Transition Kerry's Sustainable Energy Community Roadmap

An Action Plan for County Kerry's Transition to 100% Renewable Energy Supply

"Our aim is to support the community of Kerry develop a strong, positive vision of its sustainable energy future and plan the journey for its realisation."

Consultancy Team:

XD Sustainable Energy Consulting Ltd
Lead consultants and co-ordinators

Author: Xavier Dubuisson, xavier@xdconsulting.eu

Limerick Institute of Technology – Tipperary
Sustainable energy community development specialists

Author: Seamus Hoyne, shoyne@tippinst.ie

Aalborg University, Denmark
Energy planning specialists

Author: David Connolly, david@plan.aau.dk

Samsø Energy Academy
100% RE Community pioneers

Author: Peter Christensen, pc@energiakademiet.dk

The study was co-funded by:

Table of Contents

List of Figures

List of Tables

Abbreviations

O&M: operation and maintenance

SEC: sustainable energy community

PES: Primary energy supply

GHG: greenhouse gas(es)

CHP: combined heat and power

IRES: intermittent renewable energy sources

EV: electrical vehicles

V2G: vehicle to grid

NREAP: National Renewable Energy Action Plan

NEEAP: National Energy Efficiency Action Plan

kWh, MWh, GWh: kilowatt-hour, megawatt-hour (1000 kWh), gigawatt-hour (1000 MWh) – energy units;

kW, MW, GW: kilowatt, megawatt, gigawatt – power units.

RES: Renewable Energy Sources

RE: Renewable Energy

REScoop: Renewable Energy Co-operative

Introduction to the Study and Executive Summary

Introduction to the study

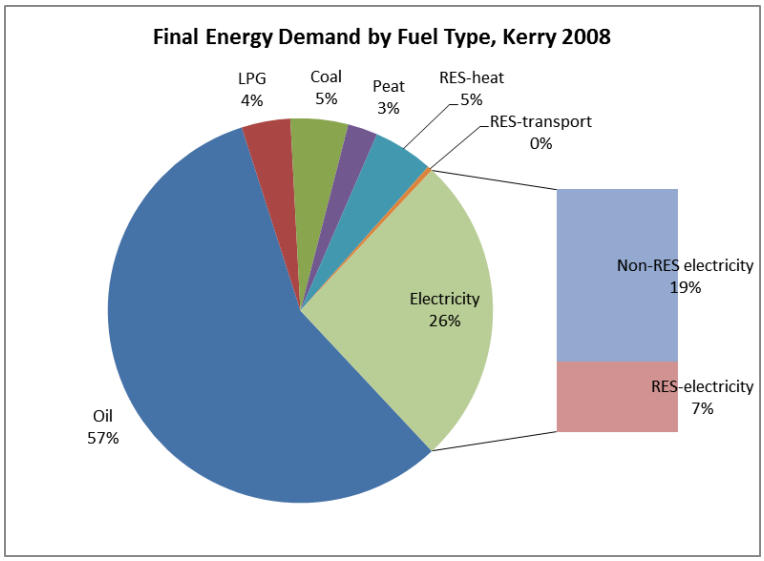
This study was commissioned by Transition Kerry, a community initiative aiming to accelerate the change to a more resilient, sustainable future for the population of Kerry. The study was undertaken by a consortium led by XD Sustainable Energy Consulting Ltd and completed in November 2013, and was supported by Kerry local authorities as well as North East Kerry Development Partnership and South Kerry Development Partnership with Leader funding.

