to explain the inter-regional differences shown in Tables 2 and 3. They reflect many factors, including natural and comparative advantages, historical and institutional specificities and divergent policy strategies. For the purposes of this paper, the information in the tables establishes the starting point for future renewable energy developments. When considering the projections made for future production and use, it is useful to bear in mind the current extent of development and penetration of these energies in different world regions and sectors.

[8] The Philippines and Indonesia are in second and third place behind the US in terms of installed capacity for generating electricity from geothermal energy.

Table 2: Use of waste and renewable energy for electricity and heat, OECD and non-OECD, 2008

	Energy Source											Total re-newable energy
	Munici-pal Waste	Indust-rial Waste	Primary Solid Biomass	Biogas	Liquid Biofuels	Geo-thermal	Solar Thermal	Hydro	Solar Photovol taics	Tide, Wave, Ocean	Wind	
Share (%) in total renewables used for gross electricity generation												Total (GWh[1] 1000s)
Total OECD	3.0	0.5	6.6	1.7	0.2	2.2	0.0	74.9	0.6	0.0	10.2	1843.8
Total non-OECD	0.1	0.1	2.0	0.0	0.0	1.2	0.0	95.0	0.0	0.0	1.5	2007.4
Share (%) in total renewables used for gross heat generation												Total (TJ[2] 1000s))
Total OECD	39.7	2.0	52.1	2.8	0.9	2.6	0.0					474.9
Total non-OECD	0.0	51.3	48.5	0.1	0.0	0.0	0.0					157.9

Source: IEA, 2010a.

1. Giga watt hour (10^9 watt hours). 2. Terajoules (10^{12} joules). One watt hour=3600 joules.

Table 3a: Balance sheet for waste and renewable energy sources, total OECD, 2008

	Municipal Waste	Indust-rial Waste	Primary Solid Biomass	Biogas	Liquid Biofuels	Geo-thermal	Solar Thermal
Unit	*1000 TJ*[1]	*1000 TJ*	*1000 TJ*	*1000 TJ*	*1000 tonnes*[2]	*1000 TJ*	*1000 TJ*
Production	1064.7	285.4	6262.6	554.4	44.6	1282.8	162.6
Imports	0	0.3	122.1	0	6.4	0	0
Exports	0	0	-42.1	0	-3.6	0	0
Stock Changes	-0.0	0.0	0.3	0	-0.7	0	0
Domestic Supply	**1064.7**	**285.7**	**6342.9**	**554.5**	**46.8**	**1282.8**	**162.6**
Transformation	**935.3**	**89.1**	**1423.4**	**405.3**	**1.9**	**1114.5**	**8.4**
Final Consumption	**129.4**	**196.2**	**4915.3**	**144.7**	**44.9**	**162.3**	**154.2**
	Final consumption share by use, per source						
Industry	41.3	99.0	52.0	85.1	2.5	7.5	3.5
Transport	0.0	0.0	0.0	0.6	97.5	0.0	0.0
Residential	0.4	0.0	44.3	1.7	0.0	61.7	87.6
Commercial and Public Services	58.4	1.0	2.1	11.4	0.0	21.0	7.0
Agriculture and Forestry	0.0	0.0	1.6	1.1	0.0	3.5	0.4
Other	0.0	0.0	0.0	0.1	0.0	6.2	1.5

Table 3b: Balance sheet for waste and renewable energy sources, total non-OECD, 2008

	Municipal Waste	Indust-rial Waste	Primary Solid Biomass	Biogas	Liquid Biofuels	Geo-thermal	Solar Thermal
Unit	*1000 TJ*[1]	*1000 TJ*	*1000 TJ*	*1000 TJ*	*1000 tonnes*[2]	*1000 TJ*	*1000 TJ*
Production	43.0	146.3	40607.4	312.3	26.1	1162.4	299.2
Imports	0	0	2.2	0	0.2	0	0
Exports	0	0	-26.8	0	-5.2	0	0
Stock Changes	0	.5	2.4	0	0.8	0	0
Domestic Supply	**43.0**	**146.8**	**40585.1**	**313.0**	**21.9**	**1162.4**	**299.2**
Transformation	**43.0**	**122.3**	**3981.9**	**2.1**	**0**	**1145.2**	**0.0**
Final Consumption	**0**	**17.0**	**36049.7**	**310.6**	**21.8**	**13.7**	**299.2**
	Final consumption share by use per source						
Industry	0.0	91.0	13.3	0.0	0.0	0.4	0.0
Transport	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Residential	0.0	0.0	84.3	99.9	0.0	23.3	18.7
Commercial and Public Services	0.0	7.1	1.3	0.1	0.0	61.5	0.4
Agriculture and Forestry	0.0	1.9	0.6	0.0	0.0	11.5	0.0
Other	0.0	0.0	0.0	0.0	0.0	3.3	80.9

Source: IEA, 2010a.

1. Terajoules (10^{12} joules). 2. Tonnes of energy equivalent. 3. Combined heat and power.

Tables 2 and 3 mask the fact that some of the renewable energies originating in the land-based and agrifood sectors, but whose shares are still quite small, have been growing very rapidly. For example, installed wind power worldwide increased almost six-fold between 1993 and 2000, and almost eight-fold between 2000 and 2009 (EurObserver'ER, 2010b). In the four-year period 2005-2009 alone, the USA saw growth of 297% in generated wind power (as against 15% growth for US renewable energy as a whole) (IEA, 2010a).

Table 4: Solar photovoltaic capacity, selected countries, 2000-2009

Country	Installed capacity, MW	
	2009	Growth, %, 2000-2009
Australia	183.6	529
Canada	94.6	1214
Germany	9845.0	12954
Japan	2627.2	696
South Korea	441.9	10948
Spain	3523.0	176050
Switzerland	73.6	381
USA	1641.6	1083

Source: IEA-PVPS (2010).

One of the fastest growing forms of renewable energy has been (still very small) solar photovoltaics. Table 4 shows the exponential growth in installed solar photovoltaic capacity in selected OECD countries between 2000 and 2009. Also by way of illustrating the rapid dynamics of renewable energy production, Table 5 reports the rapid growth rates of various renewables produced or consumed in the EU during the first decade of this century.

Table 5: Changes in renewable energy production (consumption), EU-27

Total growth in primary energy production, %					Total growth in consumption,%
2004-2008			2004-2009		2004-2009
All renewable energy	Wind power	Photovoltaic power	Energy from primary solid biomass	Agricultural biogas	Biofuels
91	97	1340	24	701	511

Source: EurObserver Interactive Database (2010).

2.4 Projected potential renewable energy

A number of projections of future renewable energy availability and consumption have been produced in recent years. It is not always stated, when reporting the potential of a particular form of renewable energy to satisfy future energy demand, what assumptions have been made about the production of other renewables that may compete for the same primary energy resource, what is assumed about underlying trends (GDP growth, fossil fuel prices, and so on) and what policies are assumed to be in place. Therefore, a synthesis of the results of different studies would undoubtedly be misleading because of double counting, and omissions or inconsistent underlying assumptions. Instead, we briefly review some of these projections on a selective basis to illustrate the prevailing optimism regarding the untapped potential for renewable energy, and in particular energy from the rural sector.

Under the IEA's New Policies Scenario (which assumes 'cautious implementation' of countries' announced pledges regarding GHG-emissions targets and reductions in subsidies to fossil fuels), global primary energy demand increases by 36% between 2008 and 2035, while over the same period the share met by 'modern renewable energies' (all those identified in Table 1 with leading roles played by hydropower and wind) doubles from 7% to 14% (IEA, 2010c). The rapid growth of solar PV is projected to continue, but its share will still be small (2%) by 2035.

In another study, Eisentraut (2010) presents the growth in energy from primary biomass in two GHG-emission-reduction scenarios: the 450 Scenario (defined in IEA, 2009a), which requires the atmospheric concentration of CO2 to be stabilised at 450 ppm, and the Blue Map 2050 scenario (as set out in IEA, 2008b) which assumes a global emissions reduction target of 50% by 2050. To achieve the 450 Scenario target requires the implementation of a structured framework of effective international policy mechanisms. The Blue Map Scenario assumes the required technological development to achieve the relevant targets. The projections for primary biomass demand, and in particular biofuel demand, under these two scenarios (and their corresponding 'no further action' reference scenarios) are reproduced in Table 6 (quantities in exajoules).

Table 6: Climate change mitigation scenarios, renewable energy projections (EJ)

	IEA (2009a)		IEA (2008b)	
	Reference Scenario 2030	**450 Scenario 2030**	**Baseline Scenario 2050**	**Blue Map Scenario 2050**
World primary energy demand	**705.2**	**604.3**	**977**	**750**
Of which, primary biomass demand	**67.4**	**82.0**	**53.8**	**84.1**
Total final biomass energy consumption	**53.3**	**60.7**	**53.8**	**84.1**
Of which, biofuels	**5.6**	**11.7**	**4.5**	**29.1**
Biofuel share of total transport fuel, %	**4.0**	**9.3**	**2.2**	**26.0**

Source: Compiled from Eisentraut, 2010.

These scenario projections show a colossal increase in future demand and utilisation of biomass for renewable energy, and strong reliance on biofuels. In the Blue Map Scenario, about 160 million hectares of land are required for biofuels by 2050, roughly two-thirds of which are for BtL synthetic diesel, one quarter for ethanol from cellulosic feedstocks and the rest for cane ethanol. The projected shares of first-generation grain ethanol and biodiesel from oilseeds are already very small by the early 2030s.

With more aggressive policies and more ambitious targets, the contribution of bioenergy to final energy demand could be much greater than these projections suggest. For example, IEA (2009c) estimated the global energy *potential* of biomass - without degrading biodiversity, soils, or water resources, and taking into account growing population and demand - to be between 25% and 33% of global energy supply by 2050. It should be noted that there is no real consensus around any particular set of estimates, or their interpretation.

Beurskens and Hekkenberg (2010) analysed the National Biomass Plans of 26 EU countries, developed in compliance with the European Renewable Energy Directive (2009/20/EC), in order to project future renewable energy production in the EU in the year 2020. Renewable energies from all sources are projected to increase by 78% from 2010 to 2020 (148% growth between 2005 and 2020), with strongest growth in renewable transport fuel (an increase of 107% from 2010 to 2020). Electricity from biomass should grow from 9.7 to 19.7 Mtoe between 2010 and 2020, to represent about 19% of total renewable electricity in 2020. Within this total, electricity from solid biomass increases from 6.4 to 13.1 Mtoe, and that from biogas[9] from 2.5 to 5.4 Mtoe (Beurskens and Hekkenberg, 2010, p.18).

Projections for renewable energy growth and potential from non-biological energy sources are also high. For example, although wind power provides about 3.3 thousand MW (less than 2% of Canada's electricity consumption), CanWEA[10] (2008) has developed a strategy for this sector to reach 55 thousand MW by 2025, or 20% of Canada's electricity demand. How this can be achieved, and the collateral benefits, are outlined in its strategy document.

EEA (2009) considered the potential for wind energy to satisfy future EU electricity demand. Distinguishing between on-shore and off-shore capacity, and taking two target years, 2020 and 2030, wind energy's contribution was estimated in three different ways: (a) technical potential (b) environmentally constrained potential (where it was assumed that Natura 2000 areas and other EU areas enjoying protection for environmental reasons would remain free of wind turbines) and (c) economically competitive potential, based on energy price projections (but not excluding Natura 2000 areas). Under the assumptions for (c), it was estimated that EU wind power could provide three times the total electricity demand projected for the EU in 2020, and 7 times the demand projected for 2030, with most of the capacity located on-shore. Planned wind-power generation falls far short of this potential: Beurskens and Hekkenberg (2010) estimate that electricity from wind power will jump from 14.1 Mtoe in 2010 to 42.4 Mtoe in 2020, but this will still only represent 40.7% of all renewable electricity and a smaller share of total electricity demand.

This discrepancy highlights the importance of distinguishing between estimated potentials, which are based largely on assessments of resource availability and technological possibilities, and planned or targeted future production, which take account of economic, institutional and political conditions and constraints. Moreover, whether or not countries' intentions and targets for future renewable energy production will be achieved depends, *inter alia*, on the policy incentives provided for switching to greener energy use, and how market participants respond to them. The following section summarises past and current renewable energy policies across various countries before going on to consider what more needs to be done and how it can be done more effectively.

3. Review of current polices

"Three factors affect renewables cost and market growth: the intensity and availability of the natural energy resource, the maturity of each renewable technology and the market rules set by governments" (IEA, 2005). The current supply and use of each renewable energy, and the balance between renewable energies on the energy market, are undoubtedly the result of all three factors, with actions by governments possibly the most important of the three. Indeed, it might be argued that, in the case of renewable energies, the presence or lack of specific government policies have had a strong influence on the first two factors as well.

[9] From all sources: landfill, municipal sewage, agricultural crops and residues, and food processing wastes.
[10] CanWEA (Canadian Wind Energy Association) is a non-profit trade association.

Figure 2: Support for renewable energy at different points in the supply chain

Research, technological development	Fixed factors	Financing	Production	Storage & distribution	Consumption
▪ Subsidies ▪ Removal of regulatory risk & administrat-ive barriers ▪ Demonst-ration and pilot facilities	▪ Subsidies	▪ Risk-reducing; risk-sharing fiscal arrange-ments ▪ Investment subsidies ▪ Investment incentives ▪ Loan guarantees	▪ Production-linked payments & tax credits ▪ Tax exemptions ▪ Long-term contracts; obligation to purchase ▪ Guaranteed prices ▪ Government tenders ▪ Market price support (tariff protection)	▪ Subsidies for storage ▪ Subsidies for distribution infrastruc-ture	▪ Consumer awareness; consumer confidence-building campaigns ▪ Consumer subsidies ▪ Product standards ▪ Mandates or targets for consumption or market share
	Intermediate inputs		**By-products**		**Complementary goods**
	▪ Subsidies		▪ Various measures, as above		▪ Subsidies
➡ **product flow** ➡ ➡ ➡ ➡ ➡ ➡ ➡ ➡ ➡ ➡ ➡ ➡ **product flow** ➡ ➡ ➡					

Adapted from Steenblik (2007), Figure 3.1, p.18.

Figure 2 summarises the different stages of a typical supply chain for a renewable energy, showing the various points along the chain where policy incentives and support mechanisms can be applied. It is followed by a discussion of the types of policies that have been used for renewable energies across the OECD area.

The support measures in Figure 2 are for the most part standard policy instruments that are routinely applied in a wide range of market contexts in order to influence the choices of decision-makers at different points in the marketing chain. However, in addition to these measures, the decentralised supply of renewable energy and various technical features specific to particular renewable energies have given rise to some new instruments, which are described in the following paragraphs.

