Promoting environmental justice through industrial symbiosis: developing pelletised wood fuel to tackle Scottish rural fuel poverty

Barbara Illsley*

Town and Regional Planning
School of Social Sciences
University of Dundee
Dundee DD1 4HT, Scotland, UK
Fax: 01382 204234
E-mail: b.m.illsley@dundee.ac.uk
*Corresponding author

Tony Jackson and Bill Lynch

Town and Regional Planning
School of Social Sciences
University of Dundee
Dundee DD1 4HT, Scotland, UK
E-mail: a.a.jackson@dundee.ac.uk
E-mail: w.lynch.@dundee.ac.uk

Abstract: Scottish Executive policymakers are seeking to promote sustainable regional development programmes that combine economic, environmental and social objectives. A primary aim is to deliver environmental justice, offering disadvantaged groups the opportunity to improve their quality of life through measures that improve access to environmental goods and services. This paper examines the theoretical arguments for promoting wood processing clusters, based on industrial ecology principles, as a means of addressing rural fuel poverty. Drawing on a study undertaken in Perth and Kinross, Scotland, it explores the potential for using wood biomass from a rapidly growing Scottish forest industry sector to establish a commercially viable market for pelletised wood fuel. The paper identifies the logistical and policy issues that must be addressed before such an initiative can be successfully launched.

Keywords: environmental justice; industrial symbiosis; fuel poverty; Scottish forest industries; pelletised wood fuel; Energy Service Companies; ESCOs.

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Biographical notes: Barbara Illsley is Convener of Town and Regional Planning at the University of Dundee, Scotland. A Professional Planner, she has practical experience in local government, and teaching and research interests that include environmental justice, community governance and land

use planning practice. An active member of the Royal Town Planning Institute for more than 20 years, Barbara is currently involved in collaborative research into small towns and resilience in northern British Columbia.

Tony Jackson is a Senior Lecturer in Town and Regional Planning at the University of Dundee, Scotland. He worked in resource management and development in Africa, before taking up academic posts in economic and environmental management. He has researched and practised in, and published widely on, sustainable development, ecological modernisation and industrial ecology, within an international perspective.

Bill Lynch is a former Programme Director for the MA degree in Environmental Management at the University of Dundee and he has published widely on planning and environmental matters. He is currently on secondment to Learning and Teaching Scotland tasked with assisting the integration of sustainable development within the formal school curriculum in Scotland.

1 Introduction: rural fuel poverty as a social element of industrial symbiosis

The current Scottish administration came into office in 2003 on a pledge to put environmental issues at the forefront of its legislative programme, stating that it wanted "a Scotland that delivers sustainable development; that puts environmental concerns at the heart of public policy and secures environmental justice for all of Scotland's communities" (SE, 2003, p.5). This commitment reflected in part the inclinations of its First Minister who, when first elected to office, promised in a major policy speech that environmental and social justice would be the main themes driving his administration, observing that "the people who have the most urgent environmental concerns in Scotland are those who daily cope with the consequences of a poor quality of life, and live in a rotten environment" (SE, 2002a, para. 18). Tackling fuel poverty is an integral part of this political agenda (SE, 2005a).

Ensuring that every home is adequately and affordably heated is a key objective of current energy and social inclusion policies. The Scottish Fuel Poverty Strategy (SE, 2002b) set targets for the eradication of fuel poverty, a problem facing an estimated three hundred thousand households in 2002. According to the Strategy, a household is considered to be in fuel poverty if it needs to spend 10% or more of its income on household fuel use in order to maintain a satisfactory heating regime. Three main factors contribute to fuel poverty: firstly, there is a strong inverse relationship with incomes; secondly, the energy efficiency of homes, that is the thermal quality of the building and the efficiency of the system of heating, has a major impact on total energy needs; and thirdly, the price and availability of fuel affects fuel poverty levels.

A number of government measures have been put in place to address fuel poverty. The National Minimum Wage and New Deal are aimed at tackling low incomes, whilst Warm Deal and the Central Heating Programme are designed to improve the energy efficiency of peoples' homes. With regard to fuel costs, the introduction of competition into the electricity and gas supply industries initially had a positive impact, although recent energy price rises are likely to result in an increase in the number of fuel-poor households (The Times, 2005). However, in the Scottish context there is a strong

additional spatial dimension to the problem, since in many rural parts households do not have access to the cheapest form of domestic fuel, mains gas. One potential solution is the development of biomass energy. Biomass, and more particularly wood, has the potential to make a positive contribution to energy needs, not simply in terms of electricity generation for the National Grid but more significantly as a direct source of space heating for local energy networks. Its potential in addressing the problem of fuel poverty has been widely recognised (RCEP, 2004; EAS, 2004; Biomass Task Force, 2005).