The overall objective of the study is to help the community of Kerry develop a strong, positive vision of its sustainable energy future and plan the journey for the transition of the county towards 100% renewable energy supply by 2030. The specific objectives of the study were to:

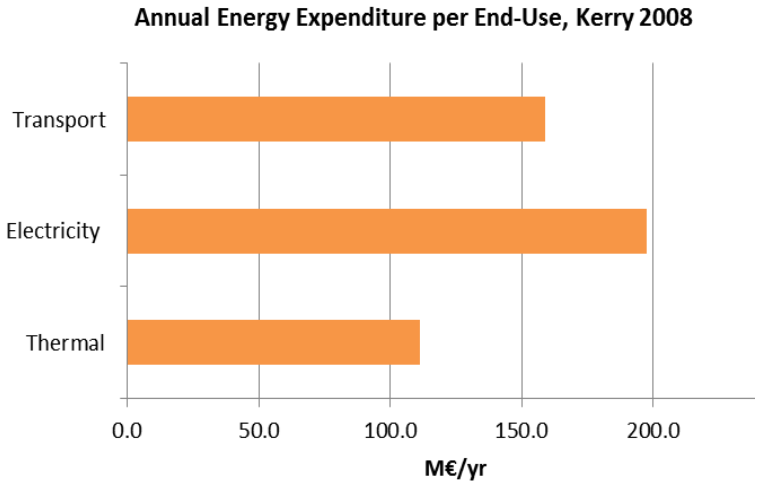
- Define the energy balance (supply and demand), energy expenditure and energy-related CO2 emissions for the county for a baseline year (2008), against which energy efficiency and renewable energy targets for the county can be set;
- Review the energy infrastructure currently in place in the county and assess the potential renewable energy resource available within county Kerry's boundaries and offshore along its coastline;
- Model and compare different scenarios for the transition of the energy systems in Kerry towards 100% renewable energy supply, assessing their economic, social and environmental impacts;
- Analyse the framework for community participation in renewable energy development in Kerry and define a roadmap for community-based renewable energy co-operatives to become a key driver in the energy transition of the county.

Energy and Emissions Balance in county Kerry

The energy balance of the county was developed for 2008 as baseline year, using a mixture of bottom-up data collected via surveys and 'top-down' data extrapolated from national statistics. The analysis breaks down energy demand by socio-economic sector and by fuel, and translates energy demand in related CO2 emissions and energy expenditure.

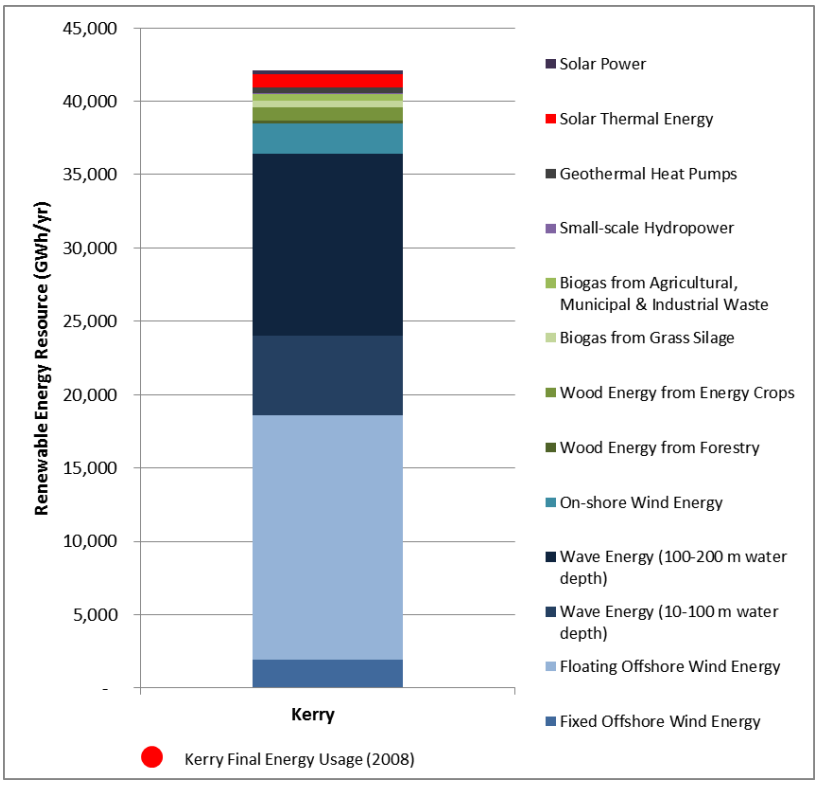


The total energy demand was estimated at almost 4 TWh/year in 2008, equivalent to 345 thousand tonnes of oil per year. Kerry is highly dependent on oil for its energy usage (57%), showing its prime importance as a heating fuel and transport fuel. Solid fuels, a traditional home heating source, occupy a significantly higher share of energy demand in Kerry (12%) compared to national usage (7%).