The production of primary solid biomass, whether used for biofuels or conversion to other energies, is spatially dispersed whereas its transformation into a usable energy source tends to take place at a much larger scale in more centralised processing facilities. Generally, the same kind of marketing and transport infrastructure that exists for other raw materials like food crops and timber takes care of the logistics of this link in the energy supply chain. By contrast, other renewable energies that are generated directly on-farm, notably agricultural biogas, and electricity from biogas, or from wind and solar energy captured on-farm, present a new logistical challenge. Unless it is possible to move, and hence to trade, the resulting energy off the farm, the incentives for on-farm energy production are limited, and the scope for switching to a greener energy supply from this particular source is constrained by the extent of each farm's own energy consumption.

This problem has been solved in many countries by allowing farmers to feed surplus electricity generated on-farm into the commercial grid supply. In a smaller number of countries biogas can also be supplied to the natural gas grid, once the farm-produced biogas has been upgraded to satisfy the quality standards of commercial natural gas.[11] *Grid access* overcomes the limit set on farm-generated energy by own-consumption, and creates scope for stronger incentives to expand on-farm production. The importance of grid access is well recognised. For example, the EU's Renewable Energy Directive requires member states to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities and the electrical system in order to ensure grid access for renewable energy.[12]

There are several options for remunerating energy fed into a commercial grid. *Net metering* uses just one meter, which offsets flows of energy into the grid against flows from the grid. The external supplier is charged for the net volume of energy received from the grid. This allows the farmer to supplement his own supply by recourse to the grid when his consumption need exceeds his system's capacity, and to off-load surplus when his system is supplying in excess of his consumption need, thus effectively using the grid as a storage mechanism. With many net metering systems, once consumption from the grid has been fully offset, there is no further advantage to the producer; other systems may fix an upper limit to the amount that can be fed to the grid. NNEC (2009) reviews the variants of the net metering system that were operating across 42 US states in 2009, and offers guidelines for best practice.

Feed-in tariffs can provide a much stronger and more targeted set of incentives to small-scale energy producers. This system requires the use of two meters in order to record consumption and supply flows separately, which allows different prices to be set for each of the flows. The prices for energy purchased by the grid operator are fixed in advance in line with energy-policy targets and are generally based on the cost of generating the renewable energy supplied. Therefore, they usually differentiate between energy generated from different sources, and may also take the size of the external supply unit into account to reflect cost differences due to economies of scale. The rates are often designed to be degressive over time so as to move in line with expected technological change and general cost reductions.

The feed-in tariff system offers an incentive to supply green energy that is independent of the extent of the supplier's own energy use, and that can target energy from particular renewable resources or specific technologies. Feed-in tariff systems usually involve guaranteed and unlimited grid access and long-term contracts (20-25 years). They have become the dominant payment model in the EU, although net metering is still the norm in the USA and Canada.[13]

Feed-in premiums are fixed bonuses paid to the energy producer on top of the electricity market price. This payment mechanism removes part of the external supplier's price risk, but allows payments to retain some responsiveness to market conditions. This mechanism is used by a number of Australian states, and some EU member countries.

In a system regulated by a *Renewables Obligation* (RO) (some EU countries) or a *Renewable Portfolio Standard* (RPS) (US), energy supply companies are required to source a given share of their supply from renewable energy resources. External renewable energy producers earn

[11] Although there are cases reported of farm-produced biogas being sold to a nearby single customer for use without upgrading to a more refined quality standard, this option is limited in rural areas.

[12] However, it has been noted (EC, 2009, p.6) that where large electricity companies and utilities exercise market power, problems concerning grid access can arise.

[13] Ontario's Green Energy and Green Economy Act (October, 2009) launched the FIT (Feed-in Tariff) (for installations over 10 kW) and microFIT (for very small installations such as photovoltaic roof panels) programmes, considered to be the first such schemes in North America. Although they are modelled on European feed-in tariffs, an additional condition requires minimum levels of Ontario content in order to qualify for the programmes. Similarly, under the terms of a recent call for tender for 2,000 MW of wind-generated electricity, Hydro-Québec requires developers to guarantee the expenditure of at least 30% of wind-turbine costs in the Gaspé region and at least 60% of total wind-farm costs in Quebec. See http://www.canada.com/montrealgazette/news/business/story.html?id=18dd2152-16a4-483e-92a7-3f274d28f69e

certificates for every unit of energy produced and can sell these certificates to the supply companies, which are then deemed to have complied with their obligation up to the purchased certified amount. In this system, the renewable energy producer's 'incentive price' is the market price for the non-renewable form of the energy plus the price per unit from the sale of *green certificates*.

Renewables obligations need not be tied to particular types of renewable energy, and where this is the case, they are thought to encourage price competition between the various forms of renewable energy. That is, a RO fixes the quantity of the particular renewable or of total renewables (as a share of total supply) but allows the market to determine both the 'basic' price and the price for the green certificate, and hence the total price per unit received by the external supplier. By contrast, the feed-in tariff fixes the incentive price of each renewable energy and leaves the 'market' (i.e. the response of potential investors in renewable energy capacity to the price incentive) to determine the quantity of each renewable energy produced.

The RO and RPS approaches are thought to have some drawbacks for agriculture-based energy producers.[14] Although designed on the premise of market competition, in reality the market situation may resemble more closely that of oligopsony (several very large buyers – the energy supply companies or utilities –and many small energy producers). In such a case, 'market forces' can exert strong downward pressure on green certificate prices paid to external renewable energy suppliers. Moreover, the use of green certificates means a riskier environment for investors in renewable energy production, since not only is the price received for the certificates market-determined but it is also vulnerable to changes over time in the policy-determined renewables shares. A further criticism is that this system can introduce potential distortions by creating artificially segmented markets if shares are fixed for specific types of renewable energy, or for renewable energies taken together, rather than helping to promote their integration into mainstream energy markets.[15] This criticism has also been levelled at biofuel mandates (Steenblik, 2007, p.40), which confer a legal priority to liquid transport fuels over other competing demands of the same biomass feedstocks. This priority treatment may also distort the balance of technological development within the broader bioenergy market.

With a *tendering system*, the government calls for tenders for the supply of a certain amount of a given renewable energy, which is then produced under contract at the price resulting from the tender and with the additional costs being passed on to the purchaser through a specific levy. While competitive tendering systems theoretically make optimum use of market forces, they can have a stop-go nature that does not provide stable conditions for suppliers. Tendering has been used by a few EU member states for some types of renewable energy.

The above incentive measures are in use in many countries and for a number of renewable energies. In the context of Figure 2, they come under items 'long-term contracts', 'obligation to purchase', 'guaranteed prices', 'government tenders' and 'mandates or targets for consumption or market share'. They all, in one way or another, aim to enhance the market incentives faced by renewable-energy producers. Where grid access and renewable energy payments are implemented, they are usually available to any renewable energy producer wanting to supply energy to the large utilities. As well as farmers, specialised renewable

[14] For an in-depth critique of the approach based on a market quota and green certificates, see Fouquet (2007) and Mitchell and Connor (2004). Comparing ten years' experience in Denmark, Germany and the UK, Lipp (2007) concludes that the ability of the feed-in tariffs used in the first two countries to address the needs of the sector has been one of the most important factors behind their leading world position in renewable energy development. For arguments supporting the RO and RPS approaches rather than feed-in tariffs, see Jansen (2003).

[15] Footnote 21 describes a situation where the benefits of green certificates may outweigh these disadvantages.

energy companies, municipalities operating landfill sites, even households with a few solar PV panels on their garage roofs can use the scheme. However, these systems are particularly important for the agricultural sector. Its spatial dispersion incurs the disadvantage of decentralisation but also the advantage of a vast capacity to capture ‘free’ wind and solar energy. In addition, it is a major potential supplier of biomass, not least in the form of farm waste for which there is no other high-value competing demand. These opportunities for on-farm energy generation and its commercialisation unlock enormous potential for the sector to supply green energy on a large scale.

The following paragraphs give some examples of current policies and support measures for the renewable energy sources that are the focus of this report. Again, the purpose is illustrative only.

Biofuels

The following provides a concise summary of the wide range of policies used by governments at various levels to support the production and consumption of biofuels. More detailed information can be found in the series of reports issued by the Global Subsidies Initiative.[16]

Grants for research and development relating to various stages in the supply chain are awarded by most biofuel-producing countries. For example, the American Recovery and Reinvestment Act of 2009 earmarked an additional $800 million for biofuel research, development, and demonstration projects, on top of existing commitments.

Subsidies for fixed factors include measures like reductions in labour taxes paid by workers in the biofuel industry (e.g., in a few US states) or concessionary treatment regarding land acquisition for constructing new production facilities, often provided by municipalities.

Subsidies for intermediate inputs include measures like the EU energy crop payment on set-aside land (dating from 1993) and the separate EU Energy Crop Scheme (2003). Both these subsidies are now discontinued.

Investment subsidies and incentives include capital grants and loan guarantees to support the construction of new biofuel facilities, accelerated capital depreciation provisions, credit subsidies and public-private partnerships for production infrastructure, all of which are used extensively to support biofuels within the OECD area.

Tariff protection: ethanol, as an agricultural product, is protected by high tariffs in many biofuel-producing countries; biodiesel, classified as a chemical, is generally subject to comparatively low tariffs (in the range of 2% to 10%).

Tax credits and exemptions from excise taxes are used by many countries.[17] In most OECD countries, biofuels are exempt from, or enjoy a reduction in, fuel-excise duties (sometimes this may be specific to certain types of biofuel or certain blends, or may depend on the feedstock or the biofuel being produced within the relevant tax jurisdiction). Income tax credits are also used by some countries.

Direct production subsidies are provided in a number of countries, notably Canada for all biofuels and the United States for biofuels produced by “small” facilities (those producing up to 227 million litres a year), and for any producers using cellulosic biomass as a feedstock.

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[16] See https://www.globalsubsidies.org/biofuels.

[17] Steenblik (2007) estimated that this item accounted for roughly 40-55% of total US support to ethanol and biodiesel in 2006 (Table 4.1, p.29). In the fiscal year 2009, US biofuel tax credits reduced the federal excise tax yield by about $6 billion below what they would have been without the credits CBO (2010).

Market guarantees (indicative targets for biofuel content, biofuel incorporation quotas, blending mandates, or purchase mandates) have been fixed in many countries, but are generally considered to be relatively ineffectual. The tendency over time is for countries to move from voluntary or indicative targets to mandatory binding targets. The United States is the only country so far to have adopted a specific blending mandate for second-generation biofuels (Eisentraut, 2010).

Subsidies for storage and distribution take various forms. Governments commonly underwrite part of the cost of upgrading or creating new distribution infrastructure (United States at federal level, several US states, Australia and some EU countries). Other ways of subsidising these costs include income tax credits (for example, in the US). Most of this support has gone to ethanol, because its more corrosive nature necessitates the upgrading of existing facilities.

Subsidies for complementary goods, in the case of biofuel support, mainly take the form of subsidies or regulatory concessions for flexible-fuel vehicles, capable of running on high-ethanol fuel blends (e.g. United States, Sweden).

Although the agricultural sector supplies the feedstock for biofuel, most of the biofuel support described above occurs elsewhere in the chain, and in particular downstream from agriculture. This is less paradoxical than it may seem. When demand for agricultural crops increases due to increased demand for first-generation biofuels, crop prices rise. Farmers are well used to responding to price incentives for crops that they routinely produce, and no extra inducement is needed to encourage their supply. But whether or not demand for biofuels increases depends on what is happening further down the supply chain and on final markets.

It is crucial to recognise that the functioning of the whole chain needs to be taken into account when considering whether and where to stimulate renewable energy use. It may be the case that stimulating final demand is a sufficient condition for success in switching the economy to greener energy use. In a well-functioning chain, increases in demand for the final product will be transmitted to other chain segments, including feedstock producers. In theory, incentives and benefits will be transmitted back up the chain to *all* chain participants providing both information and value-added are competitively distributed along the chain.

In the case of second-generation fuels, by contrast, the feedstocks that will be demanded are not routinely produced by farmers, and their production will require the farmer to make a commitment that extends beyond the annual crop cycle. Training, risk-reducing arrangements (e.g. multi-year contracts or price guarantees) or other additional incentives might be necessary temporary measures in order to achieve a rapid initial farmer response to demand for these new feedstocks.

Although most biofuel support does not target farmers, a few governments, with a rural development objective in mind, have adopted support measures for biofuel production designed also to help farmers. An example was Minnesota's explicitly targeted farmer-owned ethanol co-operatives in its Ethanol Production Facility Loan Program (terminated in 1999). In Canada, the ecoAgricultural Biofuels Capital Initiative (funded up to 2012) supports investment in biofuel production facilities that involve at least 5% agricultural producer equity. In the mid 2000s, Austria was providing support for biofuel production facilities on up to 55% of the total investment costs providing farmer ownership is at least 50% (Steenblik, 2007). The US 'small producer tax credit' intends to facilitate the participation of farmer co-operatives and local enterprises in the production stage. This incentive favours biodiesel plants, which tend to be smaller than those for ethanol.

Finally, it is worth noting that although only the United States has implemented an explicit blending mandate for second-generation biofuels (from 2010 onwards), various legal constraints (minimum GHG emission savings, environmental sustainability criteria and so on) enshrined in both the US Renewable Fuels Standard and the EU's Renewable Energy Directive also implicitly favour second-generation biofuels (Eisentraut, 2010). Indeed, the latter stipulates that second-generation biofuels should carry double weight in the mandated target share for renewables in transport fuel, which creates stronger incentives for these fuels.

Biogas

Investment subsidies and incentives: Article 20 (b)(v) of the EU's Rural Development Regulation (1698/2005) encourages member states to provide support for operations related to energy supply. This has given rise to various supported projects (co-financed by the member state and EU-level funding) including on-farm biomass digestion. In addition, member states may have their own national support programmes for installing on-farm anaerobic digesters.

In the United States, on-farm biogas producers have tended to respond to federal grants and loans instead of tax credits (although also available) because many farmers lack sufficient passive income to qualify for the credits (Great Plains Institute, 2010). A recently announced private-public partnership (USDA, 2009) aims to reduce GHG emissions from the US dairy sector by 25% through government research initiatives and also contains support for marketing of anaerobic digesters to dairy producers.[18]

Tax exemptions: in some countries (e.g. Finland, Switzerland, Sweden from the start of 2011 and Germany until mid-2010) biogas is exempt from fuel tax when used as a transport fuel.