Academics and policymakers in the UK have been paying increasing attention in recent years to the emerging concept of environmental justice, with fuel poverty seen as an integral part of its agenda (Lucas *et al*., 2004; Bulkeley and Walker, 2005; Fairburn *et al*., 2005; Chalmers and Colvin, 2005). Widely recognised as both contested and problematic, the concept has been defined as "the equal protection and meaningful involvement of all people with respect to the development, implementation and enforcement of environmental laws, regulations, and policies, and the equitable distribution of environmental benefits" (The Commonwealth of Massachusetts, 2002, p.2). This requires much more than simply concern for the inequitable distribution of environmental risks. It encompasses consideration of the quality-of-life outcomes of environmental decision-making, together with a focus on the political processes by which decisions are made. Seen in this light, there is a clear connection between the environmental justice and sustainable development discourses, a point recognised by Agyeman and Evans (2004) in their concept of 'just sustainability', which stresses the interdependence of social justice, ecological stewardship and economic wellbeing. The challenge is to find a way to combine these agendas and to devise policies which deliver social, economic and environmental benefits.

Industrial Ecology (IE) has the potential to contribute to the delivery of environmental justice aspects of sustainable development, since it explores the processing linkages within industrial systems, and considers how such systems can best interact with the environment and society. Its agenda is directly concerned with fostering industrial processes that balance the economic, ecological and social dimensions of sustainable development in ways that deliver more efficient and equitable outcomes. Hitherto, however, most advocates of industrial ecosystems have tended to adopt an engineering/technological approach to sustainable development, one that mimics natural ecosystems which "recycle most essential nutrients using only energy from the sun to 'drive' the system" (Ayres and Ayres, 1996, p.278). Successful IE clusters are said to be able to transform 'through-put' into 'round-put', minimising demands on the external environment (Korhonen and Snäkin, 2005). Material cycle loops are progressively closed on-site through "reducing wastes and pollution in the materials-intensive sectors by exploiting opportunities for using the low-value by-products (*i.e.*, wastes) of certain processes as raw materials for others" (Ayres and Ayres, 1996, p.6).

This desire to mimic natural ecosystems has encouraged the IE discourse to emphasise the interface between the economic and environmental dimensions of sustainable development. Much less attention has been given to IE's social dimension and the effect of industrial processes on the sustainability of local communities, particularly those in remote resource-based settlements. The potential for community heating systems located within close radius of IE sites (Dunn and Steinemann, 1998), and the contribution that such sites might make to local employment (Deutz and Gibbs, 2004), are the only social aspects that have attracted any serious attention in the IE

literature. This neglect of the wider social dimension may be attributable to the contention by early IE advocates such as Frosch and Gallopoulos (1989) that the lower processing and disposal costs created by industrial symbiosis would be quickly passed on to consumers in the form of lower prices. In practice, however, regional policy is predicated on the widespread presence of market failure that allows many communities to miss out on such benefits unless special efforts are made to integrate technical innovations in a spatial context (Gibbs *et al.*, 2005). More recently, Korhonen *et al.* (2004) suggest that, given the presence of such market failure, IE needs to move on from the narrow consideration of engineered, technical solutions to environmental problems to a broader focus on the policy and decision-making context in which the discourse must operate.

This paper explores these relatively neglected social policy dimensions of industrial ecology in the context of wood biomass fuel production and its role in tackling fuel poverty. It begins by reviewing the IE potential of wood processing clusters in a Scottish context. It then examines the potential for extending the concept of industrial symbiosis off-site to promote the social aspects of promoting social inclusion in remote rural communities. This examination draws on the findings of recent fieldwork undertaken in Perth and Kinross, Scotland, to assess the scope for using pelletised wood fuel production to tackle rural fuel poverty. The paper concludes by demonstrating the importance of putting an appropriate policy framework in place in order to achieve regionally sustainable development and environmental justice.