Overall energy usage in the county is responsible for the emission of 1.22 million tonnes of CO2 per year, equivalent to 8.8 tonne per person. The social cost of energy-related CO2 emissions in the county is estimated at c. €28 million per year. Energy expenditure is almost €470 million per year in Kerry, equivalent to approx. €3,230 per capita per year. The residential sector spends €227 million on energy or an average of €4,300 per year per household on car fuels, heating and electricity.

Renewable Energy Resources Potential



Using a combination of published statistical data and know-how, we conducted a comprehensive assessment of the potential renewable energy resources available to meet Kerry's energy demand. The bulk of the resource lies with on-shore and offshore wind energy as well as wave energy, which together can potentially generate an amount of electricity equivalent to over 5 times the total final energy demand of the county.

The theoretical potential of biomass in the study area has been estimated at circa 2 TWh/yr or 50% of the final energy

consumption in the area. The potential consists primarily in woody biomass from forestry and energy crops (55% of total biomass). Grass silage together with other wet organic by-products of agriculture, municipalities and industry can be digested anaerobically for producing biogas (0.9 TWh/yr potential). Solar technologies have an energy potential of 1.2 TWh/yr, or over 30% of the county's final energy demand. Geothermal heat pumps could also provide a substantial part of the thermal energy demand in the county and could play an important role as an energy storage technology.

The total figure of 42 TWh of renewable energy resource potentially available in the study area, including its adjacent offshore area, is encouraging when compared to the final energy demand of the region (10.6 times more).

Technological Pathways to 100% Renewable Energy Systems in Kerry

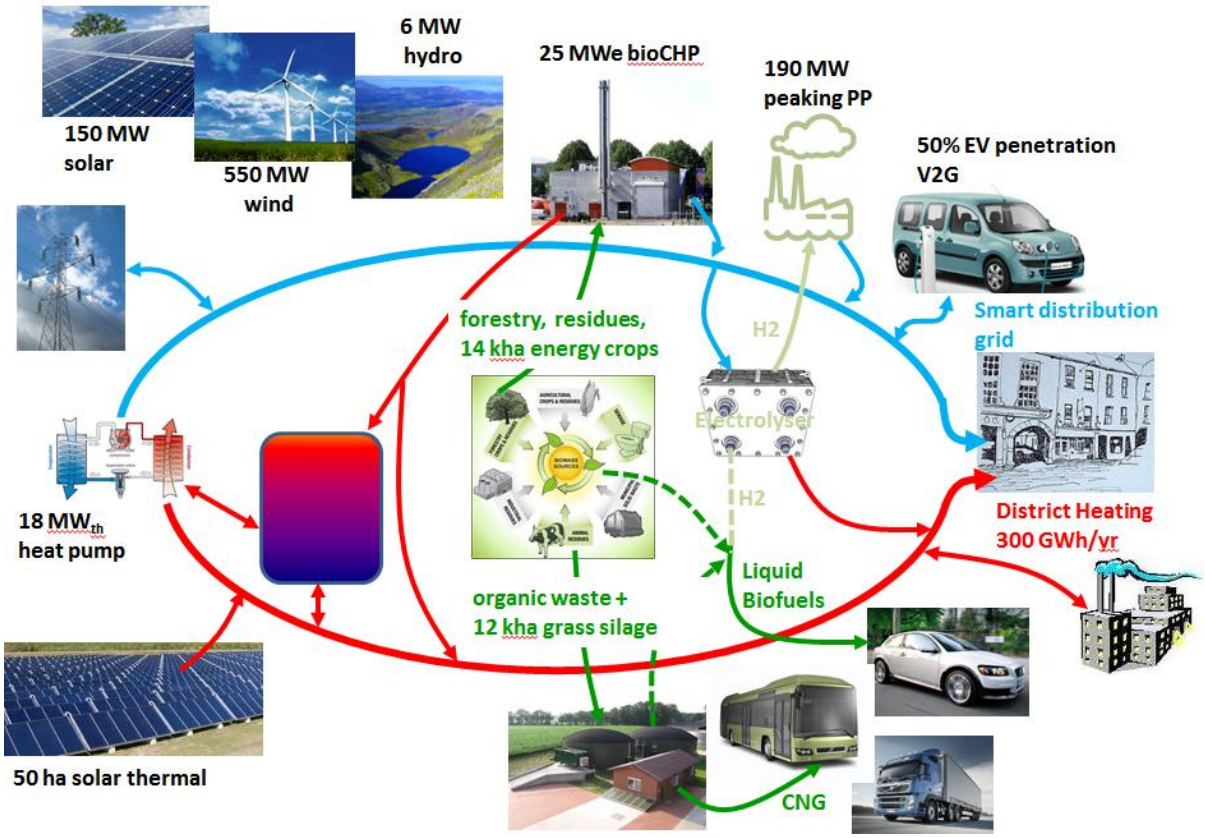
The next step was to explore technological pathways for the transition of the Kerry energy system to 100% renewable energy supply within the next 17 years. To do so, we undertook a process of iterative modelling of a series of future energy system scenarios with EnergyPLAN, a software developed by the University of Aalborg in Denmark. The model aims to optimise the technical operation of the overall energy system by integrating electricity, thermal and transport systems, while balancing supply and demand within the region. The model provides a series of technical, environmental and economic indicators on the basis of which these scenarios can be compared.