Various combinations of *grid access, long-term contracts, obligations to purchase and incentive prices* for electricity generated on-farm (including from biogas) are offered in many countries. Far fewer countries so far have set up channels for farmers to supply gas to the commercial gas market. One example is Germany, where priority access is granted for supplying biomethane to the natural gas grid, with responsibility for most of the costs of grid injection to be borne by the grid operators rather than the biogas suppliers (Deutscher Bundestag, 2000; EurObserver'ER, 2010c). Another is France, whose Energy Performance Plan (PPE) includes measures targeting agriculture (2009-13) that back on-farm methanisation investments, offer a specific biogas feed-in tariff for biogas generated using livestock effluent and remove bottle-necks to biomethane grid injection (EurObserver'ER, 2010c).[19]

There is a widespread view that agricultural biogas is currently one of the least well exploited renewable energy sources, despite its many advantages to farmers and its clear credentials as a win-win option in the context of greener growth. In 2008, the European Parliament (European Parliament, 2009) passed a resolution calling on the other EU institutions and member states to develop a coherent biogas policy, not least with respect to biogas from agricultural sources. The statistics are revealing. In 2009, Germany produced just over half of the total biogas (from all sources) in EU25, and nearly 85% of Germany's biogas came from agriculture. The second largest producer, the UK, was responsible for another 19.5% of the EU25 total, and

[18] According to USDA (2009), dairy operations with anaerobic digesters routinely generate enough electricity to power 200 homes, yet only about 2% of dairies for which a digester would be profitable currently use this technology.

[19] A €19 million tender, launched in March 2009, recruited 82 agricultural methanisation projects amounting to 23MW of electrical capacity, followed by another €7 million tender in June 2010.

this came exclusively from landfill sites.[20] The remaining 30% of the total was produced in the other 23 EU member countries. These figures alone suggest a huge untapped on-farm technical potential within the EU. In the USA, the Great Plains Institute (GPI, 2010, pp.9-10) concluded that 'the current policy environment at the state and federal level does not recognise the immense resource potential from biogas. Without additional mechanisms and incentives geared towards diverse biogas utilisations and expanded ownership or management models, biogas development will struggle to grow and an opportunity will be missed…'.

Although biogas producers in the agricultural sector benefit from various types of incentive and support, it appears somewhat patchy and lacking coordination. Even if some farm-based biogas production receives the support provided (via, for example, feed-in tariffs) to the end-use renewable energies generated by the biogas[21], what seems to be generally lacking is a well integrated set of policies that take as their starting point the potential for small-scale biogas production on farms or in farmer-owned cooperatives, and that systematically provide relevant incentives for the various alternative conversion options and distribution channels.

This lack of coordinated policies for optimising the specific potential of on-farm biogas production could stem from the heterogeneity inherent in biogas supply and demand: on the one hand, the diversity of biogas production options (from landfill sites, municipal sewage, and on-farm from manure, energy crops and plant residues), and on the other hand, the multiplicity of energy forms that it can produce on-farm (electricity, combined heat and power, biogas for off-farm heating, biogas for on-farm or off-farm upgrading to natural gas or transport fuel).

Wind power

Research and development support is used by numerous countries, particularly in relation to off-shore wind power installations.

Capital grants and loan guarantees have been used by some countries to stimulate new wind power installations. However, as on-shore wind energy is reaching a point where, given certain climatic, technological and market conditions, it can often compete successfully with non-renewable energy sources, policies are is now shifting to measures for stimulating private investment in wind energy (IEA, 2009b). These measures aim to attract private capital by reducing investor risk and increasing investor confidence. This can be done, for example, by removing regulatory delays and complexities, fostering public-private partnerships, and improving grid access and market mechanisms relating to the power output of wind turbines.

Tax credits and tax exemptions have been used in various countries to stimulate wind power generation. Moreover, more targeted tax exemptions have been successful in attracting small suppliers and promoting a more decentralised, community-based production structure for wind power generation. For example, targeted tax exemptions have promoted the rapid expansion of cooperative wind farms (Denmark, the Netherlands, Germany, the United Kingdom, Australia). Any profit from these cooperative ventures is often reinvested in the local community.

Long-term contracts, obligations to purchase, and market guarantees: feed-in tariffs and feed-in premiums, net metering systems, and RPS (with or without tradable green certificates) are all in use around the OECD area. In Europe, feed-in tariffs for electricity generated by on-

[20] For comparison, in December 2008, 19% and 8.5% of EU25 dairy cows (a prime source of slurry for on-farm biogas generation) were in Germany and the UK, respectively.

[21] But not always: according to Taglia (2010), current RPS policies in the United States do not credit all forms of energy generated from agricultural biogas.

shore wind turbines are among the lowest in the feed-in tariff spectrum, reflecting the relatively low production costs for this type of renewable energy. Typically, feed-in tariffs for wind-generated electricity in Europe allow for a rate of return in the range of 5-10%.

The cost structure is very different between on-shore and off-shore wind power generation, not only because of the more accommodating conditions for installing turbines and grid connections on-shore, but also because the off-shore industry is still in its relative infancy.[22] Support via feed-in tariffs for off-shore wind farm operation (outside the scope of this paper) is significantly higher per kWh of power generated.

Solar photovoltaic (PV) power

IEA-PVPS (2010, p.32) tabulates 13 commonly used support measures for solar PV power generation (most of which have already been mentioned above) and their frequency of use across 20 IEA member countries. This source does not identify separately those measures, if any, that apply specifically to PV power generation on farms or in rural environments, and it may be that some of the incentive measures listed are restricted to residential premises or urban settings.[23] Only in the United States are all 13 measures reported as being used, but this probably indicates heterogeneity between states in their choice of measures, rather than over-instrumentation in all states. Subject to these uncertainties of interpretation, it is possible to draw out some trends from the table.

Research and development is stimulated in various countries by research grants and government participation alongside the private sector in funding early-stage PV research.

Direct capital subsidies are used in 11 of the 20 countries.

Tax credits are used by seven countries, among which the only EU member state is France. The US federal tax credit for the installation of solar electricity capacity has recently been extended and will run until 2016.

Long-term contracts, obligation to purchase, guaranteed prices, or combinations of these instruments, are provided through feed-in tariffs, tariff premiums, or net metering in most countries. Only four countries (Australia, Austria, Switzerland and the USA) are reported as having PV-specific green certificate schemes[24], even though these countries are also shown as having feed-in tariffs for PV electricity. This suggests, first, that the majority of countries think that the differentiation provided by PV-specific feed-in tariff rates is sufficient to provide the price incentives necessary for targeting the development of this type of energy and second, that where both a feed-in tariff and PV quotas are in use, they may well apply to

[22] In 2008, Denmark decided to use a tendering process to develop off-shore wind capacity (EC, 2008). French tariffs for wind energy have remained unchanged (except for inflation-index adjustments) since 2006, and are currently too low to attract off-shore investment. France will therefore launch tenders in 2011 to develop off-shore wind capacity (EurObserver'ER, 2010b).

[23] IEA (2009d) notes that, although rural PV installations were originally seen as a solution to the problem of rural electrification specifically in remote areas, some countries are now beginning to target the agricultural sector as such. For example, Japan has introduced subsidies to promote renewable energy use in agriculture, forestry and fisheries, which cover part of the cost of installing PV systems at facilities like refrigerated warehouses for agricultural products, livestock housing and biomass conversion facilities.

[24] Sixteen states use these so-called 'Solar Renewable Energy Certificates' (SRECs). Another 14 or so states operate an RPS system in which certificates for solar energy typically carry a multiplier of 2 or more (a multiplier of 2 for solar energy means that PV energy producers receive two certificates per unit of electricity produced rather than one). However, in states where wind energy is particularly cheap, this has apparently proved insufficient to make solar power competitive, and hence the decision to 'ring-fence' a minimum share of solar energy using SRECs (see U.S. Department of Energy, 2010a).

different segments of supply (or, in the case of the United States, to regimes in different states).

The over-heating of the PV market in some EU countries (most notably, Spain) in 2008 illustrates some of the risks of policy intervention in energy markets. Attractive feed-in tariff rates in Spain stimulated a very rapid increase in installed capacity, some of which later proved to be of dubious quality. A situation of excess supply and grid overload resulted.[25] The Spanish economy was at that moment also entering a steep downturn due to the global economic crisis, and feed-in tariffs were lowered sharply. This precipitated a collapse of the market for new installations, the disappearance of thousands of jobs, and a general loss of confidence from which the market is slowly recovering. Elsewhere in Europe, government reactions to rapid rates of uptake were less extreme and the collapse of other national PV markets was avoided. However, the lesson was learnt by all participants, and the strong need for stable policies that are sustainable in the long term was underlined.

Solid biomass

As shown in Table 2, solid biomass is currently a major renewable energy source globally (a poor second after hydropower for electricity, but dominant as a source for heating).

Within the EU, the greater part of solid biomass comes from forest waste and industrial by-products. It is estimated that less than one quarter of woody biomass comes directly from forest removals. But this is not so in the rest of the world, where deforestation remains a real threat. There is wide variation in conversion efficiency between different conversion methods (household stoves and boilers, cogeneration (combined heat and power) plants and district heating plants, large-scale power stations and waste incineration), and also in GHG-emission savings, depending on the feedstock used (European Commission, 2010b). Maximising the potential to reduce carbon emissions, and providing stronger guarantees of sustainability in a more general sense, are current concerns of EU policy makers.

There is no overall EU policy framework for solid biomass (or biomass in general). Each member state has developed its own policy approach, depending on historical, economic and institutional specificities. For example, Sweden’s carbon tax (increasing sharply since its introduction in 1991) has given a strong boost to renewable heat, with the result that in 2008 biomass (direct consumption *in situ* or delivered from a district heating network) became the main source of household heating (EurObserver’ER, 2010a). In Austria, a long-standing federal scheme involving soft loans, direct subsidies and a reduction in value added tax on wood has helped to promote district heating using biomass (IEA, 2003). There is considerable variation among member states in the share of their biomass energy used specifically for electricity generation; in the EU as a whole, this use of biomass is growing strongly.

In June 2010, EU member states submitted their National Biomass Plans as required by the Renewable Energy Directive (2008). Summarising these plans for 26 countries, Beurskens and Hekkenberg (2010, Table 2, p.17) estimate that solid biomass will provide 72% of total renewable energy used for electricity and heating in the EU in 2020, and 32% of renewable energy for all uses (including electricity and transport). Considering only bioenergy, solid biomass is expected to provide the lion’s share (89%) of the EU’s total bioenergy in 2020. The Baltic countries, and to a lesser extent Finland and Sweden, rely heavily on expanding heating from biomass to reach their 2020 renewable energy targets. In other EU member countries, the planned renewables portfolio is more diversified. Differences in national approaches reflect a combination of comparative advantage and policy preferences.

[25] Only a tiny share of the EU’s PV production is off-grid (EurObserver’ER, 2010d).

In the United States, federal bioenergy policies appear to have concentrated on biofuels, with conversion of solid biomass to other forms of energy attracting relatively little policy interest.[26] The Energy Policy Act of 1992 introduced incentives for electricity generation from renewable sources including biomass, but was no longer available for new projects after 2003. However, various initiatives exist at state level.

A recent overview of the priorities for developing energy from biomass in the USA (US Department of Energy, 2010b) stressed the maturity of the sector, with its hundreds of successful commercial-scale operations, but also emphasised the huge scope for better exploiting more recently developed technologies and end-uses. The document sets out in detail the role that future policies might play in achieving this, and identifies a number of challenges. According to the report's authors, incentives for the uptake of new technologies need to be strengthened. For example, there is still a large technical potential for upgrading some biopower facilities into higher-efficiency combined heat and power systems. Inevitably, higher performing technologies make greater demands on the smooth operation of biomass supply systems, where there is also much to be done. The report mentions, among the barriers to realising a 'widespread, sustainable U.S. biopower industry', the uncertainty of the policy and regulatory climate itself and stresses the heterogeneity of the sector as it currently exists, including scale of operation, conversion method, type of feedstocks used, and ownership profile.

4. Policies for optimising the development and contribution of green energy

4.1 Some general principles

Commenting on the range of intervention options shown in Figure 2, Steenblik (2007) pointed out that open-ended, production-stimulating subsidies tend to be the most costly and inefficient way of stimulating the chain; by contrast, support for capital investment is usually finite in amount and duration, and more easily terminated, whereas 'support for R&D is, by comparison (apart from the chance of supporting non-viable technologies), a relatively "no-regrets policy"' (p.53).

It is true that individual policy measures have intrinsic features that to an extent predetermine their efficiency when implemented in particular situations. However, when considering how best to stimulate the performance of an interrelated set of supply chains, the expected performance of an individual policy instrument, considered in isolation, is not the only relevant criterion. The issue is rather whether the package as a whole is coherent and not over-instrumented, whether the measures target the most appropriate points in each supply chain and whether there are synergies rather than duplication or conflict between the various measures in the package.

This section proposes an approach for guiding and evaluating policy choices in the renewable energy sector that draws on ideas developed in two complementary areas of previous work. First, over decades of policy analysis and recommendation, the OECD has distilled a set of general principles to guide policy intervention, on which more concrete best practice recommendations for particular objectives and sectors can be based (subsection 4.1). Second, international bodies like the International Energy Authority (see, for example, IEA, 2003, 2008c) and the Global Subsidies Initiative (see, for example, GSI, 2010) have developed

[26] An overview is given at http://www1.eere.energy.gov/biomass/federal_biomass.html.

guidelines for rational and effective policies specifically for the energy sector (subsection 4.2).

Governments intervene in markets for many reasons, which usually intend either to improve the functioning of the market (efficiency-enhancing measures) or to alter its outcome in favour of one group of stakeholders at the expense of another group (redistributive measures). In general, economic theory shows that the former set of measures have the potential to improve the welfare of all concerned, whereas the second set of measures inevitably reduces collective social welfare. Therefore, there is a strong recommendation in favour of the former type of efficiency-enhancing measure, with the proviso that governments should also take care that the resulting net gain is shared fairly among social groups.

Although it is recognised that measures of the second redistributive type may be inevitable on equity grounds or for reasons of *force majeure*, they would ideally be time-limited. The policy challenge here is to change the underlying conditions so that, in the longer term, the perceived need for redistributive measures is removed altogether or so that these measures can be replaced by efficiency-enhancing intervention. Although this ideal longer-term outcome is still far off in most current real world situations, it remains a key aspiration behind much OECD policy guidance.