2 The IE potential of wood processing

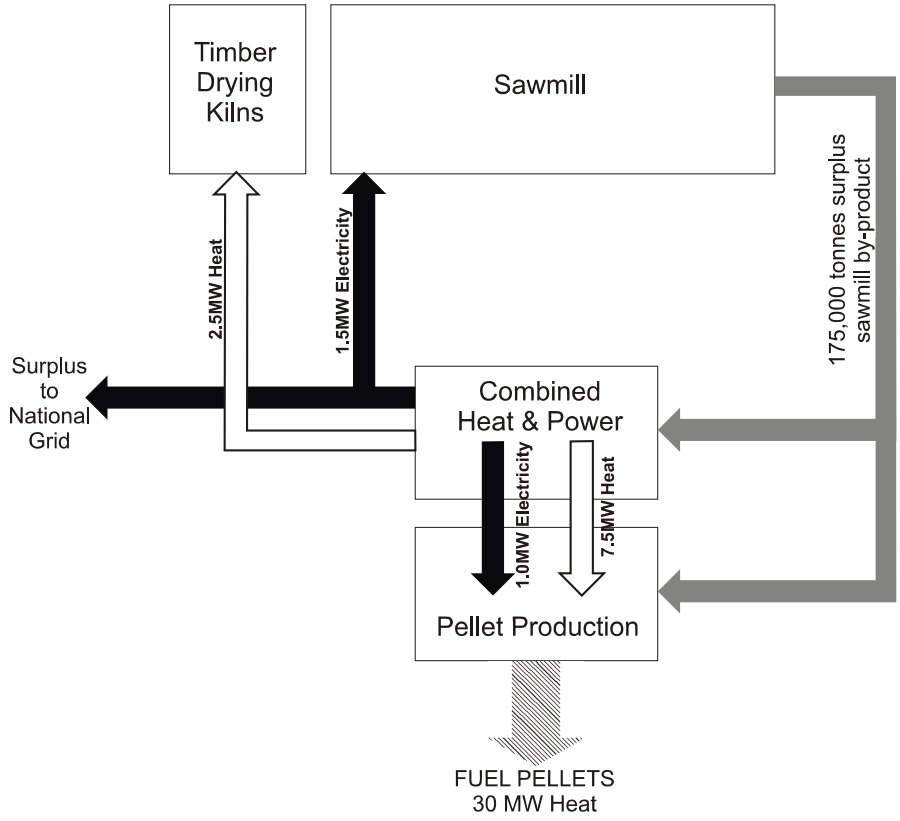
Wood as a source of heat takes a number of forms, most notably as logs, wood chips and wood pellets. Logs are most often used in domestic settings to fuel open fires or wood burning stoves; however, these tend to be labour intensive to operate and in addition require significant storage space for the drying of the logs. Wood chips are made from low grade wood from forestry plantations and sawmilling residues and they are most suited for use in small and medium sized boilers located in business and commercial situations, such as schools and workshops. Wood pellets are a processed form of biomass fuel which can be made from a variety of materials, including straw, specially grown energy crops, and recovered wood such as recycled pallets, but they are most often derived from sawdust and wood chips. These are the co-products of other wood processing processes and, as a result, there are symbiotic advantages to clustering wood pellet production with these other activities (DTI, 2001). Pellets can be used in boilers of all sizes, including those designed for the domestic market. Modern wood pellet stoves, the majority of which are imported to the UK, have electronic ignition, thermostatic control and automatic feed from a storage hopper, all features which make them relatively convenient to use (SFIC, 2002).

The primary commodity market for forest industry clusters, sawn timber, accounts for only 50% of the volume of logs processed by a sawmill. Stand-alone plants in remote locations often dispose of the remaining wood fibre as waste: the use of beehive burners is still a common practice for such sites in British Columbia. Integrated forest industry clusters offer a far more efficient IE alternative, exploiting wood fibre's biomass energy potential through on-site Combined Heat and Power (CHP) plants. Such clusters not only reduce the off-site energy demands for primary products, they also enable the residues of

sawn timber processing to be processed cheaply into commercially viable secondary products, with any surplus energy exported via the electricity grid. The resulting added on-site value represents a closing of the loop, limiting the external demands of the forest industry sector on the environment both as a source and as a sink (Korhonen, 2002).

