REBIOGEN

Community Sustainable Energy Centres

A model for Ireland

tcbb RESOURCE

Towards a low-carbon economy

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Contents

1 EXECUTIVE SUMMARY 2
2 RESEARCH METHODOLOGY 11
3 BACKGROUND AND PROJECT OBJECTIVES 12
4 EXAMPLES OF COMMUNITY BASED BIOENERGY DEVELOPMENTS 14
4.1 Community Involvement 14
4.2 Attitude & Behaviour Change with Regard to Energy 15
4.3 Concepts & Definitions of Community Participation and Ownership 16
4.4 Denmark 18
4.5 Germany 23
4.6 Austria 29
4.7 Sweden 34
4.8 Other Case Studies – France and the UK 35
4.9 Models for Ireland 36
5 DEVELOPING ROUTES TO MARKET FOR BIOENERGY 38
5.1 Biogas and Biomethane 40
5.2 Renewable Heat and Power 50
6 MOBILISING THE FEEDSTOCK SUPPLY CHAIN 67
6.1 Increasing Feedstock Supplies from Municipal Waste 69
6.2 Mobilising Feedstock Supplies from Agriculture and Agri Food Processing 72
6.3 Feedstock Supplies from Forestry 75
7 TECHNOLOGY DEPLOYMENT AND DEVELOPMENT 79
7.1 AD Technology advancements and considerations for new deployments. 80
7.2 Facilitating ATT Deployment for RES-H or CHP. 81
7.3 Thermal or CHP Energy for Individual Applications 82
7.4 General Technology Deployment Issues 83
8 FACILITATING FUNDING AND ACCESS TO FINANCE 85
9 IMPACT 92
9.1.1 Contribution to GHG Mitigation and Renewable Energy Objectives 92
9.1.2 Contributions to Waste Management, Agricultural and Forestry Objectives 93
9.1.3 Contribution to Rural Economic Development 93
10 APPENDICES 94

1 EXECUTIVE SUMMARY

Community based bioenergy projects can process local supplies of wastes and residues (RESIDUES) as well as purpose grown biomass sourced from the Agri-food, Municipal Waste, Forestry and Marine (AMFM) sectors to make a measurable contribution toward multiple sustainability objectives, including:

- Decarbonisation of energy supply;
- Improving waste management and resource efficiency, as well as mitigating environmental impact in AMFM sectors to improve environmental sustainability;
- Sustainable rural job creation; and
- Reductions in energy poverty.

Examples of EU community based bioenergy schemes, predominantly organised to supply either biogas, biomass solid fuels or thermal and electrical energy, provide a guide as to how such schemes could be developed in Ireland.

A range of issues, however, preclude development of a vibrant bioenergy sector. These include:

- The demand for bioenergy is driven by the relative cost, which is greater than the cost of conventional fossil-based fuels;

- The lack of heat distribution infrastructure as well as the current frameworks governing access to the gas and power grids pose barriers to timely and cost-effective access to energy markets;

- Barriers to feedstock mobilisation including legacy market structures and fragmentation in sources of feedstock that preclude scale, increase cost and inhibit deployment of technology to convert unprocessed feedstocks to more useful forms;

- Bioenergy technologies require adaptations and better integration to improve plant availability & efficiency, improve productivity and reduce cost of energy;

- Public perceptions of waste/residue to energy technologies, deployment of which can potentially make the greatest near-term contribution to sustainability objectives, pose barriers to technology deployment. Considerations include public lack of awareness and distrust of technology, concerns over site proximity to amenities and perceived emissions risks that are exacerbated by deficits in public information and facilities for emissions and process monitoring;

- Risk averse capital markets that limit financing options;

While development of a vibrant bioenergy sector can make a significant contribution to Ireland's sustainability objectives, the drivers for bioenergy applications are societal and environmental rather than commercial. This increases the complexity of the business case for community based bioenergy and residue-to-energy models. Energy pricing is currently dictated by the low price of fossil fuels, which means that cost of bioenergy is uncompetitive. Support measures are required to develop the bioenergy supply chain, to educate and inform the public, and promote market penetration of bioenergy outputs. Producer incentives will be required until such time that markets and supply chains are sufficiently mature to support the transition to market led mechanisms. Timely development of the supply chains will enable a progressive transition toward obligatory integration of renewable energy into the energy mix, offering a sustainable market outlet for cost-effective bioenergy (the establishment period).

REBIOGEN reviewed examples of community based schemes to determine how they may be adapted to develop the bioenergy sector in Ireland. REBIOGEN evaluated the technical and economic factors in respect of different models to determine the key criteria underpinning technical and economic viability. The review was undertaken with a view to balancing the potential cost to the State against the potential beneficial impacts of projects as measured by sustainability drivers.

Roles for Community Based Schemes

REBIOGEN identified several different roles that could be developed in the context of community based bioenergy schemes. These include:

- **DEVELOPING ROUTES TO MARKET FOR HEAT, POWER AND BIOGAS** – routes to market are lacking for heat and biogas outputs. Deployment of this infrastructure is capital intensive, requiring state support that can potentially be routed through community schemes to develop:
  - District heating schemes that aggregate community energy demands to provide a stable route to market for thermal outputs. Properly supported, ATT residue-to-energy applications can optimise contributions to sustainability objectives while minimising support cost to the State;
    - District heat networks are capital intensive, and economic viability is dependent on maximising linear heat demand density (MWh_T distributed per metre of pipeline network). A marketing strategy is required to optimise linear heat density in rural population centres, which can include:
      - Engaging industrial and commercial demand (REBIOGEN's review indicates c. 20 – 25 GWh of commercial demand is required to support networks of 20-km length)
      - Community scheme funding of Customer Premise Equipment (CPE), ie., the heat exchanger, meter and other units installed in each building connected; coupled with energy efficiency reviews of premises;
      - Initial discounting of energy sales;
      - Introduction of prospective mandate that will obligate connection to the district heat network when available (coupled with mechanisms to ensure energy via district heat costs less than conventional energy)
  - Routes to market for biogas that can include:
    - Biogas collection networks that aggregate biogas production for shared upgrade / grid injection, providing routes to market for biomethane. The economics of pipeline construction, relative to the cost of gas upgrade and delivery via virtual grid, requires a minimum scale and concentration of biogas production ranging from 20 – 30 GWh_T of biogas per 10 – 15 km of pipeline;

  - Virtual grid operations that support biogas production in dispersed locations, providing upgrade and compression infrastructure to ensure biogas is upgraded to an acceptable standard prior to being compressed and transported for grid injection. Alternatively, biomethane can be valorised in compressed blends with natural gas (BioCNG), supplied to off grid applications, via micro-grid infrastructure and/or gaseous transport infrastructure that provide alternative routes to market;

  - Construction and operation of pipelines to support industrial valorisation of biogas in dilute form (i.e. with moisture and sulphur removed but not the CO_2) which will avoid the energetic and financial cost of upgrade to biomethane.

    - Development of routes to market for biogas must be undertaken co-incidentally with development of AD production infrastructure. Designing market supports for biogas production that are separate from those supporting upgrade and distribution will facilitate market flexibility. It will avoid overpayment of supports where they are not required. It will allow separate parties to perform each separate function, which may subsequently ease the transitioning of the biogas upgrade and distribution function into the conventional gas distribution framework, once de-risked;

    - Development of routes to market for biogas will require finalisation of regulatory frameworks that govern distribution of both biomethane (via the gas grid and virtual grid) as well as dilute biogas.

- **FEEDSTOCK SUPPLY SERVICES** – revenues from low value energy outputs are often insufficient to cover transfer costs for purpose grown feedstocks. Energy recovery from residues can mitigate high feedstock costs, which community based schemes can enable via:

  – Mobilising municipal waste resources by deploying communal waste conditioning technologies at waste sites to condition waste fractions to standards more suited for energy recovery. Communal waste conditioning equipment could include food waste de-packaging to condition source separated food waste for AD and/or separation and shredding equipment to condition mixed black bin wastes to RDF/SRF standards suitable for ATT;

    - Deployment of communal waste conditioning equipment will require adaptations to market protocols to improve aggregation of local municipal waste resources. Improved municipal waste management protocols could include –

      - Community based information programme;
      - Incentives to increase 3-bin pay-by-weight kerbside collection;
      - Grass green waste collection programmes;
      - A sustainability certification programme that reflects the proximity principle by rewarding licensed waste collectors (and/or their customers) for sustainable local processing of municipal waste (once made available). Monetisation could

be achieved via discounts against gate fees for local processing of wastes for energy recovery;

- Deploying high efficiency drying and comminution technology may facilitate conditioning of moist waste residues (e.g. WWT sludge or septic tank sludge, for example) into a dried fibre material that can be blended with construction wood waste or SRF to create a low-cost biomass solid fuel.

– Mobilising agricultural feedstocks by developing rural service depots with facilities to aggregate and temporarily store agricultural feedstock supplies until required. REBIOGEN's review indicates that with appropriate process management, it can be less costly, energetically and economically, to transport feedstocks for centralised energy recovery compared to the cost of extending routes to market and deploying capital infrastructure at remote sites. Examples of services might include improved slurry management and organic nutrient recycling that will reduce farmer costs and/or facilitate increased stocking rates;

- Improving slurry dewatering and nutrient recovery / recycling protocols will require technology development;

- Rural service depots can grow silage for community based AD. Leasing land and leveraging community centre staff, equipment and nutrients to grow silage can be less costly than purchasing silage. It can mobilise "hidden hectares" bringing non-productive land into production without impacting on the local price of fodder;

- Mobilising agricultural residues for energy recovery will require remuneration of farmers, which can include:

  - Developing a sustainability certification scheme to validate sustainable manure management or nutrient recycling to enable an increased stocking rate;
  - Providing support services such as slurry dewatering, solids removal and filtrate discharge at the cost of the community depot funded by incremental payments for community based energy projects, as proposed under the recent RESS consultation;
  - Adaptations of existing direct farm payment schemes to remunerate the farmer for participation in a community based programme.

- Deploying high efficiency drying and comminution technology may facilitate conditioning of moist agri-food residues (poultry litter, equine manure, de-watered slurry solids, AD digestates, straw etc.) into a dried fibre material that can be blended with forestry residues to create a low-cost biomass solid fuel.

– Mobilising forestry feedstocks by developing a biomass trade centre that can aggregate and condition (e.g., dry, chip, homogenise or torrify) feedstocks sourced from a fragmented private forestry sector. The environmental and economic sustainability of these activities can be optimised if high-efficiency drying technology can be deployed in an environment where the low-grade residual heat can be sold via district heating. Such an entity could supply blended, homogenised and densified solid fuel to the community scheme generate renewable heat or CHP, or alternatively supply solid fuels for individual applications as part of an ESCO service;

- Mobilising forestry residues (e.g. thinnings and brash) for energy recovery will provide a means to control the cost of feedstock while remunerating foresters. This may be accomplished by:

  - providing a market outlet for woody biomass residues, which in the case of solid fuel sales could be structured as a consignment sale;

  - Developing a sustainability certification programme to promote timely thinning of forestry plots by adapting the current structure of interim forestry payments to offer a supplemental payment for forestry thinning which, together with the proceeds of sale, can remunerate the cost of thinning;

  - Funding of such as payment could leverage the difference between the NPV of harvest proceeds that currently exceed the NPV of interim payments by a significant margin, to structure an advance against final harvest proceeds. A system of advance payments will require administrative management that could be undertaken in the community scheme. It may minimise concerns otherwise arising over exceeding the state aid “de minimus” threshold, as the advance would be repayable, and the only portion that would qualify as state aid is the difference between a discounted finance rate relative to State established rates.

- **SUPPLYING THERMAL, ELECTRICAL and BIOGAS ENERGY** – to meet community energy demands by:

  - Deploying Anaerobic Digestion (AD) technology to generate biogas from community wastes, residues and energy crops. Biogas can be valorised either in dilute form, supplying local industrial applications, or as biomethane, which can be distributed to supply the national demand. Deployment of AD infrastructure will have to be undertaken co-incidentally with development of routes to market.

  - Deploying biomass boilers and/or Advanced Thermal Treatment (ATT) technology to generate biomass RES-H or combined heat and power (CHP).

    - Deployment of energy generation infrastructure must be undertaken in conjunction with development of routes to market for the energy outputs. Given the lead times associated with developing district heat networks as well as the variability of local thermal demands, CHP for co-generation of heat and power may be more economical, as it is able to leverage the mature market structures underpinning access to the national electricity pool to provide a stable revenue stream during the ramp up period. On an ongoing basis, revenues earned from accessing the national electricity market will also offset the seasonal and daily variation in local thermal demands, improving overall financial stability.

- Vertical integration of energy marketing with energy production may allow community schemes to retail bundled thermal and electrical energy. Vertical integration may facilitate competition against retail prices of conventional forms of energy, which may allow community schemes to improve margins while leveraging state supports to offer competitive pricing to consumers.

- Bio-based CHP may integrate with wind or solar projects. Under changes being introduced in the Single Electricity Market, the "balance responsibility" principle will require individual generators to bear financial responsibility for the imbalances to which they give rise. Predictable bio-based CHP may overcome some of the increased uncertainty that may otherwise arise in respect of intermittent wind or solar technologies.

- Energy efficiency measures require CHP schemes to qualify with high efficiency (HE) criteria to earn high RES E premiums for bio based RES E. Multi-faceted energy generation / distribution infrastructure may require numerous adaptations to comply with HE criteria. The timing may not facilitate compliance with HE criteria from commencement (if ever). Introduction of a grace period prior to enforcement of the HE criteria, or preferably re-introduction of lower subventions for RES E outputs from non-HE CHP, would be significant enablers of waste/residue-to-energy developments;

  - Development of integrated energy generation and distribution models will give rise to new questions as to what qualifies as an economically justifiable use of heat (e.g. such as the heat needed to dry waste prior to ATT processing, for example). Pre-emptive consultations and decisions that confirm such matters would be an enabler of integrated community schemes.

– Developing Energy Services (ESCO) capabilities to assist with procurement, deployment and operation of biomass technologies that supply individual commercial thermal or CHP demand. Remuneration of the capital and feedstock costs associated with conventional woody biomass boilers may require a significant ongoing RHI. Deploying ATT technologies such as FBC that can process a blend of low cost residues may reduce the support requirements, however require finalisation of regulatory frameworks that allow deployment. The costs associated with such services can potentially be reduced if they can leverage staffing and other resources sourced in the context of larger, integrated community bioenergy schemes.

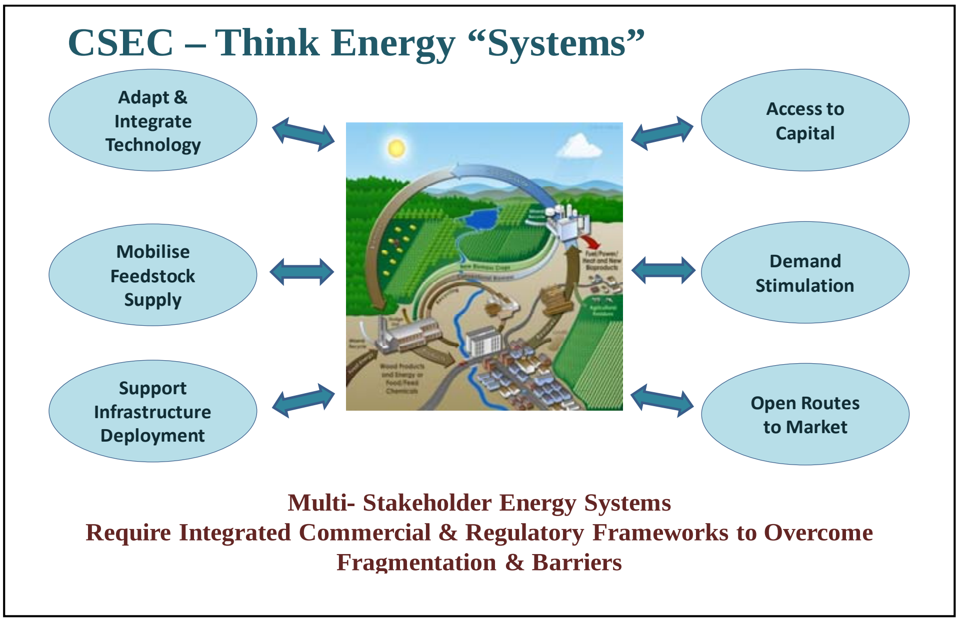
- **COMMUNITY INFORMATION AND EDUCATION PROGRAMMES** – Given the impact that public attitudes have on the success of bioenergy planning applications, especially in respect of energy recovery from wastes and residues, community schemes may fulfil a vital function by providing validated and unbiased information in respect of the importance of transitioning to a more sustainable, decarbonised energy supply, as well as the real risks, impacts and benefits of the different forms of energy and nutrient recovery.

- **OPTIMISING ACCESS TO PUBLIC FUNDING AND FINANCE** – Community based schemes will require public funding to address market failures and uncertainties. Provision of State Aid is subject to public perceptions that give rise to concerns if high levels of aid are provided to private commercial interests. Additionally, access to State Aid is governed by certain EU and State regulatory structures that establish maximum aid intensities, as well as limit levels of aid provided to any single undertaking, without notification to the EC. Organising community schemes as collaborative public private partnerships, with an appropriate public body as a participant, may provide a route to optimise EU and State contributions within the constraints posed by these considerations.

- **MINIMISING COST TO THE STATE** – Community based PPP structures can be utilised to integrate disparate stakeholders into a coherent supply chain. They can attract EU support funding to deploy infrastructure cost efficiently, which may assist to attract the required commercial expertise and commercial funding while going someway to assuage public concerns regarding benefits accruing from funding via the public purse. They can reduce risk associated with feedstock supply, as well as contribute to development of the emissions and regulatory oversight protocols required to minimise regulatory flux. As the supply chain matures and confidence in the business model grows, participation of local authorities or other state actors can give way to a market led structures, allowing the State to exit while recouping the initial investment for the taxpayer. This integrated approach will minimise cost to the State for development of a viable bioenergy sector.

Model for Community Based Schemes

Bioenergy viability is highly inter-dependent on integrated development of viable feedstock supplies, technology deployments, routes to market and demand stimulation. Accordingly, one of the most significant contributions that community based bioenergy schemes can make is to act as the "system integrator" addressing the disparate requirements of different stakeholders to ensure each of the respective elements is organised into an integrated, coherent supply chain in a manner that underpins economic viability.



The REBIOGEN review concludes that under certain conditions, it may be technically and economically feasible to develop integrated models that meet community energy and environmental objectives by recovering renewable energy and nutrients from sustainably co-processing the community's wastes, residues and purpose grown biomass in accordance with the much-overlooked proximity and self-sufficiency principles enshrined in waste legislation. There are multiple stakeholders in bioenergy value chains, and the community of stakeholders is highly fragmented. Exploitation of the opportunity requires an integrated strategy that engages each of the stakeholders in a collaborative effort. Adaptations to certain market structures and operating paradigms, as well as commercial and regulatory frameworks, will be required to overcome legacy market structures that may otherwise pose barriers to development.

Designing and supporting community schemes to undertake an integrated approach to market development offers a route for the State to create a viable bioenergy sector. Direct investment in such schemes offers a route for the State to achieve its objectives, as well as ultimately recouping some of its costs on exit, transferring operational responsibilities to market participants. Alternatively, the government can use per unit energy subsidies (REFIT/RHI) to create significant demand such that energy consumers force migration to renewable options, though this creates a very costly and ongoing requirement for state subvention without the chance to recoup the cost of supply chain development.

A pre-requisite to the economic viability of community based bioenergy models is the finalisation of policy matters currently being discussed, including:

- Market supports such as a Biomethane Feed-In Tariff (BFIT) for biomethane of guaranteed origin placed on the market;

- Finalisation of regulatory frameworks governing construction and operation of biogas collection networks, operation of virtual grid facilities and injection of biomethane into the gas grid;

- Application of the Biofuel Blending Obligation (BBO) to gaseous transport fuels;

- Finalisation of the Greengas Certification protocol[1] to validate sustainability of biomethane production and track biomethane production, transfers, end use and incentive redemptions;

- Introduction of a viable Renewable Heat Incentive (RHI) to support marketing of RES H, including a small premium for deployment of distributed energy models where local energy sources are used to meet local energy demands;

- Development of frameworks that govern construction and operation of publicly funded district heating schemes;

- Re-activation of a moderate Renewable Energy Support Scheme (RESS or historically referenced as REFIT, terms which are used interchangeably herein) that complies with the changes anticipated in compliance with the transition to the I-SEM, and which works in conjunction with RHI incentives to support RES E generated from distributed, community energy recovery (CHP) from residues;

[1] www.ierc.ie/news/irelands-first-green-gas-certificate-scheme-step-closer-launch-greengascert-research-project/

- Adaptation of Regional Assembly operations programmes to enable access to ERDF funding and finance mechanisms that support investment in "public benefit" renewable energy projects (or introduction of a similar capital investment support programmes);

- Mandatory introduction of pay-by-weight 3-bin waste collection system and corresponding incentive and enforcement protocols to generate an increased supply of better quality, source-separated food wastes and green waste for energy recovery;
- Adaptation of existing DAFM Greening Payments or introduction of alternative incentives to promote supply of manures and other agricultural residues as feedstock, linked to nitrates regulations compliance.

There is scope for further policy development at governmental level to better define the evolving role of local authorities in community energy schemes, that could see them become more actively involved (directly or indirectly) in renewable energy activities (as per proposed RED II draft[2]) and waste management optimisation and enforcement. Participation of local authorities in community based bioenergy models is essential, to act as a focal point and provide the leadership, as well as route for public funding support, on which community based models will rely. While REBIOGEN believes the community bioenergy concept is consistent with local authority environmental, waste management regulation & enforcement, urban renewal and energy planning remits, recent trends increasingly transfer operational responsibilities for some key roles from public management to the private sector.

These topics all form part of an ongoing active policy debate on support for development of a viable bioenergy sector in Ireland, and clarity on these matters is expected in the future.

Community Sustainable Energy Centre (CSEC) Programme Prototype –To present the findings in a practical context, the REBIOGEN findings are contextualised as if a hypothetical CSEC prototype is developed in North County Tipperary. The hypothetical illustration reflects deployment of anaerobic digestion (AD) technology to generate biogas from source separated food waste, animal by-products (ABP) and grass. It assumes biogas is marketed in dilute form to satisfy nearby industrial demand, with the balance upgraded and supplied to the national pool via injection into the gas grid. It reflects deployment of advanced thermal treatment (ATT) technologies to generate combined heat and power (CHP) from local supplies of agricultural & forestry residues as well as municipal waste and agri-food residue fractions. It assumes the ATT technologies are co-developed with a district heating network constructed to offer renewably sourced heat at competitive prices while the RES E energy outputs are exported via the power grid to the national pool.

The REBIOGEN review illustrates financing of a project with EU grants coupled with State-funded equity and loan guarantees to fund infrastructure deployment which, as the market matures, can be recoupled, allowing the State to progressively exit the programme and transfer the operational responsibilities and risk to market participants. REBIOGEN's review indicates that the CSEC cash flow can remunerate the net capital investment, and that the CSEC model can make a measurable contribution to Ireland's sustainability objectives. Pursuant to introduction of the relevant policy initiatives and market supports, the illustration projects revenue growth over a 5-year period of up to €8.5m per annum, resulting in an

[2] COM (2016) 767. Proposal for a Directive of The European Parliament and Of the Council on the promotion of the use of energy from renewable sources.

annual cash flow projected at € 3.8m. It projects direct employment would grow to 28 FTE's and would indirectly support additional employment in the service and support sectors.

The CSEC model is dependent on introduction of RHI and RESS supports as well as changes to waste and residue management paradigms. REBIOGEN believes these changes would be consistent with State renewable energy and sustainability objectives. Successful development of a prototype would provide a model that can be replicated across the country, underpinning a viable sustainable national renewable energy strategy, as well as one of the most advanced renewable energy processing centres in Europe.

2 RESEARCH METHODOLOGY

REBIOGEN investigates the different considerations that impact viability of an integrated CSEC model designed to recover renewable energy and nutrients from fragmented local supplies of AMFM biomass residues, to improve the environmental sustainability of the AMFM supply chains as well as a contributing toward decarbonisation of the energy mix. The investigation has been undertaken to identify the practical considerations that impact development of a vibrant community based bioenergy sector in Ireland.

In preparation of this report REBIOGEN gathered data from a series of literature reviews, structured interviews, site visits and informal discussions with expert contributors and stakeholders to identify those opportunities and issues that impact bioenergy and waste-to-energy applications in Ireland. Data was obtained from publications issued by relevant domestic and international public bodies such as CSO, DAFM, DCENR, EPA, EUROSTAT, FAO, SEAI, Teagasc, BIM, etc. as well as from review of published, peer reviewed research papers sourced from reputable publications. This information is considered to be accurate and reliable. Additional data has been gathered from media, industry and industry trade association publications and presentations. Where possible, this data has been cross referenced or validated against corresponding information sourced from independent experts or published public sources. Where validation was not possible, information was reviewed against REBIOGEN's understanding of prevailing market conditions, making judgements as to accuracy and reliability.

In addition to literature reviews, REBIOGEN undertook a series of structured interviews with industry experts to gather information, collect data, and source expert opinions, insights and evaluations that informed the preparation of observations, analysis and conclusions incorporated in this report. Formal interviews had a semi-structured format in that the interviewer had a prepared list of questions however the interview also allowed for freedom of discussion where a point of interest was made while answering a question. This allowed the informants to speak somewhat freely on a relevant topic without being confined by a set of closed questions. The selection of formal interviewees was based on their expertise as determined by position or longstanding participation in relevant institutions or industries, as well as by history in respect of publications or other relevant factors.

In addition to structured interviews, REBIOGEN undertook a range of informal interviews with industry experts and stakeholders across a range of bio-economic topics. REBIOGEN attended site visits, as well as relevant and reputable conferences and workshops, to gather information used to inform the observations, analysis and conclusions presented herein. In gathering data, REBIOGEN used its reasonable efforts to ensure that contributions were sourced from expert sources with the knowledge, background and standing that would reasonably be expected of competent and knowledgeable contributors to research activities of this type. Some of the information included herein comprises perceptions and anecdotal evidence. It includes judgements as to prevailing market circumstances or likely future outcomes in respect of certain market developments or opportunities. In selecting contributors and referencing sources of information used to inform these judgements, REBIOGEN cross referenced contributions to sources of acknowledged expertise or published data. Where it was not possible to validate contributions against accepted factual data, REBIOGEN authors relied on their experience and history in the domestic and international bioenergy and biorefining industries to make judgements as to the validity of the contributions, which it believes adequate for the purposes of this research.

A list of interviewees can be seen in Appendix 9.

Economic viability is an overarching consideration in respect of bioenergy's role in the energy mix. Economic viability is influenced by a wide variety of factors, which differ depending on specific bioenergy applications. To illustrate some of the issues that impact bioenergy economic viability, a series of micro-economic analyses have been prepared, the details and assumptions from which are documented in the report Appendices 3 to 8.

3 BACKGROUND AND PROJECT OBJECTIVES

Irish and EU sustainability objectives target balanced economic growth that can leverage supplies of local renewable resources as raw materials to underpin sustainable re-industrialisation of the economy, underpinning employment, the tax base and a sustainable balance of trade. They target societal cohesion, distributing wealth and resources more equitably across rural and urban sectors of society. They target improved health and wellbeing by mitigating environmental and ecological impact, meeting the needs of current generations while leaving the planet in a state fit for future generations. These sustainability objectives are reinforced in a wide range of strategies, policy initiatives and implementation measures (broadly termed Sustainability Policy) that more specifically target:

- *Energy decarbonisation and climate change mitigation;*
- *Resource efficiency, waste minimisation, closed-loop, circular economy principles;*
- *Energy and resource security;*
- *Maintenance of soil, water and air quality;*
- *Habitat maintenance to support bio-diversity;*
- *Sustainable re-industrialisation to maintain a productive manufacturing base;*
- *Development of a knowledge based economy to improve wealth creation and retention.*

Sustainability drivers in the form of legislative frameworks promote the transition to a low carbon economy that will progressively displace finite supplies of fossil fuels and other extractive raw materials with local renewable resources utilised in efficient, clean processes.

Ireland's Agri-Food, Marine, Forestry and Municipal Waste (AMFM) sectors generate volumes of outputs including residues, by-products & wastes, (henceforth collectively referred to as residues) that are currently under-utilised, sometimes exported at low value (e.g., municipal wastes) and many times incurring substantial costs to manage. The Irish climate generates one of the highest biomass growth rates in the EU and Ireland boasts an expanding forestry sector and a large land bank not otherwise suitable for food production (e.g. bogs, drainage areas, peat fields, verges etc.). Sustainability drivers present opportunities to exploit these resources for bioenergy and nutrient recovery (RES OUTPUTS).

Ireland is obliged to meet EU defined targets for reducing greenhouse gas emissions and renewable energy substitution in both the short term (2020), medium term (2030) and long term (2050). Failure to do so will result in substantial fines. EU Directives provide the legal framework that obliges the State to implement policies to support deployment of RES across a range of technologies and scales to harness Ireland's renewable resources. Ireland's 2020 RES target requires 40% of electricity, 12% of heat and 10% of transport energy to be generated from renewable sources, as per NREAP. This translates to an overall renewable energy (RE) target of 16%. Statistics from 2015 show renewables at 25.3% RES-E, 6.5% RES-H, 5.7% for RES-T and 9.1% overall.

Table 1: Ireland's 2020 renewable energy targets

Energy vector	Percentage of final energy consumption	2020 Renewable energy Target	2015 (Actual)	2030 target
Electricity	19%	40%	25.3%	TBD*
Thermal Energy	41%	12%	6.5%	TBD*
Transport energy	40%	10%	5.7%	TBD*
Total (IRL)	**100%**	**16%**	**9.1%**	TBD*
Total EU RE	-	20%	16.7%	27%

Source: *SEAI 2017.* **To be finalised.*

Ireland therefore needs to almost double its RE capacity in less than two and a half years if it is to avoid fines for non-compliance with the mandatory targets. Recent estimates by an Oireachtais committee[3] of the potential fines are as high as €610m by 2020 rising to €3.7-5.5 billion by 2030. Heat & transport targets are proving to be the most difficult for Ireland to meet due in part to the diffuse nature in which this energy is consumed. Residual biomass can play a large role meeting such demands in the form of thermal energy supplied for individual demands or distributed over district heating to meet aggregated demand. Biogas can potentially displace natural gas to meet thermal energy demand, and can also supply renewable transport fuels as well as harnessed for electricity generation. The RES-H contribution must keep pace with the predicted increase in total heat consumption in absolute terms if the target is to be reached.

The REBIOGEN review focuses primarily on applications that can make contributions to RES-H objectives, as meeting this objective poses the greatest challenge. Alternative technologies are available to contribute to the RES-E obligation, such as wind technologies reinforced with localised (end-user) biogas CHP. While a certain proportion of the RES E demand may be met from community-based CHP, wind technologies are mature and can leverage a "free" wind resource, which is likely to require lesser support payments which can minimise the cost to the State. Achievement of the RES-T objective, other than to increase use of compressed biomethane fuel solutions, will likely require technology deployments that are outside of the technical remit and capabilities of community based schemes. In this context the REBIOGEN objectives as stated in proposal are as follows:

- Ascertain the principal non-financial barriers hampering the development of distributed energy recovery from Ireland's most abundant supplies of biomass wastes & residues in respect of current market structures and their relation to current EU and national energy, waste and environmental policies and targets;

[3] irishtimes.com/business/economy/state-may-face-610m-climate-bill-in-2020-says-dail-committee-

- Identify the processing technology options for specific residue streams, including pre-treatments, required to efficiently and economically valorise their energy content in a distributed context;
- Assess valorisation options for renewable energy that minimise requirement for ongoing, high state subventions;
- Assess policy interventions which are required to mobilise supply of feedstock and stimulate the wider roll-out of technologies which will capture the value of waste and residues in the context of distributed generation particularly within and for the benefit of industry and agriculture; and
- Review how the respective market structures, technologies and commercial frameworks can be integrated to devise a viable business model which leverages a combination of technologies to mobilise a variety of residue feedstock types in a region to generate the required scale for plant viability and which maximise revenues from outputs.

4 EXAMPLES OF COMMUNITY BASED BIOENERGY DEVELOPMENTS

4.1 Community Involvement

Biomass technologies can convert a wide variety of organic matter such as wood, manure, sewage, household waste as well as certain agricultural crops and crop residues into heat, electricity and biomethane. Besides offering a clean alternative to fossil fuels, thereby reducing Ireland's energy related emissions, conversion of these resources also offsets some of the costs associated with waste treatment and disposal, reduces waste related methane emissions and creating sustainable local employment. However, none of these benefits will be experienced should Ireland fail to address the existing barriers or take measures to de-risk technology and business models or to promote development across the various sectors concerned. Community structures will be integral to fulfilling much of the potential from the available resources.

Bioenergy is unique among the spectrum of renewable energy resources in that it can produce a variety of homogenous energy carriers. Inputs are tangible raw materials whose availability is often a function of other human activities and economic value chains. Bioenergy resources are often diffuse in their occurrence (except where resources are collected for other purposes and residues arise in food or fibre processing) and their collection, conversion and associated residues/emissions management can impact on the community adjacent to these supply chain activities.