100% renewable energy scenarios were benchmarked against the 2008 baseline and against a business as usual scenario representing a continuation of the current national policy for renewable energy. Future energy system scenarios included for a 25% reduction in final energy use by 2030 through energy efficiency. Out of the modelling process, the following energy system transformation scenario emerges as the most advantageous for the county:

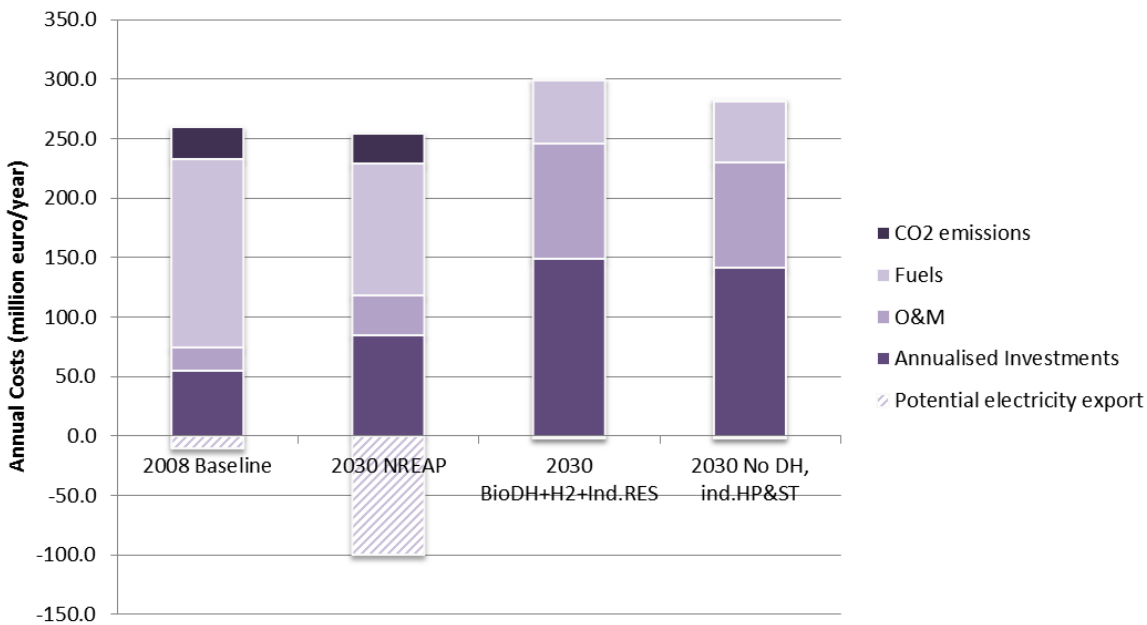
"By 2030, the county will be capable of becoming energy self-sufficient on the basis of its own renewable energy resource. Households, businesses and industry in larger towns will be supplied renewable heat via district heating systems harnessing heat from wood-fired power stations, industrial processes and large solar arrays. Rural dwellers will have switched to heat pumps and solar heating systems, supplemented with wood stoves. In terms of electricity supply, wind energy will cover up to 45% of total energy requirements of the county. Solar power will also play a significant role in the electricity mix.