Policy interventions that correct for market failure are clearly efficiency-enhancing. 'Market failure' describes any situation wherein underlying conditions prevent markets from functioning in a way that realises all opportunities for mutually beneficial exchanges of resources or final goods. The extreme case of market failure is where the market for a scarce resource is missing altogether (the case of public goods and many externalities), or where markets exist but under-perform because some relevant participants (e.g. future generations) are not represented, or because relevant incentives are distorted or blunted (e.g. not all participants have access to – or belief in – relevant information), or due to market imperfections arising from market power and vested interests of some participants, or because circumstances have changed in such a way that existing institutional arrangements and market infrastructure are now obsolete and constrain the way the market functions.

It is important to distinguish between permanent and temporary market failures. In the second case, corrective policy measures should be designed from the outset to be time-limited, and if possible should be accompanied by other measures that remove the underlying cause of the market failure, thereby permitting the future phasing out of policy intervention in the relevant market altogether.

The polluter pays principle (PPP) (see, for example, OECD, 1992) is another cornerstone of OECD policy guidance, which has been enshrined in much national legislation and various international agreements. The PPP was first adopted by OECD members in 1972 as an economic principle for allocating the costs of pollution prevention and control, with what constitutes 'pollution' defined in relation to the relevant legislation in force. In essence, it states that the polluter should bear the cost of all steps that he is legally bound to take to protect the environment, and he should not receive any government assistance (e.g. subsidies, fiscal concessions) for doing so. Over the years, the polluter's liability according to this principle has been gradually extended to encompass an increasing share of the full social costs of any pollution he causes, with the application of the principle being progressively extended to cover various concrete cases and special circumstances in a more explicit way.

A further basic principle of effective, minimally-distorting policy intervention recommends that measures should be targeted as closely as possible to the decision that the policy seeks to influence. This principle applies to policy design generally, whether it aims to be efficiency-enhancing or redistributive. It is particularly relevant for policies that seek to improve the functioning of a complex supply chain, and where policy interventions are theoretically possible at many points in the chain. It implies that a good understanding of the functioning of the chain is needed in order to identify those decision points where incentives need to be boosted and where particular constraints have to be overcome. Its corollary is that indiscriminate stimulation of the chain may result in redundant measures and wasteful support for decisions that would have been taken in any case.

4.2 Creating sustainable markets for renewable energies

The IEA (IEA, 2003) analysed 22 case studies reporting successful programmes for promoting the use of renewable (and a few non-renewable but 'cleaner') energies with the aim of drawing up some generalisable best-practice guidelines. Adopting three different, complementary perspectives (dubbed 'research, development and deployment', 'market barriers' and 'market transformation'), it offers some valuable insights into how the general principles in the previous section might be translated into more concrete recommendations for stimulating a major technological shift in the energy sector, and in society at large.

The first perspective focuses on the innovation process, industry strategies and the learning that is associated with new technologies. More investment in research is an urgent priority. The market failure rationale for government spending on research is well supported in the economics literature: when left to themselves, private decision-makers invest in an amount of research that is sub-optimal from society's point of view unless they are sure to be able to capture all the benefits of their research by taking out patents, issuing licences and so on. Therefore, governments have an undisputed role to play in stimulating and financing research on new technologies. However, the usual caveats must be expressed here. The market failure rationale for government support applies more strongly to basic, technology-neutral research than to near-market or technology-specific is development. The risk of government-supported research crowding out research that would otherwise be undertaken by the private sector should always be taken into account, as well as the possibility that technology-specific research is biased towards existing industries keen to defend their current position against new competing technologies.

In addition, IEA (2003) underlines the crucial role of government support for the process of institutional and technology learning that involves getting a new technology from promising or successful research and near-market development to effective market deployment. The value of demonstration projects and pilot schemes is emphasised, as is the potential role of niche markets where end-users might be willing to pay more in the initial stages of marketing a technology, but where at the same time experience can be gained that is of great value in developing the technology for a subsequent wider, more commercial up-take.

Second, market barriers to renewable energy up-take are manifold. IEA (2003, Table 4.1, p.65) presents a non-exhaustive list ten types of (often overlapping) market barriers, and the policy interventions that can reduce them. Although many of these barriers are not themselves the result of market failure, they can often become causes of market failure unless they are removed. Examples are the inertia of markets based on established technologies (whereas new technologies by their very nature may require very different marketing mechanisms), and the very high 'search' costs for would-be 'first-in-the-field' consumers (it may not be economically feasible for producers to provide easy access to product information in the very early stages of marketing a product). It is stressed that new market infrastructure for new technologies may have to be built 'from the ground up'.

The so-called 'infant industry' argument, which used to be adopted to justify using trade barriers to protect fledgling domestic industries facing international competition from well-established industries using the same technology, has in recent decades been discredited as a blunt instrument that is likely to foster inefficiencies and prevent domestic market reforms that would allow the new industry to develop in a sustainable way (see, for example, Baldwin, 1969; Messerlin, 2006). IEA (2003, pp.69 and following) argues that this reasoning does not apply in the case of support measures for introducing and developing the market for a *new technology* having the potential to supersede existing technologies. In this case, a *dynamic* perspective is needed, which leads to very different conclusions.

The argument is as follows. First, support programmes for developing a market are usually targeted to specific initial market barriers and allocated for a limited duration. They are therefore less likely to become permanent 'crutches' fostering inefficiencies than legislated tariffs are in the infant industry case. Second, if investment in market development is left to individual firms, under-investment will result unless each firm can appropriate the return on its own investment without its competitors also benefiting (a genuine market-failure argument). Finally, many aspects of market development are irreversible (such as establishing the new technology or product in the market place and gaining consumer acceptance, or realising scale economies as the market grows), so that the longer-term sustainability of the market will not be dependent on continuing market support.

The thrust of this argument is *not* that new forms of renewable energy enjoy exceptional circumstances that make the infant industry argument valid, but rather that the negative aura surrounding the infant industry argument, which was developed to defend a quite different situation, is not a relevant reason for opposing temporary targeted support for developing the market for a new technology in a way that will subsequently ensure its survival without subsidies under competitive conditions in a mature market.

IEA (2003, p.81) explains its third perspective as follows: 'The term *market transformation* has a particular meaning in the context of energy policy; it refers to a significant or even radical change in the distribution of products in a given market, in which the most efficient products substantially displace the least efficient ones. A *market transformation programme* refers to actions taken by government … to facilitate the market transformation process. In effect, the long-term objective of most such initiatives is to make an energy-efficient technology or product-type the preferred 'norm' in a market place…'. This objective fits very closely with the current Green Growth Strategy.

A market transformation programme involves a change in the market for a particular *class of products*, and encompasses (if necessary) all segments of the supply chains of these products, including the suppliers of ancillary goods and services. Although this involves governments influencing market decisions, the emphasis is 'on designing that influence so as to interfere with normal market processes as little as possible… (and on) encouraging competition in the aspects of products that determine energy efficiency and emissions' (IEA, 2003, p.85). The aim is to improve the market environment for private decision-making by dealing with 'non-economic barriers like administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and …social acceptance issues' (IEA, 2008c).

The 'missing market' argument, which as mentioned above would justify intervention on the grounds of market failure, is sometimes invoked to support the creation by governments of markets for carbon emissions, i.e. markets in which 'rights' to emit greenhouse gases, measured in units of carbon equivalent, are traded between polluting firms. A pre-condition for such a market is that the total amount of allowed emissions is controlled ('capped') through the issue by government of a given quantity of emission rights. Some proponents wrongly believe that such a measure succeeds in internalising the previously unpriced externality and goes a long way towards ‘solving’ the GHG emission problem.

Unfortunately, this is far from being the case. Market failure still exists in so far as future generations, who will have to live with the consequences of GHG emissions by current generations, are not represented in today’s emissions market. If they were, they would probably trade with current generations to take *more* emission rights off the market altogether, the cap would be lower and the market price for the right to emit would be higher. What the cap and trade system does is to reallocate the capped quantity of emission rights, fixed according to *today*’s political consensus, in such a way that the emissions are caused by those polluting activities whose output has the highest market value for *current* generations. In other words, it reallocates the burden imposed by the cap so as to minimise the welfare reduction for current consumers. This reduces the social cost of the cap, and may well increase its political acceptability. Moreover, it creates an incentive for permit holders to respond to emissions being capped by switching to renewable energies and making investments to improve energy efficiency, especially if it is expected that the cap will be reduced in the future. However, this does not *per se* render superfluous other policy measures that *accelerate* these actions and thereby allow the cap to be reduced more quickly, for a given welfare loss to consumers.

The general implications of the PPP for the present discussion are also clear. Since the PPP defines pollution in relation to legislation in force, it provides not grounds for attributing responsibility for greenhouse gases already accumulated and their current consequences to today’s fossil fuel industries. Throughout much of the life of these industries, such environmental concern as there was about their growing use focused on local and then terrestrial impacts (e.g. air quality in traffic-congested areas, impact of acid rain on areas downwind of coal-fired power stations). The possible consequences for changes in the upper atmosphere and the global climate were unimagined. In the absence of competitive alternatives and as long as fossil fuels were low-hanging fruit, the creation of a fossil fuel-dependent economy and the subsidies that promoted the modern world’s reliance on fossil fuels seemed to be more in the public interest.

However, given what is now known about these consequences, and as societal concern is rapidly being translated into legally binding acts to mitigate the climate-change process, it is irrational to continue subsidising fossil fuels.[27] Control and reduction of GHG emissions are core objectives of the Green Growth Strategy. Compatibility with the PPP in this context calls for a fundamental rebalancing of support going to the energy sector generally, in a way that explicitly considers the potential of each type of energy to contribute to this strategy.

Moreover, the longer-term impacts of removing fossil fuel subsidies appear to be far from catastrophic. The impact of multilateral fossil fuel subsidy removal on GDP by 2050 would appear to be relatively small in most countries and regions, ranging from a 2.6% positive impact in India to a negative impact of under 5% in the region composed of some Balkan countries plus the former Soviet Union[28] (OECD, 2010b, Figure 4, p.34).

[27] Owen (2006) shows that when the estimated externality costs due to fossil fuel combustion are internalised into the price of the resulting electricity output, a number of renewable technologies become financially competitive with coal-fired plants. Although combined cycle natural gas technology would dominate both coal and renewables given current technologies and market conditions, under the assumption of mature renewable technologies and economies of scale, renewable technologies would have a significant social cost advantage if all externalities of power production were internalised. He concludes that ‘incorporating environmental externalities explicitly into the electricity tariff today would serve to hasten this transition process’.

[28] Only two other countries/blocs – OPEC and Canada – have negative GDP consequences, of less than 2%.

The IEA, the OECD, OPEC, and the World Bank (2010), dubbed the 'IGO-4', assembling recent estimates of support to fossil fuels, put the amount in the order of nearly USD 700 billion in 2008 (the ratio of consumption to production subsidies was over 5:1). In an attempt to 'normalise' these figures, one could argue that non-fossil fuel industries taken together (including nuclear energy) also receive significant subsidies and that account should be taken of the taxes that are raised on fossil fuels (mainly transport fuels). This reasoning is hardly relevant in the presence of an explicit objective to phase out fossil fuel use and replace it by renewable, green energy. In the present context and given the objectives of the Green Growth Strategy, it would of course make little sense to subsidise green energies with the aim of helping them to compete against fossil fuels when the latter are also being heavily subsidised. However, it needs to be borne in mind that subsidies to renewable energies are largely provided by OECD countries, whereas the bulk of subsidies to fossil fuels are being paid in emerging developing countries (such as Iraq, Iran and Venezuela).

This does not mean that the transition phase will be easy. However, the G-20 proposal to begin by identifying and reducing those specific fossil-fuel subsidies that are 'inefficient' (because they encourage 'wasteful' as opposed to 'necessary, basic' consumption) is unoperational even as a first tentative step, because it is not based on any objectively formulated, consensual definition of these terms.[29] This pessimistic assessment is heightened by the IGO-4 report's recommendation that implementation of the proposal 'requires understanding the circumstances of each country, and the impact of the different subsidies in use. As such it remains in the remit of sovereign decision making' (p.9). Thus, international pressure to move collectively in this direction is effectively emasculated.

4.3 Maximising the potential of renewable energy from the rural and agrifood sectors

Specificities of the farming sector

First, it is useful to rehearse some of the characteristics of the agricultural sector and rural areas in OECD countries. The dominant operating entity in farming is still the family farm or small private (usually family-owned) company, whose main role as food and fibre producer has been unchanged for generations. The scale of each operating unit is small compared with the structure of many highly capitalised, technology-dependent industries, and individual units may be quite capital-constrained. Hence, most farmers are quite risk-averse. Moreover, many farmers are used to an annual cropping cycle that leaves them free to correct bad choices or adjust to changed circumstances within one to three 12-month periods.[30] It follows that longer-term decisions to invest and acquire skills in order to produce renewable energy on-farm are not part of their normal business. It follows that farmers will be encouraged to make a long-term commitment to renewable energy production by long-term guarantees about the stability of prices and policies (contracts, strong political commitments) and deterred by increased risk, unstable markets and policy fluctuations.

De Jager and Rathmann (2008) looked at the role of policy in reducing the financing cost of projects that use renewable-energy technologies. Although the study did not focus specifically on farming enterprises or small businesses, its main conclusions are very relevant also to them. Among its recommendations are that governments should make a credible long-term

[29] It goes without saying that *all* subsidies that are inefficient in the usual sense of the term should be removed in the interests of effective policy-making and good governance. Moreover, the terms 'wasteful' and 'basic' are very subjective and susceptible to biased interpretation.

[30] This is not to deny that some items of farm capital equipment and fixed investment is specific to producing a particular commodity or using a given technology, and therefore can lock a farm into a longer-term commitment to produce particular commodities or in a particular way.

commitment towards renewable energy, and should do all in their power to reduce risks by removing planning and administrative barriers and delays.[31] They should incentivise downstream players (i.e. grid operators, energy utilities) to adopt more transparent and non-discriminatory procedures, encourage risk-sharing (either with government itself via loan guarantees or government project participation, or by facilitating cooperative approaches among non-government participants), give priority to demonstration projects and market introduction campaigns, and provide low-interest loans and other measures that align the debt term with the technical lifetime of the project.

A combination of these actions by government would provide a long-term, stable and transparent policy environment that reduces investor risk. This is particularly relevant for agriculture, for the reasons given above. At the same time, however, a policy commitment to long-term stability must not cause governments to be over-cautious about setting ambitious targets or to delay improving policy design over time as more experience it gained.

Another feature of agricultural activity is its spatial dispersion and (typically) its geographic distance from industrial centres and consumption hubs. The logistics for delivering farm-generated renewable energy to the relevant market or organising biomass supply chains, as well as building the infrastructure needed to support new technologies (availability of skilled advice and maintenance networks) may need to be put in place from scratch, and this cannot be done by one or two farmers. Until it is operational, many potential renewable energy producers and energy resource suppliers may be unwilling to put their toe in the water. There may be a time-limited role for policy to stimulate the development of this infrastructure.