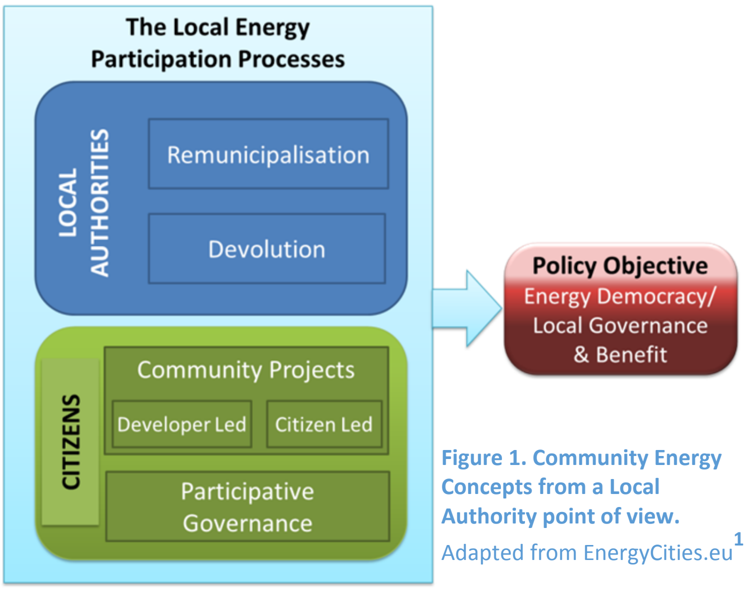


Figure 1. Community Energy Concepts from a Local Authority point of view.
Adapted from EnergyCities.eu[1]

"Community ownership of renewable energy has the potential to create 'energy citizenship' through an increased empowerment of the local population due to feelings of control and self-sufficiency, increased awareness towards patterns of energy production and consumption as well as increased awareness towards environmental problems” [4]

The Department of Energy’s 2015 White Paper, entitled Ireland's Transition to a Low Carbon Energy Future 2015-2030, called for a fundamental cultural shift in Irish society, or the creation of the Irish Energy citizen, asserting that if Ireland is indeed to become a low carbon society, it is of paramount importance that we ensure widespread public participation, as a society and as individuals, fundamentally altering how we perceive energy consumption.[5]

It is internationally understood that the transition to low carbon sustainable energy generation is only possible with the incorporation of significant decentralised generation and harnessing of distributed energy resources. This inevitably brings energy infrastructure into closer contact with communities. Such energy projects need to be not only acceptable but, preferably, beneficial to the communities in which they are located. Participation in the development and often some level of citizen or municipal ownership can be the key to their success. The resilience of the country’s energy infrastructure is strengthened by a diversity of generator sizes, resource types and ownership models.

Communities therefore have a key role to play in accelerating the energy transition. Community gain or benefit from a project developed by a large external company does not have the same impact - having a stake in this sense is far more powerful than ‘benefit’ alone.

The Danish cooperative energy culture started with a single project that had to tackle multiple barriers before becoming operational. Once finished the project became an example for like-minded groups and accelerated the development of these projects and increased the political pressure to remove barriers to their development. Ireland now seems to be in the same position as Denmark just when this movement started. Communities of citizens all over Europe, often with their local authorities’ direct involvement, are now creating projects where they own and are actively involved in development and running an energy resource.

4.2 Attitude & Behaviour Change with Regard to Energy

Altering social behaviour is a broad and complex issue, an in-depth analysis of which is beyond the scope of this report. However, it seems uncontroversial to state that an individual’s behaviour has two main spheres of influence, the internal and the external. The former contains personal variables such as personal values, emotional disposition, thought processes, and “entrenched habits”.[6] The latter is everything external to the individual, that is, the social and physical environment. It is commonly recognised that these two interplay, and that the social environment has a great deal of influence on how one thinks and behaves. In Ireland, and indeed across the world, the most intimate spheres of social interaction, beyond one’s personal family and social circle, is the local community. The fundamental point is that counteracting global climate change is a question of ensuring we, as a society of individuals, take

[4] Musall, F.D. and O. Kuik, Local acceptance of renewable energy—A case study from southeast Germany. Energy Policy, 2011. 39(6): p. 3252-3260.
[5] Ratinen, M. and P. Lund, Policy inclusiveness and niche development: Examples from wind energy and photovoltaics in Denmark, Germany, Finland, and Spain. Energy Research & Social Science, 2015. 6(Supplement C): p. 136-145
[6] Schweiker, M. and M. Shukuya, Comparative effects of building envelope improvements and occupant behavioural changes on the exergy consumption for heating and cooling. Energy Policy, 2010. 38(6): p. 2976-2986.

responsibility; the issue being "why should individuals invest time and resources when they can free ride on the efforts of others?"[7]

While the involvement of local actors in the deployment of bioenergy facilities does not necessarily encounter these issues, because it offers personal incentives beyond one's concerns about society's direction overall. However, it does offer us the opportunity to introduce the conversation as an economic opportunity, and therefore, manifest macro concerns in the micro level.

The community level is commonly held as the most appropriate micro unit on which to build a sustainable society: A community is a social unit, and therefore through the creation of norms and socially enforced behaviours, communities can serve as self-moderating organisms. The "embeddedness" of individuals within their "political, social, institutional and ideological context" means that group identity has a profound effect on the behaviour of group members.[7] This shared identity, which is often present within communities, contributes to feelings of solidarity, shared values, trust, and the creation of norms and patterns of behaviour which are "necessary to overcome collective action problems".[8] It therefore appears that government legislation aimed at creating the energy citizen would be best served using policies aimed at shaping and encouraging energy conscious behaviour within communities[9,10] If we are serious about creating the "energy citizen", an autonomous agent aware of his or her social responsibilities, and willing to alter his or her behaviour in line with Ireland's energy goals, then we must not only delegate "responsibilities", but also offer opportunities.[11]

4.3 Concepts & Definitions of Community Participation and Ownership

Community ownership and participation are broad and ambiguous terms and have different meanings across jurisdictions. If community participation is organised purely on financial returns from energy generation, the benefits from community schemes may be distributed very narrowly. For Example, if community schemes are organised as small cooperatives owned by three or four farmers (rather than widely among many individuals) who jointly invest in a biogas installation or wind turbines, all profits and responsibilities are shared between themselves. In such cases beneficiaries tend to be citizens who have cash resources and want to invest in the scheme. Alternatively, projects may be led by a developer who offers options to purchase equity to local groups or individuals. In these instances, community ownership benefits residents who have money to invest and those without money are not able to share the benefits. Accordingly, the design of community based schemes may need to consider additional means of engaging community participants, including a variety of means to distribute benefits. For example, developing community schemes in a manner that reduces the energy costs of all community members may be one means of broadly distributing benefits. Integration of measures that can remunerate large groups of feedstock contributors may be another. Community projects may distribute remaining profits in the scheme to charitable causes, thereby offering benefits to those who have limited financial means.

[7] Bomberg, E. and N. McEwen, Mobilizing community energy. Energy Policy, 2012. 51(Supplement C): p. 435-444.
[8] Ostrom, E., Chapter 24 Common-pool resources and institutions: Toward a revised theory, in Handbook of Agricultural Economics. 2002, Elsevier. p. 1315-1339.
[9] Rae, C. and F. Bradley, Energy autonomy in sustainable communities—A review of key issues. Renewable and Sustainable Energy Reviews, 2012. 16(9): p. 6497-6506.
[10] Walker, G., et al., Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. Energy Policy, 2010. 38(6): p. 2655-2663.
[11] Goedkoop, F. and P. Devine-Wright, Partnership or placation? The role of trust and justice in the shared ownership of renewable energy projects. Energy Research & Social Science, 2016. 17(Supplement C): p. 135-146.

Involvement of the local authority can be effective in redistributing the benefits to all citizens be that through provision of low cost or free heat or power for social housing, the elderly or vulnerable for alleviation of energy poverty, or through the diversion of profits to provide or subsidise other public amenities that all citizens can utilise.

The proposed draft RED II[Error! Bookmark not defined.] promotes development of community based renewable energy projects in (Article 22 - Renewable energy communities), and outlines proposed conditions pursuant to which Member States are obligated to ensure non-discriminatory market outlets are available for RES OUTPUTS and, without prejudice to State aid rules when designing support schemes, to take account the specificities of renewable energy communities. For purposes of this obligation, a renewable energy community is defined as an SME or a not-for- profit organisation, the shareholders or members of which cooperate in the generation, distribution, storage or supply of energy from renewable sources, fulfilling at least four out of the following criteria:

- shareholders or members are natural persons, local authorities including municipalities, or SMEs operating in the fields or renewable energy;
- at least 51% of the shareholders or members with voting rights of the entity are natural persons;
- at least 51% of the shares or participation rights of the entity are owned by local members, (i.e. representatives of local public and local private socio-economic interests or citizen having a direct interest in the community activity and its impacts);
- at least 51% of the seats in the board of directors or managing bodies of the entity are reserved to local members (i.e. representatives of local public and local private socio-economic interests or citizens having a direct interest in the community activity) and its impacts;
- the community has not installed more than 18 MW of renewable capacity for electricity, heating and cooling and transport as a yearly average in the previous 5 years.

The RED II proposals are consistent with another important trend visible across Europe; that of "Remunicipalisation" which refers to returning operational activities and/or infrastructure considered to be public services (and previously outsourced to private organisations) to local public authority control. Such initiatives are not just about recovering ownership of network infrastructure; they also nurture the ambition of strategically positioning the local authority as a major player along the whole value chain and make it a central instrument of its local energy strategy, as can be seen with the examples of many EU cities and towns, e.g., Stuttgart, Bristol and the Occitanie Regional Council, France.[12]

According to several surveys across Europe there is a preference among citizens for public services to be in municipal control rather than in the hands of private enterprise. The analyses of these results have concluded from this that municipal management is therefore perceived as an assurance that citizen value will be placed before shareholder value.[13]

Proximity with consumer-citizens, the capacity for local operators to quickly adapt to their needs and the priority given to the general interest, are also a major advantage in a competitive environment. As noted in a 2012 German report, the brand image associated with proximity and public interest is "the primary resource of Stadtwerke" (municipal works/infrastructure). This brand image is what determines the

[12] Berlo, K., & Wagner, O. (2015). Widerstände und Chancen von Rekommunalisierungen. Présenté à 9. Eurosolar Konferenz « Stadtwerke mit erneuerbaren Energien ».
[13] Bauer et al., 2012; Berlo, Wagner, & Heenen, 2017; Hall et al., 2013.

consumers' energy consumption.[14] In Germany, despite their relatively small size, around 1,000 Stadtwerke are operating in the energy sector which represents more than half of the energy supply market (54% for electricity, 56% for gas, 67% of heating networks). In France, the public company Sorégies in the Vienne county has approximately 150,000 electricity and gas customers, UEM in Metz boasts 161,000 electricity customers and runs one of the biggest heating networks in France, whereas GEG in Grenoble has 157,000 customers. In the United Kingdom, municipal energy suppliers have rapidly gained ground thanks to their competitive offers and local engagement, e.g., LECCY Liverpool.

To better understand the new local energy ownership momentum initiated by citizens and local authorities in Europe, an analysis of the stimuli and success factors behind these initiatives is necessary. Leaving aside local challenges and specific national contexts, several cross-cutting issues can be identified. According to EnergyCities.eu the issues and motivations which emerged from an analysis can be grouped in four categories:

- Increasing political influence over local energy management;
- Ensuring that economic flows benefit the local area;
- Reinforcing links with citizens;
- Taking advantage of potential synergies between the various sectors and players.

The following section details the successful policy initiatives which were instrumental in the development of the bioenergy sector in countries considered leaders in that sector as well as measures which helped cooperative, community and municipal projects be a large part of the impetus for the growth of bioenergy.

4.4 Denmark

In Denmark the RE sector development very much in tandem with community energy schemes. The oil crises of the 1970s made Danish policy makers acutely aware of the dangers associate with being so heavily dependent on energy imports from politically unstable and often hostile regions. Therefore, to secure an indigenous supply of energy, as well as to capitalise on a clear commercial opportunity, Denmark has since become a global leader in not only the development and deployment of renewable technologies, but also the necessary policy frameworks purposed to facilitate such deployment. Decades of innovative policy, and continuous investment in renewable R&D, have resulted in approximately 53% of Danish electricity consumption now supplied from renewable sources.

While strong Wind and PV deployment have been the main contributors to this achievement, Denmark has also managed to secure a strong supply of bioenergy. Approximately 65% of Danish households are currently connected to a district heating system (68% of which are CHP), over half of which use biomass for fuel.[15,16] Denmark has been extremely successful at developing the bioenergy sector and therefore offers a fitting jurisdiction for our analysis.

Emergence of Biomass Sector

[14] Theron, 2012, p. 11
[15] Regulation and Planning of District Heating in Denmark. 2017, Danish Energy Agency.
[16] Grohnheit, J.S.G.S.B.O.S.L.V.S.H.G.P.E. *Experiences with biomass in Denmark.* 2014.

After initially slow development due to numerous operational failures, Danish biomass technology has improved enormously since the 1970s. The first phase of substantial biomass deployment came in the early 1980s, when North Jutland invested substantially in biomass CHP plants. However, funding was later withdrawn when it was realised that these plants were not preforming as well as had been hoped.

During the mid-1980s the price of oil fell substantially, a situation which made the fledgling renewable industry entirely uncompetitive. In reaction to this change of circumstance the Danish state authorities, anxious not to remain dependent on imports fuels, made a concerted effort to promote and maintain a domestic supply of energy. Rather than simply moving back to the then cheaper form of energy, the Danish government invested heavily in the exploration for domestic natural gas, as well as in the subsidisation of RES. An energy tax was levied on liquid fossil fuels which ensured that RES and natural gas remained somewhat competitive.

During this time, concerned about the leakage of nitrates into the water table, the Danish Environmental Protection Agency published a damning report about Danish farming practice, which ultimately resulted in a number of agro-environmental regulations set out in the first "Water Action Plan"[17] As a result of this report the Danish government implemented restrictions on the number of animals which could be kept on a hectare of land, the maximum nitrate concentration per hectare, and forced farmers to build storage facilities capable of holding 6-9 months' worth of manure.[18]

Centralised Anaerobic Digesters and District Heating Networks – The resultant increase in agricultural production costs were not very well received by the farming community. The Danish Energy Authority and several public bodies, however, saw this as an opportunity to promote centralised biogas plants. This culminated in the launch of the Biogas Action Programme (BAP), to promote the construction of biogas plants, increase R&D funding and support information diffusion. The scheme initially offered grants of up to 40% of AD construction costs as well as a finance scheme with long term low interest loans. Grant levels were later reduced to 30% in 2012. A fixed price support scheme was also implemented, and biomass was exempted from the energy tax. BAP was extremely successful and resulted in the construction of five new plants between 1988-91, and one or two plants per year until the scheme was discontinued in 2002.[17] This period was the most successful era in Danish bioenergy deployment with over 20 large centralised plants and 60 farm scale operations constructed during this period.

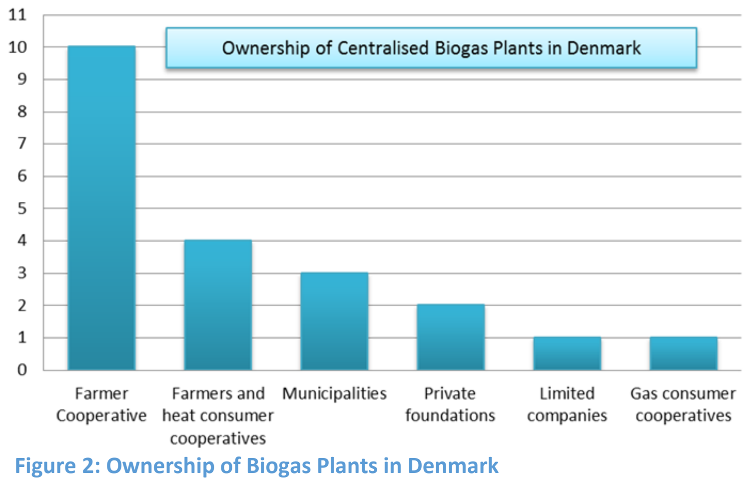


Figure 2: Ownership of Biogas Plants in Denmark

Despite initial success, the construction of these facilities slowed to a halt by 1999, due to several policy reforms that made these facilities less attractive to investors. The 1999 "Danish Energy Reform", which was purposed to completely overhaul the country's energy system, served to increase uncertainty for investors. This reform, by changing the payment schemes from

[17] Raven, R.P.J.M. and K.H. Gregersen, Biogas plants in Denmark: successes and setbacks. Renewable and Sustainable Energy Reviews, 2007. 11(1): p. 116-132.
[18] Hjort-Gregersen, K., Danish experience with AD plants and future direction. 2014.

a fixed rate to a variable rate, and reforming the nature of the subsidy scheme, increased uncertainty, and reduced investor confidence; naturally leading to a decrease in deployment.

Emergence of small scale AD plants- Through the 1990s the sending of waste to landfill sites or incineration plants was made increasingly expensive as a result of incremental tax increases; in 1987 it cost 40DKK/ton for landfill and incineration, which by 2000 had increased to 260DKK/ton and 335DKK/ton for incineration and landfill respectively.[17] Legislators also made it illegal to dispose of organic material in landfills, which incentivised municipalities to approach existing biogas plants for the purpose of treating household organic waste. Farm scale plant technology had also become increasingly efficient and economically viable, which coupled with increased farm size, lead to a massive increase in farm scale plant deployment. The Danish authorities also reintroduced supports of up to 40% of construction costs for farm scale AD plants. A group of experts was formed for monitoring the technical and financial performance of farm scale biomass plants, improving efficiency and investor confidence.[17]

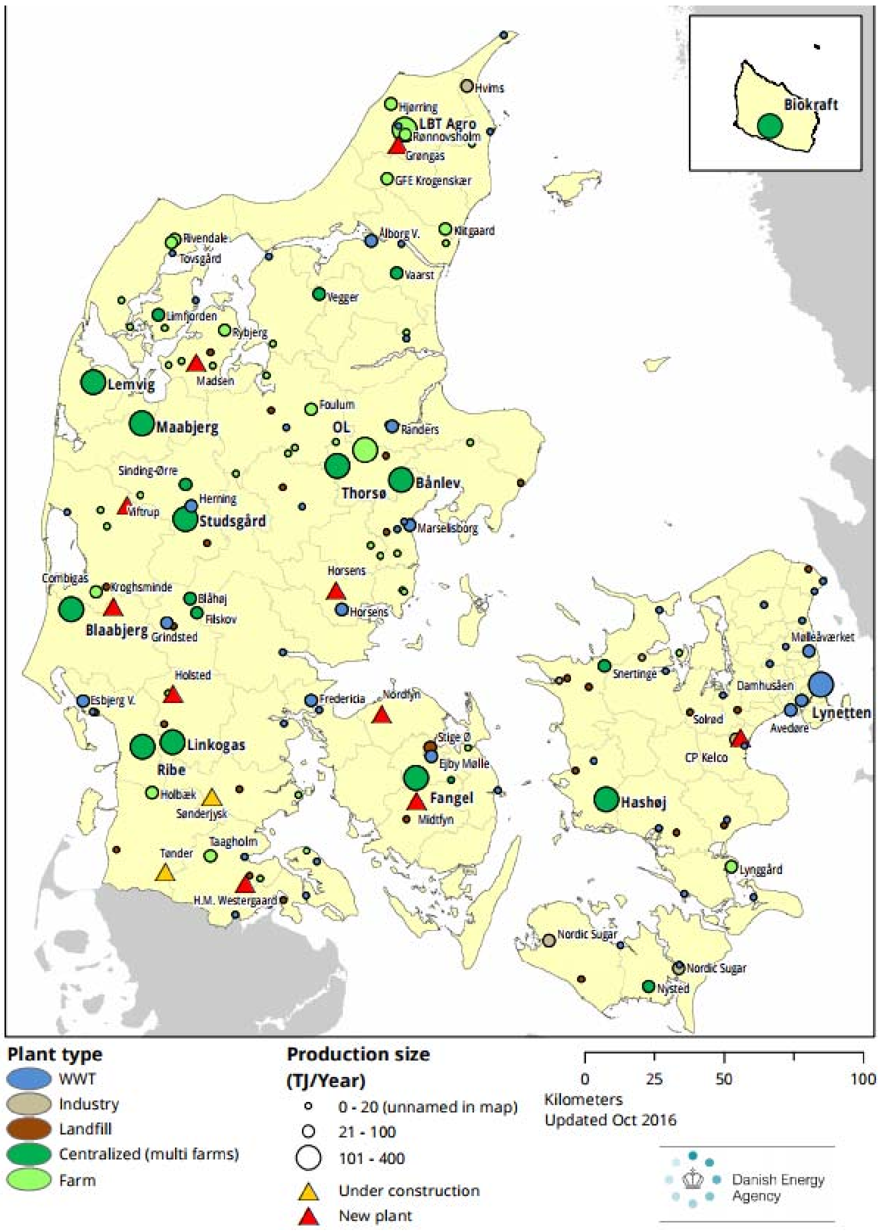


Figure 3: Map of Biogas plants in Denmark (20 TJ/year=700kW)

Bottom-Up Approach- Several different interest groups, including Farmers, Academics, Plant Company Owners and Public Authorities were encouraged to form networks for information diffusion, and collaboration. The increase in the technical and economic efficiency of Danish bioenergy technology has been attributed, in part, to this factor.[17,18]

As shown above, farmer cooperatives are the dominant ownership model for biomass facilities in Denmark. Cooperative organisation is commonplace in Denmark, and one which is particularly suited to biomass facilities. Cooperatives serve to economise the transportation and distribution of organic material to and from the biomass plants.[18] They also ensure the supply of quality biomass inputs. The involvement of farmers in the production of bioenergy means they personally benefit from the supply of high quality biomass inputs. This model also helps to integrate the supply chain, providing supply certainty.

These co-ops built large storage units, in which individual farmers could rent space to avoid having to set up individual farming scale storage. These large storage facilities also allowed for farmers with excess manure deposits to transfer it to those with a deficit. These co-ops were financed with loans and grants from the government.

To promote energy recovery from animal manures the Danish government offered additional subsidies for plants capable of producing upgraded, grid-injectable methane. In 2012 a subsidy was introduced for gas production into the national gas grid; this was structured as an investment subsidy of 30% of eligible capital costs. There was an addition to the prevailing support for biogas provided that at least 75% came from manure. This has served to further increase the economic feasibility of Danish biogas plants as they now have an additional market for their biogas, which was previously only of use to CHP district heating plants.

Denmark now has an AD sector which utilises over 1 million tonnes of manure, and 0.3 million tonnes of organic material annually. Most of the centralised biogas plants are owned by cooperatives, usually consisting of local farmers/forestry owners, while approximately 5 are owned by large utility companies.[19] Of the existing bioenergy facilities, the majority are capable of producing heat and electricity, while a minority are only equipped with heat producing technology.

Combination of Organic material - The biomass material used in Denmark's centralised biogas plants varies depending on the available resources; however, the majority are fuelled by cow and/or pig slurry, which is often mixed with fish processing waste. Some plants also utilities household bio-waste as well as dairy and poultry waste. Co-digestion has been shown to improve yields by up to 20%. Plants also received a gate fee for the processing of waste, further contributing to economic viability. The country's biomass industry has since become a victim of its own success, as demand for organic material now exceeds domestic supply, requiring increased biomass imports.

District Heating and Danish Energy Policy- Denmark is also well known for the prevalence of district heating systems, which were easily converted to be supplied predominantly by AD biogas. Initially, district heating schemes were supplied by direct recovery of heat from CHP, which is somewhat inefficient as the supply of heat does not always directly coincide with the demand. In more recent Danish CHP facilities have been equipped with short-term heat storage facilities. This has allowed for heating to be fed onto the system when the market requires it, not simply as a function of when it happens to be generated; the use of these systems in conjunction with the other forms of renewable energies has allowed for a more uniform and stable supply of energy to Danish consumers.[15]

The Heating Supply Act from 1979 banned the use of electric heating systems in households with access to a district heating systems or natural gas lines. Currently, less than 5% of households now use electric heating systems or gas. This act was amended in 1994 to mandate households to connect to a district heating system if it was in their area; this legislation required households to pay a connection fee irrespective of whether they would use the heat. This has helped to develop the revenue stream to

[19] Seadi, T.A. Danish centralised biogas plants - plant description Bioenergy department, University of Southern Denmark.

remunerate the capital costs associated with setting up a district heating facility by providing a guaranteed customer base.

Construction of district heating schemes is capital intensive. To help reduce the cost of credit municipalities will often act as guarantors for funds which will be used for the construction of district heating plants. This serves to reduce the risk of credit and therefore ensures low interest repayment costs; the payback period is usually 20 years.

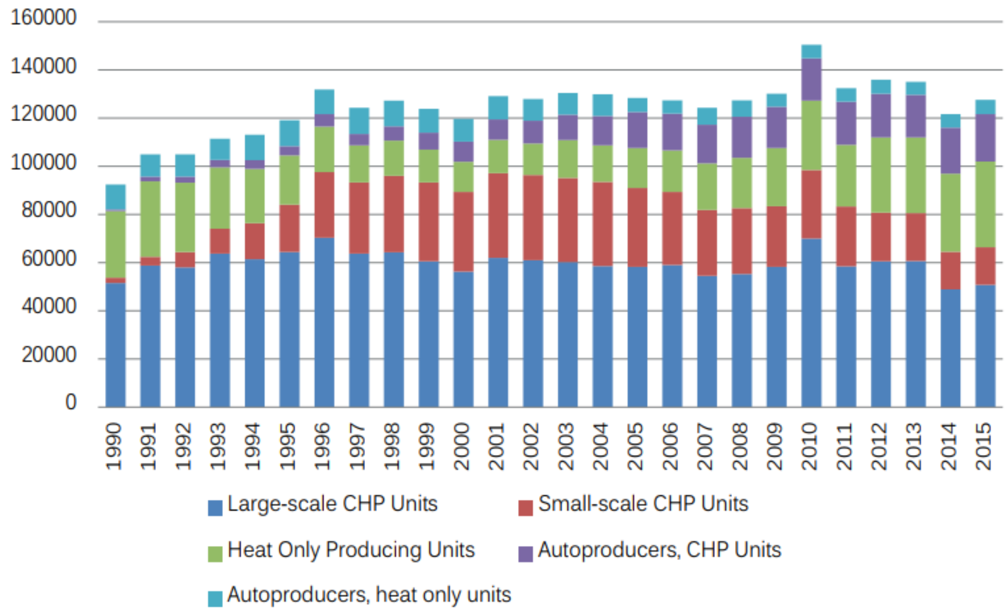


Figure 4: District heating production by type Grohnheit, 2014**.**

Case Study: North Jutland – "Village Energy Project." - Because of the growing improvement in biomass conversion technology, there was renewed interest in the development of centralised biomass plants in the early 1980s. The county council of North Jutland, in conjunction with numerous local stakeholders, established the "village energy project". This project outlined a desire to construct several biogas facilities for supplying the local area with renewable heat and electricity. The primary aims of this project was to reduce the county's carbon footprint, increase security of energy supply and provide local employment.

The construction of the first plant began in 1984 and was completed the following year by the North Jutland county council, and run by an entirely locally owned company called Vester Hjermitsiev; four of the seven board members were appointed by the local community, and the other three came from the board of director of the Vester Hjermitsiev district heat company, also a local institution. The project was partially funded by the county council, which lent the group €1.4m, the remainder was provided by the state government in the form of a € 0.5m grant. The plant was initially set up to process manure, but was later adapted to utilise other forms of organic waste. The plant is supplied with slurry from 5 local pig and cattle farms, which is co-digested with flotation sludge from the fish processing industry, tannery waste and smaller amounts of fodder waste.

There were several technical issues in the beginning, largely due to issues with the gas system, heat pump and pre-sanitation equipment. As a result, the plant was reconstructed in 1988-89, a situation which massively improved the plant's operational efficiency. Under the "Village Energy Project", an additional two plants were constructed in the following years. However, despite considerable improvement on small scale production, these plants did not meet expectations, and the county council later withdrew its support.

While the scheme was ultimately disbanded due to the implementation of underdeveloped technology, the model itself offers some key insights. This project was very successful in galvanising the relevant actors, securing the necessary funding, increasing local employment, reducing emissions and ensuring a stable supply of locally produced energy.

Factors for success in Denmark - Key factors that have been identified in respect of successful Danish projects include:

- Subsidisation of capex was required to facilitate high set up costs. In Denmark this initially took the form of a 40% capital grant, which was later reduced.
- Policy must create certainty for investors.
- Farmer involvement in plant deployment helps to mobilise a stable and adequate supply of organic materials.
- Farmers ought to be incentivised to channel their waste to biomass plant by making all other options relatively expensive or ruled out by regulation.
- The setting up of information groups can massively improve information diffusion.
- Bottom up approaches can help mobilise the appropriate interest groups.
- Specialised agencies help remove uncertainty and provide for investor confidence.
- Local involvement helps engender interest and awareness around the energy transition.
- The finite supply of organic material must be considered.

4.5 Germany

The German energy transition has been put emphasis on the decentralisation and democratisation of energy production, something which has been facilitated by an institutional framework constructed to support citizen involvement. Germany is like both Denmark and Austria in that policy makers began investigating alternative forms of energy generation because of the 1970s oil crisis. Since then Germany has invested enormously in R&D, and therefore, has positioned itself to capitalise on the demand for renewables technology in other EU nations through the creation of a strong renewables manufacturing base.[20] The RE technology industry employs approximately 371,000 people, 100,000 of which are associated with export activities.

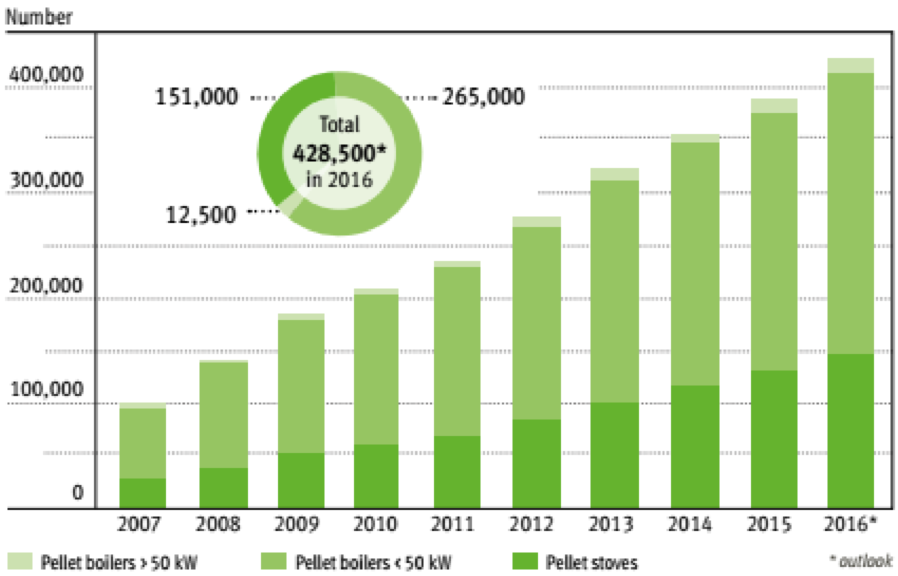


Figure 5. Installed Pellet Boilers in Germany.

District Heating - In Germany, renewable district heating is also strongly promoted, both in large cities and small towns. District heating is regulated in the same way as local energy networks, (EU legislation lays down specific requirements for grid operators to allow third party suppliers to access transmission and distribution networks for gas and electricity). This has helped to promote a strong presence of municipal ownership of DH. To ensure investments are covered by sufficient demand, under defined legal conditions local governments have the authority to require

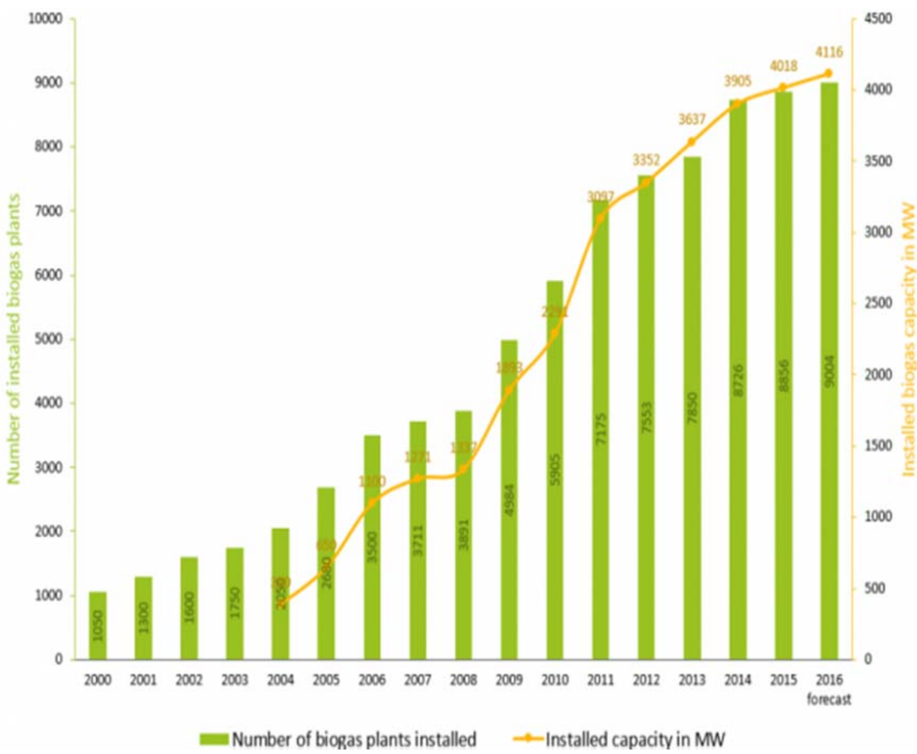


Figure 6. Growth in German biogas plant deployments (2000-2016)

[20] Ratinen, M. and P. Lund, *Policy inclusiveness and niche development: Examples from wind energy and photovoltaics in Denmark, Germany, Finland, and Spain.* Energy Research & Social Science, 2015. 6(Supplement C): p. 136-145.

local building owners to connect to the network.[21] These laws are established according to the individual state (Länder). This legal tool has been particularly useful for local governments that aim to pursue climate protection, and in particular to develop renewable heating schemes.