Biomass is the other pillar of future renewable-based energy system scenarios, as a primary fuel to supply heat, electricity and transport fuels (50% of the overall primary energy requirement). Meeting future biomass fuel needs will require an ambitious programme of supply chain development to mobilise existing feedstock and create new sources with energy crop cultivation.

The energy system and its users will have a high degree of intelligence enabled by IT solutions, and will be capable of responding to intermittent renewable energy supply by adapting their energy usage, using battery storage in electric vehicles, storing heat with heat pumps, etc. Hydrogen production will also play a key role in balancing supply and demand within the county."



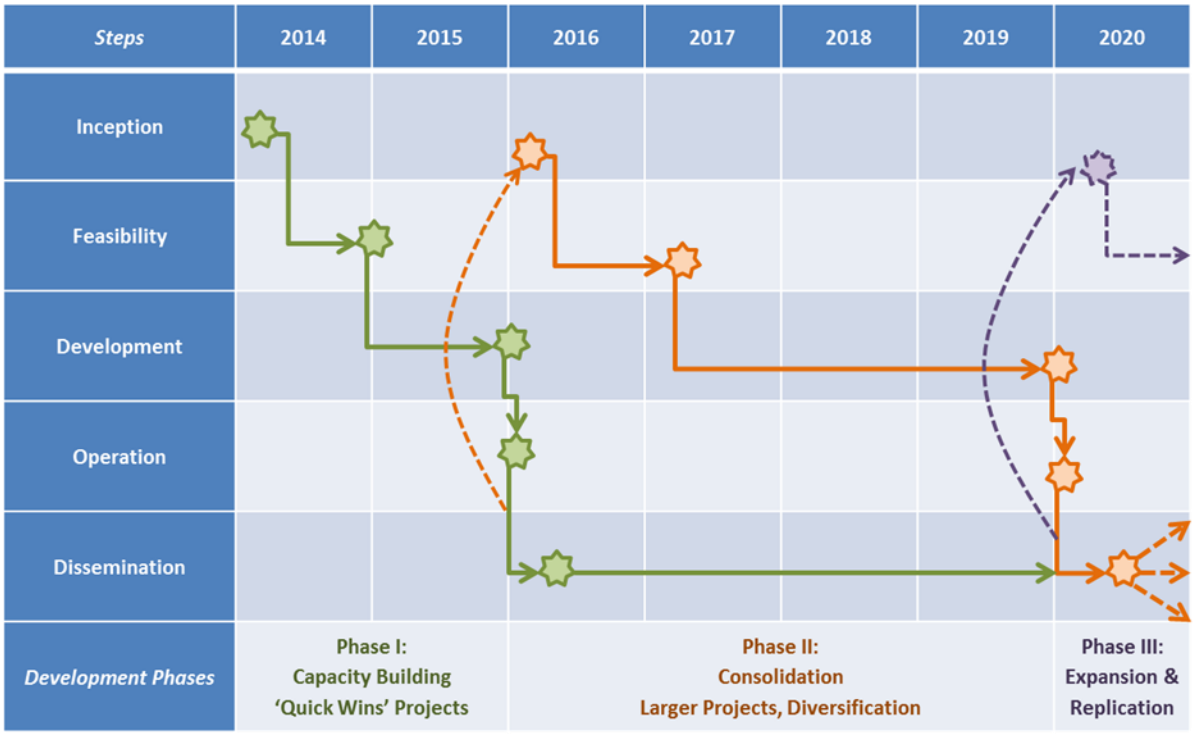
The technological transformation of the energy system of the county will require a long-term investment plan which could total up to 1.8 billion euro. However, the increase in capital cost will be largely compensated by the elimination of the county's fossil fuel expenditure – the bulk of which leaves the local economy. Overall, the total annual economic costs of the recommended 100% renewable energy system in 2030 will be 15% higher than those calculated for the 2008 baseline scenario.