Information gaps and administrative hurdles are another deterrent for the farmer. He may be interested in developing the energy-producing potential of his farm, but before incorporating renewable energy activities into his farm plan, he needs to be able to discuss with experts questions like: what is the optimal extent of on-farm biomass processing on his farm? What are the advantages of scaling-up by joining in with neighbouring farms, or trying to organise a community approach? Which form of renewable energy production is best suited to his particular farm and type of farming, or should multiple opportunities be taken if they are each economically attractive? He also needs legal and tax advice, technical training, information about the various administrative steps that have to be taken and the confidence that these steps can be completed in finite time.

A farm's management expertise is often one person deep: this person is the farmer himself, who must also manage all aspects of the farm. The fact that, in many countries, a dynamic group of farmers is taking the lead in managing the farm's resources from an energy perspective and becoming involved in on-farm renewable energy production should not blind policy makers to the fact that full exploitation of this potential in agriculture, and its maximum penetration of final energy markets, requires the participation of the great majority of farmers who are much more cautious in responding to new opportunities and very time-constrained by daily farming operations.

Thus, the specificities of the farming sector give rise to adoption barriers that need to be taken into account by policy makers. It may well be that, at least in the early stages when there is insufficient critical mass, targeted incentives will be required. At a later stage, when

[31] Comparing the share of renewable electricity in Germany with that of England and Wales, Mitchell *et al.* (2006) argue that the reduction in generators' risk provided by Germany's feed-in tariff system relative to the renewables options policy operated in England and Wales is a key element in explaining Germany's success. De Jager and Rathman (2008, Table 6-1, p.129) show that Germany has lower capital costs than the USA, Canada, the Netherlands, the UK and France for a variety of renewable technologies, which – according to the authors – is specifically due to the long-term stability of Germany's policy environment.

participating farmers are numerous, private market provision of many of these services is likely to emerge.

A further feature of the agricultural sector in many OECD countries is the ageing of the farmer workforce. In many OECD countries and regions these days, the average farmer is in his middle or late 50s, and may be less inclined to adopt on-farm energy-saving or energy-generating measures. This means that, in the very short term, particularly strong incentives might be needed to achieve a large uptake of new on-farm renewable energy initiatives commensurate with the sector's potential. It also means, however, that with the more rapid structural change that will occur when these older farmers exit, new farm operators with a different perspective on the opportunities for transforming farm-based resources into marketable outputs may more easily enter the sector. Indeed, the redefinition of the farmer's role as food and energy producer may make the sector more attractive to a new generation of entrepreneurial farmers.

This suggests that energy awareness and skills should be incorporated into the education and training of potential young farmers, and that this could contribute very positively to the process of redefining the farmer's role (just as, several decades ago, a new emphasis on environmental custodianship was brought into the education of young farmers.

In sum, policy makers could pursue further the opportunities offered by inter-generational change in the farming context to facilitate the change of mind set needed to give momentum to green growth.

What is needed now?

Much research is still needed into better and more flexible technologies for exploiting unused or under-used bioenergy resources on farms and in rural areas. For example, development of higher-yielding, lower-input, drought-resistant and salt-tolerant feedstocks is a priority, and more knowledge is needed about the performance over time of new energy crops, the synergies among them and with existing crops, and the most suitable production systems for them in particular regions and climatic zones. In some cases, their environmental impact needs further study.

The modular packaging of technologies, processes and storage systems greatly facilitates their adoption on farms. However, questions of optimal scale, and appropriate combinations of energy cropping, wind and solar power capture and food production are not all resolved and more account needs to be taken of regional specificities in developing optimal on-farm systems. This kind of developmental research should be done in close cooperation with farmers in on-farm trials, and may not need to rely on government support. Technologies that allow more of the value-added to be captured on-farm by farmers are particularly interesting, as this will give a bigger boost to farm incomes and hence provide stronger market-oriented (rather than policy driven) incentives. An example is the research and development effort currently looking at technologies and protocols for small-scale methanisation and injection into natural gas grids (Weiland, 2010).

Research and development should not stop, however, with upstream technologies. More socio-economic, behavioural research is needed to understand the reasons why some farmers adopt renewable energy technologies and others do not. What are the concrete bottlenecks and psychological factors that prevent producers responding fully to the incentives that already exist? Constraints might include uncertainty about the long-term future of the farm's livestock production unit, lack of confidence or need for training regarding the unfamiliar technology, personal preferences and motivation of producers who see themselves as farmers in the traditional sense, or community pressures based on misplaced 'nimby-ism[32]'. And what incentives would overcome these constraints?

Moreover, it follows from the 'whole-chain' approach that research efforts should concentrate on what appear to be under-utilised opportunities, bottlenecks and constraints *anywhere* along the supply chains that lead from primary renewable energy resources through to end-use energy markets. Prioritising research efforts so as to pinpoint missed economic opportunities needs an integrated understanding of the technologies, decision processes and chain dynamics. The results of this research should have the greatest spin-off for designing better policies to increase the efficiency of the chain.

Depending on the type of energy involved and the organisation of the national market, there are also various opportunities for direct government action to improve the operation of the chain downstream from farming. Governments should look to questions of structure and firm concentration in market segments between energy resource suppliers and final consumers, in order to make sure that market power and uncompetitive behaviour do not exist that would blunt incentives or act as barriers.

There are also, of course, technical problems to be solved downstream, not least in the case of renewable energies that are generated intermittently (wind and solar power) or whose raw materials (types of biomass) are in seasonal supply. In particular, it is foreseen that when a much larger share of the electricity supply is green, total supply will become more variable in the short term. One key component in enabling greater use of intermittent power sources is the 'smart grid': an electricity delivery system that monitors and automatically optimises the operation of its interconnected elements, including the equipment of end-use consumers that can automatically adjust their demand for power in response to signals from the grid, thereby effectively increasing the flexibility of power demand in order to match that of supply (see Ahm, 2010; Ogimoto, 2010). A smart grid would also transmit one-day-ahead forecasts of supply to end-using systems that could then optimise their own decentralised storage possibilities. There is also intense research and development underway on commercial applications of innovative kinds of supply-side energy storage.[33] Public-private partnerships could be an effective way of stimulating the kind of large-scale ventures that may be needed to fully exploit these possibilities.

In the complex process of market development, there is a role for government in setting up and organising the enforcement of technical standards for biomass and waste, in order to reduce market transaction costs, increase user confidence and develop social acceptance. Regarding the latter, individuals as consumers are conditioned to be price-conscious. As long as the environmental costs of fossil fuels are not fully reflected in their market price, some energy consumers will automatically exclude higher-priced renewable alternatives or display hostility to mandated consumption of renewable energies. Other problems of social acceptance stem from attitudes concerning environmental effects, technological risks or simply unwillingness to change that are often based on erroneous or incomplete information.

The renewable energies produced in the rural and agrifood sectors may be the easiest to sell to socially concerned individuals on the basis of their ultra-low carbon footprint, their respect for environmental sustainability and their parsimony with respect to scarce resources. To the extent that farmers and rural communities still retain the respect of society at large as custodians of natural resources and producers of 'healthy', life-sustaining commodities, this

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[32] NIMBY ('not-in-my-back-yard') is said of someone who supports actions for the public good as long as they occur sufficiently far away that he will experience none of the real or imagined negative externalities.

[33] Such as heat storage using phase-changing molten salts (see, for example, Sharma and Sagara, 2005), or storage of electricity through temporary conversion to hydrogen (see, for example, Anderson and Leach, 2004).

image may be an advantage in helping consumers to accept energies derived from biomass or produced on-farm. Here, governments can help by demonstrating a positive long-term commitment to the rural sector in its role as energy producer and by maintaining incentives that highlight the major contribution to energy supply that society now requires from its agricultural producers in order to deal with climate change.

Success story: Green electricity in Germany

Background. The 1973 oil crisis was the first stimulus for Germany's renewable energy strategy, which initially focussed on research into alternative energy provision. Other economic measures began a few years later. They received a strong boost after the Chernobyl disaster in 1986 when public opinion swung massively against nuclear power. Several measures were adopted aiming to stimulate the market for renewables (notably, wind and solar power).

Main legislation. The path-breaking 1990 *Electricity Feed-in Law* required electricity utilities to provide grid access to external renewable electricity generators at feed-in tariffs of 65-90% of the average final-customer tariff (Lauber and Lutz, 2004). After repeated attempts to liberalise the powerful energy supply industry, the controversial *Energy Reform Act* of 1998 was passed. This was followed by the *Renewable Energy Sources Act* of 2000, reaffirming the feed-in tariff framework and providing more long-term security for renewable electricity generators.

Success and prospects. In 2009, electricity from renewable sources was over 16% of total electricity use (6.5% and 5.2% of total use from wind power and bioenergy, respectively). The share of total energy use from renewable sources was over 10%, with 7% of total energy use from biomass alone. In September 2010, ambitious new targets for renewables - well in excess of those set by EU policy - were adopted: 18% of total energy use by 2020, and 60% by 2050, 35% of electricity use by 2020 and 80% by 2050 from renewable resources, accompanied a 50% saving in electricity consumption by 2050 relative to the 2008 level.

Key elements. *Market creation* (feed-in tariffs, grid access); *appropriate incentives*, targeted on energy delivered rather than capacity installed; *level playing field regarding costs* (tariff rates that take account of external costs of conventional energy generation) (Jacobsson and Lauber, 2006); *broadly based policy network*, including the investment goods industry, environmental groups, activists and the wider public as well as the main players; *long-term perspective* spanning several decades for completing the transition to a cost-competitive green energy system; *strong political commitment* when needed in the face of public controversy and entrenched interests; *strong social acceptance*, with for example many thousands of small investors in citizens' wind farms.

Controversy. Germany's renewable energy policy has not been without its critics (see, for example, Frondel *et al*., 2009). The main charges are that, *first*, the level of feed-in tariffs is not cost-effective (this criticism has been levelled particularly at the tariffs for solar PV electricity, which in 2008 were over three times those for electricity from biomass and nearly five times those for on-shore wind-generated electricity). *Second*, it has not led to lower GHG emissions because the resulting substitution of electricity from renewables for fossil-fuel-derived electricity has not been accompanied by a corresponding reduction in the cap set by the European Emission Trading System; this has kept the price of emissions lower than otherwise and freed up certificates for use by other, more polluting sectors. The effect has been a shift in total carbon emissions, rather than a reduction. *Third*, the claimed increase in jobs has been overstated, and disappears when the loss of jobs due to the effect of higher electricity prices throughout the economy is taken into account.

The question of energy market fragmentation might also be studied in a number of countries. In the EU, energy supply tends to be organised at national level, and energy policies are largely decided by each member state within rather general EU guidelines. In the US, energy policy is formulated at two levels, federal and state, with the more operational details of energy systems and their regulation remaining under the control of state jurisdictions. This picture is repeated in Australia and Canada. The result is a fragmentation of energy markets and policies and the lack of a ‘level playing field’ over areas where markets for many other goods and services are virtually fully integrated.

The European Commission recently studied this issue and recognised that the integration of energy markets and energy policies could simplify conditions for investors, optimise site location decisions, give a potential boost to economies of scale and ‘provide a clearer framework for efficient exploitation of renewable energy across the Union’ (European Commission, 2008, p.13). Nonetheless, the time was considered not to be ripe for forcing market and policy integration, and the recommendation was to aim instead for gradual harmonisation as countries voluntarily align themselves with best-practice procedures already adopted by certain other member states. Among the grounds for this conclusion was the need to maintain the stability of the existing arrangements and avoid disrupting emerging markets.

However, the question remains open as to whether the increasing mobilisation of agriculture as a supplier of renewable energy, a sector for which policies are largely formulated at EU level and for which product markets are well integrated across the EU as a whole, sits well with the organisation of energy markets and policies within national frontiers. Other OECD countries where a similar situation exists may also have reached a point where an in-depth re-examination of current market and policy fragmentation is called for.

Getting intervention right

The issue of *where* it is most effective to intervene in the often complex supply chains for renewable energies has already been identified as a crucial one. Since each supply chain differs depending on the raw energy resource it uses and its particular structure, there is no one-size-fits-all recommendation. The general principles underlying these choices are, however, the following. Intervention and support should focus on those links in the chain where incentives are currently most lacking, where short-term adjustment costs are highest, where institutions are weak or administration is particularly heavy, and where there are market failure barriers that inhibit the creation of private markets or their correct functioning. It is not necessary to intervene in every segment of the chain, but the chain must function so that endogenous or policy-induced incentives in particular segments can be transmitted to the other chain participants. Having said this, it is also worth recalling that a policy package targeting several points in a complex supply chain increases the risk of duplication or redundancy of policy measures.

The principles that have been elaborated in the previous two subsections can be illustrated, both in the observance and the breach, by current policies for first-generation biofuels in developed countries. As already mentioned, extra policy measures are generally not used to stimulate farmers’ production of agricultural crops to feed biofuel demand since, as long as commodity markets are working to signal the increase in demand for their output, this is sufficient and measures specifically to stimulate crop feedstocks would be redundant. This is sound economic logic.

Other features of biofuel support packages have, however, been criticised. According to Steenblik (2007), the policy mix in a number of countries contains some redundant instruments. For example, a binding consumption mandate alone is enough to guarantee a final market. Given this, the only justification for combining production subsidies with a consumption mandate (as is done in the United States, Canada and some EU member states) would be to reduce costs to final users. Not only would a cost reduction weaken the incentive to conserve fuel, it is debatable whether a subsidy to producers is an effective measure for achieving a cost reduction for consumers, given that policy measures are more efficient the more closely they target the desired objective and the tendency for lower production costs not to be fully passed on in the final price.

It can also be argued that in a greener economy where energy is used less wastefully, a higher relative price for transport fuel is not in conflict with underlying objectives and certainly does not send a perverse signal. Moreover, if governments want to cushion low-income households against higher energy prices, assistance targeted to these groups would be more cost-effective than a blanket subsidy.

Subsidising flexible-fuel vehicles (which can run on a blend containing up to 85% ethanol) and fuel distribution network adaptation to make E85 blends more widely available have also been criticised by the GSI (Steenblik, 2007) as inefficient and costly measures. 'It is the overall displacement rate of petroleum fuels rather than the specific blends in which it is consumed that matters, whether the policy objective be energy security or reduced greenhouse-gas emissions. The same benefits could be achieved through more widespread use of E10 (a blend of 10% ethanol and 90% gasoline), which any car built since 1980 can safely run on' (*op.cit*., p.56). It is recommended that these decisions should be left to market forces (Steenblik, 2007).