The symbiotic potential of a site designed to include an integrated pelletising mill is illustrated in Figure 1. The pelletisation process involves milling wood residues to a consistent size, drying the sawdust to raise calorific content, and compressing and extruding the prepared sawdust to produce pellets. The natural lignin in the wood acts as a binding agent. Adding a CHP plant, fired by residual wood fibre, to a wood processing cluster allows on-site production of electricity. This in turn serves as a source of heat for drying the sawdust prior to pelletisation (RCEP, 2004). These arrangements offer considerable on-site economies for pelletisation, since the key processing cost involves the drying of the product to reduce bulk and enhance the calorific content of the pellet.

Figure 1 Balcas Ltd., Enniskillen: Plant Schematic



Source: Adapted from Kidney (2005)

From the perspective of the economy as a whole, wood biomass represents what is essentially a free good. The opportunity costs of wood fuel IE are minimal or even negative, because this is a by-product of processing existing inputs of raw material more efficiently into primary products, enabling the costs of energy consumption and waste

disposal to be reduced and the savings transformed instead into useful secondary products. However, key to the success of this process is not the technical efficiency of the integrated on-site plant, but whether site operators can exploit this free endowment of wood biomass in ways that enable them to secure an adequate share of the potential resource savings created by IE processes to establish financially viable markets for the resulting by-products. If market failure caused by institutional constraints is present, this may not happen. Even though IE offers the prospect of low cost on-site processing of residual fibre into heating fuel, a market for the fuel still needs to be created. In many continental EU Member States such a market has been established and the pelletised fuel sector has rapidly expanded with the help of tax regimes favouring renewable energy use. The research reported in this paper was focused on exploring the reasons for Scotland's failure to emulate the buoyant wood fuel markets of countries such as Sweden and Austria (SFIC, 2003), despite having a similarly abundant forest resource base and rural communities inaccessible to mains gas supplies.

Justification for the favourable fiscal treatment offered by some EU Member States to establish local energy network based on using wood biomass to deliver low-cost space heating can be found in its environmental advantages. Pellets are produced from a renewable resource which, over its life cycle, is virtually carbon neutral. Increasing the use of such low cost, biomass energy provides an attractive way of seeking to achieve Kyoto targets for the reduction of emissions from greenhouse gases. With the inclusion of a bio-mass CHP plant, clusters can become self-sufficient in energy use, reducing both the economic and ecological costs involved in the process (RCEP, 2004). Transport movements can also be minimised if the timber is sourced locally.

In terms of the social benefits derived from a wood biomass strategy, the most obvious is job creation. New on-site jobs are likely within a wood processing cluster and such developments may also help secure and perhaps expand the number of off-site jobs both upstream in the harvesting of timber and downstream in distribution and the installation and maintenance of boilers. However, an additional and largely neglected social benefit of linking the introduction of pellet manufacture to a wood processing cluster is the contribution this can make to the alleviation of rural fuel poverty. The establishment of a pelleted wood fuel market to address rural fuel poverty offers a range of socially inclusive attractions. While fuel costs are continually fluctuating, comparisons suggest that in areas not linked to the main natural gas network wood pellets are competitive in price with alternative domestic heating fuels such as electricity, oil and liquid petroleum gas (Luker, 2004; RCEP, 2004). Advocates of wood pellet appliances argue that pellets are clean, efficient, produce few emissions and very small quantities of ash, due to high combustion levels and low moisture content. Locally produced wood pellets would increase fuel choice in rural areas and could provide an attractive alternative source of supply. At the present time, however, the capital costs of installing modern wood pellet boilers are higher than competitive systems, acting as a disincentive to their uptake.

The new pellet plant at Enniskillen, Northern Ireland, officially opened in November 2005 and supported by grants from the EU Structural Funds programmes of regional assistance, offers an excellent UK example of an on-site wood processing venture with a regional development remit (Figure 1). Following the development of a new, automated sawmill in 2000, Balcas Ltd. decided to invest in a 15 MW CHP biomass plant and a wood pellet mill on-site to utilise the growing surplus of residues. The CHP plant, which

is fuelled by wood pellets, has allowed the site to become self-sufficient in energy, saving an estimated £0.5 million a year in energy costs. Surplus electricity generated is sold to the national grid. The pellet mill, the largest such facility in the UK, has the capacity each year to convert 180 000 tonnes of wet residues into 50 000 tonnes of pellets, with the heat produced by the CHP plant being used to dry the sawdust prior to pelletisation. The company estimates that 42 MW of energy derived from fossil fuels is being replaced by the equivalent from renewable energy sources. The whole project will secure 1000 jobs in the local economy and meet the energy needs of a quarter of Northern Ireland's new rural homes in the next decade (Kidney, 2005). The following section considers the potential for extending IE to socially symbiotic issues such as rural fuel poverty, by developing a similar wood processing cluster, including pellet manufacture, in Scotland.