In addition, the local production of biomass fuels, the construction, operation and maintenance of the new energy infrastructure will result in the creation of up to 2700 new local jobs compared to 2008. Finally, the transition to renewable energy naturally results in CO2 emission reductions totalling 1 billion tonne per year compared to 2008 emissions, worth €27 million euro per year in carbon credits.

Community Participation in the Renewable Energy Transition

Our assessment of the barriers and opportunities for community participation in the renewable energy transition indicate that these are intrinsically linked with the centralised and monopolistic nature of the current energy system. Other challenges and opportunities are inherent to how community groups are organised, relying for the most part on volunteers, and how they compensate for limited financial resources with social capital. Given the radical transformation of the institutional, policy and infrastructural framework required by the transition, the models of community participation and pathways for the transition are still to be defined in Ireland.



Our recommendation is for community groups to adopt a co-operative business model when for renewable energy project development, promoting local ownership, democratic and transparent business principles. The proposed roadmap for renewable energy coops (REScoops) in Kerry articulates a process of capacity building, starting with accessible projects, before tackling larger developments and diversifications into other products and services. Outreach will play an important role in promoting community buy-in and in disseminating the REScoop model to other communities in the county. Finally, a review of the wider transition of the county's energy system indicates that it will require a full-scale mobilisation of human resources and capital, driven by a long-term multi-stakeholders partnership. REScoops and other community groups should be pivotal in this revolution to make sure that local communities take full advantage of the opportunities it will present.

Chapter I.
County Kerry's Energy and Emissions Balance

1 Introduction

The first step of the Kerry SEC Roadmap project was to establish an energy balance (supply and demand) and energy-related CO2 emissions for the county. The objective of an energy balance is to identify the energy used within a region and to categorise it by sector and by fuel in order to establish a baseline for a reference year against which sustainable energy targets for the county can be set. In addition, the analysis establishes an historical profile of energy demand from 1990 to 2008, and makes projections for future use based on current trends as well as energy reduction and renewable energy supply targets. Energy use is then translated into related CO2 emissions as well as energy expenditure in the county providing indicators of the economic and environmental impacts of current usage and future changes.

The data collected and the analysis performed served as a basis for Kerry County Council's Sustainable Energy Action Plan submission to the EU Covenant of Mayors (Kerry County Council, 2013).

2 Baseline Final Energy and Emissions Inventory

2.1 Methodology

The baseline year for Co. Kerry's final energy and emissions inventory was taken as 2008 due to the good availability of energy demand data for that year. Final energy consumption was estimated on the basis of a comprehensive collection and analysis of data from a wide range of sources. Energy usage was derived as much as possible from localised data i.e. directly relevant to energy users in Co. Kerry. When such data was not available, energy usage was derived from national energy consumption statistics and apportioned to Co. Kerry according to suitable demographic or economic indicators. We explain briefly below the methodology applied for each socio-economic sector.

2.1.1 Residential

The housing stock of Co. Kerry was profiled on the basis of the Irish Central Statistics Office (CSO)'s Population Census 2011 and subdivided according to 'year built on' categories to reflect varying thermal performance standards with the age of properties. Only permanently occupied housing was considered (Co. Kerry has a large proportion of unoccupied houses– c.25% , a large number of them holiday homes). The thermal energy usage was then established for each age group on the basis of an analysis of Building Energy Rating data provided by the Sustainable Energy Authority of Ireland (SEAI), with a sample of over 13,000 residential BERs pertaining to the county. Average thermal usage figures derived from this methodology were then compared with national statistics from SEAI and from the extensive monitoring of energy usage in a sample of 300 rural housing units in Tipperary under the EU SERVE[1] project (Bell, Hoyne, & Petersen, 2013). This comparison showed a high level of correlation between the theoretical usage under the BER analysis and the monitored data.