In both these cases, in-depth analysis would be needed to identify the actual beneficiaries of these policy measures in the present context, and to quantify their impact in terms of additional litres of ethanol substituted for fossil fuels, or in terms of extra tons of GHG emissions saved. The above criticisms suggest the impact could be quite low.

Consumption targets and mandates for renewable transport fuel are also criticised in the literature. For example, with regard to these measures Jansen (2003, p.2) exhorts the European Commission to 'fully address the issue of the low efficiency of this policy instrument, relative to other options, in securing energy supply and reducing greenhouse gas emissions. Lessons from the Common Agricultural Policy should be taken to heart by fully charting the risks of creating new vested interests'.

Finally, the question of the overall coherence of the support provided to different renewable energies produced by the rural sector needs to be addressed. Some years ago, Jansen (2003), in reviewing the EU regulatory framework for renewable energy, already strongly recommended better integration of the support system for biofuels with those for other renewable energies, warning that unless targets are set for each renewable option at a similar level of ambition, distortions can be created that impede the development of the renewable energy sector as a whole and that can have negative consequences for other linked objectives, such as those related to the environment and energy security. This approach is gradually being recognised in EU policy making. The recommendation appears to be pertinent to the mix of policies being used in other OECD countries also.

Moreover, it will be important to avoid any conflict in the future when more energy-efficient second-generation biofuels become commercially available. Once second-generation fuels are on the market, rather than supporting supply chains and markets for both first- and second-generation biofuels so that they compete with each other, support for first-generation biofuels should be phased out as quickly as possible while allowing the market to substitute between the fuels according to cost differentials within an overall biofuel mandate.[34] In essence, cost-efficient support, should support be provided, requires total support (from consumer and

[34] Long-term simulations project a disappearance of most first-generation biofuels form the market by the early 2030s (see section 2.3).

government) per unit of the desired outcome (e.g. GHG emission reduction) to be equalised over the various competing renewable energies.[35]

Of course, the idea of measuring the performance of renewable energy policies solely in terms of GHG reductions is controversial in the case of a green growth strategy in which the switch to greener energy is driven by multiple objectives of which reducing GHG emissions is only one. The next section discusses renewable energy supply from the rural sector in the light of a few other green growth objectives.

5. Rural renewable energy and other objectives of green growth

5.1 Rural renewable energy, environmental impact and sustainability

Global economic growth is not possible without a secure and affordable energy supply. The rapid growth seen in the twentieth century was made possible by abundant fossil energy. However, fossil energy sources (petroleum, coal, natural gas) when used release their stored carbon dioxide into the atmosphere, which contributes largely to the global warming that is threatening the ecological balance of the planet as well as many local populations and ecosystems. Moreover, they are in finite and dwindling supply, such that the cost of prospecting for them and developing techniques for extracting their stored energy from lower-yielding or less accessible materials is ever increasing. Their replacement by renewable energy sources with zero or very small GHG emissions is the key to decoupling economic growth from the major environmental threat that we face today on a global scale.

To the extent that bioenergy crops compete with food crops and increase the area of land under cultivation, they can still represent a potential environmental threat (see footnote 7). If vegetation rich in stored carbon is removed in order to bring new land into cultivation to produce crops diverted to energy use elsewhere, the immediate release of greenhouse gas may not be offset by the savings from the ensuing renewable energy production for many years (Searchinger et al, 2007, Searchinger, 2010). This is the phenomenon of so-called *indirect* land use change, which is caused by market forces acting to change the use of land that is not itself involved a specific bioenergy supply chain, and that may be situated on the other side of the world. This phenomenon has been hotly debated as one of the unintended consequences of the biofuel mandates adopted by a number of countries in the first decade of this century.

The EU's Renewable Energy Directive of 2008 contains a number of sustainability criteria (relating to the way the feedstock was produced and the size of the GHG reduction achieved) that must be fulfilled by renewable energies used in the EU. These criteria already pose a particular challenge in the case of imported biofuels (for example, regarding the verification and enforcement of the criteria in import-source countries, and their potential compatibility with WTO regulations). It seems clear, however, that they are impossible to enforce in the case of the food crops that might be displaced to high carbon storage sites or environmentally sensitive areas by the greater demand for biofuels and biofuel feedstocks in the EU.

[35] Interestingly, CBO (2010) found that the cost to US taxpayers in 2009 of reducing GHG emissions per metric ton of CO_2 equivalents *through biofuel tax credits alone* was about $750 for corn ethanol, about $275 per metric ton of CO_2e for cellulosic ethanol, and about $300 per metric ton of CO_2e for biodiesel. These estimates do not reflect any emissions due to indirect land use change triggered by the fuel feedstock demand. When these effects are taken into account, the taxpayer cost of reducing emissions would be higher and the relative costs of reducing emissions by each biofuel would change, substantially in some cases (p.viii). It is unknown whether, if all support to these fuels were included, these relative differences would be smaller or larger

This raises the question of who along any particular causal chain is responsible for GHG emissions, which is not unconnected to the issue of who should bear the cost of reducing them. As Kim *et al*. (2009) have written: "The United States currently does not hold any of its domestic industries responsible for its greenhouse gas emissions. Thus the greenhouse gas standards established for renewable fuels such as corn ethanol in the Energy Independence and Security Act (EISA) of 2007 set a higher standard for that industry than for any other domestic industry". This comment also holds in essence for the EU (see previous paragraph).

Of course, the fixing of standards still stops short of the concept of *extended producer responsibility* (EPR)[36], which is gaining ground in consumer goods legislation in some countries. This concept goes beyond the polluter pays principle to make manufacturers responsible for the entire lifecycle of the products and packaging they produce, and aims to internalise all environmental costs of products into their price.

And yet even the EPR, if it were applied here, would not confer liability for *indirect* land use change effects. As Kim *et al.* (2009, p.1) remark: "Holding domestic industries responsible for the environmental performance of their own supply chain, over which they may exert some control, is perhaps desirable (direct land use change in this case). However, holding domestic industries responsible for greenhouse gas emissions by their competitors worldwide through market forces (via indirect land use change in this case) is fraught with a host of ethical and pragmatic difficulties".

So far, an agreed and effective legal framework does not exist, and certainly not at international level, for dealing with these unintended side effects of increasing biomass production. However, given the globalisation of production and markets, and the global nature of the climate change threat, it is at international level that a regulatory mechanism is ultimately needed.

The indirect land use change issue is not relevant to renewable energies that do not compete with food crops for land, such as off-shore wind power[37] or technologies using waste biomass. However, environmental protection is a multi-faceted concept that does not stop with global temperatures and climatic stability. Whether and how each of the renewable energy options discussed in this paper permits the decoupling of economic growth from *other* potential environmental impacts is also an issue of importance.

The use of renewable energy sources may have (more terrestrial) environmental impacts, some of which are also harmful. Even those technologies that exploit 'free' energy sources like wind and solar heat or light may have unintended environmental consequences given that their production facilities or points of capture are sited in specific locations and they interact with their surroundings.[38]

For example, the potential invasiveness of promising species of dedicated energy crops and the threat to biodiversity of introducing non-native species are well recognised (Eisentraut, 2010; EEA, 2007), as is their sometimes (beneficial) potential for improving soil carbon and fertility and reducing soil erosion. EEA (2007) raises concerns about the implications for fresh-water supplies of greater demand for biomass in general, and the risk of soil depletion from the removal of large quantities of biomass from working land. Although some potential positive environmental effects of on-farm biogas generation have already been mentioned,

[36] An extension of the polluter pays principle, first published in English in Lindhqvist (1992). See OECD (2004b, 2005).

[37] On-shore wind power (installed turbines and access roads) may compete with areas that would otherwise be used for food production. The challenge is to site them where this competition is minimised.

[38] This applies not only to *all* the renewable energies discussed in this report, but also to tidal and wave power, hydropower, geothermal power and of course nuclear power.

other studies express concern for possible eutrophication of watercourses if oxygen-depleted wastewater from anaerobic digesters is released into them untreated. Clearly, most or all of the bioenergy options analysed in this report have their own environmental implications, some of which could be harmful and costly if not anticipated by appropriate legislation or best-practice guidelines.

Putting the appropriate legislation and guidelines in place is the approach being increasingly taken by governments and other public bodies. For example, the European Commission (2010a) reports the procedures in place to minimise the impact of wind turbines on birds and bats and on the habitat of other wild species. A proposed new wind-power installation must undergo a Strategic Environmental Assessment (following Directive 2001/42/EC) or an Environmental Impact Assessment (following Directive 85/337/EEC, amended in 1997 and 2003), depending on whether the project is initiated at the level of a public programme or is an individual public or private project. Furthermore, any wind power project that is likely to affect a Natura 2000 site (an EU-wide network of sites designated for bird and habitat protection under the Birds and Habitat Directives) has to undergo an Appropriate Assessment where these environmental aspects are specifically addressed.

Apart from birds, bats and biodiversity, there has been concern in a number of regions about the visual and amenity impact of wind farms, and individual jurisdictions and advisory bodies have issued their own guidelines. For example, Scottish National Heritage has developed guidelines and provides case-by-case advice concerning the cumulative effects of wind farms (SNH, 2005), their potential impact on wild land (SNH, 2007), small-scale projects that do not require a formal environmental impact assessment (SNH, 2008), and the siting and designing of wind farms in particular landscapes and topographies (SNH, 2009). This kind of careful *ex ante* approach is important for avoiding unintended environmental damage, and for increasing social acceptance of these developments. In many places, local authorities are anxious about the effect of the inappropriate siting of wind or solar farms in their area on tourism. However, adverse effects on tourism need not always be the case: press reports indicate that several wind farms in Canada have actually become tourist attractions.[39]

This very brief overview suggests that, while renewable energy production in rural areas is rarely free of *unintended* environmental spillovers, they need not be *unforeseen*. With appropriate strengthening of legislation, development of guidelines and *ex ante* assessments, and more informed awareness, it should be largely possible to ensure that the switch to greener energy does not conflict with other rural environmental goals.

5.2 Renewable energy, job creation and rural development

A recurring theme in the political debate surrounding the replacement of fossil fuel energy by energy from renewable resources is its scope for creating new and different employment opportunities. Promising claims and predictions are regularly made for renewable energy in this context. For example, when, in 2008, the US federal tax credit (30%) for solar power was extended for eight years as part of the financial bail-out bill (H.R. 1424), it was announced that it would create an estimated 440 thousand permanent jobs. The ethanol industry is credited with creating nearly 154 thousand jobs in the US in 2005 alone, thereby increasing household income by $5.7 billion (Worldwatch Institute, 2006). Furthermore, according to the US Council of Economic Advisers, the approximately US $90 billion of Recovery Act investments will save or create about 720 thousand job-years by the end of 2012, of which '…

[39] "Canada wind farms blow away turbine tourists", *The Edmonton Journal*, 3 October 2007.

approximately two-thirds of the job-years represent work on clean energy projects' (OECD, 2010c, p.27).

The European Commission has stated that the biomass and biofuel sectors have 'generated additional jobs. In 2005, non-grid biomass use accounted for 600 thousand employees, biomass grid and biofuels contributed over 100 thousand employees and biogas around 50,000' (EC, 2009, p.7). Official figures for Germany indicate that over 300 thousand people were employed in the renewable energy sector in 2009, especially in small and medium-sized businesses.[40]

This order of magnitude for the job-creating potential of the renew able energy sector, and of the biofuel industry in particular, has been challenged. For example, Swenson (2006) reviewed some of the economic impacts claimed for ethanol production in Iowa and analysed the 'tendency … to overstate, over-describe, and outright double-count economic activity linked to ethanol and other biofuels production' (p.1). Even when these projections are based on model simulations rather than simpler more *ad hoc* methods, serious over-estimates can occur especially because marginal effects are based on average input-output coefficients (a common criticism of input-output studies), final demand multipliers are too high and − most crucially − all the agricultural input is generally considered to be additional net production, rather than a switch in use of existing production, or a switch in land use from some other productive output. Swenson (2006) also criticised the tendency to over-state the impact on the local economy of siting plants in rural areas, especially the high multipliers assumed for construction activities. Low and Isserman (2008) modelled the impact of a new ethanol plant on a hypothetical rural economy in Iowa, carefully stating all assumptions and taking account of all reasonable indirect and induced effects in the country. They came to the conclusion that the main effect on the local economy in terms of job creation is from the operation of the ethanol plant itself (p.26).

A further issue is the extent to which local employment effects can be extrapolated to the economy as a whole. As has been pointed out by Kammen *et al*. (2004), Freshwater (2010) and others, the issue at the macro level for green growth is the number of *net new jobs* that are provided in the economy as a whole, after accounting for those jobs that are destroyed, and at the level of rural communities, *what kind of jobs* they are and *where* they are located.

First, in order to measure net new job creation, not only should jobs created directly by a renewable energy project be taken into account, but also those indirectly generated by multiplier effects if unemployed resources are set to work, those lost in fossil fuel energy production because of the energy switch and others lost throughout the economy if the switch to renewables increases energy prices, thereby leaving less income for spending on other goods and services. Finally, not only should manufacturing jobs related to the new technologies (e.g. solar PV panels) for domestic use also be counted in but also any additional jobs that arise if these sectors become internationally competitive due to an increase in production scale and start exporting.

As Kammen *et al.* (2004) explain, an economy-wide input-output model is needed to capture all these induced employment effects. These authors reviewed thirteen studies claiming to analyse the employment effects of various renewable energies. Only five of them used an

[40] Of these, 64,700 alone were employed in production, distribution and installation in the PV industry. When updating the Colorado Renewable Portfolio Standard from 20% to 30% in the 2010 Legislative Session as House Bill 1001, it was estimated to lead to 33,500 jobs by 2020. The target of meeting 20% of Canada's electricity demand from wind power by 2025 is estimated to create 50 thousand jobs (CanWEA, 2008). These are simply examples of the many claims made.

input-output model. More generally, it certainly cannot be assumed that all the publicly available estimates of the job-creating potential of clean energy production report the full *net* increase in jobs. It is usually not even stated whether a particular figure covers only direct employment effects or also some (more or less *ad hoc*) estimate of some or all of the other possible augmenting and offsetting employment changes.

Second, it is important to distinguish between jobs in manufacturing, construction and installation on the one hand, and on the other hand those in operation and maintenance, fuel processing, extraction and processing (Kammen *et al.*, 2004). The former occur at the start of a new project, whereas the latter continue throughout the project's lifetime. With the exception of energy production from biomass, most jobs in the renewable energy sector are in manufacturing and installation, whereas those in the fossil fuel sector are in operation and maintenance, and fuel processing. Third, the type of job that is created tends to determine its location. Jobs in equipment manufacturing are probably not located in rural areas, whereas even when new installations are sited in rural areas the work may well be carried out by itinerant teams of specialised workers who are not locally resident. By contrast, employment in biomass production is rurally based.