3 Wood processing clusters: the Scottish context

Although Scotland has yet to exploit the market for wood products used for heating purposes, either as an export opportunity or for domestic use, interest has been stimulated recently by concerns about climate change, the likely increase in softwood timber supplies, commitments to sustainable development and a desire to eradicate fuel poverty (SE, 2005b). A key driver of this interest is to be found in the prediction that the supply of plantation timber in Scotland, particularly from conifer forests, will almost double from six million tonnes to ten million tonnes over the next decade as a result of the harvesting of the commercial forests planted in the 1960s and 1970s (Bidwells, 2002). Despite this boost to its inventories, the Scottish forest industries sector faces an uncertain outlook, with falling sawn timber prices compounded by strong international competition. Domestic supplies of softwood available for harvesting are likely soon to exceed UK market capacity for sawn timber, while growing volumes of recycled pallets and paper will similarly place a falling backstop price on the markets for virgin chip and pulp. As a result, it is likely that the amount of wood fibre available for energy purposes will grow rapidly over the next two decades. Since these supplies are already in the pipeline and do not require any further commitment of resources in the form of additional plantings, they represent an endowment of renewable energy that can be made available at minimal opportunity cost. Any new investment in primary wood processing capacity will automatically generate additional wood fibre co-products. Domestic heating offers a potential new market for such residuals.

The Scottish Forest Industries Cluster, set up in 2000 to support companies and organisations across all parts of the forestry sector, has played a major role in encouraging research into the potential use of wood fuel in Scotland. While the possible use of timber co-products as a source of heat received only a passing mention in the Cluster's first strategic action plan, Roots for Growth (SFIC, 2000), subsequent reports examined the case for encouraging uptake of wood fuel technology as part of Scotland's energy policy for the 21st century (SFIC, 2002; Bidwells, 2002) and investigated the commercial prospects for developing a wood pellet manufacturing plant in Scotland (SFIC, 2003). Drawing on successful exemplars from elsewhere in Europe, these reports considered the requirements for establishing a wood pellet industry, including available resources and market opportunities.

The SFIC study estimated capital and annual running costs for two new pellet plants, one in central Scotland, using dry residues with 10% moisture content, and one in the north of Scotland using green sawmill co-products. Since the study focused on commercial sales and established that the existing demand for pellets in Scotland and the UK was limited, it was argued that any new Scottish plant would have to be competitive in the wider European market. The report concluded that the economic case for establishing a pelletising plant was marginal at that time but it was suggested "there could be a potential market for pellets in the rural domestic areas and for institutional and commercial heating" (SFIC, 2003, p.20). The lack of a local market and the absence of a supply infrastructure were identified as limiting factors.

4 Perth and Kinross study

It was against this background that, late in 2003, the Geddes Institute at the Dundee University was commissioned by Save Costs and Reduce Fuel (SCARF) to carry out a study into the potential for locally-sourced wood fuel to provide a means of increasing fuel choice and addressing fuel poverty in off-mains gas communities in Perth and Kinross, Scotland, while at the same time generating economic and environmental benefits for the area. SCARF's mission is to work through partnership to promote sustainable use of energy, eradicate fuel poverty and create sustainable employment and training opportunities. This research was also supported by a range of other agencies including Perth and Kinross Council, Forest Enterprise, the Energy Savings Trust and WWF Scotland.