2.1.2 Commercial Services

The energy demand of commercial services in Co. Kerry was established on the basis of a comprehensive analysis of demand in Tralee and Killarney, the two major towns in Co. Kerry, by a group of interns working with Kerry Co. Council. Energy consumption for a sample of circa 5000 businesses was measured or estimated on the basis of floor area, business type, occupation patterns as well as energy usage indicators provided by

[1] See http://servecommunity.ie/ for details.

SEAI in its Energy Mapping Tool. An average thermal and electrical energy demand per business type was determined on the basis of this sample and applied to the remaining population of businesses in Co. Kerry. The full population of businesses was established according to the Rates Collection (local tax on commercial premises) data provided by the Local Authorities of the county.

2.1.3 Industry

Industry energy usage was determined on the basis of usage data at national level taken from SEAI's annual energy balance for 2008 and apportioned according to the ratio between Kerry and national industry fuel and power input in the sector as a whole (data taken from the CSO). Unfortunately, county level statistics on the industrial sub-sectors are not available from the CSO for anonymity reasons and it was therefore not possible to reflect the specificities of industrial activity in Kerry in energy usage terms. Large industrial energy users will be contacted separately with a view to obtain energy consumption for the reference year and measure their significance in the overall energy usage profile of the county. However, we will assume for county's energy balance that their energy usage is better accounted for at a national level since their production is intended for a broader market than the county.

2.1.4 Public Services

Local authority energy usage data is collected on an annual basis by Kerry Co. Council for county and town councils' activities and submitted to SEAI for the purpose of monitoring the implementation of the National Energy Action Plan (NEAP). The Irish public sector is committed to reduce its energy demand by 30% by 2020 under NEAP.

Energy usage data was also obtained for national public services based in Kerry such as the Health Service Executive (actual data), primary and secondary schools (estimates), as well as Tralee Institute of Technology (actual).

2.1.5 Agriculture

Agriculture energy usage was determined on the basis of usage at national level taken from SEAI's annual energy balance for 2008 and apportioned according to the ratio of Kerry versus national farmed area (as per the Agricultural Census 2010). Specific energy usage data per agricultural system is not available, but on the whole the profile of agriculture in Kerry is somewhat similar to the national one (except for a lower share of tillage).

2.1.6 Transport

Detailed statistics on the transport sector in Kerry were obtained from the CSO (2008) to establish a fairly accurate profile of the vehicle fleet in Kerry, the average number of km driven (or tonne.km for transport of goods) and average fuel usage per vehicle type. Transport energy usage was distributed between the different sectors according to their main transport requirements e.g. residential (private cars), commercial services (goods transport), public services (goods transport and utilitarian vehicles such as waste collection), agriculture (machinery), industry (goods transport). With regard to freight, it was assumed that 70% of freight is for the commercial services sector and 30% for the industrial sector.

2.2 Final Energy Demand

Final energy consumption covers all energy supplied to the final consumer for all energy uses. It is usually disaggregated into the final end-use sectors: industry, transport, households, services and agriculture.

In Table 1, we have also disaggregated transport between its different users in order to emphasize the weight of transport in each of the socio-economic subgroups in Kerry: households, industry, services and agriculture. The total final energy demand in 2008 is estimated at close to 4 TWh/yr, or almost 3% of the national energy demand. The ratio between Kerry and national energy demand is in line with the Kerry/national population ratio which stands at 3.2% (CSO, 2011).