Using appropriate analytical tools, Kammen *et al.* (2004) compared the employment needs of five energy scenarios: three were characterised by a 20% renewable energy share made up of varying proportions of biomass energy, wind and solar PV power, and two were pure fossil fuel scenarios (one consisting of half coal and half natural gas, the other of 100% natural gas). Taking account of different capacity constraints (for example, plant closure for maintenance work or inactivity due to lack of wind or absence of sunlight at night) and after adjusting for the average lifetime of different types of energy-generating facilities, they estimated that the renewable scenario with the highest biomass energy content (85% of the renewable share) gave rise to nearly three times more total employment in an average year (for a standardised energy output) than the 100% natural gas scenario.

Moreover, the 'winning' scenario provided more jobs in both operations and maintenance *and* in manufacturing, construction and installation, with over three times more jobs in the former category than in the latter. Even in the renewable scenario where only 40% of the renewable share came from biomass (wind power dominated), employment generation was more than twice that of the natural gas scenario, although with manufacturing, construction and installation accounting for 60% of the jobs. These results appear to indicate that renewable energies *can* generate more jobs, and that biomass energy is likely to provide more permanent jobs in rural areas.

Thornley *et al*. (2008) also concluded that renewable energy technologies require more labour than conventional energy technologies yielding the same energy output. In addition, there are differences according to the type of feedstock used. Comparing the job implications of producing electricity from miscanthus and short-rotation coppice, Thornley *et al*. found that although the former requires more direct agricultural labour, its processing stage is less labour-intensive and its overall job-generating potential is lower. Taking into account agricultural labour, transport and feedstock processing, employment at the conversion plant and within the equipment supply chain, and the multiplier employment impact, their results show that electricity from power-only biomass technologies is less labour-intensive (about 1.27 man years/GWhe) than electricity from CHP plants, but they warn that the conclusion per unit of *total* energy produced could change if the heat generated from CHP plants were also taken into account.

Although Thornley *et al.* (2008) found that technology and scale of operation made little difference to the employment per GWhe in power-only plants, Plieninger *et al.* (2006)

concluded from German evidence that the size of bioenergy plants influences their location and hence the benefit they provide to rural areas, with smaller plants contributing more to rural income generation.

It is important to point out that the above comparisons focus on jobs created per unit of energy produced, and ignore the relative *costs* of generating these jobs in the different scenarios − costs that would ultimately be passed on to consumers thereby influencing demand in final markets.

Less is known about whether the ownership structure of facilities for producing green energy affects rural incomes. Much has been written about community wind-energy cooperatives, which are widespread in Denmark and Germany, and are present on a smaller scale in many other countries. However, hard evidence is lacking regarding their impact on the local economy. Unlike the conventional wind farm, which is owned and operated by a company that leases the land from the landowner at a fixed rental or on a royalty basis, the community-owned wind farm gives local owners more control over the project and a share in the profit. Local owners may also be the main users of the electricity generated, and such projects can be successful even at quite a small scale. Thus, another advantage of the community model is that it may allow the installation of wind-power generation in areas that would not interest larger businesses.

Evidence regarding the impact of farmer ownership of bioenergy processing facilities on rural economies is also sparse. Swenson and Eathington (2006) looked at the impact of local ownership of ethanol plants on the local community in Iowa. They found that the local jobs multiplier (that is, the total increase in local jobs relative to the increase in jobs directly attributable to the processing facility) increased with the level of local ownership in the plant. However, they concluded that half to two-thirds of those extra jobs could have been due to the exceptionally high returns enjoyed by the industry during the period studied. They expected the impact of local ownership during times of normal industrial profits to be more modest.

There is more evidence that on-farm ownership and operation of biogas production facilities can boost farm incomes when there is an attractive feed-in tariff and an appropriate on-farm or local supply of raw input. However, the spin-off for local job creation seems small. Indeed, a number of companies are now supplying biogas digesters as a turn-key product, complete with after-sales service. These companies operate over a large area, and do not need to be locally based.

Summarising, it is important to account for all employment effects (direct and indirect) across the economy before drawing conclusions about the job-creating potential of clean energy technologies. The share of any new employment that is in rural areas depends on whether the technology uses biomass or a ‘free’ energy resource, how labour intensive the energy crop cultivation or the farm waste management systems that provide the biomass are, how much energy conversion is actually done on the farm, and how decentralised the energy production capacity is.

The trade-off between production scale and cost, on the one hand, and decentralisation, location in rural areas and rural job creation on the other hand is implicit in some of the above discussion. At the policy level, hard choices may have to be made between more efficient renewable-energy solutions and rural job creation. As with any multi-objective strategy, here too objectives may not always be fully compatible, and should be prioritised according to the specifics of each situation where a potential conflict arises.

6. Discussion and conclusions

For some decades, the knowledge that the fossil-fuel abundance that drove the rapid economic growth of the twentieth century was finite has focused attention on the eventual need for new sources of energy. Nonetheless, there seemed to be plenty of time to develop appropriate solutions. More recently, however, the mounting evidence of global climate change caused by the release of stored carbon on an unprecedented scale has given new urgency to the problem of finding non-fossil energy alternatives. In the last few years, the food price spikes observed around the world and their severe impact on the world's poorest people have reawakened the spectre of food insecurity, which is rendered more threatening by the projections of world population growth in the coming decades. And finally, the global economic crisis, from which many economies still have to emerge, has heightened awareness of how much more difficult it is to solve underlying problems and change economic direction in a climate of stagnation and widespread joblessness.

These developments have shaped the goals and set the constraints for the Green Growth Strategy endorsed by OECD member countries: economic development that provides acceptable living standards and reduces poverty globally while respecting and promoting long-run environmental values − in short, a "decoupling" of environmental impacts from economic growth. A key element of the strategy is the shift to more sustainable and "cleaner" energy sources − that is, energies that are both renewable and have a significantly smaller carbon footprint.

There is a widespread scientific consensus that agriculture (including the agrifood chain) and, more generally, the rural sector have considerable potential for providing renewable energy, both by supplying the biomass (including waste products) needed as feedstocks for various forms of renewable energy, and by utilising the spatial dimension of rural land (much of which is under the ownership of farmers) as a catchment area for the 'free' resources wind and solar energy. The potential contribution of renewable energy from these sources is considered to be of comparable importance to that of geothermal, hydroelectric, wave or tidal power, and generally has fewer technological, environmental and cost uncertainties. Moreover, these energy sources are less competitive with food production than dedicated crops.

Various projections in different countries and over different time horizons indicate that the existence of this unused capacity makes the switch from a fossil-energy-based economy to one driven by renewables feasible from a technical viewpoint. However, optimising the energy-supplying potential of rural areas will involve the majority of farming businesses becoming excess suppliers of energy feedstocks or energy itself to the market, in just the same way that they are currently commercial suppliers of food commodities.

In this scenario, the farmer will be seen – and will see himself – as the producer of a wider range of socially-valued commodities than hitherto. Starting from the same renewable resource base as always (land and other associated natural resources, labour and capital), society will expect him to produce not only food, fibre and environmental public goods, but also renewable energy and other biomass for transformation into renewable energy. Farm waste products will be commoditised.

As long as prices correctly reflect underlying economic values, this should be a win-win situation: new income-earning opportunities are created for farmers while at the same time the energy switch that is central to the green-growth strategy is facilitated. Farmers will be encouraged to adopt this new self-image and play their new role if prices offer appropriate incentives based on longer-term potentials, perceived risks are low, and the necessary logistic and technical support infrastructure is in place.

The question is whether market forces, in response to growing shortages, increasing environmental risks and the pressure of changing relative prices, can alone achieve this transformation on a sufficiently large scale and quickly enough to offer a timely answer to the urgent problems that inspired the Green Growth Strategy. The answer to this question is provided by the very existence of the Strategy and its acknowledged need for concerted policy action at global level according to strong policy guidelines.

This underlying context must be borne in mind when weighing up the evidence presented in this paper on the rural sector's potential to supply renewable energy, and its review of the policy measures that might develop this potential. For years, OECD member governments have been exhorted in the name of economic efficiency to withdraw distorting market interventions so as to allow market participants themselves, acting *en masse*, to interpret and respond to changes in underlying demand and supply. It might be wondered whether − at least in the area covered by this paper − the Green Growth Strategy does not partly contradict this position by encouraging new forms of government intervention in areas that until now have not received so much policy attention.

An answer to this question would be the following: in a "business-as-usual" context, and leaving aside cases of market failure that cannot be addressed by correcting their causes, the recommendation to let the market perform its role of transmitting information between buyer and sellers via price, and balancing supply and demand, remains a valid one. This recommendation is always conditional, of course, on the existence of appropriate market infrastructure, including supportive commercial and consumer-protection legislation. However, a situation where political leaders concur that a fundamental change of direction is needed, and that their economies should be set on a new development path as matter of some urgency, is not a "business-as-usual" context. Rather than falling back on the mantra of "leave it to the market", the challenge is to devise guidelines for interventions that stimulate change in the desired direction while at the same time minimising their scope for distorting markets or leading to policy failures.

The elements of these guidelines are hardly new, yet it is worth summarising the most important of them. Interventions should be time-limited in order to avoid creating vested interests and − the reverse side of the coin − existing obsolete policies should be phased out despite any opposition from vested interests already created. Any genuine public good items deemed necessary for attaining the objective should be identified and, subject to the usual *ex ante* (cost-benefit) evaluation, should be provided. The focus should be on the whole chain of a product or activity, rather than simply one segment of the chain (the most vociferous?), in order to optimise the choice of *where* to intervene if intervention is deemed necessary. Barriers to market entry should be removed at all points in the chain, and the infrastructure for the correct functioning of each market in the chain should be in place. These are all actions within the remit of government policy.

As regards specific intervention measures, they should be targeted as precisely as possible on achieving the desired result, should respect the polluter pays principle, and should be based on a price set where externalities are internalised (if it is not possible to internalise them in reality). In addition, lessons from past policy failure or under-performance need to be learnt. There are already some instructive examples in the area of renewable energy policies, such as the policy-induced over-heating of the solar PV market in a number of European countries several years ago, the distortions created by targeting specific technologies too soon (the biofuel sector comes readily to mind), and the lack of coordination between renewable energy policies and the carbon emissions cap in the European ETS (see the box on Germany's green energy).

Three more specific conclusions emerge from the review of policies and principles in the paper. First, energy policy needs a longer-term horizon fixed according to longer-term trends and expected conditions. It is important to provide a stable decision-making environment in which adoption of new technologies will thrive and one in which policy incentives will converge over time on conditions that are sustainable with reduced or minimal support once the switch is well underway. In particular, market and infrastructural development should be irreversible processes that may need transitional support in earlier stages but should be designed so as to be self-sustaining when critical mass is achieved.

Second, creating the conditions just described will require policy makers to take a whole-chain approach to the challenge of promoting bio- and other land-based renewable energies. Such an approach should begin by removing obstacles to the development of a final market for the various renewable energies produced. This challenge has various aspects, including combating consumer reticence and ignorance, harmonising and enforcing product standards, removing existing subsidies on competing fossil energies, promoting a price structure that reflects the true environmental and other external costs of each energy alternative, adopting new instruments that recognise the peculiarities of new production and delivery conditions, and avoiding various types of policy distortion (such as mandates for particular kinds of renewable energy).

Working back up the chain from the final market, direct policy intervention may be needed to overcome constraints and incentivise particular players at one or more intermediate points in the chain. However, policy measures should be a targeted response to specific instances of under-performance, and should not proceed from the idea that indiscriminate intervention at each or any point in the chain *must* be helpful.

Third, the rebalancing of support between different energies should involve not just support to production and consumption activities but also support to research and development. Renewable energy production and deployment are arguably at a point where research money from all sources could be particularly fruitful in terms of economic and social benefit. Publicly-funded research should focus more strongly on basic research, whose public good content is greatest, than on seeking specific technological solutions. It is also important for research efforts not to ignore the institutional, organisational and attitudinal dimensions involved in switching the economy from a non-renewable to a renewable energy base.

References

Ahm, P. (2010), “The European Eco Grid Project – Demonstrating the Efficient Operation of a Distribution Power System with High Penetration of Many and Variable Renewable Energy Resources’, paper presented at the Joint IEA PVPS on “PV in Tomorrow’s Electricity Grids: Problem or Panacea?”, Valencia, 9 September 2010.

Anderson, D. and M. Leach (2004), “Harvesting and Redistributing Renewable Energy: on the Role of Gas and Electricity Grids to Overcome Intermittency Through the Generation and Storage of Hydrogen”, *Energy Policy*, Vol. 32, pp. 1603-1614.

Baldwin, R.E. (1969), “The Case Against Infant-Industry Tariff Protection”, *Journal of Political Economy*, Vol. 77, pp.295-305.

Beurskens, L.W.M. and M. Hekkenberg (2010), Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States (covering 26 countries), Report ECN-E--10-069, Energy Research Centre of the Netherlands, Petten.

Birkmose, T. (2010), “Biogas and Slurry Separation in Danish Agriculture”, paper presented at the IEA Workshop on Digestate and Biogas Utilization, Copenhagen, 27 May 2010.

Braun, R., P. Weiland and A. Wellinger (2010), Biogas from Energy Crop Digestion, IEA Bioenergy. International Energy Agency, Paris. Available at http://www.iea-biogas.net/Dokumente/energycrop_def_Low_Res.pdf.

CanWEA (2008). Wind Vision 2025: Powering Canada’s Future. Canadian Wind Energy Association, Ottawa.

CBO (2010), Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals, Report by the Congress of the United States, Congressional Budget Office, July 2010.

Crolla, A. (2010), “Assessment of Environmental Impacts from On-farm Manure Digesters”, paper presented at the IEA Workshop on Digestate and Biogas Utilization, Copenhagen, 27 May 2010.

de Jager, D. and M. Rathmann (2008), Policy Instrument Design to Reduce Financing Costs in Renewable Energy Technology Projects, study performed by ECOFYS, Ultrecht, The Netherlands for the International Energy Agency – Renewable Energy Technology Deployment, Paris, France. Available at http://www.iea-retd.org/files/RETD_PID0810_Main.pdf

Deutscher Bundestag (German Federal Government) (2000). Act on Granting Priority to Renewable Energy Sources (Renewable Energy Sources Act). Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin. Available at: http://www.wind-works.org/FeedLaws/Germany/GermanEEG2000.pdf

EEA (2007), Estimating the Environmentally Compatible Bioenergy Potential from Agriculture, EEA Technical Report No 12/2007, European Environment Agency, Copenhagen.