State Policy - The most influential piece of German RE legislation is the Renewable Energy Act (EEG), 2000, which has been subject to multiple amendments since, the most recent of which (2017) gave preferential grid access to renewable energy over fossil fuels, and smaller producers over large corporations.[22] It also offered comprehensive feed in tariffs to subsidise RE.[23],[24] The feed-in tariffs, by offering a guaranteed rate of return, served to give German citizens the option to become "prosumers", or simultaneously producers and consumers, something which was particularly supportive of public acceptance and civic participation of wind energy.

The initial phase of the EEG (2000-2009) supported the growth in RES generation, and offered generous feed-in tariffs (FIT) in order to make RE competitive with fossil fuels. To incentivise investment, the German FIT scheme factored in the capital costs plus and an additional rate of return. The scheme aimed to provide "Transparency, Longevity and Certainty" for investors.[25] The EEG also obliged grid operators to connect any viable bioenergy facility to the grid, and made them liable for any lost earnings were they to fail to do so.[26]

This policy framework has been reformed several times since 2000. Under the 2009 EEG amendment bonus payments were made available to producers capable of meeting any or all the following criterion:

- Generation of pipeline-grade biomethane
- Utilisation of highly efficient conversion technologies (HE CHP);
- Use of energy crop and manure as feedstock;
- Adherence to biogas air quality regulations.[25]

These benefits could all be claimed at the same time, which lead to some producers receiving excessive compensation, causing a steady increase in consumer electricity prices. Some of these measures were later revised to remove complexity, as well as avoid being overly generous with consumer funds. As a result, the subsequent 2012 EEG amendment implemented several key reforms; bonuses for facilities over 750kW using energy crop and manure were removed, and to qualify for support producers were limited to a maximum of 60% silage and maize input. Biogas facilities also only qualified for support if a minimum of 60% of the heat produced in the creation of electricity was used, or if the bioenergy came from a minimum of 60% slurry.[27] The 2012 reform also included bonuses for the following;

- A separate tariff was introduced for biogas facilities which utilised landfill gas (up to 750kW);
- Small scale biogas plants of 75kW or less were also made eligible for a separate tariff of 25c/kWh if they used a minimum of 80% manure.[25] (Note - any plant availing of either of these subsidies was not eligible for any other bonuses).

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[21] Köch, W (2014). Regulation of Energy Networks in Germany. Special research conducted for ClientEarth.
[22] Comparing old and new: Changes to Germany's Renewable Energy Act. 2014: Clean Energy Wire.
[23] Hall, S., T.J. Foxon, and R. Bolton, Financing the civic energy sector: How financial institutions affect ownership models in Germany and the United Kingdom. Energy Research & Social Science, 2016. 12: p. 5-15.
[24] The German Feed in Tariff. 2017. www.res-legal.eu
[25] Joself, M.F., The Germany Feed in Tariff; recent policy changes. 2012, Deutsche Bank.
[26] Appunn, K., Defining features of the |Renewable Energy Act (EEG). 2014.
[27] IEA, 2012 Amendment of the Renewable Energy Act (EEG2012). 2012.

The 2012 reform also implemented a market premium option which was made available to bioenergy producers, by which producers would trade directly on the wholesale energy market, receiving the spot price and a monthly market premium. The market premium was sufficient to bring the price received up to the prevailing feed in tariff price, plus a management bonus included to mitigate the costs of trading on the wholesale market.[25] As a result of the mounting costs associated with supporting RE, this reform mandated direct marketing, mandating producers to negotiate Purchase Power Agreements (PPAs) with energy supply companies to try to match or better the centrally calculated wholesale price. It also laid the foundation for a public tendering for all bioenergy projects greater than $500kW_e$. This policy also implemented expansion corridors, by which a certain annual quota of deployment receives full support, and any additional deployments will receive a reduced level of support; this was 100MW for bioenergy production.[28,29]

The EEG framework has resulted in exponential growth in the bioenergy sector, particularly regarding biogas CHP plants; with over 8,900 currently in operation. The growth in biogas output has been impressive; biogas plants produced 3,600 GWh in 2005, which increased to 19,200 GWh by 2011.[30]

There are also 183 biogas plants in Germany capable of upgrading to biomethane; 140 ADs accepting household waste; 700 thermal plants fired on solid biomass (waste wood and forestry residue) and 180 liquid biomass (plant oil or ethanol powered engines) plants. As a result of a continuous effort to fine tune public policy and the financial support mechanisms, bioenergy has become a very important element in Germanys energy mix; contributing 50TWh of electricity and 88% of the country's renewable heating in 2015.[30,31]

German Project Financing - In general, bioenergy has been very well supported in Germany, receiving €6.2 billion in 2015; the second largest allocation of renewable funding after solar. Of the 6.17c/kWh paid by consumers in the form of a renewable energy surcharge, bioenergy received 1.57c (2015).[31] All energy users, with the exception of some energy intensive industries (which are exempt in order to maintain international competitiveness) are obliged to pay a premium on their utility bill, which amounted to 18% of the retail price in 2013. This rather substantial cost has been of considerable concern to German policy makers, giving rise to efforts to find mechanisms capable of bringing down consumer costs.

The initial fixed FIT was constructed to factor in the costs of capital investment and a generous rate of return. Bioenergy received a fixed FIT on a 15 to 20 years basis in line with technology specific production costs. The EEG framework, by offering a secure rate of return has been instrumental in securing greater citizen involvement in the energy transition.[31,32] However, subsidy support has been significantly reduced through consecutive reforms in line with falling production costs. As part of the 2012 EEG amendment there was an overall reduction of 10-15% in the tariffs. Biogas plants also only qualified for the FIT if they either utilised 60% manure, or if 60% of the heat produced from power generation was captured for consumption. The most recent 2017 EEG reform has mandated a tendering process, as a means of reducing electricity prices and bringing the RE production more in line with fundamental market forces.

The most recent FIT levels are listed below;

[28] IEA, 2014 Amendment of the Renewable Energy Source Act (2014). 2014.
[29] Renewable Energy Sources Act (EEG, latest version EEG 2017). 2017: lse.ac.uk.
[30] Nicola, S.-L., Feed-in Tariff (EEG feed-in tariff). 2017: RES Legal.
[31] Appunn, K., *Bioenergy in Germany – facts and figures on development, support and investment*. 2016.
[32] FACTS AND FIGURES. 2017: Surprisingly Ingenious

- Biogas from bio-waste – 13.05c to 14.88c/kWh
- Biogas from manure – 23.15c kWh, minus .2c if the plant is less than 75/kW
- Landfill gas – 5.66-8.17c/kWh
- Sewage gas 5.66c – 6.49/kWh
- Biomass 5.72 -13.32c/kWh[30]

The Cooperative Model - Renewable energy cooperatives are extremely prevalent in Germany, constituting 21% of the 34GW of installed capacity under citizen ownership by 2016. In 2013, €1.2 billion euros was invested in the renewable sector by approximately 130,000 individual citizens.[33] In 2012, the total installation of renewable energy in Germany was 53GW, of which 51% was owned by local citizens or farmer; approximately 42.2% of all bioenergy facilities are citizen owned. Local ownership is said to increase local identification with the community energy policy. A community business tax means that 70% of the tax revenue is kept locally, and thus provides an incentive for local municipalities to work with developers. This "democratisation" of the German energy system contributes to the retention of local value, a feeling of empowerment among the local community, and has been the catalysts for populous participation and acceptance. Essentially, the broad availability of the Feed-in Tariffs meant individual citizens could participate in, and personally benefit from, the country's energy transition.

Germany has two business models for cooperative biomass deployment:

- The first of which is the cooperative model, in which everyone carries an equal say in the decision-making process, irrespective of the amount of capital they have invested. This model is particularly attractive to individuals seeking an active involvement in the management process. It also allows for more individuals to have more than just a financial involvement, stakeholders are financially motivated to become actively involved in local energy policy. In total there exist over 754 renewable energy cooperatives in Germany, approximately 25% of which manage bioenergy facilities. Citizens have invested over €426 million in these co-ops, half of which is borrowed from cooperative banks, or through subsidised low interest loans provided by banks like KfW, a state owned financial institution.[34] Buy in varies from €50-€5,000 per share, with the purchasing of the lowest cost shares often requiring a minimum quantity. The personal liability for these businesses is limited to the capital invested.

- The second model is called a Close-end fund, which consists of two types of stakeholders, limited partners, generally local citizens, and general partners, who oversee the day to day business management. The income made from these investments come with some attractive fiscal incentives: The company's income is treated as a series of individual incomes, and therefore is not liable for any corporation tax, and any losses made in the first year of production can be offset against tax on other income streams. The differentiating factor for the Close-end model is that citizen investors (limited partners) have no say in the decision-making process, which is entirely determined by the general partners.[34] Therefore, these models are not suited to individuals wishing to take an active role in the running of the business. However, this model also avoids the delays and

[33] Hall, S., T.J. Foxon, and R. Bolton, Financing the civic energy sector: How financial institutions affect ownership models in Germany & United Kingdom. Energy Research & Social Science, 2016. 12: p. 5-15.
[34] Yildiz, Ö., Financing renewable energy infrastructures via financial citizen participation–The case of Germany. Renewable Energy, 2014. 68: p. 677-685.

transactions costs associated with ensuring consensus among stakeholders which can be very tedious and time consuming. The Close-end are more profit orientated business models than the cooperative model, and tend to deal with larger more expensive projects.[35]

One of the main drivers of German bioenergy deployment well-established funding mechanisms such as KfW, a state-owned bank, which offers long term low interest loans to cooperatives seeking to install a biomass district heating system or CHP. KfW offers loans of up to €25m per project, will cover up to 100% of the initial investment costs, provides fixed interest rates for 10 years and allows for a free "start-up period" in which no repayments will be required. KfW administers many of its loans through local banks including many cooperative banks.

Case Study: The Energy Re-Municipalisation Process in Hamburg - The energy re-municipalisation initiative in Hamburg is one of the most emblematic in Germany both in terms of its scope and by the grassroots involvement that it generated. In 1999, the privatisation of the former municipal utility HEW had been widely criticised by part of the opposition and by citizens. In 2009, the city council decided to re-establish a public energy supplier, Hamburg Energie, fully owned by the municipal water company. The new company experienced rapid growth, recording 100,000 customers for its gas and renewable electricity offer and positive financial results after just 5 years in existence. But citizens wanted to go further: in 2010, local environmental and charity organisations launched a citizen's initiative, Unser Hamburg – Unser Netz (Our Hamburg – Our Network), to demand a local referendum on the public takeover of all energy networks (electricity, gas and heat). The "yes" had it with 50.9% of the votes, encouraging the initiative to set up a community cooperative (Energienetz Hamburg e.G.), which raised over €50m from the community to help finance the takeover of the networks and develop RE projects. Following this vote (a binding vote for elected representatives), the city council organised the takeover of the power grid by the new operator Stromnetz Hamburg GmbH in 2014, which also became the new concessionaire for the next 20 years. The City also has a minority stake (25.1%) in the private companies owning and managing the gas and heat networks. A full takeover of these networks is planned in 2018 and 2019 respectively.

Economic issues were central to the referendum debate. Those against the takeover put forward the huge cost -almost €2bn in total- of buying back the electricity, gas and heat networks for the city, but this was in fact an investment in vital and economically productive assets, resulting in a profit of €35m in 2014 for the new public operator from managing the electricity distribution network (excluding production and supply activities), in addition to the €60m paid directly to the city as concession rights. Management of the gas and heat distribution grids also generated profits in 2014 of €25m and €62m respectively.[36]

As municipally-owned entities with a public service mandate local public energy companies can help reconnect the local authority and its citizens, illustrating a valuable opportunity for local authorities to reinforce proximity and use it as a comparative advantage in the local energy market. In many cases, especially in Germany, bringing energy back into local public ownership is an actual demand coming from citizens, as illustrated by the Berlin, Hamburg or London examples.

[35] Vaughan-Morris, C.L.A.P.G., Cost and financing aspects of community renewable energy projects VOLUME II: GERMAN CASE STUDY. 2016, IEA.

[36] Geschäftsbericht 2014. HGV Hamburger Gesellschaft für Vermögens- und Beteiligungsmanagement, 2015.

The argument in favour of greater local public intervention in the economy has also been reinforced by the recent economic and financial crisis which has strongly undermined confidence in large companies and "market forces".[37]

Success factors in Germany – Factors considered key to the success of the German sector include:

- Stable policy creates investor confidence;
- Generous subsidies spur deployment, although cause consumer energy prices to rise substantially;
- The presence of financial institutions which offer preferential credit terms allows for a greater diversity of ownership; and
- Capital subsidies are necessary to cover the high installation costs.

4.6 Austria

Austria, much like Denmark, was forced to reconsider the structure of its energy system because of the 1970s oil crises, and has since been very successful in its transition from fossil fuels to renewable energies. Austrian policy makers have managed to achieve a diverse range of renewable technology including PV, Wind, Hydro and Biofuels. This has been ensured by the implementation of legislative policies aimed at removing uncertainty, improving technological and economic development, and to incentives the creation of a thriving manufacturing industry. While hydro constitutes the lion's share of renewable generation (84%), 10% of renewable electricity is derived from biomass; 55% of which is generated by CHP plants. Woody biomass is the predominant fuel type, with 81% of bioenergy generation coming in this form; which is to be expected since over 45% of the country's land mass is covered in forestry.[38]

Austria is a world leader in biomass boiler technology, an industry which employs approximately 3,600 people and manufactures over 50,000 biomass boilers each year; producing over 25% of the EU's biomass boilers annually. It also boasts the highest penetration of small scale biomass heating systems in the world, with an average of 40% of electricity being sourced locally.[39,40]

District heating is a very important feature of the Austrian energy system, providing 15% of the total energy consumption in Upper Austria, making use of 1,150,100 tons of solid biomass, leading to a reduction in 1,000,000 tonnes of CO_2 annually. Upper Austria has been particularly effective in deploying biomass facilities, given the concentration of forestry coverage within the region. The concentration of resource has been one of the key drivers for the rapid and efficient deployment of biomass technology. The defining factors of Austria's biomass industry are as follows:

Austrian Cooperative Business Model - Prior to the development of the Austrian biomass industry approximately 50% of the output from their forests went directly to commercial uses, with an additional 20-30% being left on the forest floor for environmental purposes. This meant that between 20-30% of the forest's output was going completely unused. Local farmers and forest owners, seeing this as an opportunity to secure additional income streams, began to consider the development of biomass plants as a means of putting this residue biomass to productive use.

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[37] Becker et al., 2015; Halmer & Hauenschild,2014; Kishimoto et al., 2015; Lell, 2010
[38] Höher, L.P.G.K.M., National policy landscapes: Austria. 2014. 81% of bioenergy generation.
[39] Dell, C.E.C.Ö.B.A.B.B.N.R.G., Biomass heating in Upper Austria Green energy, green jobs, 2010.
[40] IEA, Energy Policies of IEA Countries; Austria. 2014.

Cooperatives emerged as the most prominent business model for capitalising on the excess forest residue. These cooperatives began as non-profit making entities; however, the focus has begun to change in recent years, with bioenergy beginning to be perceived as a viable way to supplement a farmer's income; this has to some degree been influenced by the fact that famers noticed the money that was being made by German famers.

These groups have since been heavily involved in the setting up of biomass district heating facilities for the purpose of supplying schools, government buildings and local businesses with heat and electricity, with over 300 currently in operation.[40] Cooperatives seeking to install a district heating system can receive investment grants of up to 40% of the initial set up cost, a scheme which draws on EU regional development funding (ERDF) as well as internal state funding.

These cooperatives usually consist of about 10 members, with the members themselves supplying over 70% of the biomass inputs. This business model, as outlined previously, clearly helps to mitigate some of the problems hindering greater deployment in Ireland. The involvement of local farmers and forestry owners in both the supply of inputs, and the biomass facilities themselves, serves to both integrate the supply chain and incentivise the supply of high quality biomass inputs.

Austrian State Policy -
Austrian policy has underpinned exponential growth in renewable deployment over the last 25 years. There are three avenues through which the government has managed to support biomass deployment; financial incentives, legislative frameworks, and promotional activities.

Austria offers very comprehensive financial support in the form of generous capital investment reimbursements, guaranteed feed in tariffs, and grid priority access. There has also been a strict regulatory measure put in place governing efficiency and emission standards, which has served to promote the development of bioenergy technology. Finally, in conjunction with the financial and legislative support, the Austrian authorities have been very successful in stimulating demand through promotional campaigns, as well as providing the necessary information through specialised agencies. These agencies provide expert advice to individuals hoping to participate in the country's energy transition, but lacking in the relevant knowhow. To facilitate greater levels of renewable deployment, Austria has invested enormous sums of money in the development of biomass technology; this has led to the exponential development of their biomass boiler manufacturing industry, creating strong local employment. Simply put, state policy has managed to both stimulate demand as well as support supply.

Strict Austrian Emissions and Efficiency standards - The progressive increase in emissions and efficiency standards has forced Austrian biomass boiler manufactures to steadily improve the performance and efficiency of their technology. As a result, Austria is now one of the most advanced producers of bioenergy related technology in the world. While this has obvious domestic benefits, in terms of reduced carbon emissions as well as providing energy security, it has also given Austrian manufacturers a clear advance over their international competition; leading to an exponential growth in exports. This in turn has created local employed, increased the country's tax revenues and offered an overall boost to the Austrian economy.[29]

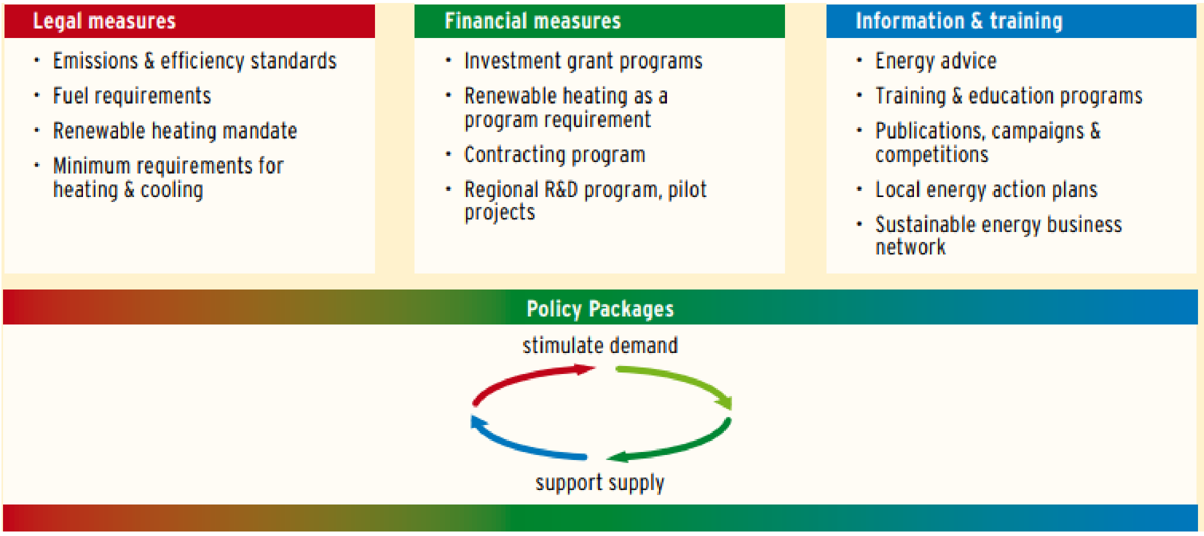

Figure 7. Austrian policy measures to develop the biomass supply chain (Dell 2010)

Specialised Agencies - OO Energiesparverband ("Energy Saving Council") is a state sponsored agency made up of a network of over 160 different companies and institutions. Its purpose is to provide homeowners, public agencies and businesses with expert energy advice, removing any uncertainty about how best to move towards a more sustainable energy future. They offer their services to over 15,000 interested parties annually.[38] The consultation is free of charge to home owners and public agencies, while commercial groups are required to pay just 25% of the fee. Their services help create certainty for investors and individuals seeking to install a biomass boiler, a situation which has contributed enormously to deployment.

The Chamber of Agriculture provides economic and technical advice to farmers seeking to construct biomass district heating. As noted previously, one of the main barriers to entry in the Irish biomass market is a clear lack of expertise, a situation which could easily be remedied were institutions like OO Energiesparverband to be established, and sufficiently funded.

Education and Training - To develop the biomass supply chain infrastructure Austrian legislators established several educational centres. "Energy Academy" offers over 30 training and information seminars on a wide range of areas, and includes courses aimed solely at the technical elements involved in the deployment of a district heating system. There are numerous other institutions aimed at upskilling the Austrian work force such as "Eco-installers", which offers training in renewable energy technology more generally, and the "State agriculture schools", which offers technical training to farmers.

Financial Support - There are several support mechanisms in place in Upper Austria which help to mitigate some of the high set up costs involved in a biomass facility. Homeowners can avail of grants of up to 50% of the investment costs, while non-residential actors can receive up to 40%. There also exists a dedicated fund specifically set up to facilitate cooperatives seeking to install a district heating system.[39]

Between 2009 and 2020 the Austrian federal government has dedicated €90 million to support further deployment of renewable energies. Each federal state, of which there are 9, can also offer their own investment incentives and subsidy schemes; some offer fixed subsidies while others will cover a certain percentage of the investment. The principal investment grant for renewable energies differs according to the type of technology; however, bioenergy is extremely well supported. There is a standard reimbursement rate of between 30-45% of the investment costs, which can be increased by a maximum of 10% depending on the type of biomass utilised, with potential of an additional 10% for small scale operations.

Domestic and commercial biomass boilers receive capital grants according to their capacity as follows:

- 0 - 50 kW - €120 per kW;
- 51 - 400 kW - €60 per kW, to a maximum of 30% of the investment costs.[38,41]

Structuring the capital grants such that they benefit the end-user allows the energy infrastructure subsidy scheme to rely on the EU "de minimus" threshold which allows EU member states to grant up to €200,000 of state funding to any single undertaking. In the Austrian scheme, a plant greater than 400kW receives a standard reimbursement of 20% with an additional 10% awarded depending on the technology. In addition to the capital grants to end users, the Austrian government also offers a FIT for RES-E which varies by technology. Biomass and biogas receive generous feed-in tariffs on a 15-year basis, listed below (2015 figures).[38,41,42]

- Sewage gas - 5.88c/kWh;
- Landfill gas - 4.9c/kWh;
- Compact Biomass (Forest woodchips or straw) - 8.81c/kWh to 13.86c/kWh depending on production capacity;
- Waste with high biogenic content- same as compact biomass for sawdust and bark minus 25%, and minus 40% for solid wood waste;
- Liquid biomass - 5.68c/kWh with a bonus of 2c/kWh for CHP;
- Biomass from agrarian production capacity – 12.8c/kWh to 19.31c/kWh;
- Note: FITs payable for 15 years.

To support energy delivery via an ESCO model, set up the "energy contracting program", which offered these specialist groups additional subsidisation of up to 13.5% of the investment costs, on top of the existing grant programs. Over 140 new district heating systems have been set up under this model.

Case Study: Buchkirchen District Heating Cooperative - Four farmers in a small agricultural town in Upper Austria exploited the excess biomass residue from their forest plots by setting up a small-scale district heating system in 2007. The project took only 3.5 months from start to finish, and now supplies heat to over of 26 residential, commercial and public-sector customers. The project cost €1,100,000, of which 30% was subsidised by the national government, 15-20% came from customers paying their connection fees in advance, which was also state sponsored, 15% was self-funded, and the rest was sourced via term loans subject to repayment over a 15-year period.

The project utilises 1,200-1,400 tonnes of woody biomass annually, for supplying local schools, kindergartens, municipal halls and family homes with electricity and heat through 1.8km of underground piping.[43]

[41] Borek, F., Subsidy (Environmental Assistance in Austria - UFI). 2017.
[42] Taxes and incentives for renewable energy. 2015, KPMG.
[43] For Four Farmers, Woodchip Boilers Drive an Expanding Business. 2009; Available from: www.biomasscenter.org/images/stories/buchkirchen.pdf.

The area is not widely forested, farmers only own small woodlots averaging c. five hectares each. The four farmers who own the plant supply a lot of the wood, but also buy from neighbours. There is always sufficient wood as the woods need thinning, but that activity has been neglected until now. More farmers are expected to do thinning and improve the quality of their forests now that we have a market for woodchips. The district heating system helps ensure resources remain within the local economy; it also reduces emissions, and creates an economic incentive for farmers to tend to their forestry. The project requires very little labour as most of the system is automated, and in the event an issue arises, the biomass unit is installed with software capable of notifying one of the farmers.

Overall the project is not very labour intensive, offers an extra income stream to each member, and provides the community with a few positive externalities mentioned above. This is a clear example of how a community biomass district heating plant can offer farmers a form of income to supplement their existing revenues without requiring excessive labour expenditure.

Case Study: Biomass logistic and trade centre in Waldstein Styria **-** The Styria region has the highest penetration of biomass boilers in Austria, installing over 10,000 in the period from 2001-12. To address the quality standards required to ensure efficient operation of biomass boilers, local community stakeholders established a biomass supply chain network capable of ensuring a stable supply of high quality biomass material. The biomass logistics and trade centre (BTC) had several key objectives;

- Establish a professional and reliable supply structure for wood biomass to replace the previous informal arrangement.
- Mobilise local actors and raise awareness about the benefits and requirements of biomass technology.
- Offer farmers additional revenue streams.[44]

The project is organised as a farming/forestry cooperative. Under the cooperative, individual members had wood delivery rights according to their share in the capital stock of the cooperative. Suppliers were to deliver their wood to a centralised depot where it would be processed into different biomass products, which were then sold on the regional market.

The investment cost was funded through cooperative member investment in conjunction with “Measure 122” funding; a European funding mechanism allocated for the ‘Improvement of the economic value of forests measure” and helped fund the construction of a storage building and the installation of a drying system. (In Ireland Measure 122 helped pay for new forestry access roads). Private investors paid for the tractors, a lift truck, as well as financing the renting of a yard; the total investment was €200,000. An awareness-raising and marketing campaign was then launched. The project was a resounding success, and has offered the following benefits;

- The project ultimately resulted in 9 long terms jobs;
- Members received a higher price for their biomass because the centre became recognised as a brand where consumers could access quality assured biomass product;
- Awareness about the benefits of biomass was raised in the community;
- The biomass value chain was strengthened;

[44] Biomass Trade Centre Waldstein ‘Biomassehof Waldstein’. 2013, European Network for Rural Development.

- The success of the project encouraged other jurisdictions to establish BTCs, thereby increase the level of biomass deployment in Austria and across Europe.

The biomass logistic and trade centre model has been rolled out in over six other jurisdictions throughout Styria, and other provinces within Austria.

Success factors for Austria- some of the key factors that have underpinned success of Austrian community based schemes include:

- Cooperative models help integrate the supply chain and incentivise the supply of quality inputs;
- Expert agencies offer help to create investor confidence, providing consultation services which smoothen out deployment;
- Strong state support is required to ease the high set up costs;
- Educational centres help create the required skill base;
- Stable and consistent policy frameworks create investor confidence and encourage greater deployment; and
- Investment in R&D offers long term benefits to industry.

4.7 Sweden

Sweden benefits from a very large forestry sector, as well as from a large district heating infrastructure, which is the largest user of bioenergy in Sweden. Use of fossil fuels dominated in the 1970s but has gradually been replaced by energy from biomass, municipal and industrial waste, waste wood, geothermal heat, heat pumps and industrial waste heat. More than 40% of the fuel used for DH production is currently bioenergy.[45]

Common boiler types are solid biomass boilers adapted to forestry fuels with moisture content between 35-50%. The traditional grate boiler is still common, but among newly built plants the fluidised bed combustion (FBC) boilers dominate. See Appendix 2.

The first DH grid was established in Sweden more than 100 years ago, in a hospital area in Vasastan in Stockholm. By the 1950s, the DH concept had been adopted by all major cities in Sweden and the expansion has continued since then. Today, DH in Sweden has about 80% of the market share for apartment buildings, and in total more than 50% of the market share for heat.[46]

Before the market deregulation in 1996, all DH utilities in Sweden were owned by municipal authorities. Today there are over 220 energy utilities that produce and distribute heat, both private and public, although most are in fact still municipal. EON and Fortum are the largest private actors, and together with Vattenfall AB and Göteborgs Energi are the largest overall suppliers, with several grids across the country.[47]

At the other end of the scale, there are DH systems with 10-20 GWh heat delivered per year, such as Lekeberg Bioenergi AB near Örebro, which is owned by local farmers who supply most of the fuel from their own farms and forests. The DH sector is currently facing challenges such as saturated markets,

[45] Swedish District Heating Association publication of heat statistics, 2014
[46] Swedish District Heating Association publication of statistics, 2014
[47] Swedish Energy Market Inspectorate publication of energy statistics, 2014

energy efficiency measures (reducing demand), competition from individual heat solutions such as heat pumps and low consumer trust due to lack of competition on the market. Distribution grids for heat were long considered to be natural monopolies, as multiple grids in a region would be too expensive to benefit consumers. Hence, each owner of a DH grid had a monopoly. However, the monopoly situation in the DH sector has led to weak incentives to keep costs and prices low.

Third party access (TPA) is a system that obliges the owners of distribution grids (for heat, gas, electricity etc.) to allow regulated access to third parties for energy distribution to end-users. A TPA system for the Swedish DH market has been discussed and investigated for several years, and came into force in August 2014, as an amendment to the Swedish Act on District Heating.[48]

4.8 Other Case Studies – France and the UK

Similar examples of community based projects arise in other jurisdictions.

Case Study: Le Mené, France – In France, the Community of Communes of Le Mené in Brittany is a good example of rural energy transition in France. With 6,500 inhabitants, this association of municipalities was one of the pioneers and founders of the positive energy territory (TEPOS) network. In the early 2000s, the association commissioned a survey of local renewable energy potential (biogas, wind, solar, wood biomass, etc.) which resulted in the publication in 2005 of a strategic plan aimed at reaching 100% renewable energy by 2025. On the initiative of local elected representatives, farmers and citizens, the association successively bought a CHP plant producing biogas from slurry and bio-waste (a €15m investment), a vegetable oil fuel plant (rapeseed), a community wind farm (€8m), two district heating networks, wood boilers and several solar plants and energy-neutral social housing units. To encourage local economic development, the association of communes has also created a business incubator (Menerpôle) as well as an energy business park.

Case Study: London- Citizen Engagement in Favour of a Public Energy Operator - Increasing energy prices and fuel poverty have become major issues in the United Kingdom. Seeing that large scale private energy companies were not looking for a satisfactory solution, a coalition of citizens, associations and trade unions joined forces to create Switched on London in 2016. This campaign advocates for a public energy operator to be set up in the Greater London area as a not-for profit organisation integrating open and participative governance and is aiming to promote renewable energy and deliver affordable prices.[49] Relatively unknown at the beginning, the campaign succeeded by making the question of a public operator a major topic of the May 2016 municipal elections. The new mayor of London, Sadiq Khan (Labour), who describes himself as the "greenest mayor in the history of London" is committed to create a public energy supplier (Energy for Londoners) for the urban area, which is expected to start operating in the next 12 months. The campaign inspired similar initiatives in other cities: a citizen campaign (Energy Democracy Greater Manchester) was launched in Manchester in 2016 and Liverpool City Council has already set up its own public supplier, Liverpool Energy Community Company.

[48] Swedish Code of Statues, 2014
[49] NEF, 2016

4.9 Models for Ireland

A review of different community models that have been successfully developed in other jurisdictions highlights the benefits that can be derived from engaging community participants and capitalising on existing resources, as well as the need for State support to overcome the range of barriers that otherwise constrain exploitation of the opportunity.

In an Irish context, given the immaturity of the bioenergy sector, an integrated programme prioritising waste/residue-to-energy may provide the best opportunity of making a timely, measurable contribution to the State's combined sustainability objectives, including binding EU targets. Deployment of such projects in rural population centres may be able to leverage the existing community based structures.

Emphasising energy recovery from wastes and residues will moderate feedstock costs, which are otherwise a significant component of bioenergy costs. An integrated programme can facilitate coincidental development of the supply chain protocols, which will be required to aggregate feedstocks and underpin economies of scale. An integrated approach would incorporate infrastructure development to create routes to market for bioenergy heat and biogas outputs, as well as facilitate deployment of processing infrastructure that can work together to optimise energy efficiency and environmental mitigation. Scale, efficiency, support infrastructure and changes to market paradigms will ultimately be required to facilitate transition to market led structures, which over time will minimise the cost to the State.

To illustrate how an integrated programme might be developed, REBIOGEN prepared a detailed illustration of a hypothetical Community Sustainable Energy Concept (CSEC) that includes:

- Deployment of mature and market tested AD technology to generate biogas from food waste, animal by-products (ABP) and grass sourced from a leased land bank. The illustration reflects marketing of a proportion of biogas directly to industrial users in the form of dilute biogas, and assumes upgrade of the balance to biomethane for distribution via the gas grid, or alternatively for compressions and blending with natural gas to service off-grid consumers via the virtual grid. It assumes engagement of a licensed gas supplier to facilitate marketing of the gaseous outputs.

- Deployment of advanced thermal treatment (ATT) technology to generate CHP, supplemented with facilities to increase RES H outputs during peak demand, from 2 different feedstock streams, including –

  - A municipal waste derived solid recovered fuel (SRF) blend offering a route to valorise local supplies of municipal waste, reducing waste processing cost. ATT from SRF will generate an ash residue which is not suited for nutrient recycling via land spread, and must be further processed into a construction aggregate or disposed of in accordance with waste management regulations;

  - A blend of agri-food residues and animal by products, supplemented with forestry residues to maintain heating value, that once processed thermally will generate biochar or ash residues suitable for nutrient recovery or recycling via land spread.