Perth and Kinross is a largely rural area, located at the edge of the Scottish Highlands, with significant public and private forestry plantations. Although the majority of the population reside in the main urban settlements, a significant minority, some 20 000 people, live in communities which are not connected to the mains gas network and, as a result, these residents are dependent on other forms of energy for domestic heating. The area has a higher that average proportion of households categorised as in fuel poverty (23.2%) than in Scotland as a whole (13%), and addressing this problem is a key council priority (PKC, 2004). There were three main elements to the study: a review of existing initiatives and research in this field, including industry material relating to wood pellets, the availability of grants and comparative research projects; a survey of representatives of the potential supply chain for wood fuel heating; and a series of focus groups with residents from off-mains gas communities to discover their views about wood as a fuel. Questionnaires were sent to estate owners, forestry consultants, wood processors and equipment suppliers, in order to find out levels of awareness of wood pellet manufacture, and to establish views on the potential benefits and problems of establishing a local wood pellet market. Response rates varied from 16% in the case of producers to 50% for wood processors. Five focus groups, involving a total of 45 residents, were held in off-mains gas communities across the council area. While many of the participants burned wood in the form of logs, few had heard of wood pellets as a form of heating and the focus groups allowed the issues associated with this form of fuel to be explored and debated in some depth.

With regard to the existing wood fuel supply infrastructure in Perth and Kinross, the questionnaires revealed small-scale, patchy coverage based on existing forest and sawmill operations which would not meet the needs of a scheme designed to alleviate

rural fuel poverty. With the exception of responses from the public sector, wood producers and processors had limited knowledge of wood pellets as a form of processed wood fuel, but suggested a genuine interest in finding out more. A number of estates are unhappy with the current market for timber and stated that they would welcome the development of an alternative market. Asked to comment on the potential benefits of establishing a domestic wood fuel market, all respondents commented on the economic advantages and the importance of local resource use. Potential barriers were felt to be cost, continuity of supply, and inertia. The high capital costs of pelletisation equipment and the absence of a UK market were raised by the sawmill respondents. The only business in the area currently offering wood pellet stoves and boilers for sale to the public reported high levels of interest but few sales, suggesting a lack of confidence in the technology and fuel.

Although views put forward at the focus groups were extremely varied at each of the meetings, depending on personal circumstances and experiences, it became clear that most households had more than one source of heating, with electric fires, wood or multi-fuel stoves supplementing their main fuel, which was typically oil, LPG or electricity. A small number of households were still dependant on open coal fires, offering the greatest potential for carbon reductions if converted to renewable alternatives. Most participants were unhappy with their existing arrangements, commenting specifically on the comparatively high costs of fuel compared to mains gas equivalents, and inconvenience.

Participants were asked to consider their current attitude to wood heating systems and there was a mixed response with no clear agreement. Most seemed to assume that wood fuel meant logs and their experience related to burning logs in stoves that could also burn coal. Asked to consider possible reasons for using wood fuel heating systems, environmental factors were put forward as well as economic ones. There was a great deal of interest in the fact that wood is carbon neutral, wood was perceived as natural and totally non-polluting and the fact that wood can help support local jobs. Awareness of grants to householders was limited. Generally, there was a positive reaction to the potential for wood pellet heating systems but only if both appliances and the fuel itself could be provided at competitive prices. There were a number of reservations, however, particularly relating to the need to replace existing heating boilers with new systems which are relatively unknown in Scotland. The possible development of district heating schemes was discussed and there was agreement that this would make sense when new communities or groups of houses were being built. Several people were aware of such schemes in Europe.

5 Discussion

It is clear from the experience elsewhere in the world, such as Canada, Austria and Northern Ireland that in the right circumstances on-site technical symbiosis within wood processing clusters can be successful, creating new wood pellet businesses and generating a range of benefits linked to reductions in resource consumption, costs and waste. Yet this poses two questions in a Scottish context: why has the development of wood pellet manufacture been slow to evolve here, give the abundant supplies of harvestable timber, and how can the on-site advantages of IE be extended to include wider social benefits, such as addressing fuel poverty?

The Perth and Kinross study highlights an interesting dilemma: without identifiable demand for wood pellets, the industry is unlikely to invest in the necessary equipment to manufacture the product, while at the same time, without reliable supplies, demand will be limited (Illsley *et al*., 2004). The study found a great interest within Perth and Kinross in the development of a local wood pellet industry but the respondents highlighted barriers which are seen to be hindering its development, here and in the rest of the country (Biomass Task Force, 2005).

Market uncertainty appears to be deterring entrepreneurial initiative in this field at present. The wood-supply infrastructure is limited and fragmented with many of those operating within it having little knowledge or understanding of the technology or business potential of wood pellet production (RCEP, 2004; SE, 2005b). Domec *et al*. (2005) highlight the importance of public awareness and understanding of biomass technologies in supporting its growth and suggest that for some, biomass is seen as a 'poor man's fuel'. This view was endorsed by some of residents in the survey but others were excited by the prospect of modern, efficient, and automated wood pellet technology. Attempts have been made to promote these new technologies but, as was shown by the experience of the heating supplier in Perth, the message has not yet convinced the general public.