EEA (2009), Europe's Onshore and Offshore Wind Energy Potential: An Assessment of Environmental and Economic Constraints, EEA Technical report No 6/2009, Copenhagen.

Eisentraut, A. (2010), Sustainable Production of Second-Generation Biofuels: Potential and Perspectives in Major Economies and Developing Countries, Information Paper, International Energy Agency, Paris.

EurObserver’ER (2007), Biogas Barometer, *Systèmes solaires – Le Journal des Énergies Renouvelables* no. 179, May 2007, L’Observatoire des énergies renouvelables, Paris.

EurObserver’ER (2010a), Solid Biomass Barometer, *Le Journal des Énergies Renouvelables* no. 200, November 2010, L’Observatoire des énergies renouvelables, Paris.

EurObserver’ER (2010b), Wind Energy Barometer, *Le Journal du l’éolien-No.6*, March 2010, L’Observatoire des énergies renouvelables, Paris.

EurObserver’ER (2010c), Biogas Barometer, *Le Journal des Énergies Renouvelables* no. 200, November 2010, L’Observatoire des énergies renouvelables, Paris.

EurObserver’ER (2010d), Photovoltaic Barometer. *Le Journal des Énergies Renouvelables* no. 196, April 2010, L’Observatoire des énergies renouvelables, Paris.

EurObserver’ER (2010?), Biofuels Barometer. *Le Journal des Énergies Renouvelables* no. 198, July 2010, L’Observatoire des énergies renouvelables, Paris.

European Commission (2005). The support of electricity from renewable energy sources. Communication from the Commission. COM(2005) 627 final, Brussels.

European Commission (2005). Biomass Action Plan. Communication from the Commission. COM(2005) 628 final, Brussels.

European Commission (2008). The support of electricity from renewable energy sources. Commission Staff Working Document, SEC(2008) 57, Brussels. Available at http://ec.europa.eu/energy/climate_actions/doc/2008_res_working_document_en.pdf

European Commission (2009). The Renewable Energy Progress Report: Commission Report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the implementation of the EU Biomass Action Plan, COM(2005)628. Communication from the Commission to the Council and the European Parliament. COM(2009) 192 final, Brussels.

European Commission (2010a). EU Guidance on wind energy development in accordance with the EU nature legislation. Natura 2000 Guidance document, Brussels.

European Commission (2010b). Report from the Commission to the Council and the European Parliament on Sustainability Requirements for the Use of Solid and Gaseous Biomass Sources in Electricity, Heating and Cooling, COM (2010) 11, Brussels.

European Parliament (2008). Resolution of 12 March 2008 on Sustainable Agriculture and Biogas: a need for review of EU legislation (2007/2107(INI)), Official Journal of the EC, (2009/C 66 E/05).

Fouquet, D. (ed.) (2007), Prices for Renewable Energies in Europe: Feed-in Tariffs Versus Quota Systems: A Comparison, Report 2006/7, European Renewable Energy Federation (EREF), Brussels. available at http://www.eref-europe.org/dls/pdf/2007/eref_price_report_06_07.pdf.

Freshwater, D. (2010), "Green Power, Green Jobs", paper presented at the OECD Workshop on Production of Renewable Energy as a Regional Development Policy in Rural Areas, Montreal, 15 September 2010.

Frondel, M., N. Ritter, C.M. Schmidt and C. Vance (2009), Economic Impacts from the Promotion of Renewable Energy Technologies: The German Experience, Ruhr Economic Papers #156, Essen, Germany.

Gilkinson, S. (2008), Mechanical Separation of Slurry on Northern Ireland Dairy Farms, CAFRE Technical Note, Department of Agriculture and Rural Development of Northern Ireland.

Great Plains Institute (2010), Spotlight on Biogas: Policies for Utilization and Deployment in the MidWest. Great Plains Institute, Minneapolis MN.

GSI (Global Subsisides Initiative) (2010), Fossil-fuel Subsidies, Their Impacts and the Path to Reform: A Summary of Key Findings, The Global Subsidies Initiative, International Institute for Sustainable Development (IISD), Geneva.

IEA (2003), Creating Markets for Energy Technologies, OECD/IEA, Paris.

IEA (2005), Renewable Energy Markets – Fact Sheet, OECD/IEA, Paris.

IEA (2008a), From 1st- to 2nd-Generation Biofuel Technologies: An Overview of Current Industry and RD&D Activities, OECD/IEA, Paris.

IEA (2008b), Energy Technology Perspectives 2008: Scenarios and Strategies to 2050, OECD/IEA, Paris.

IEA (2008c), Deploying Renewables: Principles for Effective Policies, IEA, Paris.

IEA (2009a), World Energy Outlook 2009, OECD/IEA, Paris.

IEA (2009b), Technology Roadmap: Wind Energy, OECD/IEA, Paris

IEA (2009c), Better Use of Biomass for Energy, position paper of IEA RETD (Renewable Energy Technology deployment) and IEA Bioenergy, December 2009, IEA, Paris.

IEA (2009d), PVPS Annual Report 2009, Implementing Agreement on Photovoltaic Power Systems, IEEA, Paris.

IEA (2010a), Key Statistics. Downloadable from http://www.iea.org/stats/index.asp.

IEA (2010b), Analysis of the Scope of Energy Subsidies and Suggestions for the G-20 Initiative, joint report from IEA, OPEC, OECD and the WORLD BANK. Prepared for submission to the G-20 Summit Meeting, Toronto (Canada), 26-27 June 2010.

IEA (2010c), World Energy Outlook 2010, OECD/IEA, Paris.

IEA-PVPS (International Energy Agency – Photovoltaic Power Systems) (2010), Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries between 1992 and 2009, International Energy Agency, Paris. Available at http://www.iea-pvps.org/.

Jacobsson, S. and V. Lauber (2006), “The Politics and Policy of Energy System Transformation—Explaining the German Diffusion of Renewable Energy Technology”, *Energy Policy*, Vol. 34, pp. 256–276.

Jansen, J.C. (2003), Policy Support for Renewable Energy in the European Union: A Review of the Regulatory Framework and Suggestions for Adjustment, ECN-C--03-113, Energy Research Centre of the Netherlands, Petten.

Kammen, D.M., K. Kapadia and M. Fripp (2004), Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?, report of the Renewable and Appropriate Energy Laboratory of the Energy an Resources Group, Goldman School of Public Policy, University of California, Berkeley CA.

Kim, H. , S. Kim, and B.E. Dale (2009), “Biofuels, Land Use Change, and Greenhouse Gas Emissions: Some Unexplored Variables”, *Environmental Science and Technology*, Vol. 43, pp. 961–967.

Koplow, D. (2007), Biofuels - At What Cost ? Government Support for Ethanol and Biodiesel in the United States : 2007 Update, The Global Subsidies Initiative, International Institute for Sustainable Development (IISD), Geneva.

Lauber, V. and M. Lutz (2004), “Three Decades of Renewable Electricity Policies in Germany”, *Energy and Environment*, Vol. 15, pp. 599-623.

Lindhqvist, T. (1992), “Extended Producer Responsibility”, in Lindhqvst, T. (ed), Extended Responsibility as a Strategy to Promote Cleaner Products, proceedings of an invited seminar held at Trolleholm Castle, 4-5 May 1992, Department of Industrial Environmental Economics, Lund.

Lipp, J. (2007), “Lessons for Effective Renewable Energy Policy from Denmark, Germany and the United Kingdom”, *Energy Policy*, Vol. 35, pp. 5481-5495.

Low, S.A. and A.M. Isserman (2008), "Ethanol: Implications for Rural Communities", paper presented at the American Agricultural Economics Association Annual Meeting, Orlando, Florida, July 27-29, 2008.

Messerlin, P.A. (2006), Enlarging the Vision for Trade Policy Space: Special and Differentiated Treatment and Infant Industry Issues, *The World Economy*, Vol. 29, pp. 1395-1407.

Mitchell, C. and P. Connor (2004), "Renewable Energy Policy in the UK, 1990 –2003", *Energy Policy*, Vol. 32, pp.1935-1947.

Mitchell, C., D. Bauknecht and P.M. Connor (2006), "Effectiveness Through Risk Reduction: A Comparison of the Renewable Obligation in England and Wales and the Feed-In System in Germany", *Energy Policy,* Vol.34, pp. 297-305.

NNEC (Network for New Energy Choices) (2009), Freeing the Grid: Best and Worst Practices in State Net Metering Policies and Interconnection Procedures, NNEC, New York. Available at: http://www.newenergychoices.org/uploads/FreeingTheGrid2009.pdf.

OECD (1992), The Polluter-Pays Principle, OCDE/GD(92)81, Environment Directorate, OECD, Paris.

OECD (2004a), Biomass and Agriculture: Sustainability, Markets and Policies. Proceedings of an OECD Workshop on Biomass and Agriculture, held in Vienna 10-13 June, 2003, hosted by the Austrian government, ISBN 92-64-10555-7, OECD, Paris.

OECD (2004b), Economic Aspects of Extended Producer Responsibility, OECD, Paris.

OECD (2005), EPR Policies and Product Design: Economic Theory and Selected Case Studies, ENV/EPOC/WGWPR(2005)9/FINAL, Environment Directorate, Environment Policy Committee, OECD, Paris.

OECD (2008), Biofuel Support Policies: An Economic Assessment, ISBN 978-92-64-04992-2, OECD, Paris.

OECD (2009a), OECD and Green Growth: Statement on OECD's Green Growth Strategy, OECD, Paris. Available at http://www.oecd.org/dataoecd/42/28/44273385.pdf

OECD (2009b),The Bioeconomy to 2030: Designing a Policy Agenda, OECD, Paris.

OECD (2010a), Bioheat, Biopower and Biogas: Developments and Implications for Agriculture, ISBN 978-92-64-08586-2, OECD, Paris.

OECD (2010b), Measuring Support to Energy — Version 1.0, Background Paper to the Joint Report by IEA, OPEC, OECD and World Bank on "Analysis of the Scope of Energy Subsidies and Suggestions for the G-20 Initiative", May 2010. Available at http://www.oecd.org/dataoecd/62/63/45339216.pdf

OECD (2010c), Interim Report of the Green Growth Strategy: Implementing Our Commitment for a Sustainable Future, Meeting of the OECD Council at Ministerial Level, 27-28 May 2010, OECD, Paris. Available at http://www.oecd.org/dataoecd/62/63/45339216.pdf

Ogimoto, K. (2010), "System Wide Issues Related to Massive Penetration of PV in the Electricity Systems", paper presented at the Joint IEA PVPS on "PV in Tomorrow's Electricity Grids: Problem or Panacea?", Valencia, 9 September 2010.

Owen, A.D. (2006), "Renewable Energy: Externality Costs As Market Barriers", *Energy Policy*, Vol. 34, pp.632-642.

Plieninger, T., O. Bens and R.F. Hüttl (2006), "Perspectives of Bioenergy for Agriculture and Rural Areas", *Outlook on Agriculture*, Vol.35, pp.123-127.

Searchinger, T., R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.H. Yu (2008), "Use of U.S. Croplands For Biofuels Increases Greenhouse Gases Through Emissions From Land-Use Change", *Science*, Vol. 319 #5867, pp.1238-1240.

Searchinger, T.D. (2010), 'Biofuels and the Need For Additional Carbon", *Environmental Research Letters*, Vol. 5. Available at: http://iopscience.iop.org/1748-9326/5/2/024007.

Sharma, S.D. and K. Sagara (2005), "Latent Heat Storage Systems and Materials: A Review", *International Journal of Green Energy*, Vol.2, pp.1–56.

SNH (Scottish National Heritage) (2005), Cumulative effects of wind farms V2, Guidance Document, Scottish National Heritage, Inverness, Scotland.

SNH (2007), Assessing the Impacts on Wild Land, Guidance Note, Scottish National Heritage, Inverness, Scotland.

SNH (2008), National Heritage Assessment of Small-scale Wind Energy Projects Which Do Not Require Formal Environmental Impact Assessment, Guidance Note, Scottish National Heritage, Inverness, Scotland.

SNH (2009), Siting and Designing Wind Farms in the Landscape V1, Scottish National Heritage, Inverness, Scotland.

Steenblik, R. (2007), Biofuels – At What Cost? Government Support for Ethanol and Biodiesel in Selected OECD Countries, The Global Subsidies Initiative, International Institute for Sustainable Development (IISD), Geneva.

Swenson, D. and L. Eathington (2006), Determining the Regional Economic Values of Ethanol Production in Iowa Considering Different Levels of Local Investment, Staff Research Report, Department of Economics, Iowa State University, July 2006.

Swenson, D.A. (2008), "Input-Outrageous: The Economic Impacts of Modern Biofuels Production", Staff General Research Paper No. 12644, Iowa State University, Department of Economics, Ames IA.

Taglia, P.J. (2010), "Emerging Biogas Opportunities for the Biogas Sector", paper presented at the 5th AgStar National Conference, Green Bay, WI, 27-28 April 2010. Available at: http://www.epa.gov/agstar/documents/conf10/TagliaBiogasAgSTAR.pdf

Thornley, P, J. Rogers and Y. Huang (2008), "Quantification of Employment from Biomass Power Plants", *Renewable Energy,* Vol.33, pp.1922-1927.

U.S. Department of Agriculture (2009), "Agriculture secretary Vilsack, dairy producers sign historic agreement to cut greenhouse gas emissions by 25% by 2020", News Release No. 0613.09, 15 December 2009.

U.S. Department of Energy (2007), Roadmap for Bioenergy and Biobased Products in the United States, report of the Biomass Research and Development Technical Advisory Committee, Biomass Research and Development Initiative. Available at http://www.usbiomassboard.gov/pdfs/obp_roadmapv2_webkw.pdf.

U.S. Department of Energy (2010a), Solar Set-Asides in Renewables Portfolio Standards. Available At: http://www.Dsireusa.Org/Solar/Solarpolicyguide/?Id=21.

U.S. Department of Energy (2010b), Biopower Technical Strategy Workshop: Summary Report, report of a workshop held in Denver CO, 2-3 December, 2009. Available at : http://www1.eere.energy.gov/biomass/pdfs/biopower_workshop_report_december_2010 .pdf.

Weiland. P. (2010), "Experience with Grid Injection in Germany", paper presented at the IEA Workshop on Digestate and Biogas Utilization, Copenhagen, 27 May 2010.

Worldwatch Institute (2006), American Energy: The Renewable Path to Energy Security, Centre for American Progress, Worldwatch Institute, Washington DC.