- ATT feedstocks will be dried in high efficiency driers to reduce moisture content suitable for use in ATT technology. Gaseous emissions monitoring protocols and water pollution mitigation technology will be deployed to minimise environmental impact from thermal technologies.

- The illustration reflects construction of a district heating network to valorise RES H from CHP, while the power outputs are exported to the national pool. Demand for the energy outputs will be generated by a sales force deployed to market a bundled package of heat and power to residents at a discounted price, creating a demand for CSEC power and ensuring community residents benefit from development of the CSEC. A licensed electricity supplier will be engaged to facilitate marketing of the power outputs.

- The illustration provides for deployment of recovery technology to recycle N & P, mitigating environmental impact from fugitive atmospheric emissions and runoff to ground and surface waters, as well as reduce import of manufactured fertilisers. These technologies will have to be developed and optimised, with performance validated prior to deployment.

The illustration is detailed in Appendix 8. It assumes progressive deployment of AD and ATT technologies. Co-deployment of the AD and ATT processing infrastructure is assumed within the wider community “catchment” although not necessarily in the same energy market avoiding overbuild of gas and district heat networks. It reflects co-deployment of infrastructure over a short period, whereas actual infrastructure deployment can be undertaken as part of a phased community “programme”. The district heating network would be designed to first service larger commercial demands and subsequently expanded to service the broader community demand.

The illustration assumes the project is organised as a Joint Venture under a PPP incorporating the Local Authority and/or Energy Agency, commercial interests including a waste management company, agri-food processor, a project operator and licensed energy supplier as well as a community group comprised of feedstock suppliers and interested community stakeholders. It assumes state supports are provided both in the form of investment supports sourced from EU programmes for infrastructure, as well as State funding in the form of equity investment and preferential loans. It assumes introduction of operational supports structured as RESS and RHI renewable energy subsidies. REBIOGEN highlights that both types of supports may be required to kick-start development of the bioenergy sector, however notes that if investment supports are properly structured, as the market matures the State may be able to exit, transferring operational responsibility to market participants and recouping some of the State’s investment. The financial return generated on exit may ultimately minimise the cost of bioenergy supports to the State.

In respect of community based district heating, REBIOGEN undertook a social cost benefit analysis comparing the costs and benefits from the community scheme illustration against the relative impact of a baseline relevant to rural population centres comprising (a) thermal energy sourced from oil-fuelled boilers; (b) electricity sourced from the power grid and (c) waste processing pursuant to which municipal solid wastes were transported to Dublin for incineration at Poolbeg. The analysis highlights that the Net Present Value of the state aid required to underpin the NPV deficit of bioenergy costs over revenues was exceeded by the NPV of the net social benefit, particularly considering the incremental costs arising from routing waste processing to an inefficient Dublin-based incinerator as well as the benefits from displacement of imported fossil fuels with indigenous energy sources.

In undertaking this analysis, REBIOGEN attempted to apply the principals outlined in Appendix VIII of the Energy Efficiency Directive. While REBIOGEN believes the framework pursuant to which the review was undertaken is relevant, it acknowledges that the review did not deploy sufficiently robust life cycle analysis techniques and given the timeframe within which this review had to be undertaken, it acknowledges that a more robust review using a Life Cycle Assessment methodology would assist to quantify the relevant net benefits more specifically. Accordingly, the results of the social cost-benefit review should be considered illustrative rather than absolute.

Some of the issues that are relevant to development of the CSEC model, or different community based models relevant to the development of the broader bioenergy sector are discussed below.

5 DEVELOPING ROUTES TO MARKET FOR BIOENERGY

Community scheme contributions toward energy decarbonisation and other sustainability objectives will be dependent on timely development and access to viable market outlets. Key enablers that will support this requirement include:

- Development of new routes to market, or preferential access to existing routes to market, for energy outputs; as well as

- Near term market supports that levelise cost of bioenergy delivery with competing forms of delivered energy until such time that the bioenergy market has matured sufficiently to facilitate a transition to market led structures; and

- Strategies that can successfully penetrate the market for energy outputs.

Energy is a commodity and current forms of energy are reliable, convenient and inexpensive. Bioenergy must displace existing forms of energy, and market penetration strategies must overcome market inertia, demonstrating that the benefit from changing to bioenergy is worth the effort and risk. Additionally, eenergy demand profiles are specific to individual customers and to individual communities, and the form of energy supply varies by community, determined by legacy market structures.

The review of international community schemes indicate that a range of bioenergy technologies can be deployed in different configurations to displace different types and scales of fossil-fuelled energy with bioenergy outputs. The most common community scheme deployments include AD for production of biogas, biomass solid fuels from forestry resources as well as district heating schemes that uses various thermal or AD technologies for production and generation of high-grade process heat (e.g. steam), low grade space heating or a combination of renewable heat and power. Bioenergy technologies can be scaled to meet individual or aggregated community demands. Where community projects are scaled to meet aggregated community demands, energy generation infrastructure requires distribution infrastructure to access the market.

Electricity distribution infrastructure is ubiquitous, however has evolved in a historical context of fossil fuelled generation sourced from large centralised generators. The transformation of the power grid to accommodate distributed power generation is ongoing, however grid access protocols may need to be adapted to streamline the small-generator connections application process, as under current protocols the large backlog of applications can excessively delay connection offers. If grid access protocols cannot be sufficiently expedited, protocols that facilitate direct wiring (direct supply) may be required. Direct wire infrastructure however, is only appropriate for individual or small-scale applications.

Nationally, in large population centres or other centres of high thermal demand, thermal energy requirements are met by supply of grid distributed natural gas. In rural population centres not served by the gas grid, thermal energy is predominantly supplied via heating oil and distillates, and to a lesser extent by electric heat. In rural centres with a modest commercial demand that can generate a linear energy density of slightly > 2 MWh_T per linear meter, construction of district heating schemes may provide a route to market for an aggregated thermal demand. Alternatively, development of virtual grid distribution infrastructure and/or construction of community biomethane micro-grids, can provide the routes to market for biomethane. In the interest of capital efficiency, construction of heat distribution networks should avoid competition with gas distribution networks.

Energy demand fluctuates over the course of the day as well as seasonally in response to climate and industrial activity. Accordingly, flexible technology configurations, with capacity to store and release dispatchable energy outputs will help to optimise revenue opportunities from supply of integrated energy demands. Economic viability of a community based model requires that excesses (deficits) in community energy generation must be distributed (sourced) from national pools. Community schemes will require the collaboration of licensed energy suppliers to facilitate distribution (sourcing) of energy outputs or have the option to obtain "supplier lite" licenses that allows them to participate in the national markets as required by the scale of trade.

One-off large industrial demands can potentially be serviced by bespoke solutions. In Ireland, however, inertia and legacy market structures, as well as customer requirement for energy security coupled with site locations that are most often located near the gas and power grids, limit the opportunities to supply large industrial demands solely via bespoke biomass applications. Development of a viable bioenergy penetration strategy for large industry users would be a significant enabler in respect of community scheme development. Such a strategy would have to overcome the current constraints posed by the ETS sector rules, which currently preclude direct state subsidisation of renewable energy measures for ETS obligated companies. Consideration could be given to mechanisms that support low cost bioenergy delivery to industrial customers, which can provide "anchor tenants" for development of community based schemes.

Different market supports will be required to support each different form of energy and technology to enable community projects to supply the community demand in a cost-efficient manner. To be consistent with EU policy aspirations outlining a progressive migration to market structures, the REBIOGEN review indicates that initial deployment of incentives designed to develop a reliable supply chain can eventually be coupled with obligations imposed on licensed energy suppliers to procure a specified minimum of renewable electricity or gas (as well as an obligations on waste collectors or Regional Waste Authorities to divert a proportion of waste for local energy recovery in preference to other recovery routes). This eventual migration to market conditions will pressure suppliers to reduce costs and improve efficiency, increase competition and may provide better value to customers.

5.1 Biogas and Biomethane

AD is a mature technology that is widely deployed across Europe to generate biogas from a wide range of digestible AMFM residues and energy crops. The European Biogas Association (EBA) 2016[50] reports that across Europe, more than 17,500 AD plants have been deployed. Accordingly, there is very little technology de-risking required for AD deployments.

Routes to Market for biogas outputs

Biogas is a flexible energy carrier that is comprised predominantly of CO_2 and methane. It can be used on-site or in nearby applications in dilute form, or can be upgraded to biomethane and transported to serve broader energy demands. Biomethane applications compete with a range of energy carriers such as natural gas, kerosene and distillates, as well as solid fuels such as coal, peat or biomass solid fuels. The competitive positioning, relative to these other energy carriers, is determined by environmental considerations as well as by ease of use and the relative Levelised Cost of Energy (LCOE). Biomethane costs more than alternative energy carriers, however it is convenient to use, as it requires no adaptation to existing gaseous energy boilers, engines or CHP units, and generates no ash or other residues that impose residue management requirements on end users.

Biogas can be valorised via different routes to market, each of which are governed by different regulatory frameworks. Different operational protocols and technology configurations impact the respective unit LCOE:

- *Dilute Biogas for CHP or Boiler Applications* – Dilute biogas (i.e. biogas comprising c. 35% CO_2 and 65% CH_4 with moisture and H_2S removed) can be used either on site for wholesale CHP, or alternatively delivered via dilute biogas pipelines to nearby energy users to fuel end-user CHP or boiler applications. In the wholesale CHP business model, minimally conditioned (raw) biogas is used to fuel a reciprocating engine that drives a generator. The RES-E output, which comprises c. 38% of the input energy value of the biogas using modern biogas CHP engines, is exported to the grid via a grid connection (e.g. a reciprocating engine driving a generator to convert a cubic metre of biogas with a gross energy of c. 6 kWh to c. 2.4 kWh of electricity). An additional 0.5 kWh_e can potentially be recovered if high efficiency combined cycle technologies can be adapted for use at moderate scale. Wholesale RES E outputs are sold under a wholesale power purchase agreement to a licensed electricity supplier who in turn markets the power to customers. A proportion of the energy input is recovered in the form of low-grade heat from the engine coolant and high-grade heat from the engine exhaust. Biogas is dispatchable, making biogas CHP suitable for contributions toward the baseload and peak load electricity supply. Purpose designed biogas CHP engines require only minimal biogas conditioning to operate efficiently, and the cost of moisture and H_2S removal is comparatively low.

  Historically, the economic viability of AD has been supported by premium REFIT tariffs paid for RES-E outputs (discussed above). This requires engagement of a licensed supplier to market the outputs, and compliance with the high efficiency criteria established in the CHP Directive which necessitates demonstration of minimum primary energy savings calculated in part, based on the utilisation of an

[50] EBA STATISTICS 2016: http://european-biogas.eu/2016/12/21/eba-launches-6th-edition-of-the-statistical-report-of-the-european-biogas-association/

economically justifiable heat demand. In many jurisdictions across Europe, location of AD plants has often been determined by availability of feedstock supply and grid connections rather than access to heat demands. This initially resulted in predominantly rural locations that made it difficult to valorise co-generated heat, even if technically heat was utilised in compliance with the CHP Directive. Inability to valorise the heat resulted in REFIT tariff requirements that were not competitive with lower cost supplies of wind or solar RES-E.

An alternative use of dilute biogas is the transport via low pressure dilute gas pipeline to an end user, to supply a localised CHP or biomass boiler application. As noted above, CHP engines have been widely adapted to use with dilute biogas and similarly, several boiler suppliers offer biogas boilers with injectors or burners adapted for use with dilute biogas. The benefit of using dilute biogas in localised applications is that it can generally efficiently use the energy value of the fuel, and it avoids the energy and capital costs associated with upgrade. Issues in respect of dilute biogas use may include fuel quality and the potential for microbial cultures propagating in pipeline infrastructure. Finalisation of regulations governing pipeline ownership and operation, as well as health and safety standards in respect of dilute biogas supply to 3rd parties, would improve prospects for supply of dilute biogas as a route to market.

- *Biomethane Grid Injection* – Recently across Europe, biogas is increasingly being upgraded to biomethane to be delivered as a renewable component in natural gas fuel blends. Injection projects in Europe comprise approximately 430 installations for 18 TWh of maximum installed capacity at the end of 2016 and a real production of about 13 TWh/year - these are broken down per country and capacity is quantified in the table in Appendix 6. This leverages the availability of a large, established gaseous energy demand to supply biomethane as a component of a biomethane-natural gas blend. It allows a more efficient use of energy, as the energy carrier is transported to the location of an established heat demand. Biomethane is very convenient form of renewable energy for end users, as utilisation requires no adaptation of boiler or CHP technology, and requires very little end user involvement in respect of fuel delivery, storage, residue management or conversion of end user technology. Six European gas grid operators recently committed to 100% greening of their gas grids by 2050. GNI has set a target to provide 20% renewable gas via the grid by 2030 to service customers who are demanding it to comply with corporate social responsibility goals.

  Grid injection requires compliance with regulatory specifications designed to protect health and safety, guarantee certain minimum quality thresholds for consumers as well as protect the structural integrity of the pipeline network. To inject biomethane into the Irish gas grid, it must currently meet the specifications incorporated into the Gas Grid Code 2017[51] (See end of Appendix 6). The current Irish specification on O_2 levels, which has been established to avoid build-up of elemental sulphur deposits and corrosion from oxidation of trace elements, are more stringent than standards established in other EU countries (e.g. O_2 standards in Germany and the Netherlands are set at 0.5 mol% while the UK standard has recently been increased to 1.0 mol%). During AD, Oxygen can sometimes make its way into the biogas output. Ingress into process media can occur intermittently, or it can be injected purposefully for process requirements. When present at trace levels, it can be

[51] GAS GRID CODE 2017: Gas Networks Ireland, Gas Grid Code of Operations, Version 5.01, 1 January 2017 https://www.gasnetworks.ie/corporate/gas-regulation/service-for-suppliers/code-of-operations/Code-of-Operations-Version-5.01-Consolidated.pdf

difficult and costly to remove. The requirement to consistently remove O_2 to meet the Irish standard may incur unnecessary cost, and consideration should be given to a relaxation of this standard.

A range of biogas upgrade technologies are available for removal of moisture, CO_2, H_2S as well as Nitrogen compounds, O_2, siloxanes and other trace elements. These conditioning technologies can either be deployed at the point of biogas production, resulting in a gas standard that can be approved for grid injection, which facilitates transport to the injection via compression to +200 bar and containerised transport. Alternatively, dilute biogas can be transported to the grid injection point via a low-pressure collection pipeline, which facilitates deployment of shared upgrade infrastructure.

Virtual grid technology is mature, but requires deployment of upgrade technologies at each gas producer's site, the cost of which can be rate limiting. Local upgrade and road transport of biomethane in pressurised cylinders incurs an energy penalty that can be as high as 15 – 20% of the energy value of the biogas, as compressors must be deployed in multi-stage configurations to achieve the + 200 bar compression. Virtual grid requires the ongoing cost of a driver and vehicle which require high utilisation to cover costs. It does, however, open direct marketing opportunities that can supplement routes to market other than injection to the national grid (e.g. supply to off-grid gas users such as hotels, factories or CNG vehicle refuelling station). Odourisation of the gas may be required depending on the end use.

Transporting dilute biogas for grid injection requires construction of biogas collection pipelines, which is capital intensive, and accordingly requires an assured minimum biogas output (which REBIOGEN estimates at c. 20 GWh_T) to be considered efficient from a capital deployment perspective. REBIOGEN reviewed construction costs for biogas collection networks with pipeline engineers noting that, if undertaken in hardstanding surface, (i.e. roadway, pavement, etc.) would be expected to range between c. €200 - €250/m. REBIOGEN noted this rate could be substantially reduced if wayleaves could be obtained to route network construction across farmland, however REBUIGEN contributors highlighted that securing rights to cross private lands is often a significant barrier to rural infrastructure construction. ReBioGen reviewed the potential prospects for use of rural walkways such as Greenway in Co. Limerick, which is routed along a disused railway line, noting it was technically viable but ownership of land rights must be clarified, and then rights of access negotiated.

Construction of biogas collection pipelines can facilitate deployment of shared upgrade infrastructure, which is significantly less costly on a per unit basis as the capacity of the upgrade technology increases above c. 1,000 m3 per hour. Deployment of shared production infrastructure, however, requires

At the grid injection point, specialist equipment is required to monitor gas quality, as well as inject odour and small amounts of propane or LPG to facilitate compliance with gas quality standards. Compression / decompression facilities manage injection of biomethane at the accepted gas grid operating pressure, while buffer storage may be required to balance supply with capacity demand. Protocols are required for managing receipt and treatment of out-of-spec gas, which may include flaring if no other options for re-processing are available.

Grid injection can occur either at the transmission pipeline level (which operates at pressures of c. 70 bar) or at the local distribution pipeline (which operates at lower pressures of below c. 7 bar). Injection at higher pressures into the transmission network may incur somewhat higher costs, however facilitate supply of biomethane to the national demand, and accordingly is unlikely to suffer any distribution grid-capacity or demand-driven constraints that may arise if biomethane is injected to the distribution network, where demand is dictated solely by local requirements.

The scale, location and method of grid injection has a significant bearing on the cost of biomethane supply. The contribution of capital equipment costs toward unit LCOE decreases considerably as injection facility capacity increases above c. 1,000 m^3 per hour.[52] Gas collection via short haul pipeline is significantly less costly than gas collection via road transport in compressed gas cylinders, as it avoids road haulage and driver costs, and facilitates easy return of any out-of-spec gas to the upgrade unit for reconditioning.

The method for recovering biomethane upgrading and injection costs is one of the principle determinants of biomethane LCOE. Proposals have been put forward to the CER to allow socialisation of a proportion of the upgrading, delivery and injection facility capital costs, by allowing them to be incorporated into the gas grid capital cost pool with recovery spread across all gas users as part of the gas grid transport fees. Socialising recovery of grid injection capital costs is essential to the successful establishment of a viable biomethane sector, and is consistent with the public service imperative underpinning societal benefits associated with developing a renewable gas supply.

Ireland's first industrial scale renewable gas injection facility is expected to be commissioned in the next 12 months and GNI have cited the potential for development of c. 40 renewable gas injection points (provided necessary supporting policies are enacted) that would enable Irish industry and energy consumers to utilise renewable gas supplies. Continuing development of grid injection capacity will contribute to creation of a viable biomethane supply chain, and operation of open access grid injection facilities would be a suitable role for a CSEC.

Figure 8. A BioCNG tube trailer. CNG at 250 bar occupies around 4 times the volume of the amount of diesel with equivalent energy content.

Enablers that will ease development of this route to market may include the (remote) prospect of introducing national standards for wayleave payments in respect of publicly important infrastructure, facilitating deployment on private land at a predictable cost. Also, the current legislation in respect of operation of natural gas pipelines only applies to pipelines carrying gas upgraded to natural gas quality, which does not cover operation of dilute gas pipelines. Clarification of regulations governing operation of dilute gas pipelines is required.

Continuing development work is required to reduce the cost of biogas upgrade and compression, which form a significant component of the LCOE for biomethane.

- *Delivery of Compressed BioCNG via Virtual Grid or Community Micro-grids* -
  To develop gaseous energy market outlets beyond those currently served by the gas network, biomethane can be compressed and blended with natural gas (BioCNG) and delivered in high

[52] BIOGAS UPGRADE 2013: Fredric Bauer, Christian Hulteberg, Tobias Persson, Daniel Tamm; Biogas Upgrading – Review Of Commercial Technologies, Swedish Gas Technology Centre, Report 2013:270

pressure cylinders via road haulage. Compression at c. 200 – 250 bar is utilised in other jurisdictions to supply off-grid markets. It incurs an energy penalty (e.g., 10% - 15% of the energy value of the gas) however opens markets for competition with higher cost liquid hydrocarbons or LPG. Virtual grid capacity opens prospects for development of community microgrids to provide low cost gaseous energy supplies to communities not currently served by the natural gas grid. Such a role, undertaken in conjunction with GNI as microgrid operator, would be consistent with a CSEC remit. However, to realise the benefits of virtual and micro grids a governance framework is required which is likely to be centred on health and safety aspects as well as provisions for ensuring security and quality of energy supply

- *Bio CNG Transport Fuels:* Compressed Natural Gas (CNG) transport applications across the EU are growing rapidly with 1,270,000 CNG vehicles in use across EU-28 in early 2016, as gaseous fuels generate less particulate, NOx and CO_2 emissions than petrol or diesel and CNG vehicles can be refuelled rapidly, avoiding waiting times otherwise associated with recharging electric vehicles, for example. A cubic metre of compressed biomethane contains roughly the same energy value as a litre_ of diesel and costs substantially less, underpinned in part by favourable taxation measures applicable to gaseous fuels. Gas Networks Ireland (GNI) aims to provide 5% of the energy used in commercial transport and 10% of the energy used in buses from CNG or biomethane by 2024. CNG vehicles require modification to the drive train and fuel supply to use gaseous fuels. While the modified vehicles cost more than conventional petrol or diesel models, the incremental cost is offset by the lower fuel costs (when favourable tax regime is in place), the economics of which is attractive in bus and HGV vehicles that consume large quantities of fuel. Most major vehicle manufacturers supply CNG vehicles in a range of models (including right hand drive buses and HGVs). Initially, to avoid concerns over access to re fuelling points until nationwide re fuelling infrastructure can be rolled out, CNG vehicle applications may be most appropriate for captive fleets. As biomethane can be used interchangeably with natural gas, it can be increasingly incorporated into the gaseous fuel blend to provide the renewable component of gaseous transport fuels. A previous review by TCBB indicated that the prices that could be derived from valorisation of biomethane as a transport fuels (which are determined in part by the relative cost of diesel) may result in support levels that are less than those required to support biomethane valorised in other applications. Accordingly, to promote wider deployment of CNG transport applications, deployment of CNG refuelling infrastructure would be an appropriate activity for a CSEC, especially if it is located on a radial route of an urban centre. The EU Connecting Europe Facility will co-fund a project[53] to deploy 14 CNG refuelling stations along Ireland's core transport network in the coming years examine the impact of the introduction of CNG on the operation of the

Figure 9. Causeway study refuelling sites. *Source GNI.*

53 https://www.gasnetworks.ie/business/natural-gas-in-transport/the-causeway-project/

gas network. A biomethane injection point connected to a large AD plant will be built to as part of this project.

Relative Costs of Accessing the Gas Grid

REBIOGEN prepared a comparative review of the costs associated with transportation, upgrade and injection required to access gas grid distribution under various scenarios. The review noted the estimated costs for a shared grid injection-only facility were projected at €11.70 per $MWh_{T,}$ while the costs for construction and operation of a 15km biogas collection pipeline together with shared upgrade facilities, versus the per MWh_T cost of remote deployment of upgrade technology and transport via virtual grid were projected at €55.17 versus €57.70 respectively. The analysis notes that, given the capital costs associated with collection pipelines, economic cost-effectiveness requires a minimum scale and concentration of biogas production of c. 20 – 30 GWh_T to support a pipeline ranging from 10-15km in length. For more dispersed biogas production, on site upgrade and compression for transport via compressed road haulage is most cost-effective option. The assumptions and detail calculations supporting these costs are detailed in Appendix 6.

REBIOGEN's review of the optimal cost distribution in respect of biogas production (SEE Appendix 7) arises when dilute biogas is piped a very short distance for use in adjacent industrial applications (either end-user CHP or boiler applications) as this minimises the energetic and financial costs of conditioning and compression.

Environmental benefits of biomethane

The EU JRC[54] default value for GHG emissions from combustion of natural gas are calculated at 71.7g CO_{2-eq} per MJ of energy output. The corresponding GHG emissions from various biogas and biomethane production routes range from -86g CO_{2-eq} per MJ of energy output for biogas from manure where digestates are stored in a closed environment, to 63g CO_{2-eq} per MJ of energy output arising from biogas produced from maize where the digestates are stored in an open environment. The negative factor arising from manure derived biomethane relates to the mitigation of emissions that otherwise arise when manure is disposed of via land spread. In each biomethane production route reviewed, the relative GHG emissions represented a significant savings over emissions from natural gas. Accordingly, it is accepted that increasing the use of biomethane in grid connected domestic and industrial boilers will contribute toward RES-H and GHG emissions target.

In a comparative analysis[55] of well-to-tank and tank-to-wheel GHG emissions passenger vehicles using compressed biomethane (CBM), (produced from biogenic feedstocks) show an 88% reduction compared to petrol. Where diesel was the comparator fuel – for CBM fuelled articulated trucks the reduction figure was 39%, large rigid trucks 78% and for buses 82%. This is on an annualised, well-to-wheels basis and represents the study's low-emissions scenario. The high-emissions scenario corresponded to 78%(cars), 35%, 65% and 68% respectively. Interestingly the data from this report shows that for all types of road vehicles except for petrol cars, there are no net GHG benefits associated with shifting from conventional

[54] JRC Science and Technology Reports -Solid and gaseous bioenergy pathways: Input values and GHG emissions, Jacopo Giuntoli, Alessandro Agostini, Robert Edwards, Luisa Marelli, 2015 Version 1a

[55] Ricardo Energy & Environment, UK. The role of natural gas and biomethane in the transport sector, Report for Transport and Environment (T&E). Ref. ED 61479 16/02/2016

liquid fossil fuels to fossil-based natural gas. According to inventory data[56] compiled by EU agencies reductions in emissions of air pollutants such as NOx, SOx and particulate matter result from conversion to methane based transport fuels. In addition to decarbonisation of transport biomethane can also play a role in curbing urban air pollution where electric transport is not viable such as in large vehicles which need to enter urban areas. Additional research[57] recently carried out by ICCT indicates that methane leakage can seriously undermine any GHG benefits of using methane powered vehicles indicating that only the highest performing new technology, in which methane slip is maintained below the best performing solutions, should be considered for modifying diesel engines to run on CNG.

Biomethane Production in Ireland

To determine the impact that replication of the EU success would have in Ireland, SEAI commissioned an assessment[58] of the economic costs and benefits associated with biogas. It included a high-level review of 4 different development scenarios, beginning with a waste-to-energy base case (which was anticipated to be the case that delivered the lowest biomethane LCOE) and increasing integrating levels of more costly purpose grown feedstocks and processing technologies. The report highlighted that Ireland's AMFM sectors generate significant supplies of digestible residues capable of generating up to 5 PJ (1.38TWh) of biomethane by 2030. This equates to 2.6% of Ireland's 2015 gas energy demand. It also reported that supplementing biogas production using grass silage feedstock could generate an additional 3.5 PJ (0.97m MWh) of biomethane energy, which combined would supply c. 5.5% of Ireland's 2015 gas demand.

The same study reported that integration of biomethane into the energy mix under the scenarios noted above would mitigate between 477 and 584 kt CO_{2-eq} of GHG emissions each year (0.8-1.0% of Ireland's total) compared to use of natural gas. It noted that direct and indirect employment would be created, estimated to range between 432 and 1,191 FTEs, and that in both scenarios a net societal benefit would be generated, calculated using an accepted method of analysing the socioeconomic impact of public policy initiatives. It also highlighted that integrating greater levels of purpose grown feedstocks may result in a less compelling societal benefit.

Realisation of the potential benefits associated with a vibrant biogas sector requires a mechanism to tap the inherent market demand by establishing a viable supply chain. Biomethane costs more than natural gas. Results from research by UCC reports[59] that the estimated LCOE from biomethane production across different business models as follows:

- Large scale OFMSW model earning €100/t gate fees c. € 14.00 per MWh
- Large scale ABP slaughterhouse waste model c. € 73.00 per MWh
- Farm scale grass model c. € 97.00 per MWh
- Developer scale grass model c. €110.00 per MWh
- Farm scale grass & slurry co digestion model c. €123.00 per MWh
- Farm scale slurry digestion model c. €183.00 per MWh

[56] EMEP/EEA. (2014). Air pollutant emissions inventory guidebook, 2014 update. European Monitoring and Evaluation Programme / European Environment Agency.

[57] ICCT. (2015). Assessment of Heavy-Duty Natural Gas Vehicle Emissions: Implications and Policy Recommendations. International Council on Clean Transportation.

[58] BIOGAS ASSESSMENT: Assessment of Costs and Benefits of Biogas and Biomethane, prepared for SEAI by Ricardo Energy and Environment consultants, published June 2017

[59] MURPHY 2010: Dr Jerry Murphy, Cost of Biomethane - Grass as a source of renewable gaseous fuel, EPA funded conference,15thApril 2010, Brookfield, UCC

The results highlight that the feedstock source, together with the scale of the plant are significant determinants of the LCOE for biomethane.

Separately, REBIOGEN prepared a microeconomic analysis of biomethane costs, the results of which are consistent with Murphy's findings, and that also highlighted in an Irish context, the form of valorisation and the proximity of the AD plant to market outlets is also a significant determinant of LCOE. REBIOGEN's review indicates that for a moderate sized AD plant co-digesting a combination of 13,600 MT of grass energy crops, together with 18,000 MT of digestible food waste, green waste and ABP, AD plants located close to grid injection points can deliver biomethane at an estimated cost of €111.30 (SEE CSEC Scenario in APPENDIX 8) whereas the same plant configuration located remotely, and requiring construction of a collection pipeline, will deliver biomethane for a LCOE of €133.30 (SEE Scenario in APPENDIX 7). Conversely, a smaller scale plant digesting a higher proportion of wastes and residues, marketing its output as dilute biogas, can deliver gaseous energy to a user site at a comparative LCOE of €103.73 (See Scenario in Appendix 7).

In terms of servicing the large existing gas demand, the supply of biomethane must be referenced against the wholesale cost for supply of natural gas, which VAYU 2016[60] reports averaged c. €17.00 per MWh for winter 2016 (at the point of supply to the grid). In off-grid markets, the supply of biomethane would be referenced against the retail cost of heating oil and distillates, which as noted in the SEAI energy cost report, ranged for supply of residential customers, from € 51.45 per MWh for supplies of kerosene to € 87.66 per MWh for bulk delivery of LPG, while commercial fuel costs ranged from € 56.39 per MWh for heavy fuel oil, to € 69.25 per MWh for gasoil and € 61.41 per MWh for bulk deliveries of LPG.[61]

To develop the supply chain that can supply the currently unmet demand for biomethane, interim market supports are required that levelise the cost of biomethane supply with the cost of the competing energy carriers. To underpin economic viability, a Biomethane Feed in Tariff (BFIT), payable directly to the producer on biomethane production meeting specified sustainability criteria, is likely the most direct route to development of a viable supply chain.

Over time, as the biogas supply chain is established, it will be possible to introduce a biogas blending obligation that requires all licensed gas suppliers to incorporate an increasing proportion of biomethane into the gas blend, migrating away from BFIT supports to market oriented structures. This transition will provide an incentive for biomethane producers to become progressively more efficient, or risk losing market outlets.

Given the different routes to market for biogas, and the possibility that different operators, including community schemes, may operate virtual grid or pipeline transport, upgrade and injection facilities separately from biogas production facilities, a stratified support structure that separately remunerated each component of the value chain may minimise support costs to the state as well as provide flexibility in respect of funding and developing infrastructure.

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[60] VAYU 2016: Wholesale energy prices and implications for Irish business, presentation to Hotels Federation Joanne Daly, Head of Training & Advisory Services Vayu Energy, 2016

61 SEAI Commercial / Industrial Fuels Comparison of Energy Costs and Domestic Fuels Comparison of Energy Costs, 01 Apr, 2017

<u>*Certificates of Origin*</u> – Given the different potential uses of biogas and the different potential incentives and accounting requirements, emergence of a vibrant market for biogas will require development of a certification programme that can validate the sustainability of biogas production and underpin accounting for the transfer of biogas energy value from the point of production to the point of gas utilisation. Development of a certificate of origin programme will not only underpin the mechanism by which different types of incentives can be redeemed or accounted for, it may contribute toward reducing the cost of biomethane delivery. The proposed RED II requires certificates of origin to facilitate cross border trade in RES outputs.[2]

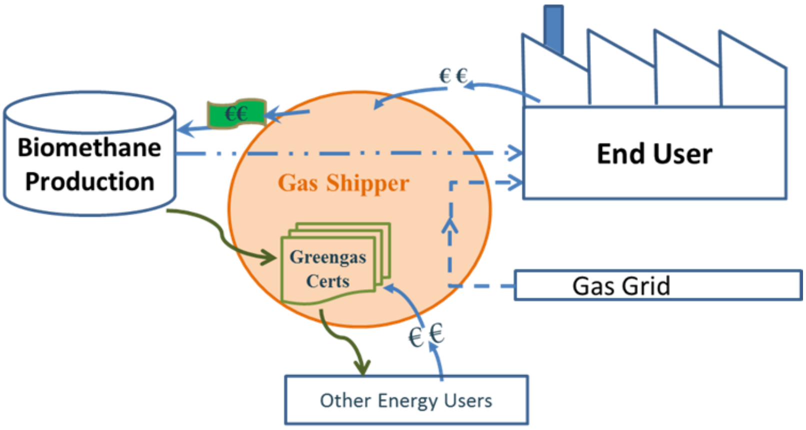

Figure 10. Certified greengas transaction, Gas Shipper & Supplier role shown in the circle.

The mechanism to qualify as a certified producer will depend on the type of verified emissions reduction product and there are numerous on the market, some for voluntary schemes and others for compliance with regulatory emissions reduction programmes (e.g. EU ETS obligations, for example). The cost to independently assess the production of gas to measure and verify the carbon saving, however, may be onerous for projects of modest scale.

Sustainability schemes are emerging to quantify and certify renewable energy sustainability, which may underpin emergence of a tradable market for renewable energy carriers. The Renewable Energy Directive (RED)[62] sets out sustainability criteria that have resulted in an internal EU market generating cross border trade in qualifying biofuels.