As with agriculture, UK energy policy has hitherto been characterised by a traditional sectoral approach to policy formulation. This encourages top-down producer initiatives that focus on measures which are intended to improve the productivity of the industries within the sector, as distinct from providing resource-based communities with more sustainable development options. Bottom-up spatially oriented policies, which seek to identify local or regional symbiotic opportunities to tie the existing resource base into sustainable social and environmental development opportunities, suffer as a consequence. This is particularly noticeable in rural communities that are located in areas with large forestry plantations.

It is widely acknowledged that the wood-for-heat sector has been overshadowed by the UK government's emphasis on renewable electricity generation (RCEP, 2004; SDCS, 2005). Support available through the Renewables Obligation for electricity generation is not available for the production of energy for heat. Early attempts to develop biomass as a fuel for electricity generation, which required the conversion of large areas of farmland into biomass crops, ran into difficulties, including public opposition (Upreti, 2004, Upham and Shackley, 2005). The availability of ample wood fuel supplies from existing Scottish forestry plantations poses far less of a challenge to public opinion, as reflected in the recent announcement of a new £90 million wood-fuelled power station at Lockerbie in the south of Scotland.

There is an urgent need to tackle Scotland's inertia in developing a policy framework for its growing endowment of local wood biomass, including its use for domestic heating purposes. Such policy intervention would allow the technological advantages of symbiosis within wood processing clusters, which are now well known, to be integrated with social symbiosis stimulated by market incentives. This could not only be used as a way of addressing the social problem of fuel poverty in rural parts of Scotland, but could also have a positive impact on the business case for wood pellet manufacture. The spread of wood pellet heating systems in domestic homes could stimulate a new market for the increasing supply of wood residues, helping to divert possible disposal to landfill. The

challenge is to find an effective means of opening up a regional market in Scotland for wood fuel pellets for domestic heating purposes, capable of linking the production of such fuel with the resolution of rural fuel poverty.

Of prime importance in this task is greater public commitment and investment in the use of heat from renewable sources, including biomass, thereby tackling the gap in energy policy (RCEP, 2004; SE, 2005b). One strategy for achieving this could be the creation of a Renewable Heat Obligation (RHO), similar to the Renewables Obligation for electricity which has been successful in creating an active market for electricity from renewable energy sources (SDCS, 2005). Those favouring adopting a RHO argue that it would stimulate both the use of biomass heat and biomass CHP, it would be cost effective and it would favour least cost approaches as it is technologically neutral. Others, such as the Biomass Task Force, have concluded that such a RHO would be largely unworkable as the suppliers granted renewable heat certificates would have no control over the numerous and typically small scale users of heat.

The Biomass Task Force recommends "focused regional solutions if national policy goals are to be delivered successfully" (Biomass Task Force, 2005, p.46) supporting the earlier call in the Wood Fuel for Warmth Report for "a more focused and integrated package of measures" as a means of supporting the emerging biomass industry (SDCS, 2005, p.iv). Although a number of aspects of public policy remain reserved to the UK government, including major fiscal matters, the devolved administration in Scotland is well placed to respond to these calls for action.

One initiative that has been attracting increasing interest (SDCS, 2005) is the creation of Energy Service Companies (ESCOs) to help the emergence of a wood fuel supply chain in Scotland. Across the world, ESCOs are delivering energy efficiency and renewable energy projects, by offering a range of services, from finance to the installation and maintenance of equipment (Vine, 2005). By providing intermediation in the financing and operation of energy services, these companies can secure contracts both for the supply of energy and for the provision of services, thus supporting a market for wood fuel producers and guaranteeing supplies to customers. For the domestic consumer, this results in cost savings in both fuel and maintenance, and engenders a sense of trust in the service. The ESCO assumes much of the risk in this situation, building confidence in the security of supply, the reliability of new technology and overall value for money.