Other frameworks are emerging that certify the sustainable origin of other forms of renewable energy carriers. Voluntary sustainability schemes for biogas and/or RES-E have been established in the UK, Sweden, Austria, Germany, the Netherlands and other EU countries. A list of approved voluntary schemes which independently verify a producer's compliance with RED criteria is published[63] by the EU Commission. In Ireland, the International Energy Research Centre (IERC) is developing a greengas certification framework to certify sustainability and account for production, transfers and usage of Irish biogas.

Discussions with developers of several of the respective national schemes indicated that, while schemes were initially established in the context of supporting development of the respective domestic markets, it was fully intended that such schemes would integrate into development of an internal EU market. It was anticipated that the market would initially develop as a virtual market, where the production and consumption of energy carriers would take place within the domestic jurisdiction to facilitate compliance with the physical requirements of differing grid and end-user technologies. The trading of the underlying

[62] RED: <u>Renewable Energy Directive (2009/28/EC)</u>, see https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

[63] https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes

certificates of sustainable origin would be available on an EU wide basis to facilitate national reporting and redemption of subventions or compliance with the respective RES obligations by ETS companies. In this context, any national sustainability framework would need to be compliant with any EU wide sustainability framework that evolved to establish the minimum criteria that defined GHG reductions.

The diagram above shows the role of the gas shipper and gas distributor as regards transacting with counterparties. The dashed line is transfer of gas by virtual grid and by gas grid, as undertaken by the gas distributor. To ensure safety and security of supply to the end user of biomethane it would be necessary to have the option to transport some natural gas from the grid in the event of problems with the AD or the upgrading unit. The solid line and shaded are represent the sale and transfer transactions, to be undertaken by a licensed supplier/shipper. The shipper receives the Greengas Certificates from the producer and can sell them to the end user if there is a need or may sell them to another energy user who requires them to offset emissions for various reasons. The gas balancing system is the accounting system that balances physical deliveries to customers with an equivalent mass of gas (less shrinkage gas) introduced at the injection points along with all associated accounting transactions.

Summary of Findings – Biogas and Biomethane

REBIOGEN discussions with stakeholders supplied anecdotal evidence of a substantial Irish demand for biomethane, given the ease with which biomethane can be integrated into existing energy applications and the substantiated improvement in GHG emissions and corresponding environmental impact arising therefrom. Public presentations from large gas consumers indicates an inherent demand for biomethane provided it can be supplied at a cost that is competitive with natural gas, and further provided that the GHG savings can be counted toward ETS or corporate environmental obligations. GNI published[64] a target of 20% renewable gas to be supplied by the gas grid by 2030, referencing its belief in the unsatisfied demand for renewable gas.

Community schemes directed toward production of a renewable gas energy carrier can leverage availability of mature AD and upgrade technologies to generate biogas from co-digestion of wastes and residues together with herbaceous energy crops, supplying different routes to market. The most cost-effective route to market is the delivery of dilute biogas for community industrial or commercial demands. The scale of individual industrial demand varies, however, and the economic viability of community schemes can be underpinned by combining supply of local demands with routes to the national pool markets, which can be exploited by valorisation via upgrade to biomethane to be delivered via the existing gas grid distribution, or alternatively via a developing virtual grid.

Enablers that will create market outlets for biomethane include:

- Introduction of support measures for funding capital investment in biogas production infrastructure, as well as a Biogas Feed in Tariff, structured in a way that remunerates biogas producers at a level and over a term necessary to stimulate development of the supply chain;

- A separate class of capital and operating support for development and operation of biogas transport, upgrade and grid injection facilities;

[64] Gas Networks Ireland. Network development plan 2015. Cork; 2015.

- Definition of obligatory measures to incorporate biomethane or biogas in the gaseous energy mix to stimulate demand for biogas / biomethane and underpin transition of the biomethane supply chain toward market structures at the expiry of the establishment period;

- Finalisation of support measures for capital investment in biogas upgrade and transport technology, as well as definition of a support scheme for the operational costs of upgrading and injecting biogas into the national grid, established at a level that ensures biomethane can be delivered to customers at costs that are competitive with the cost of delivery for natural gas;

- Finalisation of the greengas certification protocol to underpin sustainability certification and quantification / tracking of greengas production in a way that facilitates redemption of support measures at different levels for different forms of biogas/biomethane valorisation;

- Finalisation of framework to govern direct supply of dilute (raw) biogas including clarification of provisions governing ownership and operation of dilute biogas micro-grids and pipelines for linking several ADs to shared upgrade plant, as well as health and safety protocols and standards that regulate supply of dilute biogas for industrial / commercial usage;

- Development of a national wayleave protocol to facilitate procurement of rights of way for construction of infrastructure that is of national importance;

- Support mechanisms to fund the capital and operating costs for deployment of gaseous transport fuel dispensing infrastructure[65] to support gaseous transport applications;

- Finalisation of provisions that apply the Biofuel Blending Obligation provisions to incorporation of biomethane into supply of gaseous transport fuels and the extension of the tax credit for gaseous transport fuels to provide certainty for stakeholders considering the investment in CNG vehicles.

5.2 Renewable Heat and Power

Bioenergy for Thermal Applications

Community bioenergy schemes can be deployed to supply a viable and cost-effective source of renewable heat that can contribute toward the State's NREAP and 2030 Framework obligations. They can deploy new-to-market waste/residue to energy technologies to generate lower cost energy by exploiting significant supplies of wastes and residues, or alternatively can deploy, mature and market tested biomass technologies to process supplies of woody biomass or purpose grown energy crops, the cost of which generally results in a higher LCOE. Bioenergy technologies can be configured to fuel boilers to supply renewable heat in the form of high grade process heat (e.g. as steam) for industrial processes or alternatively low-grade heat for space heating. Alternatively, they can be configured to fuel CHP applications, supplying both thermal and electrical demands.

SEAI ENERGY 2015[66] identifies that the thermal energy demand in Ireland is approximately 4,562ktoe (53,056 GWh) or 33% of total Irish primary energy requirement. In respect of thermal demand, bioenergy

65 www.gasnetworks.ie/corporate/news/active-news-articles/gas-networks-ireland-laun-1/

will compete with gaseous and liquid hydrocarbons, as well as solid fuels. In the domestic and commercial space heating, bioenergy may compete with non-combustion based technologies such as solar, geothermal or heat pump technologies.

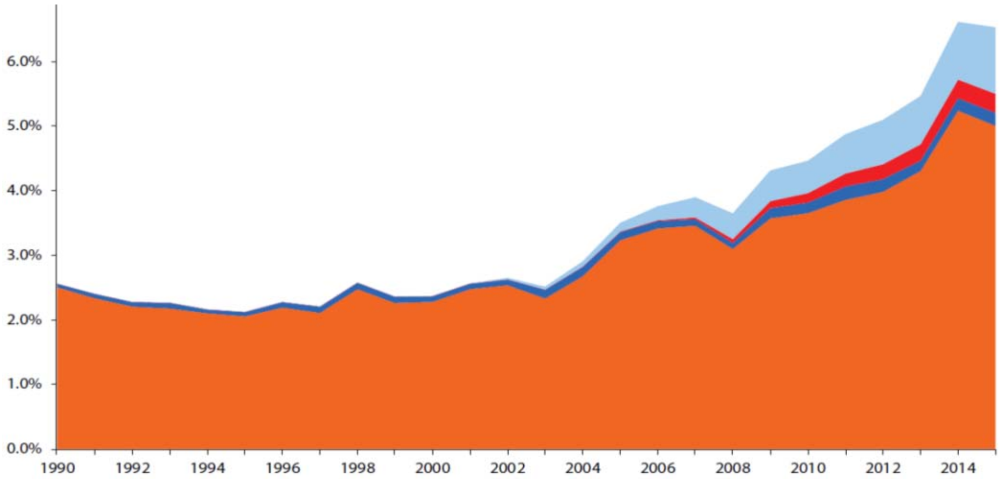

Figure 11. Renewable Energy Contribution to Thermal Energy (RES-H). SEAI 2016

The competitive positioning of each of the competing thermal technologies is influenced by the initial capital cost of the technology as well as the ongoing operational costs of fuel supply and technology maintenance. It is influence by market inertia factors including any requirement to change end user technologies and any ongoing management requirements in respect of the energy supply. It is also influenced by the relative atmospheric emissions factor, which determine the contribution to be made toward the State's environmental objectives and the likely long-term cost of compliance with environmental regulations and corporate social responsibility.

Cost of Energy - In Ireland, combustion of fossil fuels has historically met the largest proportion of the thermal demand, and the vast majority of energy plant is configured as individual boilers (or CHP units) to serve individual thermal demands. Natural gas supplies the largest proportion of the thermal energy demand. It is a very price-competitive fuel, which SEAI Energy Price 2017[67] indicates costs €24.00 per MWh for commercial customers in band I4 and € 57.27 per MWh for residential customers in band D2. Given the large global supply of natural gas and the active regulation of distribution costs, it is expected that natural gas costs will remain stable for the foreseeable future.

Heating oil or distillates supply the preponderance of the heating energy demand in areas where natural gas is not available. SEAI ENERGY PRICE 2017 reports that the price of liquid fuels to residential customers range from € 51.45 per MWh for supplies of kerosene to € 87.66 per MWh for bulk delivery of LPG. Commercial fuel costs range from € 56.39 per MWh for heavy fuel oil, to € 69.25 per MWh for gasoil and € 61.41 per MWh for bulk deliveries of LPG (Note: all prices are quoted ex VAT, including excise or carbon tax at point of delivery to the customer). Low sulphur liquid fuels have historically cost more than natural gas, the price of which is volatile and highly correlated to the price of crude oil. The recent oversupply of

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[66] SEAI 2015: Energy in Ireland 1990 – 2015 (2016 Report).

[67] SEAI ENERGY PRICE 2017: SEAI Electricity & Gas Prices In Ireland – 1st Semester (January – June) 2016, together with SEAI Domestic Fuels Comparison of Energy Costs 01 April 2017 and SEAI Commercial / Industrial Fuels Comparison of Energy Costs 01, April 2017

oil driven by development of fracking technology in North America, has driven down the price of oil and resulted in a corresponding low price for distillates. While the oversupply of oil may last for some time, market analysts ultimately expect over time that the supply and demand of oil will stabilise, and the price of distillates will correct back to historical norms.

Both natural gas and liquid fossil fuels are convenient for the customer. They are relatively clean burning fuels that generate no ash on combustion, and the fuel distribution channels are widely available, minimising requirements for customer fuel storage. Natural gas and liquid fuel end-user technologies are mature, efficient and widely deployed in the Irish market. They are supported by an established network of service technicians. The capital costs of installing gaseous or liquid fuel boiler plant is low. REBOGEN's anecdotal discussions with technology suppliers indicated that domestic space heating boilers can be installed at costs of < c. €3,500 while moderate scale commercial boilers (condensing hot water boiler rated at c. 500 Kw) could be installed for < €35,000, depending on the complexity of integration with existing plant. Gas and oil boilers are also energy efficient. Condensing boilers (which are required when installing a new or replacement gas boiler pursuant to Section L3, Building Regulations Part L amendment – S.I. No. 847 of 2007) generate efficiencies reported to exceed 90%.

Relative to natural gas or liquid fuels, solid fuels such as coal or peat are used to a lesser extent to supply Irish heating requirements. While the cost of coal and peat fuels is competitive, and solid fuel stoves and boilers are mature technologies, coal and peat have been identified as sources of $PM_{x,}$ NO_x and SO_x emissions which, given the requirements to progressively reduce atmospheric pollutants as reflected in the CAFE Directive and National Clean Air Strategy (soon to include transposition of the NEC Directive),[68] has resulted in a progressive extension of the ban on "smoky coal" in urban markets around the country.[69] Additionally, coal and peat applications require storage space for fuel and generate bottom ash when combusted, imposing a residue management requirement on the customer. The heating efficiency from combustion of solid fuels varies quite substantially based on the design of the combustion unit, with even the most efficient of solid fuel boilers being slightly less efficient than gas or liquid hydrocarbon boilers due to the moisture and ash content in the fuel, and small levels of non-combusted carbon in the ash. Accordingly, it is unlikely that coal will supply an increasing proportion of Ireland's heat demand over time; meanwhile peat products are to be gradually phased out by Bord na Móna and cutting by private operators banned.

Non-combustion technologies such as solar and geothermal technologies can also be deployed to supply low-grade space heating requirements. Solar or geothermal technologies use the energy from the sun or the ground to heat water, which is then stored in a buffer storage to be transferred for the relevant space heating or hot water application. Non-combustion technologies incur no direct fuel cost. The LCOE for heat supplied by these heating technologies are primarily a function of the capital cost of the related equipment, which can be substantial on a per unit basis given the low-grade nature of the heat supplied, as well as the cost of the electricity used to circulate water, which is generally quite inexpensive.

[68] Cleaner Air for Europe (CAFE) Directive (2008/50/EC);
Directive (EU) 2016/2284 - National Emission Ceilings (NEC) Directive governing nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2) and ammonia (NH_3). "*For all years from 2010 to 2015, Ireland persistently exceeded its emission ceilings for NOx and NMVOCs*."

[69] Dept. of Environment, Community and Local Government - Guidelines for regulatory compliance by fuel merchants and other retailers with premises located inside 'Smoky' Coal Ban restricted areas (no date).

Heat pumps extract heat from the atmosphere, or alternatively from ground sourced heat, using electrical power to operate compressors that extract heat from the atmosphere by repeatedly compressing and decompressing refrigerants in a closed cycle. The level of heat extraction is determined in part by the temperature of the environment from which the heat is being extracted. The low-grade heating or cooling is transferred to the end-use application by pumping liquid (usually water) through heat exchangers, which for space heating or cooling requirements includes cycling hot (or cold) water through radiators or underfloor heating.

In respect of heat pumps, the cost of energy is determined by the seasonally adjusted power-to-heat ratio (Coefficient of Power or COP) which measures the power requirement needed to generate a unit of thermal energy. In Ireland, a typical seasonally adjusted COP would be circa 3, which means 3 units of thermal energy are generated from consumption of 1 unit of electrical energy. In domestic applications, if daytime power is used to drive heat pumps, this would result in a cost per kWh_T of c. € .0467 (i.e. average blended cost of evening & daytime power estimated at c. €0.14 per kWh_e / 3 = €0.467 / kWh_T). Incremental costs would be required for immersion heaters to heat hot water. Commercial power costs can be lower, and technology suppliers advocate incorporation of thermal storage devices that can be deployed to facilitate increased use of power sourced at night rates to reduce the cost of heat pump sourced heating.

The capital cost of heat pumps is significant. REBIOGEN contributors noted that installation of domestic scale heat pumps could range up to > €11,000 per installation, while cost of moderate scale commercial (or building scale) heat pumps could range to costs > €55,000.

The competitive positioning of heat technologies is also influenced by the environmental emissions. The GHG emissions factors for various fuels to CO_2 equivalent GHG emissions, as published by SEAI[70] are outlined below. Continuing reliance on combustion of fossil fuels will result in non-compliance with Ireland's GHG emissions reduction obligations. Combustion of biomass fuels, on the other hand, is assumed to generate virtually no GHG emissions, as combustion merely recycles the carbon originally extracted from the atmosphere during biomass growth. In addition to GHG emissions emanating from the combustion, environmental impact arises from the specific supply chain for each energy carrier. The level of emissions is typically measured using LCA techniques, and the results are specific to the individual characteristics of the supply chain. Increased integration of renewable energy and recycled nutrients into the biomass supply chain can mitigate any concerns about sustainability of biomass use for energy supply.

From an environmental perspective, the GHG emissions emanating from solar or heat pump technologies primarily relate to the low levels of electricity consumed as part of the device operation, and are determined by the energy mix used to supply electricity to the grid.

[70] http://www.seai.ie/Your_Business/Public_Sector/FAQ/Energy_Reporting_Overview/What_are_the_carbon_emission_factors_used.html

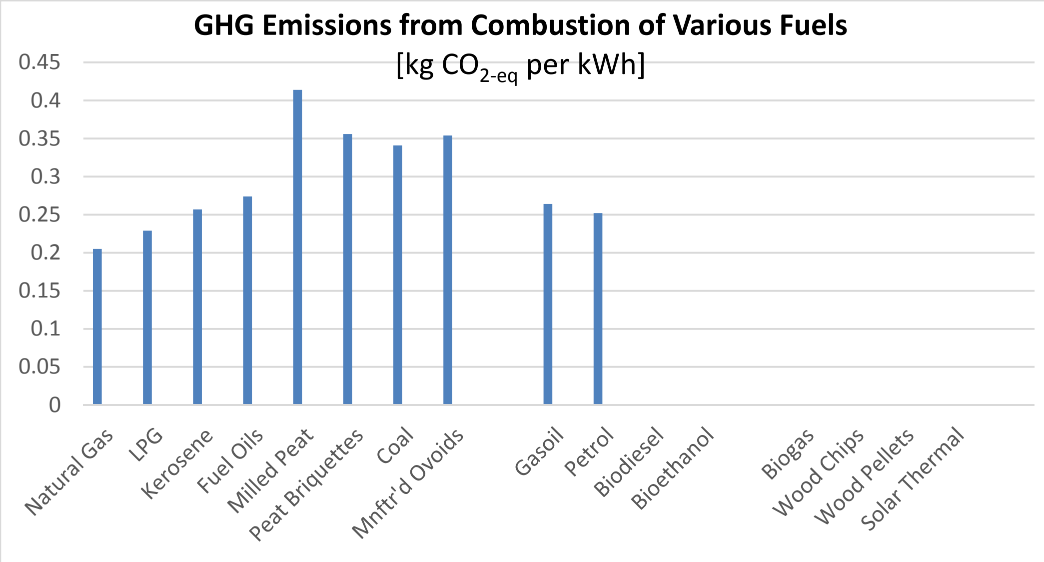

Figure 12. Carbon Emissions Intensity from Combustion of Various Fuels. SEAI 2015

Routes to Heat and Power Markets for Bioenergy

ESCO Services to Position Deployment of Individual Bioenergy Technologies - _Bioenergy technologies can be configured to supply individual heat and CHP demands. While the cost of (delivered) biomass solid fuels can be competitive with the cost of fossil based fuels, numerous publications including IrBEA's review of an Irish RHI incentive[71] highlight the fact that the cost of individual bioenergy applications exceeds that of alternative fossil fuelled alternatives. Transitioning to a biomass boiler imposes a capital cost on the end user, which can impose a financial burden especially in cash strapped SMEs. The cost differential is driven by the capital costs of bioenergy technology, which can be as high as 5 X that for natural gas or oil boilers, which is exacerbated by having to spread the capital costs across the low load factors typically arising in individual applications.

The attractiveness of individual bioenergy deployments is further influenced by the inconvenience of having to manage bulky fuel procurement and storage, as well as disposal of ash residues. These factors of inconvenience can often inhibit deployment of bioenergy technologies by all but the most dedicated energy consumers. Given that energy management does not constitute the core activity of most commercial enterprises, these factors create a certain inertia that may have to be addressed to optimise the bioenergy development potential.

These inertia factors can contribute to market apathy in respect of deployment of individual bioenergy applications. They may also require a tiered tariff support structure at levels of € 76.00 per MWh_T for energy outputs <= 1,000 MWh_T incremented by an additional € 20.00 per MWh_T for outputs in excess of 1,000 MWh_T per annum.[72]

One widely promulgated method designed to overcome market inertia, is the provision of energy services under a managed Energy Service Contracts (ESCO).[73] The European Commission's Science and Knowledge Hub identifies that ESCO arrangements are increasingly being deployed to promote renewable energy

[71] *IrBEA: Delivering a Renewable Heat Incentive for the Republic of Ireland, August 2015*
[72] *IrBEA: Delivering a Renewable Heat Incentive for the Republic of Ireland, August 2015*
[73] ESCO: https://ec.europa.eu/jrc/en/energy-efficiency/eed-support/energy-service-companies

applications across Europe. Under these arrangements, specialist renewable energy companies finance the deployment of renewable energy technologies and manage the feedstock procurement and residue removal for a customer in return for a guaranteed price per unit of energy. While such arrangements transfer the financial and technical risk of transition away from the energy user, and align renewable energy consumption with more traditional modes of energy procurement, reported that in the UK such arrangements were most prevalent in public service procurements, and that a variety of factors including transaction costs and customer perceptions, have constrained the wider use of this device in private commercial transactions. [74]

Developing an ESCO service to meet the energy requirements of moderate scale commercial applications may offer a prospective route to market for community bioenergy schemes. REBIOGEN undertook an analysis of the issues associated with provision of bioenergy services via ESCO, which in respect of a biomass boiler ESCO, purposely assuming a very high load factor of c 50%. The review indicates a reference price requirement of c. €77.50 per MWh_T (which assuming a market price payment of c. €40.00 per MWh_T would require a premium support of €37.50 per MWh_T to levelise the bioenergy cost). REBIOGEN's review of alternative technologies, such as FBC technology that can utilise a blended agri-food residue feedstock, may require a slightly lower level of support, however this is entirely dependent on the load factor and will also require finalisation of a supportive regulatory framework (in respect of emissions monitoring and waste management obligations) to support deployment of such technologies outside of farm-based applications. See Appendix 5.

District Heating Schemes to Aggregate Energy Demands - In Ireland, heating applications are predominantly satisfied by heat generation at the end-user's site, close to the point where the heat is utilised. Outside of dense population centres served by the gas grid, transitioning to low carbon energy sources can pose difficulties, as it requires behavioural changes and investment decisions across a wider spectrum of energy users. An alternative system of heat supply is district heating (DH), where heat is generated at a central point and distributed via insulated piping either in the form of steam or hot water piping. Users deploy a local heat exchange unit that regulates and meters the amount of heat provided to the site. District heating schemes have been developed in numerous locations across Europe. Currently 13% of heat is supplied by DH, mainly in Denmark, Norway, Sweden, Finland and Poland, although most heat for the residential/commercial sector, over 40%, is currently produced by natural gas in on-site boilers.[75]

Figure 12. Pipelines in a district heating scheme.

The proposed draft EU RED II notes that over 25% of the EU population live in areas suitable for DH applications. District heating and cooling systems are an enabler for higher shares of RES in the EU energy system, as they aggregate energy demand across a community of users and provide a market outlet for heat from geothermal or CHP applications, as well as from industrial waste heat sources.

[74] Nolden, Colin; Sorrell, Steve. The UK market for energy service contracts in 2014–2015, Energy Efficiency, December 2016, Volume 9, Issue 6, pp 1405–1420

[75] Connolly et al., 2013

Deployment of district heating aggregates demand which facilitates efficiencies in respect of energy recovery from biomass. It facilitates deployment of waste/residue to energy technologies which can reduce the feedstock cost. It creates scale, which facilitates deployment of process technologies to treat different types of feedstocks, converting them into energy carriers in such a way that the colocation of processes creates synergise which increase efficiency above that which individual processing and conversion plants could achieve.

District Heating Schemes in Europe

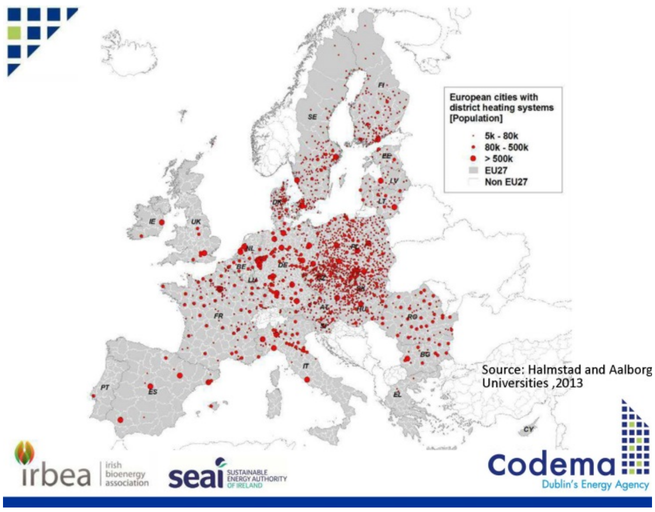

Figure 13. Source: Codema Presentation at IrBEA Conference on District Heating in Ireland Oct. 2016

Presenters at the IrBEA conference on district heating in Ireland[76] reported case studies from several locations across Europe where heat supplied via district heating was priced at a cost equivalent to that sourced from natural gas. In the context of limited availability of development capital, it may be prudent to direct district heating deployments toward markets not otherwise served by natural gas networks, which can incorporate other forms of renewable energy (e.g. biomethane).

IrBEA's District Heat Guide 2016[77] identifies that DH schemes can be cost effective in certain circumstances, and that sustainability benefits could be optimised by targeted construction of DH schemes. The *District Heat Guide* indicated that district heating schemes designed to support "anchor tenants" with large predictable heat demands, such as hotels and hospitals, can improve economic viability. This conclusion is reinforced by REBIOGEN's review in Appendix 3. Additionally, design of district heating systems to 4G standards, allowing import of intermittent waste heat supplies from various sources as well as supply of heat at much lower supply temperatures, may optimise energy efficiency, as well as ultimately reducing heating costs for end users.

REBIOGEN's review of district heat network construction notes that while networks can be designed for 4G standards, given the energy efficiency status of the housing stock, operation of district heat networks in Ireland will likely require input temperatures higher than 4G standards (e.g. c. 70-90 C^0 for example) until energy efficiency reviews and remediation measures can sufficiently improve insulation and energy loss standard to facilitate migration to 4G standards. Deployment of community district heat schemes can provide the foundation for a structured programme to undertake such reviews as funding permits.

[76] Conference presentations from Developing District Heating in Ireland, hosted by IrBEA, Marker Hotel Dublin, October 4 2016
[77] Donna Gartland, Tom Bruton: A Guide to District Heating in Ireland, Produced by Codema and BioXL on behalf of the Irish Bioenergy Association, (SEAI RDD Funded) October 2016

The economic case for construction of district heating networks can be complex. Construction of district heating networks is capital intensive. Nussbaumer (2014)[78] reported that factors such as network routing, construction surfaces, building density, steam vs. hot water energy carrier, piping size and insulation, ambient temperature, as well as timing and scale of heat load all determine the network design characteristics and the corresponding capital cost for heat distribution networks. A literature review indicates that network construction can cost up to €9,000 per connected dwelling, including estimated costs for end-user heat exchange and metering units that range between c. €2,500 to €3,000 per. This is slightly more economical than the cost of a biomass boiler with fuel storage for an individual house, and is less costly than deployment of domestic heat pumps to provide space heating. It is significantly higher than the cost of conventional gas or oil boilers, however, and will require state investment support to migrate customers.

A community's heat demand profile will have a large impact on economic viability of a DH project. Both diurnal and seasonal variations need to be well characterised. Over dimensioning of individual boilers to meet peak loads and frequent on/off cycling are to be avoided. Daily peaks and troughs can be met by hot water buffer tanks and winter peaks by staged boilers. Integration of heat technologies that can provide a dispatchable heat supply are preferential. Heat can be supplied as hot water for space heating and steam if necessary for industrial process heat. Space heating demand is highly seasonal and economic viability is likely to require at least one "anchor" customer with relatively constant demand for steam or high hot water load.

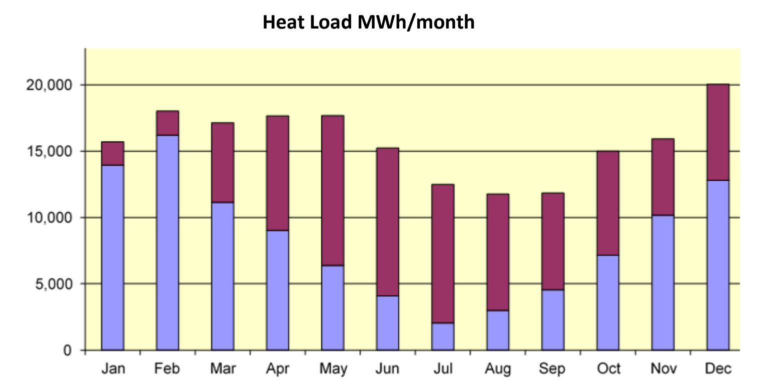

Figure 14. Nenagh and Environs: Base Heat Load + Dairy Load.
[Heat Load MWh/month]. Source: TEA from SERVE Project 2008.

The proposed EU RED II Directive promotes development of DH, and incorporates proposed criteria designed to ensure, amongst other matters, that district heating schemes can be used to distribute renewable heat. These include an obligation on Member States to ensure that district heating and cooling suppliers provide information to end-consumers on their energy performance and the share of renewable energy in their systems. Consumers will have the right to connect and disconnect unless the district network can validate a significantly better energy performance than alternative heating options. Member States will be obligated to ensure non-discriminatory access for distribution of RES H, and connection of sources of RES H supply from suppliers other than the operator of the district heating or cooling system (except in the case of capacity constraints due to competing supplies of qualifying RES H). New district heating or cooling systems may be exempted for a defined period, provided the new district

[78] Thomas Nussbaumer and Stefan Thalmann Verenum, Zürich, Switzerland Sensitivity of System Design on Heat Distribution Cost in District Heating prepared for the International Energy Agency IEA Bioenergy Task 32 and the Swiss Federal Office of Energy Zürich, 19 December 2014

heating or cooling system constitutes 'efficient district heating and cooling' as defined under the Energy Efficiency Directive.

The recast EU Energy Performance of Buildings Directive 2010[79] compels that all new public buildings must be "nearly zero energy buildings" (NZEB) by 31 December 2018. Article 6 states that governments must ensure that formal consideration is given to district or block heating or cooling (among other RES measures) for all new buildings and that such systems should consider technical, environmental and economic feasibility.

Community based energy projects can be utilised for development of DH schemes. The large front-end capital commitment required for network construction requires a marketing strategy to secure an initial stable thermal demand, and then a strategy to increase penetration to serve the aggregated demand. It may be possible to incorporate green energy obligations in public procurement mechanisms for energy requirements such that public bodies (e.g. local authority swimming pools, social housing or schools, for example) could underpin the demand that initially secures economic viability. Mandating all public sector buildings and new builds to connect to a district heating system if one is available in their area would assist to develop the market for district heating.

Thereafter, it may be possibly to use publicly sourced EU grant aid to subsidise connection costs for customers, combined with an RHI that supports the price at which heat can be supplied, to promote network deployment. Over time, introduction of a mandate to connect to available district heating schemes promote market penetration. Such a mandate would be consistent with similar regulations developed in other jurisdictions. Ensuring that energy costs as provided over district heating schemes are lower than the costs of alternative energy sources would be a pre-requisite for introduction of such a proscriptive mandate in Ireland.

District heating schemes constructed in the context of community based projects may have to adopt tariffing structures and operating protocols that allow them to operate as "open access" networks after an initial establishment period. A mechanism will be required to establish the sustainability of heat supplies proffered from 3rd party heat suppliers. A governance framework will be required to oversee how district heat networks meet their public service obligations.

REBIOGEN undertook a review of the costs of district heating scheme construction that would be applicable in rural Irish population centres (See Appendix 3). It noted that the cost of energy distribution over highly targeted networks such as those that might serve commercial or industrial parks (e.g. a 5km network distributing 25 GWh_T per annum) could distribute heat for a fee of c. €11.72 if investment is supported with EU grant aid. Heat distribution over larger networks that service entire communities may incur total costs of €34.79 per MWh_T, however with investment support in respect of capital costs may be able to charge a lesser fee of €24.30 per MWh_T and still repay net borrowings.

REBIOGEN reviewed how different types of biomass technologies could be integrated with development of district heating networks to reduce the cost of thermal energy in rural population centres (See Appendix 4). The REBIOGEN review notes that efficiencies in respect of capital costs and low load factors can potentially be overcome by integrating centralised bioenergy generation to supply an aggregated heat demand. The review indicates that the (year 5, inflated) cost of thermal energy supplied over district

[79] Energy Performance of Buildings Directive 2010/31/EU

heating networks would range from € 90.66 for biomass sourced from conventional combustion of woody biomass, to €65.82 for a model that deploys ATT technology to co-fire wastes and residues for CHP. The latter model might require a subvention estimated in the range of c. €20.00 - €22.50 if heat were marketed at a price averaging c. €46.00 per MWh_T.

Renewable Electricity

In the context of delivering thermal energy over district heating networks, community based bioenergy projects can be deployed to generate RES-E from CHP. Given the lead times associated with construction of district heating networks and development of sufficient market penetration, as well as the variability in local thermal demand (both daily and seasonally), community based district heating schemes can deploy CHP technologies to generate power as well as heat, leveraging the mature market structures that underpin access to the national electricity pool to stabilise their early stage revenues and optimise the economic viability.

Irish Market for Wholesale Electricity - In Ireland, in respect of public supply of RES E, bioenergy applications would compete with a range of alternative power generation technologies including large scale fossil fuelled generators as well as with alternative forms of RES E such as wind, solar, hydro and potentially ocean applications. The competitive positioning, relative to these other sources of electricity, is determined by environmental considerations as well as by the relative LCOE.

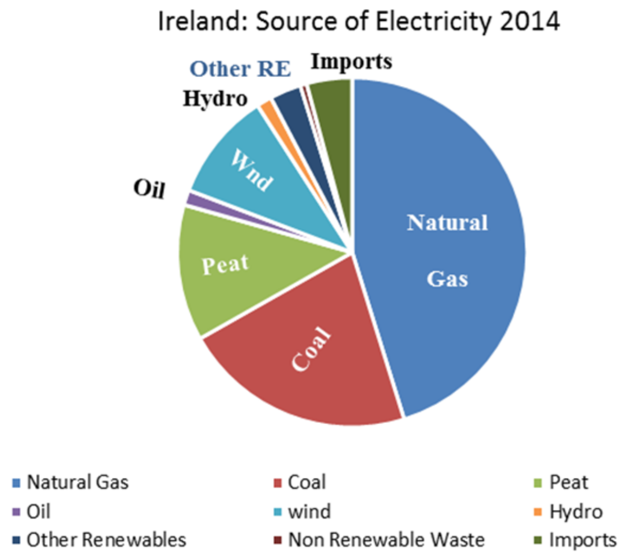

Figure 15. Source: SEAI Energy in Ireland 1990–2014 (2015)

In Ireland, utility scale electrical power is sourced predominantly from natural gas, which accounted for c. 45% of all power generation in 2014. Natural gas fuelled power generation can deploy combined cycle technologies that are capable of electrical output efficiencies that exceed 50% of the energy value of the input fuel.[80] Natural gas power plants are generally deployed at large scale to achieve economies of scale, which reduces the cost of electricity generation but makes it difficult to valorise the residual low-grade heat, as the volume of this heat generally exceeds any demand available in the reasonable vicinity of the plant.

The "centralised" power generation model results in highly competitive prices for wholesale power generation. During 2016, the average daily wholesale prices of electricity at the point of supply to the Irish grid were reported as:

Wholesale Electricity Prices at the Point of Supply to the Grid (Source: VAYU 2016):

- Average Day Electricity Prices 2016 = € 41.85 per MWh

[80] Power Engineering International- CCGT: Breaking The 60 Per Cent Efficiency Barrier, 03/01/2010, http://www.powerengineeringint.com/articles/print/volume-18/issue-3/features/ccgt-breaking-the-60-per-cent-efficiency-barrier.html

- Average Evening Electricity Prices 2016 = € 31.09 per MWh
- Weighted Average during first quarter 2017 = € 42.80 per MWh

In Ireland, coal and peat are also used as solid fuels for power generation. Solid fuel power generation technologies are typically less efficient than natural gas power plants, as fuels are conventionally used to heat boilers integrated with condensing steam turbines that generate electrical efficiencies in the range of c. 25% - 30%. They are also deployed at large scale to achieve corresponding economies of scale, and similarly find it difficult to valorise the low-grade residual heat, due to the scale of the supply and relative lack of co-located demand. This reduces the average overall energy efficiency of utility scale power generation to c. 50%, as calculated from information reported in Energy in Ireland 2014, SEAI.

Solid fossil fuel power plants contribute greatly to carbon intensity of electricity generation, as solid fuels generate higher emissions per gross energy unit than natural gas. Irish policy encourages the progressive migration away from peat and coal fuelled power generation, which SEAI reports has resulted in a reduction in carbon intensity of 49% since 1990. During 2014 however, power generation still generated on average 457 g $CO_{2\text{-eq}}$/kWh of electricity generated the average for the EU-28 is 276g $CO_{2\text{-eq}}$.

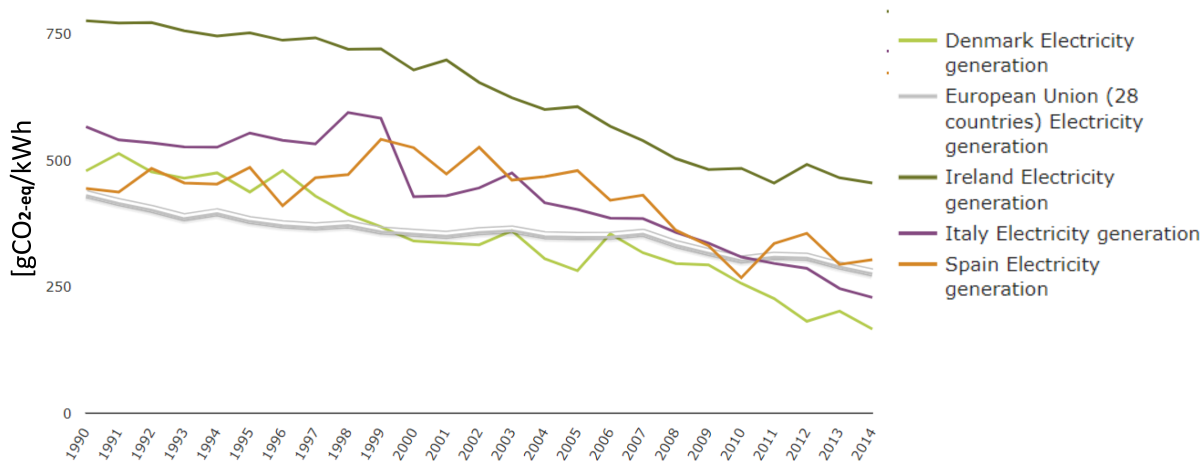

Figure 16. Electricity generation — CO_2 emission intensity. (Source: EU Environment Agency)

The carbon intensity of centralised power generation is impacted by the loss levels arising from transmission required to service Ireland's rurally dispersed population. In 2017 Eirgrid estimated[81] these transmission and distribution losses at 7-8% of total power produced. To further improve energy efficiency and reduce carbon intensity within wholesale power generation, EU strategies have been proposed that supplement the 2030 Framework[82] obligations (i.e. those requiring increased integration of RES-E into the energy mix) with a gradual transition toward distributed energy generation models. It is theorised that moderate scale distributed energy models may offer greater prospects of usefully utilising the residual heat from combustion based power generation technologies, as well as reducing transmission losses if generation is located close to demand.

[81] Eirgrid, All-Island Generation Capacity Statement 2017-2026
[82] Communication from the Commission to the European Parliament, the Council, the European Economic & Social Committee & the Committee of the Regions a Policy Framework for Climate & Energy in the Period from 2020 to 2030 - COM/2014/015.

Transitioning from large centralised generators to a more distributed energy model must be undertaken in a managed process, as generator outputs must be synchronised with the technical parameters of the grid and operational protocols must be compliant with the SEM code. In the Irish market, large scale grid connections are managed under a group processing “gate” process that allows the network operator to plan integrated grid upgrades in a geographic area to accommodate evolving market circumstances. Smaller scale projects can apply to by-pass the gate system via a non-group process, whereby grid connection offers are assessed sequentially on a first-come-first-serve basis, pursuant to technical and capacity evaluations. In the event a grid upgrade or reinforcement is required, the applicant will be requested to pay the full costs of the technical changes within a specified timeframe. In the event payment is not forthcoming, applicants forfeit their right to the grid connection offer and the technical evaluation then progresses to the next sequential application.

ESB Grid Connections 2016[83] highlighted that there is currently a large backlog of large scale renewable energy applications awaiting grid connections under the gate process. Additionally, since 2014, a large volume of small scale wind and solar RES E projects have been submitted under the non-gate process. The large number of small scale applications poses technical challenges in respect of the efficient planning, design and operation of grid infrastructure. It has resulted in a large backlog of applications that are awaiting either decisions in respect of preceding connection commitments, or sequential grid connection evaluations and offers. The non-gate process was not designed for large numbers of applications, and the preference offered to small scale projects under the non-gate process potentially exacerbates the backlog of large scale RES E projects.

To ensure a stable and cost-effective supply of power to energy consumers, power outputs from wholesale power generation are sold at wholesale prices to licensed electricity suppliers who then market the power to end users. A functional Single Electricity Market (SEM) is maintained by a designated operator pursuant to the Single Electricity Market Trading and Settlement Code, which sets the pricing and balances the power demand against the supply based on a competitive bidding process. EU RES Regs 2014[84] are incorporated into the SEM code that requires the SEM operator to give preference to RES-E when dispatching power from generators to meet demand. This provides a constant market outlet for RES-E output, provided a grid connection and suitable transmission capacity are available to service the generation site.

Community bioenergy schemes can be deployed to progressively transition toward a distributed decarbonised energy supply, including a contribution toward the RES E obligation. Their ability to increase the proportion of RES E into the energy mix, however, is sensitive to the cost of RES E generation, and low-cost energy is a key component of maintaining economic competitiveness. The cost and characteristics of RES E generation varies depending on the technology.

Ireland’s renewable electricity programme prioritises exploitation of its “free” Irish wind resource, which currently accounts for c. 20% of RES E supplies. According to the European Wind Energy Association[85] wind generated electricity costs between €0.07 - €0.10 per kWh depending on the available wind

[83] ESB GRID CONNECTION 2016: Solar Connections on the Irish Distribution System, Ivan Codd-Renewable Planning Manager, Asset Management, ESB Networks presentation to workshop: Engineers Ireland, 6th April 2016
[84] EU RES REGS 2014: Irish S.I. No. 483 Of 2014 European Union (Renewable Energy) Regulations 2014
[85] EU WIND ENERGY: European Wind Energy Association - https://www.wind-energy-the-facts.org/the-cost-of-energy-generated-by-wind-power.html

resource. This estimate is one of the lower unit costs across Irish RES E technologies and is consistent with the cost range estimated by IRENA 2015.

Wind resources, however, are intermittent. SEAI's Renewable Electricity in Ireland RES E 2015[86] reports that average wind capacity factors range between 25% and 30% of installed capacity. The intermittency can cause complications in respect of grid management, and requires a corresponding form of dispatchable capacity to guarantee a stable power supply. Additionally, deployment of new wind farms is increasingly subject to public opposition and planning issues that constrain new wind turbine capacity.

Solar PV, hydro and ocean technologies are also non-combustion based technologies that can also leverage "free" forms of primary energy to generate RES E. Wave and tidal technologies are not yet mature, however solar PV technologies are mature and widely deployed in other jurisdictions. In the Irish market, discussions with industry participants indicate that the cost of solar PV technologies has come down over the last decade, and are expected to be very competitive with the RES-E LCOE from wind. Industry sources indicate that the geographic area covering the Southern third of the country has sufficient solar profile to warrant solar PV deployment. The solar resource, however, is also variable which leads to intermittent supplies of RES E.

Progressively transitioning the wholesale electricity supply to incorporate a greater proportion of distributed units may improve carbon intensity, however any transition must also maintain a competitive economy by supplying a stable supply of electricity at equivalent or lower cost. While wind and solar technologies are likely to offer the lowest LCOE for RES-E, the intermittent outputs from these technologies will require reinforcement from flexible combustion technologies to provide reliable base load as well as address intermittency and peak load shortfalls.

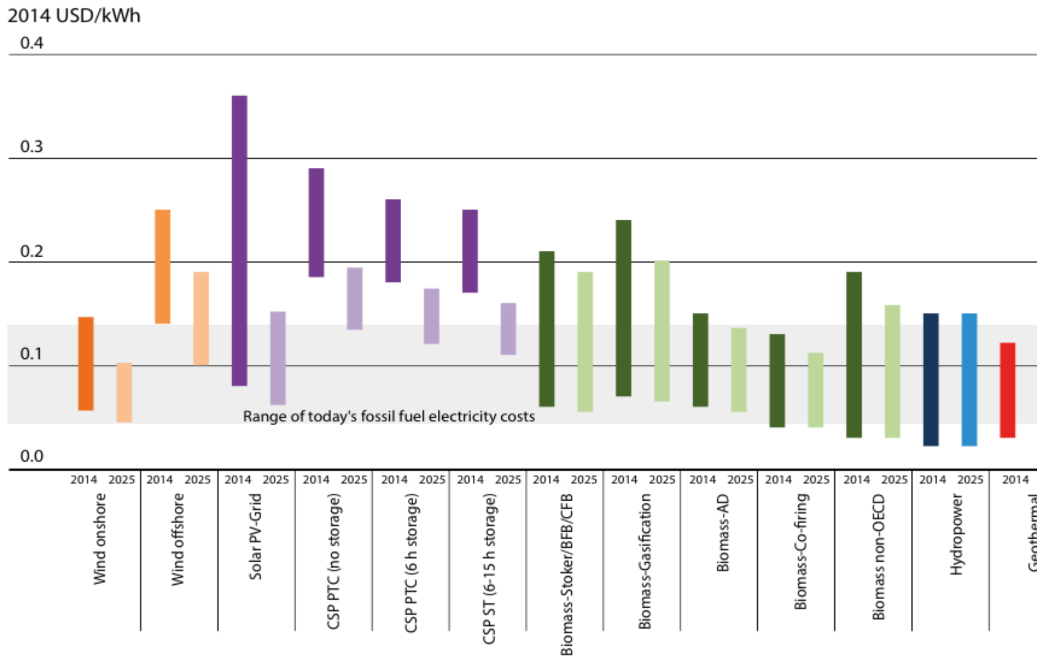

Figure 17. Levelised Cost of Renewable Electricity Generation 2014 vs 2025.
Source: IRENA 2015 report on renewable power generation costs 2014.

[86] SEAI RES E 2015: Sustainable Energy Authority Ireland- Renewable Electricity in Ireland 2015 2016 Report

The LCOE of bioenergy RES E is higher than the wholesale cost of fossil fuelled electricity, as well as other forms of RES E. IRENA 2015[87] reports the LCOE across various renewable electricity technologies as per figure 17 above.

REBIOGEN's review of models for community based schemes indicates that local ATT for co-processing wastes and residues with biomass for CHP may be an economically viable model for valorisation of waste and residue resources. See Scenarios in Appendix 4. Waste-to-energy CHP facilitates compliance with the waste hierarchy as well as with the proximity principal in respect of waste management. It is commonly deployed in other EU jurisdictions, and may constitute best practice in respect of valorising local wastes and residues, as there are limited alternative routes for sustainable valorisation of these resources. REBIOGEN's review indicates that a waste-to-CHP application could potentially generate power for a (year 5, inflated) cost of €81.00 per MWh_e if it is integrated with valorisation of the residual heat.

Economic viability of a waste-to-CHP application will require introduction of a market support for the power output component. Re-activation of the REFIT (now RESS) scheme would be a significant enabler of community based bioenergy schemes as it will provide a CHP outlet for ATT deployments that can valorise solid wastes and residues in thermal waste-to-energy CHP applications. REBIOGEN's review indicates re-introduction of a RESS scheme will provide access to a mature market outlet of national scale that can be leveraged to stabilise community scheme revenues during the establishment period. REBIOGEN estimates the (year 5, inflated) premium that would be required to support a waste-to-CHP would be c. €26.40 per MWh_e.

Introduction of a RESS support for community based bioenergy schemes will have to be consistent with the provisions of the new I-SEM protocols. These protocols are designed to transition the supply of RES E toward market led structures. Historically, the REFIT[88] programme was introduced to levelise the cost of RES E supply with other forms of energy. It has been closed for new applications since the end of 2015. The historical scheme allowed stakeholders to apply for a subvention, subject to compliance with certain criteria relating to a demonstrable capacity to deliver RES E outputs. The historical subventions for combustion based biomass technologies were higher than those for non-combustion applications. This is designed to remunerate the significant infrastructural investment as well as the cost required to procure and manage biomass feedstocks. It also reflects the energy loss resulting from combustion-based conversion.

Under the new I SEM auction protocols, the Feed-In-Premium mechanism is identified as the DCCAE's[89] preferred option for introduction of new supports. Under this option, mmarketplace participants will have to bid for subventions as capacity is advertised. Given the likely lead times associated with development of community bioenergy schemes, it is unlikely that community waste-to-CHP projects will be able to bid for new capacity in the immediate future. Accordingly, REBIOGEN believes it would be

[87] IRENA 2015: International Renewable Energy Agency - Renewable Power Generation Costs in 2014
[88] REFIT 3: Renewable Energy Feed In Tariff : A Competition For Electricity Generation From Biomass Technologies 2010-2015, published by DCCAE, http://www.dccae.gov.ie/documents/REFIT3TermsandConditionsJuly2013.pdf
[89] DCCAE: Renewable Electricity Support Scheme: Transitioning to I-SEM (Options Paper) May 2017

prudent to reserve generation capacity for such schemes, as suggested in the recent RESS consultation document.[90]

Providing capacity for community base bioenergy schemes may be beneficial to the development of other types of community schemes. Under SEM, payments for wholesale electricity generation sold into the national pool are comprised of:

- the market price for energy, which is the result of the competitive bidding process, together with
- a capacity payment that contributes toward fixed costs of maintaining available generation capacity; as well as
- a constraint or balancing payment made to generators in order to compensate for the difference between the level they were due to run at in the Market Schedule, based on a stack of cheapest generator bids, and the extent to which they were actually dispatched by the grid operator.

Under DCCAE's review of options[91] in respect of transitioning to a new I-SEM regime, the mechanism for determination of balancing and capacity payments may change, requiring the generators to accept the balancing risk and bid for capacity payments. These changes introduce an additional element of risk for variable wind based technologies, as historical balancing and capacity payments were made by the grid operator, funded by the PSO. Integrating a stable and predictable community bioenergy component into the energy supply mix may provide an element of risk mitigation, resulting in greater stability for community based wind generators.

Under the CHP Directive,[92] payment of a higher level of RESS subvention is conditional on compliance with HE criteria, which requires demonstration of a minimum 75% savings in emissions from primary energy utilisation (HE CHP). In practical terms, compliance with the CHP Directive requires utilisation of both the electrical and heat outputs to supply an economically justifiable energy demand. According to Clerens (2012)[93] it is the availability of a useful heat demand that determines the viability (and appeal) of biomass CHP applications, and accordingly community RES-E schemes are only viable in the context of a CHP configuration that serves a viable thermal demand.

In the Irish market, it has historically been difficult to identify sites with 24 x 7 heat demands, especially sites that are willing to host medium scale wholesale RES-E applications. In the absence of communal heat distribution infrastructure to aggregate heat demand, the historical structure of the REFIT subvention has been insufficient to overcome some of the financial and non-financial barriers that constrain wider exploitation of biomass RES-E applications. Development of integrated community base bioenergy projects, as illustrated herein, will provide a route for heat valorisation. The integration of a wide range of technologies required for waste processing as well as for heat distribution, however, may preclude compliance with the HE criteria. Design of the RESS support tariffs to include a lesser subvention for non-HE compliant RES E, that can be implemented to work in conjunction with an RHI, would be a significant enabler of community based projects.

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[90] DCCAE: Public Consultation on the Design of a new Renewable Electricity Support Scheme in Ireland, Sept. 2017

[91] DCCAE: Renewable Electricity Support Scheme: Transitioning to I-SEM (Options Paper) May 2017

[92] CHP Directive: DIRECTIVE 2004/8/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC

[93] CLERENS 2012: Energy Recovery Efficiency in Municipal Solid Waste-to-Energy Plants in Relation to Local Climate Conditions, May 2012, Study conducted by Clerens Consulting with the collaboration of ESWET for the European Commission Joint Research Centre Institute for Energy and Transport, Pettenf

Annual Load Shape and Demand Profiles - electricity usage generally follows some predictable patterns, e.g., with the peak demand occurring during winter weekday evenings while minimum demand occurs during summer weekend nights. Peak demand during summer months occurs much earlier in the day than it does in the winter period. Many factors impact on this electricity usage pattern throughout the year. Examples include weather, sporting or social events, holidays, and customer demand management.

Community schemes need a predictable, stable revenue base while the government must ensure subvention schemes are structured fairly, making the best use of limited government funds and to not excessively increasing power prices so as to maintain economic competitiveness. According to current load profiles, demand at night time is insufficient to warrant increased supply of RES-E. Accordingly, there may be a case for structuring the RESS supports such that daytime and including morning and evening demand peaks, is subsidised. Designing community based bioenergy projects to incorporate flexible dispatchable technologies that can respond to market demand, will be consistent with optimisation of the available support funds.

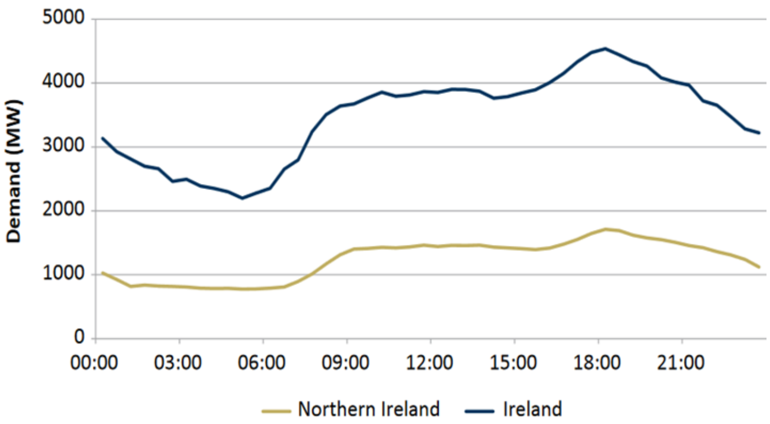

Figure 18. Typical Winter Daily Power Demand Profile. (Eirgrid)

An alternative route to revenue optimisation might include development of capabilities to act as a swing producer, generating power only at times of peak demand. ReBioGen reviewed whether community bioenergy schemes could participate in the single electricity market to take advantage of higher peak time payments. At the aforementioned hypothetical CSEC generating biogas and/or syngas this would incur the costs of a gas storage unit for over 12 hours' production volume per day. The AD and pyrolysis units would have to continue operating and the gas engine would only be switched on when the grid operator dispatched the generator for the specific trading periods. The accompanying chart shows a pareto analysis of the system marginal price (SMP) for the 17,568 trading periods in 2016. The number of 30-minute trading periods during which the system marginal price was more than 6 cents per kWh was less than 10% of the total trading periods. Even with the additional payments (capacity, imperfection, etc. equal to approx. 2c/kWh) the benefits of peak time trades are insufficient to underpin stable, predictable revenue stream adequate to remunerate capital and operating costs of a biomass based RES-E generator indicating subsidisation is required such that it supports extended durations of RES generation underpinning a stable, predictable revenue stream.

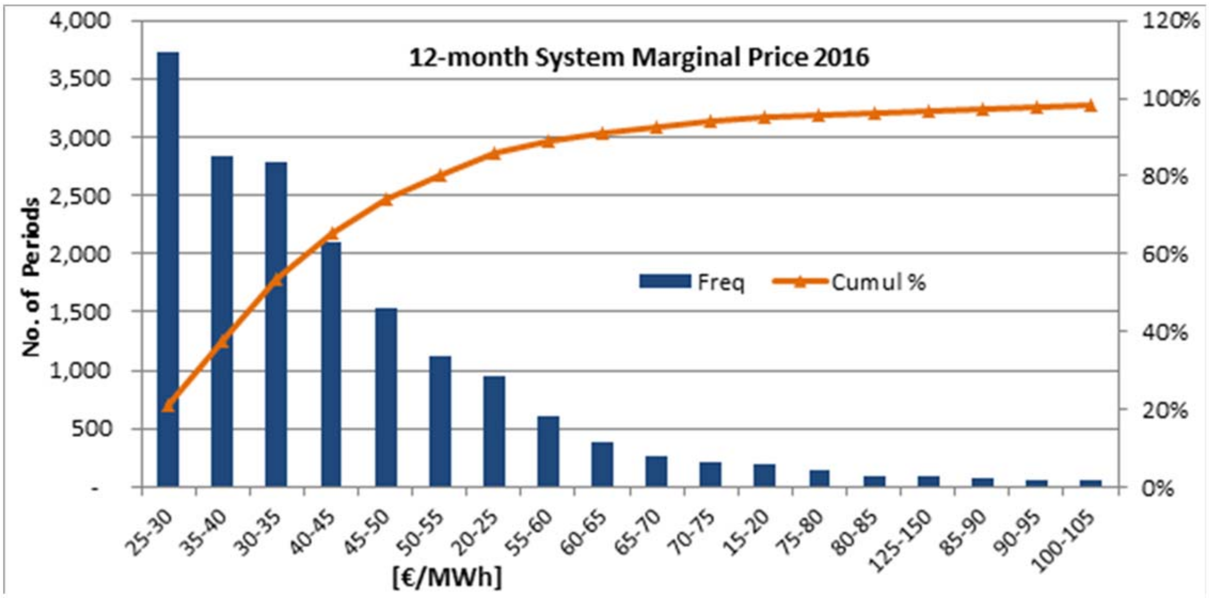

Figure 20. Frequency which each €5-price bracket occurs across all trading periods in 2016.

Marketing Community Based Heat and Power Outputs - Energy consumers have a requirement for both heat and electricity. Following examples established from larger market participants, the economic viability of community based models can potentially be enhanced by bundling both heat and power outputs to meet consumers' needs. Establishing a single point of customer contact for integrated energy needs may also increase community engagement, promoting early market penetration. While community ownership of renewable energy generation has become a popular concept, it is less common to see communities supplying consumers. However, supplying RES-E directly to consumers potentially offers community projects opportunities to offer benefits to residents through reduced prices, and to sell to consumers nationally or regionally, thereby increasing competition in supply. Furthermore, as prices of technologies such as solar continue to decrease, more citizens are interested in becoming or 'prosumers' - it is now recognised[94] that prosumers (active energy consumers who both consume and produce electricity) could dramatically change the electricity system. Communities remain largely constrained by regulatory frameworks that support market dominance by long-standing incumbents, particularly when it comes to retail supply of energy to consumers and 'auto-consumption' – production for self-consumption. Nevertheless, several countries have made it possible for citizen-based enterprises to successfully become energy market participants.

The margins from retail sales, however must exceed the cost of the customer interface and contribute to the economics of wholesale energy generation. Additionally, a minimum scale is required to ensure economic viability, as well as a mechanism that allows community based projects to collaborate with or become licensed energy suppliers.

[94] European Parliament Think Tank, Electricity "Prosumers" 11-11-2016
www.europarl.europa.eu/thinktank/en/document.html

During the last semester of 2016, the Average Cost per kWh_e supplied to the Irish consumer was reported as:[95]

- Band IC: >=500 < 2,000 MWh per annum €0.1237
- Band ID: >=2,000 < 20,000 MWh per annum €0.0994

REBIOGEN's review of the cost of energy supply, as illustrated in Appendix 3 & 4, indicates that these retail prices would be sufficient to remunerate the cost of a marketing and customer service function, provided an appropriate collaboration agreement or alternative licensing mechanism can be devised.

In addition to increasing margins and improving engagement with the local community, the capacity to directly supply energy to consumers will facilitate community schemes addressing energy poverty. An estimated 400,000 households in Ireland suffer from fuel poverty, which is defined as spending at least 10% of household income on keeping one's home warm and comfortable. This is being addressed progressively through home retrofitting programmes. Many of those households are in social housing and receive fuel allowance if their building has not already been retrofitted. District heating provides a way to further reduce energy costs for those at risk of energy poverty and to decarbonise reasonably large demands by aggregating clustered units which are under the responsibility of the local authority.

Licensed Supplier - Templederry Renewable Energy Supply Ltd., trading as Community Renewable Energy Supply (CRES), is Ireland's first community owned licenced supply company trading on the Single Electricity Market (SEM). CRES purchases and sells electricity on behalf of its customers and is working to support and promote local energy markets within communities where citizens and communities actively participate in renewable energy generation and distribution projects, for the benefit of their local community.

In November 2012 Templederry Wind Farm (4.6 MW installed capacity) in Tipperary became the first entirely community owned wind farm to connect to the National Grid, and began selling renewable electricity for the benefit of its members. The group is now producing approximately 15GWh per annum of green electricity which is enough to power 3,500 houses or the equivalent of the local town of Nenagh. The CRES example may provide a licensing model that can support development of community based schemes.

6 MOBILISING THE FEEDSTOCK SUPPLY CHAIN

Ireland's AMFM sectors generate substantial amounts of wastes and residues that can potentially be mobilised at zero or low cost. Energy recovery from residues costs less than energy recovery from purpose grown biomass, accordingly residue-to-energy applications can be prioritised to minimise the levelised cost of energy (LCOE) from integrated community projects. Bioenergy technologies can be deployed to process different types of biomass. ATT technologies such as pyrolysis, gasification and fluidised bed combustion (FBC) process dry municipal, agricultural and forestry residues, or woody biomass and purpose grown energy crops. AD technologies process wet (pasty) residues and herbaceous biomass. Energy recovery from municipal wastes offers prospects of improving waste management in

[95] SEAI REPORT on Average Energy Prices, April 2017 (EX VAT as calculated by REBIOGEN)

compliance with waste management hierarchy. Energy recovery from agricultural and agri-food residues offers prospects of transitioning to increasingly organic forms of plant nutrition and reducing GHG emissions from agriculture.

Economic viability of community bioenergy schemes is dependent on developing a consistent, cost-effective feedstock supply chain. Keys to economic viability include the ability to aggregate feedstock supplies at sufficient scale to create processing economies, while containing the overall cost of supply and transport to affordable levels. Disposal management can become rate-limiting unless combinations of feedstocks, process technology and disposal management protocols can be identified that safely minimise costs. Optimising nutrient recycling will contribute to environmental sustainability.

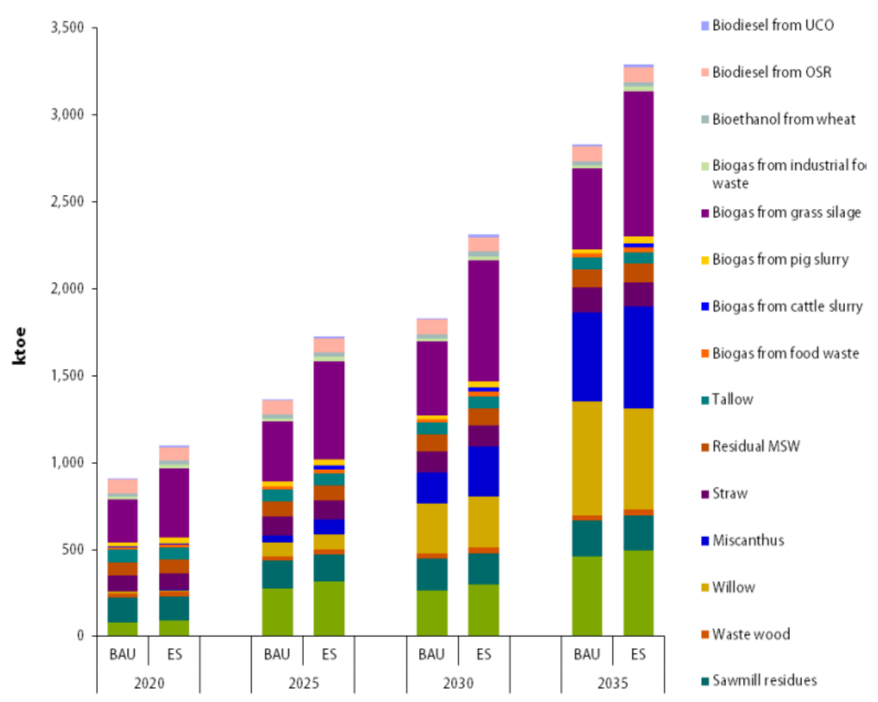

Fig. 21: Biomass potential, Ireland 2020-2035, for a range of feedstocks including residues. Source SEAI Bioenergy Supply in Ireland 2015 to 2035.

Unlike bioenergy deployments at individual companies, community deployments must configure technologies to process a diverse range of local feedstocks to create scale. Residue feedstocks are less costly than purpose grown biomass, and a range of residue feedstocks are available from local AMFM sources that are suitable for co-processing. Biomass can be sourced from non-food-producing lands (e.g. peat bogs, verges, hedges, landfill sites, etc.), while still maintaining biodiversity levels, or from lands of marginal food producing value (e.g. referenced as “Hidden Hectares”) can provide sustainable feedstock sources for renewable energy. REBIOGEN’s review notes that, especially in respect of AD, transport of residues for centralised processing at sites close to market outlets is generally less costly than deploying remote production infrastructure and extending routes to market to remote feedstock locations.

Sources of feedstock are fragmented and the character of biomass, particularly residues, can be highly heterogeneous. Adapting technology to co-process different feedstocks in blends can facilitate scale, as well as balance compositional characteristics to suit the conversion technology and ease processing. Co-processing AD feedstocks with food waste and slurry, for example, improves the robustness of the AD process as it provides buffering capacity, critical ratios of nutrients and the necessary microbial inoculum to the mix. Blending construction wood waste with SRF or forestry with dried sludges brash may improve energy recovery via advanced thermal treatment (ATT). Combusting dried digestate fibre together with residual biochar to provide the thermal load for AD can reduce the costs that otherwise burden economic viability. While technologies can adapt to some changes in feedstock characteristics, it is best to avoid frequent and rapid changes in the character of the feedstock, which can otherwise lead to process inhibitions or adjustment of equipment. Accordingly, a certain feedstock base is required to support efficient energy recovery.

Secure access to feedstock is a pre-requisite to accessing commercial finance. In an evolving market, however, constant changes to market circumstances precludes contractual security in respect of feedstock supplies. Anecdotal discussions with farmers, AD operators, composters and with waste collection companies suggest a reluctance on the part of feedstock owners to enter into fixed contracts, as in many instances feedstock suppliers are not able to guarantee volumes over the long term. For example, introduction of higher REFIT and RHI rates in NI have resulted in gate fees for digestible wastes decreasing to zero, which in turn has attracted significant supplies of wastes and residues, even those transported from distant sources.

In the context of establishing community based schemes, feedstock supplies may potentially be secured by directly engaging the feedstock producers as stakeholders in the scheme. Structuring a CSEC feedstock supply in a manner that reduces the feedstock producers' core costs or provides a non-energy revenue stream will supplement the remuneration available from energy sales. The combination of remuneration may be the best route to secure feedstock supplies.

Mobilisation of diverse sources of feedstocks calls for adaptations of existing market paradigms and varied interventions in residue management practices to make them available for energy recovery. Energy is a low value commodity output, and while energy revenues are generally sufficient to recoup modest feedstock transport costs, economic viability precludes paying high transfer prices for feedstock supplies unless supported on an ongoing basis via high support incentives. REBIOGEN review indicates that ongoing reliance on high market supports to remunerate high transfer prices may not guarantee a feedstock supply and may make it very difficult to subsequently transition to market led structures. Alternatively, funding the staffing and transport resources required to develop and manage a feedstock supply chain dedicated to community schemes, including collection of feedstock supplies from owners, improves chances of securing feedstocks for energy recovery.