To encourage the growth of ESCOs and end-use efficiency in energy supplies in the EU, a European Database of ESCOs has been established and, as of April 2005, fourteen such companies were listed in the UK. None of these are based in Scotland. There is thus a good case for setting up a specialist wood fuel ESCO which would help create a new sustainable market for wood fuel for Scotland, covering not only commercial and municipal sectors but domestic customers as well. An earlier model of this approach can be found in the Scottish Hydro-Electric Board formed under the 1943 Hydro-Electric (Scotland) Act, which stipulated that the utility should reinvest its profits to promote the economic regeneration of the Highlands (Miller, 2002, p.23). In a similar way, the new ESCO could be required to provide a service for households in off-mains gas areas that addresses questions of cost, security of fuel supply, and ongoing maintenance of equipment, all issues raised by the Perth and Kinross residents.

The current focus of activity in Scotland is on the development of local markets for wood fuel, described by SDCS (2005) as 'wood refineries'. These offer a compromise between top-down sectoral initiatives aimed at finding markets for producers, and

bottom-up spatial partnerships, aimed at bringing together producers and consumers to provide symbiotic opportunities for converting through-put into round-put. Wood refineries are targeted at commercial and municipal users and based around the use of wood chips. The Woodfuel Development Programme for the Highlands and Islands for example, which is part funded by ERDF, has supported the creation of a number of wood-fuel clusters from Lochaber to Strathspey, with wood-fuel heating systems being installed in businesses as diverse as hotels, estate offices and a nursing home. Another scheme is the Lanarkshire Biomass Project which has been set up to promote the use of renewable energy in public buildings within the North Lanarkshire Council area using wood-chip fuel. Such initiatives are important in encouraging the use of wood as a fuel, supporting the emergence of a wood fuel supply chain and creating local employment, all goals of sustainable development, but they are unlikely to play a major part in addressing the problem of rural fuel poverty as they promote the use of wood chips which are not well suited to the domestic setting.

A more fruitful approach, based on established IE principles, may be to promote the conditions suitable for the development of an integrated wood-processing cluster, including a CHP plant and wood pellet facility, manufacturing pellet fuel which could be used for the domestic heating market. The economic and environmental benefits gained through on-site industrial symbiosis would be reinforced by the social benefits of addressing fuel poverty. The foundations of such a cluster are already in place with the announcement of an £18 million expansion of the James Jones and Son sawmill at Lockerbie late in 2004, followed more recently by the proposed new wood fuelled power station in same vicinity.

6 Conclusion

The development of new sustainable markets for the products of IE, such as wood pellet fuel, may be regarded as a form of social symbiosis, encompassing ways of allowing disadvantaged communities to access the benefits of the sustainable production processes available in their regional economy. Creating policy instruments to promote social symbiosis in the use of some of the products of an IE-designed forest industry cluster not only helps deliver social benefits, such as tackling fuel poverty, but also offers synergistic benefits by enhancing the economic potential of on-site technical symbiosis and encouraging the closing of further material loops. In turn, this will convert a site-based ecological engineering exercise into a truly sustainable regional development enterprise, capable of meeting domestic needs as well as offering site operators economic and environmental benefits.

For these reasons, our local study of the undeveloped state of the market for wood fuel in one part of Scotland leads us to conclude that industrial symbiosis should be framed in an ethical context that identifies just as well as efficient outcomes. Using a broader, regional, perspective when assessing the sustainable development of Scotland's large and growing endowment of wood fibre helps highlight the issues of fuel poverty and environmental injustice to be found in rural communities co-located with local forest resources. These communities continue to bear the burdens of afforestation and remoteness, but are inexorably losing the benefits of employment opportunities in a sector increasingly mechanised and automated. Such considerations receive little attention in the sectoral strategies adopted by UK industrial and energy ministries.

As our analysis also demonstrates, justice and efficiency need not be mutually exclusive goals. In this context they work together to emphasise the need for further investment in technical symbiosis. A viable Scottish market would allow Scottish forest industry clusters to be relieved of the burden of disposing of increasing amounts of expensive waste residues, and enable Scottish wood processors to convert this into a domestic supply of renewable heating. Progress in this regard is currently frustrated by the paucity of policy initiatives available to address the market failures identified in the study. A community-oriented spatial approach to the development of the Scottish forestry resource base would overcome the somewhat narrow departmental focus evident in current policy formulation and allow the social dimensions of sustainable development of the forest industries sector to be explicitly recognised. This would assist the Scottish Executive in moving towards its target of ending fuel poverty by 2016, advancing its environmental justice agenda, while also promoting more economically and environmentally sustainable industrial development.

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