Changes in residue management practices may require coordinated action of different stakeholders including local authorities, environmental authorities (DECCAE or EPA), agricultural and forestry authorities (DAFM and Teagasc) as well as the market participants themselves. Adapting the structures of existing support frameworks, such as introduction of sustainability schemes supported by the direct payment system for farmers or interim payment system to foresters, may provide the means to incentivise feedstock owners to participate in feedstock mobilisation, while minimising cost to the State.

More detail of the descriptions, quantity and issues affecting mobilisation of specific feedstocks is detailed in Appendix 1.

6.1 Increasing Feedstock Supplies from Municipal Waste

Municipal waste streams include a range of fractions that are potentially suitable for energy recovery, including food waste and green waste streams for AD, as well as mixed black bin fractions, construction wood waste and WWT sludge fractions that may be best suited for energy recovery via ATT.

Wastes must be managed in compliance with regulations enforced by the EPA or local authority and may attract a gate fee that can offset the costs of purpose grown energy feedstocks and significantly improve bioenergy economics. Mobilising residues for energy recovery, however, can be difficult, as the waste management sector is fragmented, and public opinion is sometimes rooted in out-of-date "smokestack" technologies, e.g., mass-burn incineration, causing concerns in respect of licensing and deploying waste-to-energy developments. In the absence of historical bioenergy market outlets, waste management structures have evolved to aggregate, process and dispose of wastes at lowest cost. Existing treatment, recovery and disposal practices are sub-optimal in the context of evolving environmental objectives, however concerns over stranded capital investment can cause objections to any change in treatment practices.

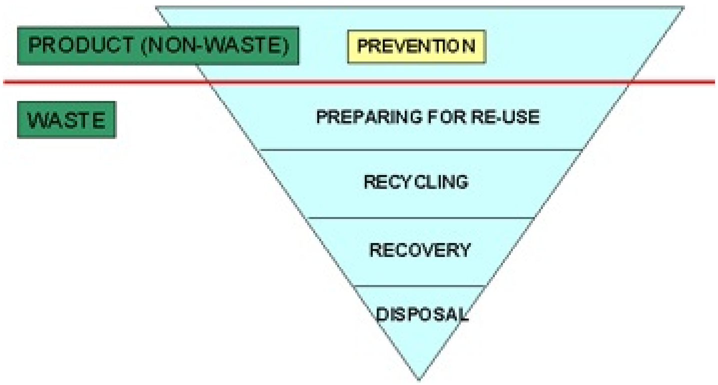

Figure 22. The waste hierarchy is the cornerstone of EU waste policies.

Legacy market structures potentially pose a barrier to transitioning toward more optimal forms of waste processing. Sourcing waste feedstocks for energy and nutrient recovery may have to compete against existing market structures, including legacy investment in capital equipment, that may pose barriers to mobilising feedstock supplies. A collaborative approach is required to mobilise waste resources for energy recovery, and the willing collaboration of local waste management companies will be required to facilitate collection and delivery of municipal waste fractions. Commercial arrangements will have to be structured in a way that reduces waste management company costs to engage waste processors in the community scheme.

REBIOGEN's review of current waste management practices indicate that in many instances, particularly in smaller rural markets, waste fractions are collected locally and then routed to transfer stations for separation and further transport to distant processing. Anecdotal evidence indicates, for example, that biodegradable wastes are delivered for composting to approved treatment plants many times at great distances from collection catchments. Additionally, significant volumes of mixed waste fractions are routed across country, or alternatively exported, for incineration. Changes in waste routing to streamline waste processing, reducing handling and transport requirements can reduce waste management companies' costs.

Energy recovery components incorporated into community projects can facilitate localised processing for RES recovery, as well as ensuring Waste Framework Directive (WFD[96]) compliant treatment routes. To incentivise waste management company collaboration, for example, community schemes could fund local deployment of communal conditioning infrastructure at existing local waste sites. Investment in de-packaging equipment to remove contaminants from food wastes, and separation and shredding infrastructure to process mixed black bin wastes for ATT, would condition wastes to standards suitable for energy recovery. Funding co-deployment of the waste processing infrastructure with energy recovery

[96] The EU landfill directive (1999/31/EC) and EU Directive 2008/98/EC on waste (Waste Framework Directive), lay down strict requirements for landfills to prevent and reduce as far as possible the negative effects of landfills on the environment, surface water, for ground water, soil, air and human health.

facilities as well as routes to market for energy outputs will provide an energy revenue stream that, together with community scheme access to investment supports for infrastructure, could moderate the gate fees otherwise required to support deployment of waste processing infrastructure on its own. Locating waste management infrastructure at existing sites will minimise planning and licensing issues.

Organising for conditioned waste fractions to be collected by the energy recovery facility at its cost will facilitate organisation of vehicular traffic in accordance with a structured traffic management plan. Collecting waste fractions for energy recovery provides a route for the community scheme to monitor and avoid routing of inappropriate waste fractions for energy recovery. The combination of these benefits will reduce local waste management companies' transfer costs, and may provide a suitable incentive for collaboration in a community scheme.

A sustainability scheme for permitted waste collectors operated through the local authorities, Regional Waste Management Authorities or National Waste Collection Permit Office (NWCPO) could be introduced to reward collectors for each tonne of waste provided to an approved community scheme for energy recovery. REBIOGEN envisages a programme where sustainability certificates would be issued by the energy plant on receipt of each load of feedstock supplied for energy recovery. Monetisation could be via gate fee rebates, sustainability payments, tax credits or alternatively incentives provided to their customers or the community in respect of the certificates accumulated.

A viable feedstock supply will require adaptations to existing food waste collection routines, including expansion of the 3-bin pay-by-weight collection system, and enforcement by licensed collectors of source segregation by household customers to gradually reduce brown bin contamination. Interviewees indicated this is not happening as the consequences of delivering contaminated brown bin material to an approved treatment plant are preferable to the administrative burden of freezing a householder's account. (See Appendix 1 section on brown bin waste for more detailed discussion on this point).

Greenwaste potentially offers a valuable and significant feedstock for energy recovery. Incorporating a community education programme to inform residents about the benefits of energy recovery may assist to mobilise supplies of grass clippings and other greenwaste via kerbside collection (e.g. as part of the brown bin collection, for example). Alteration to landscaping contracts or zero gate fees for quality material from grounds maintenance companies in addition to a conveniently located peri-urban depot (commercial bring centre) for them to deposit suitable residues at can encourage supply of grass clippings and tree cuttings.

The active support of the local authority is vital, given their role in promoting community participation, enforcement of waste management regulation and other environmental regulations, as well as their responsibility for the maintenance of civic amenity areas such as sports grounds and parklands. Although there is a tendency for mulching of grass clippings to be preferred practice by city councils for cost reasons transitioning to the use of grass collection equipment as mowers come to end of life and the planning of collection logistics, along with supplies from the National Roads Authority's land banks and private landscape companies' residues can contribute to the bioenergy resource. The food waste, grass clippings and woody greenwaste from these sources are ideal feedstocks if programme protocols can be adapted to collect and deliver these materials to the CSEC site or feedstock aggregation hub.

Environmental concerns arise over the actual impact of waste processing, particularly in respect of the impact of thermal processing on air quality, as well as on health and quality of life. An active and ongoing information programme will be required to assuage community concerns over energy recovery from wastes. Abatement measures will be required to address these concerns. Monitoring and reporting regimes, coupled with validation measures, will be required to provide comfort for community residents. Establishing a programme and procurement of equipment for emissions monitoring and validation will enable the State to ensure compliance with emissions criteria. Consideration may be given to organisation of a national consultation on waste to energy infrastructure deployments with a view to defining a national framework governing deployment. Such a discussion could be focussed on the measures required to ensure wastes and residues are processed in a safe and environmentally friendly way, without the acrimony that arises in respect of infrastructure deployments in "my back yard".

6.2 Mobilising Feedstock Supplies from Agriculture and Agri Food Processing

Agriculture and food-processing industry generate substantial supplies of residues (including manures and litters, crop residues and other animal by-products) which generally incur a very low (or zero) incremental cost to supply at the farm (factory) gate. Energy recovery from agri-food wastes and residues also offers prospects for manure management and organic nutrient recycling, which will contribute to reducing the GHG emissions from the agricultural sector. The 2015 EPA report on progress against emissions targets indicates that Ireland is unlikely to achieve its 2020 non-ETS emissions reductions targets, in part due to the difficulties in managing the agricultural emissions. Ireland is unique in that the agriculture sector is responsible for over 33%[97] of the country's GHG emissions (manure management makes up 3% of the total, see Figure 23), for which few substantial cost-effective solutions have been implemented at scale.

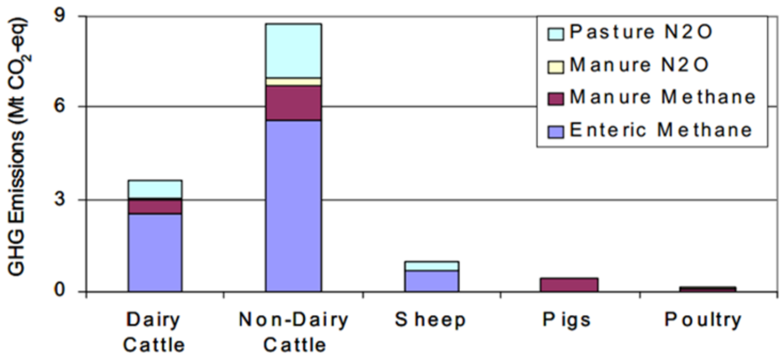

Figure 23. Sources of GHG emissions arising from livestock production in 2008. Manure Mgmt.= 3.5% of 2008 non-ETS GHGs. Source: EPA, Ireland's GHG

The economics of energy recovery from agricultural residues, however, are impacted by fragmentation in the farm sector and the low energy density of most feedstocks, these factors currently preclude economies of scale. Costs of accessing market outlets and energy distribution infrastructure, as well as costs of capital-intensive processing technology, make the economics of farm based energy projects difficult, unless supported by high ongoing market supports.

In other jurisdictions such as Sweden, Germany and Denmark, an extra premium on top of the base market supports are paid for the energy produced for the slurry fraction of AD substrates. REBIOGEN's discussions with stakeholders in Germany (who have developed the most successful AD programme of all EU member states) have indicated that they are now reviewing ways of transitioning to market led structures, and expect that reduced supports arising from this initiative may result in a significant number of AD plants becoming unviable.

REBIOGEN's review indicates that in the context of prioritising a viable source of RES H, in general the least cost route to energy valorisation of these resources may be to process them locally to a condition

[97] EPA Ireland, 13th April 2017, Ireland's Final Greenhouse Gas Emissions in 2015.

that can be aggregated and cost-effectively transported to centralised (scaled) energy recovery facilities located close to market outlets. Mobilisation of agricultural residues will require a means to remunerate the farmer to supply these materials. The low value of commodity energy outputs makes it difficult to pay transfer prices for residues unless the energy outputs are supported on an ongoing basis via high price supports. REBIOGEN's review indicated that, with the collaboration of the DAFM, it may be possible to remunerate the farmer via a combination of direct payments sourced from adaptations of existing direct payment schemes, from minimising cost and inconvenience of residue disposal as well as from energy revenue proceeds arising from farmer participation as a stakeholder in community schemes.

Additionally, community schemes can be organised to reduce cost, inconvenience and add value to farm operations. REBIOGEN reviewed the prospect of integrating staffed rural Feedstock Aggregation Hubs as part of community bioenergy schemes. Such depots could be designed to operate in collaboration with existing farm contract service providers to source and store local feedstock supplies (e.g. dewatered slurry solids or excess slurry, grass cuttings, tree cuttings, silage or straw spoilage, crop toppings, etc.) to encourage development of an agricultural supply chain. Feedstock could then be brought in bulk to the CSEC for processing as required, and nutrients returned to the agricultural lands from which they were sourced. The Biomass Aggregation Hub can provide a range of services for farmers. For example, installing technology to de-water pig slurries, collecting the solids for energy recovery while processing the liquors to a dischargeable standard, may offer pig farmers a route to avoid transport of pig slurries for land spread, which can cost up to €6/m^3. Developing a similar mobile de-watering technology for cattle slurries may mobilise a portion of the cattle slurry resource by providing slurry tank emptying services for cattle farmers during the land-spread restriction period. Arranging for hub staff to collect poultry litter or equine litter may minimise the transport cost for disposal for poultry or horse farms. Providing a route to dispose of agricultural residues may be particularly valuable for the c. 1,500 agricultural sites that suffer from excess levels of P in soils.

REBIOGEN envisages that a feedstock aggregation hub would also be able to leverage the staffing and facilities (as well as nutrients from community AD) to grow a silage energy crop. REBIOGEN reviews indicated that the cost of grass supplied as an energy crop is marginally less if it is grown by the participants, rather than purchased on the open market, especially if land can be leased at c. € 350 / ha. REBIOGEN's conversations with Teagasc indicate that non-productive hidden hectares may potentially be brought into productivity by offering land holders a lease payment to facilitate growing grass as an energy crop. This prospect may also be attractive to cattle or sheep farmers, many of which only break even from animal husbandry activities and who rely solely on direct payments for farm incomes. Leasing land for energy crops will assure a feedstock supply to a community AD scheme. The combination of residues and purpose grown energy crops will moderate the feedstock cost to the scheme. Leasing land for energy crop growth will provide a return to farmers, and it is also a means of avoiding unwanted escalations in the price of fodder, which may arise if significant volumes of silage were otherwise purchased for energy recovery.

The deployment of feedstock aggregation hubs could be undertaken in conjunction with development of an agricultural sustainability programme. REBIOGEN can envisage a process, for example, where community feedstock aggregation hubs were authorised to issue farmers with sustainability certificates for supplying slurry solids for energy and nutrient recovery, which could then be redeemed for a tax credit or supplemental Greening Payment[98] under the direct farm payment programme. Capital costs associated with slurry processing could be qualified for reimbursement under TAMS[99] programme. The adaptation of agricultural support schemes to incentivise sustainability improvements in agricultural activities is consistent with Irish policy and EU farm sustainability strategies. REBIOGEN believes such a programme could stimulate significant supplies of slurry being made available for energy recovery and nutrient recycling and help farmers who wish to increase their stocking rate to demonstrate that N is being removed from their land. Contributors highlighted that technical design of such a programme should be rigorously tested prior to implementation, to ensure it can achieve its intended result and to design it such that it could be implemented without excessive administration.

Community schemes may also be organised to collect other sources of feedstocks sourced from food processing facilities, such as paunch contents for AD or possibly meat and bone meal or agri-food WWT sludge for ATT. Organising the community scheme to collect these feedstocks from local suppliers may reduce the current cost of collection and disposal to the supplier. It can provide a route for disposal that is compliant with relevant waste and ABP regulations.

Manures sourced from agricultural sources, as well as those ABP feedstocks sourced from food processing industries, must be treated in accordance with the relevant ABP regulations[100,101] (and, in parallel, also with corresponding waste legislation if they have a specific waste code, e.g., brown bin waste – EWC 20 01 08). These regulations classify ABP into 3 categories and define the acceptable processing of each category. Class 1 ABP is specific risk material, including MBM sourced from specified fractions of animal carcasses and catering waste from international flights. It can only be disposed of via thermal processing. Currently these materials are exported to the UK for processing and anecdotal discussions with stakeholders (which REBIOGEN was unable to confirm) indicated that this may incur a significant cost to the State. Community schemes may not initially be the appropriate location for the treatment of such materials, although over time it may be possible to develop a specific expertise capable of properly disposing of specific risk material.

Class 2 includes manures and milk wastes while Class 3 includes most other ABP such as household “brown bin”, catering waste, food-processing residues and supermarket foodstuffs with expired shelf life. Class 2 and Class 3 ABP can be used in AD or other energy production, provided the treatment takes place at a DAFM approved treatment plant and complies with strict biosecurity regulations, several of which relate to use of the residues as fertilisers.

The recent publication of draft EU standards for organic fertilisers, intended to create an internal EU market for composts and digestate based fertilisers, will assist to standardise safe use of recycled organic nutrients to substitute a portion of synthetic supplies. These standards, as well as waste regulations, require wastes to be processed separately from non-waste forms of biomass. The regulatory

[98] EU Basic Payment Scheme/Greening Payment Terms & Conditions, DAFM 2017.

[99] The Targeted Agricultural Modernisation Scheme which provides farmers with grant aid to improve and/or build a specific range of farm buildings or purchase equipment that may benefit their farm businesses.

[100] EU Regulation EC 1774/2002 which defines the rules for the collection, transport, storage, handling, processing and use or disposal of all animal by-products.

[101] EU ABP Regulations transposed into Irish Law by SI 252 of 2008 European Communities (Transmissible Spongiform Encephalopathies and Animal By-Products) Regulations 2008 and SI 253 Diseases of Animals Act 1966 (Transmissible Spongiform Encephalopathies) (Fertilizer and Soil Improvers) order 2008.

requirements[102] can be found on the DAFM website. Certain materials can be both an ABP and a waste and must comply with parallel legislation enforced by DAFM and EPA respectively.

6.3 Feedstock Supplies from Forestry

Woody biomass is one of the most commonly acknowledged sources of biomass fuel for bioenergy heating applications. The continuing development of the bioenergy market, supported by the expected introduction of an RHI, may result in an increased demand for conventional woody biomass fuels (e.g. chips, dried chips or pellets from wood or SRC energy crops). COFORD reports on the availability of biomass from the Irish forestry sector indicate that, depending on the market response to an RHI, current supplies of woody biomass may be insufficient to meet demand. Industry publications also reference concerns, however, that the fragmented nature of the private forestry supply chain may result in a significant portion of small forestry plot holders not completing interim thinning in accordance with best forestry practice. REBIOGEN speculates that this may be due to the cost of thinning relative to the availability of proceeds from thinning sales.

Woody biomass boilers are a mature, efficient technology, commonly reported to be capable of capturing > 85% of the calorific value of biomass fuels as useful heat output. The IrBEA report on an RHI for Ireland however identifies that the actual energy efficiency, however, is influenced by the load factor, which in small individual applications can be quite low, resulting in much lower efficiency factors. The most common designs target use of wood chip or wood pellet fuels, as these fuels are homogenous and subject to standard classifications that specify the relevant performance criteria of the fuels. The Wood Fuel Quality Assurance scheme in Ireland is one such scheme, that incorporates the definitions of wood quality that are relevant to the wider EU market. Use of woody biomass fuels that qualify with specifications established in the quality assurance schemes can avoid problems that arise in combustion, while also enabling feed automation. Where alternative sources of biomass fuels are utilised (e.g. brash residues, energy crops or straw), specialist technology designs may be required to adjust for chemical composition or moisture content to optimise efficiency, meet ELVs or avoid technical problems such as slagging, fouling or corrosion that may result from variations in feedstock character.

The cost of woody biomass fuel is highly correlated to quality specification as well as the calorific value and combustion characteristics of the fuel, which is impacted by the moisture and ash content, energy density and chemical composition of the fuel. SEAI Comparison of Energy Costs 2017 reports that the indicative costs for woody biomass in Ireland are:

- Softwood Pellets, Bagged Delivery = € 53.12 per MWh
- Softwood Pellets, Bulk Delivery = € 50.13 per MWh
- Softwood Chips, 25% Moisture, Bulk Fuel = € 45.02 per MWh
- Softwood Chips, 35% Moisture, Bulk Fuel = € 34.98 per MWh

The global market that has developed for supply of woody biomass fuels has a significant impact on the cost of supply in Ireland. The April 2016 BIOMASS SPOT[103] report indicated the following spot market

[102] www.agriculture.gov.ie/media/migration/foodindustrydevelopmenttrademarkets/animalby-products/applicationformsconditionsforabpprocessingoperations/conditionsforms/CN11ApprovalOperationBiogasPlants200617.pdf
[103] BIOMASS SPOT: Argus Biomass Markets Market Commentary, Weekly biomass markets news and analysis, Wednesday 6 April 2016, https://www.argusmedia.com/~/media/files/pdfs/samples/argus-biomass.pdf?la=en

quotes (translated from USD to Euro using relevant exchange rates) were available on the international market:

- Biomass pellets (fob) Rotterdam = c. €29.00 per MWh
- Biomass pellets (fob) East Coast Canada = c. €25.50 per MWh
- Softwood chips (fob) East Coast USA = c. €19.50 per MWh
- Palm Kernel Shells (fob) SE Asia = c. € 16.00 per MWh.

The differential between the Irish and international cost of supply may be due to slight variations in fuel specification as well as cost of transport, delivery and taxation. Shipping rates ranged from €3.00 to €8.00 per MWh depending on (EU vs US) point of origin while estimates of local transport costs from port to point of utilisation could range from €6 - €10 per MWh. A review of the futures quotes from the same source indicates that the pricing for wood biomass fuels is seasonal, reflecting that demand for heating fuels is driven by the average temperature for the time of the year.

Biomass Exchange (Feedstock Aggregation Hub)

The cost of indigenous supplies of woody biomass is driven in part by the structure of the supply chain as discussed above, as well as by the characteristics of the fuel generated. The cost of such fuels can potentially be reduced by overcoming fragmentation and improving functionality in the biomass supply chain. A possible role for a community bioenergy scheme may include creation of a biomass exchange to supply the anticipated growth in demand for a variety of solid biomass fuels. A biomass exchange can offer a secure market outlet for local biomass outputs, ensuring fair terms, transparent pricing and a broader source of supply are available to biomass users. It can potentially offer routes to export markets for biomass fuels qualifying under wood quality assurance schemes. A biomass exchange could integrate solid fuel production technologies such as:

Figure 24. Use of space and waste heat at the former NWWT plant to condition and supply biomass solid fuels may supplement revenue opportunities.

- Biomass Chipping: pulpwood and residues from forestry harvests, as well as energy crops such as straw, Miscanthus, willow or hemp, must be chipped and separated into standardised particle sizes to facilitate use in biomass boilers;

- Biomass Drying: can utilise the residual heat from bioenergy operations to remove moisture, reducing transport costs, reducing complications that may arise during storage and increasing calorific value of biomass fuels;

- Pelletisation: To increase marketability of biomass supplies and meet contractual standards (particularly for export sales), improving storage, handling and packaging characteristics as well as improving the energy value per m^3 of low-density materials the value of some biomass materials can be increased via pelletisation. This is a capital and energy intensive process however, and requires a very low-cost supply of dry biomass as well as a low-cost supply of energy (moisture content must be brought down to c. 12%) to remunerate the pelletisation costs;

- Torrified Biomass/Bio-coal: Torrefaction is a thermochemical treatment of biomass at 200 - 320 °C under atmospheric pressure and in the absence of oxygen with variable residence times between 5 and 50 minutes. This removes chemically bound water and oxygen. The process when performed under 280°C preferentially breaks down hemicellulose, forming gaseous products like CO_2, steam and multiple organic compounds – Acids, furans, phenols and straight chain hydrocarbons (tars) - known collectively as pyro ligneous acid and have value either combusted for heat or recovered as pure chemicals. A durable, energy dense, low-smoke fuel can be produced from the solids which is resilient to microbial decay and water absorption. Torrified feedstocks are compressed into pellets, briquettes or ovoid shapes that can be used as domestic/commercial fuel in automated boilers. Brash, bark, woodchip, sawdust or any other sawmill residues are suitable as feedstock, although to avoid process inhibitions biomass must have low level of contaminants and leaf material, and be as dry as possible. In Ireland both Arigna Fuels and CPL are involved in producing such fuels. Arigna's process increases energy content from 17 MJ/Kg (10% moisture) or 13MJ/Kg (30% moisture) to 21-25MJ/Kg while preserving 85% of embodied carbon. In Ireland torrified biomass will play an important role in the near-term transitioning of domestic solid fuels from peat and coal to sustainable biomass.

Development of a community based biomass aggregation hub may create opportunities to develop customised solid fuel blends, offering market opportunities to valorise non-conventional materials supplied as solid fuels for use in controlled circumstances. For example, brash is a forestry residue comprised primarily of small branches with a higher percentage of bark. It can be cumbersome to collect and transport as it is somewhat bulky. It is heterogeneous, with a variable appearance which may result in lower quality classifications under wood fuel quality assurance schemes. It may cause combustion issues if used in smaller, less tolerant biomass boilers designed for use of standardised wood chips or pellets. Cost of harvest (at roadside) has been estimated at below c. €50 /t, however the energy value is very similar to standard woody biomass, especially if densified. ATT technologies (for example pyrolysis, gasification and fluidised bed combustion) are less sensitive to variations in fuel standards, which may open markets for use of brash as a low cost solid fuel.

Brash may also be suitable for use as a blending component with certain wastes and residues, such as dried sludges, straw, spent mushroom compost, organic fines or poultry litter. Small scale pyrolysis tests undertaken at University of Limerick have indicated excellent capacity for renewable energy recovery from blends of brash and dried sludge, for example. Disposal of agri-food or municipal WWT sludges poses a problem nationally, and disposal currently attracts a gate fee. Production of customised biomass fuel blends may facilitate deployment of ATT that meets energy requirements at low cost, as well as providing an environmentally benign way to locally dispose of sludges, eliminating potential bio-contamination and avoiding concerns that can otherwise arise from disposal via land spread. ATT applications would have to be deployed in controlled circumstances pursuant to licensing conditions that ensure compliance with environmental regulations in respect of emissions.

In an economically viable catchment area, development of a biomass exchange to pre-treat and aggregate a variety of wastes and residues to render such materials more suitable for energy recovery has merit in the context of creating the necessary scale (to remunerate capital), minimise transport, and creating a low-cost, more homogenous energy feedstock. Feedstock blends may provide the means to mitigate feedstock costs, reducing cost of energy supplied over district heating or direct to large scale industrial requirements. Component that may be suitable for customised blend may include dry and moist/pasty materials such as RDF/SRF, sludges, AD digestates, and DAF FOG. Thermal processing of these fuels would need to be done in accordance with regulations which restrict (or require notification to EPA when doing so) the mixing of certain waste types and consequences for reclassification of waste codes.

A community scheme that deploys the infrastructure necessary to dry and process low cost feedstock for its own energy generation requirements can also leverage such infrastructure to supply more conventional biomass solid fuels for use in ESCO services or for sale to third parties. Impediments to the establishment of such a feedstock aggregation hub include the paucity of bioenergy outlets and lack of demand for bioenergy – which is tied to the availability of a RHI. In respect of solid fuels derived from waste, impediments to mobilisation include reluctance of potential industrial end users to bring waste material onto the premises or alternatively the requirement to achieve end-of-waste criteria to transport the material or process it without a waste license. The requirement for thermal processing to comply with IED criteria may also pose barriers to incorporation of waste materials in solid fuel blends.

If bioenergy applications are to provide a market outlet for valorisation of indigenous biomass, the cost of indigenous supplies will have to be competitive with the cost of biomass available on the global market. They must also compete with the cost of conventional energy carriers including low cost fossil fuels such as natural gas. Integrated community schemes that co-develop routes to market for thermal outputs together with energy generation infrastructure to generate the thermal supply will provide market outlets for biomass feedstocks.

Mobilisation of forestry sector feedstocks, however, will require a means to remunerate foresters while maintaining the cost of the energy supply at manageable levels. To achieve this REBIOGEN envisages deployment of ATT infrastructure that can use blends of forestry residues combined with -0- cost agri-food or gate fee generating municipal waste feedstocks. It envisages coupling infrastructure development with a community based sustainable forestry programme to source thinning and brash residues from foresters who participate as stakeholders in the community programme.

To encourage foresters to participate in community based schemes, consideration should be given to structuring supplemental payments for supply of thinnings. Funding for such a programme could be developed in the context of existing afforestation programmes, with payments structured as an advance against proceeds of harvest. REBIOGN noted the NPV of net harvest proceeds currently substantially exceeds the NPV of interim grant payments. It indicates there may be room for making additional payments that can be recouped at harvest. Structuring payment as an advance against harvest proceeds offers prospects of avoiding concerns that would otherwise arise in respect of exceed the state aid de-minimus thresholds. It would provide a source of funding which together with the proceeds of energy revenues may remunerate the cost of thinning.

Conclusion on Feedstock

Centralised community based projects can potentially address these concerns and barriers. Economies of scale can potentially overcome the trade-off associated with cost of feedstock aggregation. Agricultural manures/ sludges will require technology improvements to be more economically dewatered, facilitating a lower cost method of aggregation from multiple farms/industries. Agricultural residues can be heterogeneous, so technology optimisation may be required to improve the efficiency of energy recovery.

Energy economics generally precludes payment of high transfer prices to source feedstocks. A market structure is required to facilitate aggregation, collection and storage of feedstocks at minimal cost until required at the processing plant. An incentive will be required to encourage feedstock owners to mobilise these residues for energy and nutrient recovery. Small adaptations to the Greening Payment (Pillar 1), or other direct farm payment schemes, may offer a route to leverage the State's existing farm support expenditure to achieve feedstock mobilisation when such activities also help compliance with Nitrates Regulations and reduce GHG emissions in the agricultural sector.

Involving feedstock suppliers in the CSEC such that they are remunerated by a share of the energy sales proceeds (based on agreed formulae) rather than paid per unit of feedstock provided may prove to be a more affordable means to engage them in feedstock supply.

If market circumstances permit, Ireland can supply large volumes of purpose grown biomass, however the biomass supply chain is highly fragmented, which increases the cost of supply. Biomass production costs, as well as suppliers' transfer pricing expectations, can constrain the economic viability of procuring purpose grown biomass.[104] Structures of direct farm or forestry payments, and the economics of bioenergy relative to the economics of alternative uses for arable land, pose barriers to re-allocation of land to supply energy crops. Sustainability concerns arise over the actual life cycle GHG savings of energy recovery from purpose-grown biomass, although such concerns can be addressed by increasingly incorporating RES and sustainable plant nutrition in the supply cycle. Adaptations to the support frameworks governing land use, and underpinning farming and forestry, may be required to promote sustainable supply of purpose grown biomass for energy recovery.

To deliver the benefits promised by a vibrant bioenergy sector, a systematic programme is required to change the market paradigms, and overcome each of the existing barriers that constrain development of an efficient supply chain. The REBioGen project investigates how community based bioenergy projects may address these barriers, and in particular how a community based sustainable energy centre (CSEC), that integrates feedstock sourcing activities, clustered energy conversion technology and development of local marketing of energy outputs and that facilitates use of local residues and biomass resources to meet local energy demands, can overcome some of the barriers that constrain development of a vibrant bioenergy sector. Life cycle thinking will need to be applied and a thorough GHG balance undertaken on process configurations, feedstock supply chains and by-product end-use to ensure the environmental impact is reduced by any proposed alternative treatment routes. Appendix 1 discusses the issues around mobilisation of specific feedstocks in more detail.

7 TECHNOLOGY DEPLOYMENT AND DEVELOPMENT

The economic viability and impact from community based schemes can be optimised if they can be appropriately scaled and located close to market outlets as well as deploy infrastructure configured to optimise energy recovery in an efficient and timely manner. The CSEC illustration as discussed herein incorporates a range of technologies that are intended to work together to optimise efficiency of energy recovery from a range of heterogeneous residues and biomass feedstocks. The focus on low cost residues as well as aggregation of feedstocks contributes to economies and results in levels of energetic efficiency

[104] SEAI, September 2016 Bioenergy Supply in Ireland 2015 – 2035.

that can reduce the bioenergy LOCE. It offers prospects for managing treatment and disposal of residues and wastes in a manner compliant with the waste processing hierarchy, as well as prospects for introducing technologies that can improve nutrient recycling, and corresponding reduce environmental impact on water and soil quality from the agricultural sector.

The proposed CSEC model incorporates 2 primary technologies, along with ancillary technologies and development requirements that are discussed more extensively in Appendix 2.

7.1 AD Technology advancements and considerations for new deployments.

Conventional CSTR anaerobic digestion technologies are mature and market tested. Continuing technology development, however, is giving rise to business models developed to cater for more recalcitrant substrates including problematic heterogeneous waste streams and blends and legacy plants being adapted to remain viable in a post subsidy environment. The UK is deploying large food waste only digesters to treat municipal waste arising and several in-vessel composting operators across the continent have modified their plants to operate as dry digesters. Mechanisms to reduce the amount of CO_2 produced from the digestion process and utilise more of the feedstock carbon for methane production are being developed. Appendix 2 details several technology advancements and required adaptations to improve the productivity and economic viability of AD.

Opportunities arise to leverage the advancements on traditional, single phase, continuously stirred tank reactor (CSTR) systems to use multiphase digestion to split the main reactions that comprise the digestion process. This can improve carbon conversion and reduce retention time by half and consequently reduce required digester size - thereby reducing capital costs. Existing plants can be retrofitted to operate in this mode and their capacities increased in line with the faster throughput.

Digesters configured for biomethane production (as opposed to CHP) generate a significant parasitic heat demand arising from the requirement to pasteurise feedstock and maintain digester temperature. If amine scrubbing is used as the biogas upgrade technology, this may generate an additional parasitic heat demand. To maintain the emissions savings arising from AD, the heat load for these digester configurations can potentially utilise some of the biogas output, although REBIOGEN's review of this option indicates that it can impact significantly on the economic viability of the process. An alternative source of renewable heat would be to deploy biomass boilers. Small scale farm digesters may have to rely on conventional biomass boilers, however larger scale AD deployments may be able to incorporate more advanced technology such as fluidised bed units that can combust combinations of dried digestates, brash and/or biochar sourced from affiliated ATT deployments. Incorporation of these technologies may reduce the cost of the parasitic heat load while maintaining the GHG emissions savings at optimal levels.

Management of the digestates can become problematic for larger plants, particularly when feedstocks are drawn from a variety of non-agricultural sources, as organic fertiliser specifications generally preclude incorporation of digestates arising from feedstocks such as municipal WWT sludge, if digestates are to be certified as "organic". Additionally, land banks need to be sourced to accept the nutrients as per regulatory defined limits. These can be increasingly difficult to locate within short geographic distances of large scale digesters, especially as the residual P levels in nearby soils accumulate. The transport cost associated with delivery of digestates to more distant locations can be significant. A community scale digester requiring disposal of c. 55,000 of (solid and liquor) digestate would require c. 1,800 vehicle movements, which if priced at €250 per trip would incur a cost of c. €450,000 per annum. Community scale digesters require a digestate management plan, which can be optimised by development / deployment of technology to separate solids from liquors. The solids can be processed to produce an organic fertiliser or alternatively used as a biomass fuel (e.g., compost, blend, or thermally treat). See Appendix 2 section on Digestate Management technology.

Separated digestate liquors may be treatable using an adapted high rate low temperature AD technology (see HRAD section in Appendix 2) to generate additional biogas from the liquor's remaining COD load. Combined with a Nitrogen removal technology this can relieve some the requirement for haulage to spreadlands, once the process's effectiveness is tested and nutrient and organic load can be certified by Teagasc (and approved by DAFM and EPA), and if the effluent stream can be classified as "soiled water" according to criteria in regulations.[105]

A variety of processes exist for nutrient recovery from such effluent but are not widespread in the agriculture sector (see Appx. 2); adapting processes to farm scale or centralised AD has been done in recent years as policy drivers converge to make direct land spreading of digestates less attractive.

7.2 Facilitating ATT Deployment for RES-H or CHP.

The CSEC model discussed herein contemplates deployment of ATT technologies to facilitate moderate scale processing of biomass, wastes and residues for RES-H or CHP within reasonable distances of where they arise. Public attitudes toward incineration of wastes / residues is likely to be a major obstacle to deployment at present. ReBioGen's analysis concludes that consideration should be given to a national public consultation, designed to create a framework for planning and deployment of waste-to-energy ATT technologies. A general debate needs to be held outside the context of a specific deployment or site to counter "NIMBYism" and clarify in concise terms the costs, benefits, externalities, emissions levels, health risks, and impacts on amenity value of public spaces and other issues. The conclusions arising from the consultation could then inform a framework for safe deployment and operation of such technologies, which may would assist timely authorisation of planning and licensing.

ATT technologies are new to market. Some technology testing and validation is still required – particularly dealing with the removal of tars and particulates to meet engine manufacturers' specifications when syngas from processing of mixed waste feedstocks is combusted in power generation equipment. Pilot scale testing will help in the validation process to establish operating parameters and obtaining data required for modelling full scale deployments.

Additional testing and validation is required to characterise the emissions arising when post-conditioned syngas generated from mixed-waste feedstocks is combusted in power generations equipment. Additional testing and validation is required to characterise the emissions arising from combustion or gasification of waste-derived biochar. Testing and characterisation of emissions will provide the relevant data to determine compliance with the emissions criteria in the IED and if, or what type of, abatement technology may be appropriate as well as the type of monitoring programme that will be required.

REBIOGEN's discussions with stakeholders indicate that there is currently a deficit within the country in respect of emissions testing equipment required to certify the character of emissions. Stakeholders currently must contract for certification services from the UK or abroad at a high cost, to certify the

[105] Statutory Instruments S.I. No. 378 of 2006 European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006.

character of ATT emissions. Procurement of emissions certification equipment, and deployment at an appropriately qualified institution, would be an enabler for increased deployment of ATT technology, which would contribute to community scheme development. A domestic resource would also assist in designing an independent monitoring and validation programme that could contribute to public confidence in respect of emissions arising from ATT, including the potential health hazards or lack thereof, concerns over which might arise from increased deployment of ATT technology.

One of the advantages of using ATT at a moderate scale (5-10 MW thermal input) in distributed waste processing is that it is more likely that process heat can be valorised. The inclusion of such heat uses in the RHI eligibility criteria will enhance the viability of the CSEC model but will come with conditions on effectiveness, additionality, etc. In this context the drying of certain residual feedstocks should be considered an eligible use of heat, after considering the impacts of alternative treatment pathways for those residues. A life-cycle energy and greenhouse gas balance will need to be undertaken on comparative treatment routes to establish their relative merits. Drying technologies which recover the latent heat of evaporation without releasing waste heat to their surrounding should be considered for part of the CSEC equipment cluster for drying feedstocks for processing on-site and in some cases for production of other feedstock blends which may be sold as fuels to third parties.

Developing a nutrient recovery technology for ash derived from Cat. 2 & 3 ABP and other soil compatible feedstocks which can be deployed at a scale to suit distributed plants will reduce the need to send ash to landfill and avoid transport of ash to overseas recovery plants as occurs today, mainly to the Netherlands where very large-scale plants are located.

Further investigations of impacts of ash recycling as an aggregate substitute will contribute to the creation of closed material loops and eliminate the need for landfilling some of the ash residues from certain energy recovery processes.

7.3 Thermal or CHP Energy for Individual Applications

Larger scale biomass boiler technologies are being discussed as a means to supply steam and hot water (or CHP) energy for individual plant or large energy user applications exhibiting constant heat demands. The boiler monitoring and attendance requirement, as well as the efficiency with which biomass boilers convert energy is due to a great degree to the quality of feedstock utilised. Biomass boilers operate most efficiently using homogenous wood pellets or chips that comply with quality control specifications such as that published under IrBEA’s Wood Quality Fuel Assurance programme.

Use of wood fuels for which biomass boilers are designed is a pre-requisite for efficient and fault free operation, as well as for economic benefit, as biomass boiler operation will be subject to efficiency and emissions criteria to be eligible for RHI.

Biomass Boilers
The conditions of the new RHI may stipulate the use of equipment with an emissions certificate as occurs in the UK for both the domestic and the non-domestic sector. To be granted the certificate manufacturers must have an accredited lab certify that their equipment does not exceed the following emission limits:

- 30g PM/GJ net thermal input;
- 150g NOx/GJ net thermal input.

Ireland may adopt the parameters and ELVs of the UK RHI and acceptance of certificates that appliance manufacturers currently have for the UK or develop its own ELVs or parameters, which may be different for urban and rural areas.

Additionally, once transposed into national legislation (required by Dec 2017) the Medium Combustion Plant (MCP) Directive[106] will dictate ELVs for dust, NOx and SO_2 emissions from combustion plants with a total rated thermal input of ≥ 1 MW and < 50 MW and will also stipulate that CO emissions from MCPs are monitored. For new MCPs, ELVs will be required to be complied with from the 20th December 2018 onwards and for existing MCPs from either 2025 or 2030 onwards, depending on their capacity.

It is likely that most of future commercial and industrial scale biomass development will fall within this capacity range, depending on the structure of the new RHI (existing plant in this scale may have ELVs applied through licence conditions, with an individual set of ELVs being determined by the EPA). Existing biomass facilities within this range include Aurivo, Ballaghadereen, Co. Roscommon (12 MW), Astellas, Killorglin and Co. Kerry (1.8 MW). Development of Mayo Renewable Power plant (42.5 MW) has been shelved. There is an exemption to the SO_2 ELV for plants burning only woody biomass.

Appliances up to ≤500 kW (rated by heat output) may be currently designed in accordance with the voluntary standard EN 303-5:2012 and thus will operate within the remit of the ELVs required by that standard. From 2020 and 2022, local space heaters and solid fuel boilers up to 500 kW will be required to comply with the eco-design requirements of Directive 2009/125/EC.

Community models structured to provide ESCO services for larger scale customers exhibiting a constant heat demand will be required to meet the relevant boiler efficiency and emissions specifications.

7.4 General Technology Deployment Issues

Clustering Technologies to Create Scale and Improve Energy Efficiency

Clustering technologies within in a community catchment area will facilitate co-processing a range of heterogeneous residue feedstocks sourced from local suppliers at zero (or very low) cost, minimising the requirement for securing homogenous feedstocks that compete with food production or have attractive alternative routes for valorisation. It will offer prospects for earning sustainable gate fees in the face of increasing competition for energy-rich residues. It will facilitate development of key processing and distribution infrastructure that will subsequently support viable integration of large scale purpose grown feedstocks, offering prospects of scale, all key considerations in respect of long term economic viability.

Clustering technologies does not necessarily imply co-location within the same community site, but rather situating each technology deployment in a manner that can access a relevant market, while at the same time facilitating efficient use of one output in a related technology deployment. An example that might be relevant to the illustration discussed herein would be use of AD digestates as a portion of a solid fuel ATT blend, or alternatively use of biochar outputs from waste-fuelled ATT as a fuel to supply the parasitic load for AD. *C*lustering technologies into integrated, synergistic systems will reduce the cost of RES energy generation by improving energy efficiency, utilising the full carbon value of biomass

[106] EU Directive 2015/2193. European Parliament (2015) eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015L2193

feedstocks and by efficiently utilising waste heat, either to improve electrical output via waste heat recovery technologies (See Appendix 2. section on WHR) or for process energy facilitating qualification with EU "high efficiency" criteria required for subvention of CHP (as per CHP Directive).

A cluster approach will facilitate aggregation of feedstocks from several different sources of supply, creating scale from an otherwise fragmented feedstock supply. A "cluster" is of a scale that will attract serious industrial interest, offering a viable model for community based distributed energy generation that can be rolled out on a national basis underpinning a viable national bio-energy strategy (possibly structured as a public private partnership (PPP). A CSEC designed in a manner that can be replicated in communities across the country, will optimise opportunities to attract large scale EU capital supports from EU support programmes and minimise incremental subvention required from the State.

Siting Community Bioenergy Schemes

The rationale for the proposed CSEC model is that several process technologies treat different types of feedstocks to convert them into several energy carriers in such a way that the colocation of processes creates synergies which increase efficiency above that which individual processing and conversion plants could achieve. Siting ATT development close to market outlets for heat or the gas grid is a crucial consideration in planning ATT because it is less costly to move feedstocks than to deploy production technology remotely and try to bring market outlets to the gas source. Some urban wastewater treatment plants or sites adjacent to them may represent ideal locations for new ATT deployment provided they can be licensed to accept external residues for treatment; waste reception, storage and treatment areas can be separated by a partition from water treatment activities.

Licensing and Permitting

Community based bioenergy operations will require planning permission, which will require an assessment of the possible environmental impact, as well as licensing under the relevant regulations. The State is responsible for ensuring compliance with industrial emissions, pollution prevention and control requirements. The purpose of waste facility licenses and permits is to ensure that the operations taking place are appropriate in the context of the local environment. They contain conditions that require the holder to install site infrastructure, keep records and undertake environmental monitoring. They dictate what wastes can be handled and the times they can be accepted among other requirements regarding emissions limit values (ELVs), etc. ATT plants that process more than three tonnes of waste per hour fall within the industrial emissions licensing regime and are also required to comply with the EU (Waste Incineration and Waste Co-Incineration Plants) Regulations 2013. These regulations also apply to AD facilities with a capacity of more than 100 tonnes per day. An application needs to be made to the EPA for such a facility.

In the case of an ATT plant processing less than 3 tonnes per hour (which is the case with the CSEC illustrated herein) a waste license must be sought from the EPA as per the Waste Management Act and the Waste Management (Licensing) Regulations 2004. This is also the approval route for AD facilities with a capacity of less than 100 tonnes per day.

Where an AD plant accepts less than 10,000 tonnes for treatment annually a waste facility permit can be sufficient. The permit application is made to the county or city council in which the activity is to take place; such permits are issued under the amended Waste Management (Facility Permit and Registration)

Regulations 2007. However, where the local authority itself is to be an operator or partner in a proposed waste management activity which falls into the regime for which a waste facility permit is required it cannot self-regulate; and in such cases permitting and regulatory oversight responsibility transfers to the EPA.

National R&D Infrastructure
The CSEC project will provide infrastructure that can be leveraged for participation in ongoing technology development programmes, offering a testbed to investigate routes to improve RES technology efficiency, further mitigate environmental impact from waste and residue processing, or develop new routes to market for RES outputs. Ongoing research can continue harnessing sources of R&D funding.

Appendix 2 discusses available technology, issues for consideration re CSEC and areas requiring further R&D.

8 FACILITATING FUNDING AND ACCESS TO FINANCE

Bioenergy deployments are capital intensive, requiring access to finance for procurement, installation and commissioning of plant and equipment, as well as for working capital. Access to private funding is uncertain, especially in immature markets that are not able to demonstrate an operational or investment history. While community base structures in other jurisdictions have been able to demonstrate an ability to attract a certain level of risk capital, they have rarely been able to fund larger-scale infrastructure deployments. Additionally, equity investments rarely fund 100% of the capital required for infrastructure deployment. They are most often leveraged with borrowings to generate a suitable risk / return profile for the investor. Project completion is heavily reliant on availability of borrowings, which in respect of bioenergy infrastructure deployments is constrained.

The inability to access capital poses a significant barrier to development of community based projects. REBIOGEN reviewed the commercial borrowing criteria that must be satisfied to access borrowings from the private financial sector. These well documented criteria include, amongst other matters:

- A revenue de-risked revenue stream comprising a secure off take for RES OUTPUTS at a tariff that can underpin economic viability over the (risk adjusted) economic life of a project;
- Secure and cost-effective access to market outlets, including regulatory frameworks that provide preferential access to power or gas grids (or other contractually assured distribution routes);
- Deployment of de risked and market proven technology;
- The contractually assured access to feedstocks over the (risk adjusted) economic life of a project;
- Security in respect of the loan balance that may include a security interest over the site and assets as well as personal guarantees from the equity partners / project developer.

These criteria are applicable to mature businesses operating in established markets. As the market matures and regulatory and commercial frameworks are finalised, it is likely that community based renewable energy projects will be able to source commercial finance. At commencement, however, given the immaturity of the Irish market, it will be difficult for a community based project to satisfy conventional commercial criteria.

Requirement for Public Funding

Bioenergy drivers are predominantly societal/environmental rather than commercial. Accordingly, manifestation of the benefits that can be derived from development of a vibrant bioenergy sector requires government intervention. REBIOGEN's review indicates community based projects will require support at multiple levels to make measurable contributions to sustainability objectives, including:

- Development of community based bioenergy projects will initially require public finance to support capital infrastructure deployment. Finance vehicles can potentially be structured as equity contributions, as grant aid, or as soft loans and/or loan guarantees;

- Introduction of market supports for energy outputs, such as RHI or RESS, the requirements of which are discussed above;

- Small adaptations of existing support programmes such as direct farm payments or interim forestry payments that are required to change supply chain paradigms and stimulate aggregation and mobilisation of feedstock supplies.

Similar challenges have arisen in other jurisdictions. As noted herein, other jurisdictions have overcome the financing issues by developing state sourced finance mechanisms for community based projects. A KfW style bank would be a significant enabler of community based projects. A combination of project finance may be required until such time that conventional finance criteria can be met.

Financial supports will need to be matched with adaptations to regulatory frameworks, as well as policy initiatives required to stimulate supply chain development, and provide secure (and preferential) routes to market for RES outputs. REBIOGEN's review indicates that as the markets mature, and as the policy initiatives designed to support community based projects mature, it is likely that conventional forms of commercial finance will become available. Properly structuring the state supports may ultimately allow the State to exit. The corresponding remuneration may offset the costs of market supports, minimising overall cost to the State.

The current market dynamic offers stakeholders an opportunity to leverage access to substantial EU funding being made available to support the transition to a low carbon economy. It offers a near term opportunity to fund infrastructure that can decarbonise the energy mix, improve waste management, mitigate environmental impact from agriculture as well as create rural employment.

Ongoing expenditure on waste or renewable energy infrastructure, public or otherwise, that does not optimise the environmental performance or harness the potential resource value for energy recovery should be reviewed in the light of EU funding mechanisms (e.g., InterReg, LIFE, ELENA, JESSICA, InnovFin) that are available to support transition to a more sustainable, circular low carbon economy. Funding from established EU programmes, provided in the form of grants, can be accessed by leveraging private and State co-funding, with the proceeds used to deploy suitable energy conversion and distribution technology in compliance with established programme criteria.

There are several potential sources of funds to consider in respect of support for community based bioenergy schemes. These include:

Ireland Strategic Investment Fund - The Ireland Strategic Investment Fund (ISIF), managed and controlled by the National Treasury Management Agency (NTMA), is an €8.0 billion sovereign development fund, the successor to the National Pensions Reserve Fund. The fund has a statutory mandate to invest on a commercial basis in a manner designed to support economic activity and employment in Ireland and has a long investment time horizon and therefore can act as a permanent or patient source of long-term capital. It has flexibility up and down the capital structure and can therefore meet changing capital needs and gaps in the marketplace. It has strong connections in both the public and private sectors and is uniquely positioned to make connections across multiple industry players developing opportunities that might otherwise go unrealised.

ISIF has a dual mandate of Investment Returns and Economic Impact meaning all transactions need to generate both risk adjusted commercial returns and economic impact in Ireland. Each investment must pass the commerciality test – this requirement imposes a direct discipline on the consideration of each investment opportunity.

ISIF is open to investment in projects, companies and funds with Irish activities and the potential for significant expansion, innovation and value improvement according to the NTMA's marketing material. Investments may take the form of new or established funds or projects and companies that exhibit development characteristics, such as significant market opportunity, and can participate in all levels of a project or company's capital structure including senior debt, mezzanine debt, traditional private equity, venture capital, preferred equity and 'special situations' e.g. turnaround, buyouts.

Investments are neither scale nor sector specific: energy including renewables, storage and emerging technologies are listed among the target sectors. The CSEC model prototype may fit the profile of candidate investment for the fund for among other reasons it will invest where there is additionality i.e., where the economic benefits would not have arisen without the ISIF's contribution, that may be the case for the CSEC as its novelty and interaction with multiple economic sectors makes it unattractive to risk averse conventional finance sources.

EIB's InnovFin **-** The European Investment Fund's (EIF) central mission is to support Europe's micro, small and medium-sized businesses (SMEs) by helping them to access finance. EIF designs and develops venture and growth capital, guarantees and microfinance instruments which specifically target this market segment. In this role, EIF fosters EU objectives in support of innovation, research and development, entrepreneurship, growth, and employment.

EIF operates the "InnovFin SME Guarantee" to provide guarantees and counter-guarantees on debt financing of between €300k and €7.5 million, which are designed to improve access to debt finance for innovative SMEs and small midcaps (up to 499 employees). The scheme has been rolled out through financial intermediaries (banks and other financial institutions) in EU Member States. Under the SME Guarantee, financial intermediaries will be guaranteed by the EIF against a proportion of their losses incurred on the debt financing. In Ireland both *Frontline Ventures Fund II Limited Partnership* and *ACT V Venture Capital Fund* participate in the scheme.

InterReg and Life EU Project Funding - There are several established EU funding programmes designed to support collaborative approaches to sustainable economic development. These include the InterReg programme, designed to respond to the key challenges identified in the cooperation program for each area (e.g., SMEs innovative capabilities, energy security and supply, resource and materials efficiency, or vulnerability to climate change events). Under the InterReg programme projects are conducted collaboratively between multidisciplinary partner organisations in a defined programme area which consists of several regions in a similar geographic area or facing similar problems due to their geography.

Eligible costs include salaries, travel, equipment, consultants, durable goods and infrastructure, of which InterReg provide up to 65% (60% for NWE area). The consortium must provide the matching funding, part of which can be in the form of in-kind contributions such as salaries of staff dedicated to the project, land and equipment.

Other EU programme funding options include the LIFE programme, the EU's funding instrument for the environment and climate action. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects relating to three priority areas: environment and resource efficiency; nature and biodiversity; and environmental governance and information. The 'Climate Action' strand covers climate change mitigation, adaptation and climate governance and information. Unlike InterReg LIFE does not need project consortia to include partners from other countries, although they can be included when there is a strong justification only and in such cases it does strengthen the proposal's merit. The matching funding rate is 50% and expenditure on eligible capital equipment must be claimed as depreciation is covered.

Bespoke ERDF Mechanism - The European Regional Development Fund (ERDF) is a European programme that offers funds to Member States for pursuit of certain broadly defined objectives. These objectives include the transition to a low carbon economy, resource efficiency and other sustainability objectives as outlined in the EU Sustainability Policy. A proportion of the ERDF funding is managed under the DAFM agricultural and rural development remit, with the balance of the funding managed via Operational Programmes submitted for approval by the managing authorities, which in Ireland include the Southern & Eastern Regional Assembly and the BMW Regional Assembly. Consideration should also be given to introduction of a bespoke channel of ERDF funds to co-fund establishment of community waste-to-energy processing infrastructure. The allocation of ERDF funding can be negotiated by the Regional Assemblies in accordance with the priorities of their existing Operational Programmes. While this will require approval at EU level, REBIOGEN's conversation with the DG Regional Development indicated such proposals would be consistent with DG Regional Development objectives.

One ERDF mechanism that is available to the respective managing authorities is the Joint European Support for Sustainable Investment in City Areas (JESSICA). JESSICA is a policy initiative of the European Commission, developed with the European Investment Bank (EIB) and supported by the Council of Europe Development Bank, which leverages funding sourced under the ERDF programme together with proceeds of funds from the EIB and the State, to guarantee borrowings that fund infrastructure required for sustainable urban development and regeneration. Amongst others, projects supported by JESSICA funding can include energy efficiency improvements, urban infrastructure (e.g. transport, water/waste water, energy) and redevelopment of brownfield sites.

The JESSICA programme funding can be comprised of a combination of loans and venture capital. It can be structured as a revolving financing programme for revenue-generating projects that, for reasons of market immaturity or other financing market failures, are not able to attract conventional financing. It may be possible to adapt the JESSICA programme to provide a large-scale funding mechanism for community based infrastructure such as replication of the CSEC project outlined herein. Development of this finance mechanism may address the market failure in respect of access to commercial finance, and may underpin a measurable contribution to Ireland's sustainability objectives.

To introduce the JESSICA programme in Ireland, several requirements must be addressed:

- A needs analysis was undertaken by PWC in 2013 to establish the need for such a programme in Ireland;
- Regional Assembly operational programmes must allocate a portion of the ERDF funding block toward a JESSICA financial instrument. Both Regional Assembly Operational Programmes 2014 - 2020 include references to this possibility, however the introduction has not yet been triggered.
- A budget line item within the State budget (and a corresponding budget holder) must be established to account for the proceeds and expenditure of the JESSICA funds;
- The JESSICA programme requires identification of matching sources of funding for the ERDF allocation. This can either be state sourced or privately sourced.
- Appointment of a managing agent may be required to assist with project evaluation and documentation. There is well established governance and operational documentation around organising and managing the investments and financing and the Managing Authorities have the option to appoint a fund manager such as the European Investment Bank.

Cost / Benefit of State Aid

As an alternative to deploying a combination of capital infrastructure finance, market support and small incentives to development of the supply chains, the State can rely solely on use of per unit energy subsidies (REFIT/RHI) to create significant demand such that energy consumers force migration to renewable options. This model has been successfully deployed in other EU markets such as Germany, Italy and the UK to stimulate deployment of bioenergy generation infrastructure. The downside of relying solely on market supports is that it creates a dependency, maintaining market structures that are highly reliant on ongoing state subventions. It avoids the market reforms that are required to make bioenergy more efficient, which subsequently eases the transition to market-led structures. It is also likely to result in greater net cost to the State as it eliminates any chance to recoup investment in supply chain development. This maintains continuing pressure on the PSO levy, which impacts industrial competitiveness and household expenses.

Irrespective of the form(s) of aid deployed, a question arises as to whether the State should provide state aid to support bioenergy. The Energy Efficiency Directive lays down a series of principles that are to be considered when evaluating the application of state aid for the development of district heating networks.

To understand the societal cost / benefit relationship that might be expected from deployment of significant levels of state aid in community based district heating, REBIOGEN's undertook a very preliminary societal cost-benefit analysis of the CSEC model reviewed herein. The review was limited to analysis of CHP derived from ATT waste-to-energy, with the thermal energy distributed via district heating. It was compared to a baseline where the thermal demand is supplied via heating oil, with power sourced from the grid and municipal solid waste transported to the Poolbeg incinerator in Dublin.

The preliminary review indicated a significant societal net benefit arising from local CSEC model. While the incremental state aid requirement was significant, and the long-term cost of bioenergy was higher than the cost of fossil fuelled energy, significant benefits arose in respect of:

- the lower costs associated with local processing of waste;

- the reduction in GHG emissions arising from the transition to renewable energy (both thermal and electric power);
- the reduction in external environmental costs associated with transition away from fossil fuels to more sustainable forms of energy; and most importantly
- the economic benefit derived from displacement of imported energy with domestically sourced energy.

While REBIOGEN attempted to apply the provisions of Appendix VIII of the Energy Efficiency Directive (EED), in undertaking this analysis, it was outside of the scope of this project. REBIOGEN notes that valuation of the benefits associated with displacement of imported energy with domestic sources of energy are not specifically referenced in the EED discussion on costs and benefits. The EED principles do reference that all externalities should be considered when undertaking an analysis, and REBIOGEN considers that this benefit is a fundamental driver that justifies the provision of state aid for domestic community energy projects. REBIOGEN notes that a similar concept was included in a Scottish review of the cost benefit associated with state aid for windfarms. It acknowledges, however, that it was unable to find an accepted scientifically validated “multiplier coefficient” that could be used to value the economic impact arising from displacement of imported energy with domestic supplies. Time limits and other constraints posed barriers to validation of the results via a comprehensive and scientifically robust manner, and accordingly such results should be viewed as a contribution to the discussion in respect of a framework structure that would be appropriate for the review of costs and benefits relevant to community based bioenergy schemes, rather than a definitive determination of the costs and benefits arising therefrom.

Additionally, given the time constraints arising in respect of the project, REBIOGEN was unable to complete a preliminary review of societal costs and benefits against alternative technologies such as heating pumps, although REBIOGEN noted that, given the cost of heating pumps, the state aid required to transition community residents from low cost oil boilers to higher cost heat pumps may well exceed that required to construct a district heating network, especially if heat pumps were deployed in a comprehensive manner to meet the entire community demand.

REBIOGEN’s review highlights the need for a framework suitable for reviews of specific circumstances relevant to individual market circumstances.

Justification for PPP Model

REBIOGEN reviewed the RED II proposals relating to the definition of community based projects. In an Irish context, given the immaturity of the market, larger scale community projects may be required to make measurable and timely contributions toward sustainability objectives. Substantial financial and technical resources, as well as efficient governance and management, will be required for such projects. Sizable projects may require a developer-led model that can source contributions from commercial interests to provide the requisite financial resources and technical skills.

Additionally, commodity priced energy outputs are low value, and the energy proceeds may be insufficient to remunerate transfer pricing in respect of feedstock supplies. Traditional transfer pricing business models may be inappropriate, giving rise to risks of non-performance. To secure feedstock supplies, site access, services and otherwise develop an integrated project in a coherent manner, a collaborative joint venture agreement may be required to specify rights and obligations accruing to each participant in the context of their role as a stakeholder.

REBIOGEN's review of the organisational structures proposed under the RED II directive indicate that a "purist" interpretation of the criteria may pose a potential barrier to sourcing private investment, as the broad-based community ownership, governance and management structures may give rise to concerns over conflicting objectives and inefficient /ineffective decision making. REBIOGEN notes that to attract private investment while still complying with the criteria proposed under RED II, that it may be prudent to establish State criteria that allows, amongst other matters:

- Community groups to be organised as one component of a collaborative joint venture, with specific commercial rights and responsibilities including a timely dispute resolution framework detailed under commercial contract or JV governance documents. Participation of a broad sector of community stakeholders may be best organised under a special purpose entity organised to comply with the requirement of the recast RED II,[107] which may include participating feedstock suppliers from the farming and forestry community as well as other community stakeholders;

- Appointment of a Trusted Intermediary to represent the interests of community participants in a collaborating JV such as the Local Authority or the associate energy agency, who could also assist with sourcing and management of public finance and hold infrastructure in public ownership, if required;

- Commercial parties with (broadly defined) community interests should be allowed to participate as qualifying community stakeholders, irrespective of size (e.g. dairy co-operatives or large energy consumers should be able to participate within the community group, for example).

A collaborative structure could be organised as a Special Purpose Public Private Partnership Vehicle (PPP SPV), governed pursuant to a PPP venture agreement that would establish the rights and responsibilities of each of the participants. The venture agreement would be expected to limit the Local Authorities' operational role and corresponding risk to avoid concerns arising in respect of activities contrary to transitioning public policy. It may, however, provide that the Local Authority own some of the infrastructure, especially given the level of public financing that will initially be required to fund deployment. It would provide the conditions pursuant to which the local commercial and community interests can increase their ownership stakes as markets mature and conventional financing sources become available. The venture agreement would establish a governance mechanism and management programme to be overseen by a Board of Directors selected from amongst public and private stakeholders. It would specify infrastructural and operational responsibilities, as well as project management responsibilities, which would likely require appointment of an infrastructure operator, skilled in technology operations and responsible for delivery of business plan, as well as for compliance with regulatory requirements. Ideally the project operator would be selected from amongst candidates that have ties to the community.

State and EU investment grants, operational supports structured as premiums per unit-energy generation as well as publicly sourced equity contributions and guaranteed debt finance may all be required to complete construction of the illustrated model. EU regulations[108] governing the application and

[107] *Proposal for a Directive of The European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources*

[108] *COMMUNICATION FROM THE COMMISSION; Guidelines on State aid for environmental protection and energy 2014-2020; (2014/C 200/01)*

notification of the EU Commission in respect of State Aid define maximum State Aid intensities that are allowable in support of renewable energy and environmental activities.

The state aid regulations allow up to 65% of the eligible capital and operational costs of renewable energy generation to be funded via state aid, a level that can be increased to 100% of eligible costs if the method used to allocate state aid is a competitive bidding process. Additional criteria limit state aid for CHP plants to those plants that meet the HE criteria. State aid rules allow funding of up to 55% of waste management applications to be funded via state aid, which if used in waste-to-energy applications must comply with the provisions of the waste management hierarchy. The regulations allow state-aid funding of up to 100% of the eligible costs for investment in renewable energy infrastructure such as district heating networks and biogas pipelines.

For purposes of calculating state aid intensities, all forms of aid relevant to an application must be aggregated. The rules, however, have been developed as if each type of application is a separate and discreet activity. In the context of integrated projects such as the CSEC illustration discussed herein, the rules can be very difficult to apply, especially given the different requirements, contingencies, limits and levels of aid allowable in respect of the different individual applications.

The state aid rules also define the maximum levels of state-aid that can be granted to any one undertaking without notification of the EC (i.e. €15m may be granted to any one undertaking without notification to the EC which REBIOGEN interprets this to mean any individual participant in a project rather than any individual project in its totality).

Structuring a community based model as a JV with the interaction of discreet components governed by commercial contract, rather than as a separate legal entity, may provide a route to define the discreet components of an integrated project as well as the designated state aid recipients. It will enable the individual components of a project to be integrated into a coherent working system to generate the efficiencies and other benefits discussed herein, and it may also enable application of the State Aid rules to each individual component of a project, optimising the overall availability of aid while complying with the regulations.

9 IMPACT

Development of a vibrant bioenergy sector will contribute toward decarbonising the energy mix, and achievement of the National Renewable Energy Action Plan (NREAP) targets as well as the progressive obligations reflected in the 2030 EU Climate Change and Renewable Energy Framework. Bioenergy applications offer routes to valorise biomass resources that will contribute to rural economic development, compliance with Nitrates Directive and with progressive EU waste management obligations established under the Waste Framework Directive. It will improve energy security, the tax base and the balance of trade as well as contributing to economic health and competitiveness by avoiding environmentally-derived constraints imposed on economic expansion or unnecessary costs, such as non-compliance penalties, otherwise imposed for failure to comply with legally binding targets.

An overview of the impact that could arise from developing 10 community based schemes as illustrated herein over a 10-year period would reflect:

9.1.1 Contribution to GHG Mitigation and Renewable Energy Objectives

Ten local CSEC projects organised as described herein would generate:

- 552,000 MWh_T of saleable thermal energy, at least 70% of which would qualify as RES H, displacing c. 47,500 toe and mitigating an estimated 99,000 tonnes $CO_{2\text{-eq}}$;
- 125,650 MWh_e of saleable electricity exported to the grid, at least 70% of which would qualify as RES E, mitigating c. 58,000 t $CO_{2\text{-eq}}$;
- 201,400 MWh of renewable gas, displacing c. 17,300 toe of natural gas and mitigating c. 41,000 t $CO_{2\text{-eq}}$.

(*Note: CO_2 mitigation calculations are estimated based on a non-life cycle basis using SEAI 2015 emissions factors)*

9.1.2 Contributions to Waste Management, Agricultural and Forestry Objectives

Ten local CSEC projects as illustrated herein would process

- 217,500 tonnes of locally sourced MSW solid wastes offering an alternative to transport to large scale urban waste incineration projects;
- 40,000 t of WWT sludge;
- 60,000 t of source separated food waste;
- 120,000 t of manures and other ABP; and
- 45,000 t of forestry residues.

9.1.3 Contribution to Rural Economic Development

Ten local CSE projects as illustrated herein would generate:

- Capital investment of c. €500m
- Annual Revenues of c. €85m
- Annual Operating Cash Flow (EBITDA) of €38.7m
- 280 FTE positions

10 APPENDICES

APPENDIX 1: BIOENERGY FEEDSTOCKS

APPENDIX 2: BIOENERGY TECHNOLOGIES

APPENDIX 3: DISTRICT HEAT NETWORKS

APPENDIX 4: BIOMASS RES H SUPPLIED VIA DISTRICT HEAT NETWORKS

APPENDIX 5: BIOMASS RES H SUPPLIED VIA ESCO SERVICES

APPENDIX 6: ROUTES TO MARKET FOR BIOGAS

APPENDIX 7: BIOMETHANE PRODUCTION

APPENDIX 8: ILLUSTRATION – AN INTEGRATED CSEC MODEL

APPENDIX 9: CONTRIBUTORS TO REBIOGEN