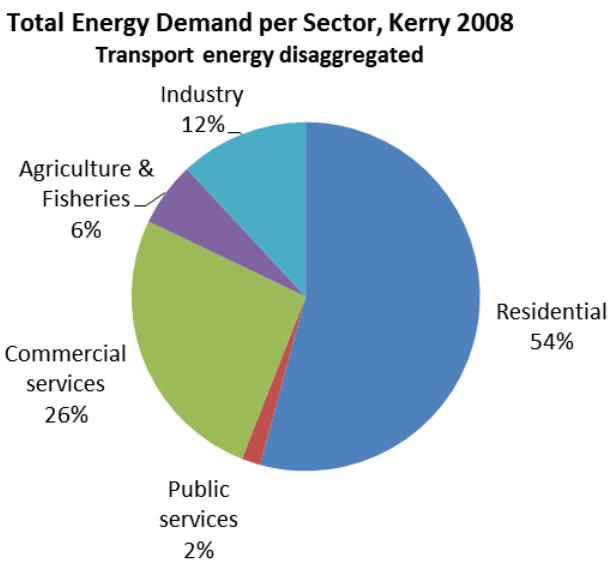


Figure 1: Share of socio-economic sectors in final energy demand in Kerry, inclusive of transport.

According to figure 1, the residential sector weighs heavily in the county's energy use, after the services sector (each sector's share includes its own transport energy use).

In terms of fuels (figure 2), Kerry is highly dependent on oil (57% or 884 GWh/yr), showing its prime importance as a heating fuel (22% of total demand) and transport fuel (35%). Between coal, peat and wood energy, solid fuel represent a total of approximately 12% (492 national level at 6.8% and reflects es. Electricity represents 26% (766 onal share of electricity at 17%.

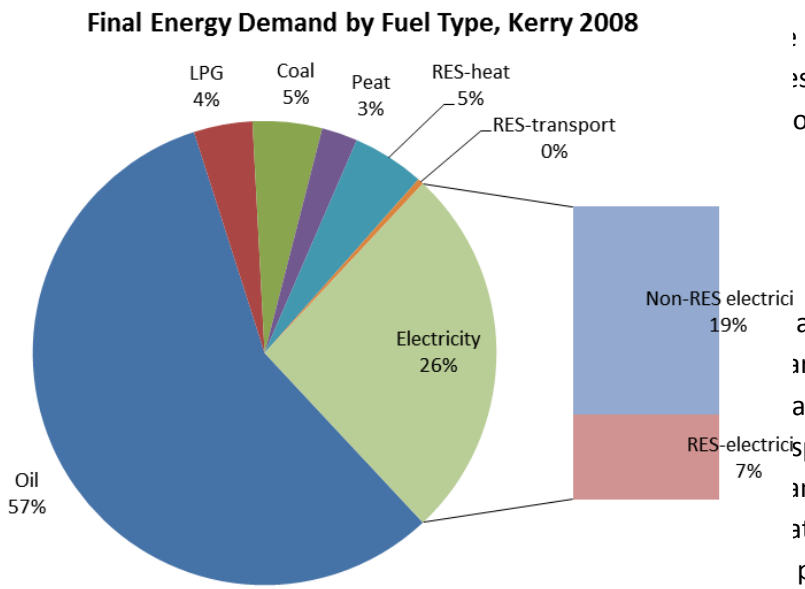


Figure 2: Share of fuel types in the final energy demand, Kerry 2008.

all sectors; this enables a better arge difference between the share act that energy use linked to the sport are not accounted for in the ance of industry in energy demand ation of the county. Despite being proportion of energy demand, in that of the other sectors.

Table 1 Final energy demand per socio-economic sector, 2008.

	Thermal								Electricity			Transport fuels	Total
Annual energy usage (GWh/yr)	Total	*Oil*	*LPG*	*Coal*	*Peat*	*Nat.Gas*	*RES-heat*	*Electricity (thermal)*	Total	*Grid_e*	*Local RES-e*		
Residential	**1207.304**	*577.857*	*60.057*	*168.949*	*99.586*	*0.000*	*180.381*	*120.474*	**237.347**	*195.2*	*42.1*	**711.898**	**2156.5**
Public services	**22.727**	*22.329*	*0.397*				*0.0001*		**37.115**	*24.9*	*7.5*	**9.936**	**69.8**
Commercial services	**336.165**	*80.236*	*102.351*	*1.483*			*0.885*	*151.210*	**364.050**	*299.4*	*64.6*	**338.547**	**1038.8**
Agriculture & Fisheries									**34.985**	*28.8*	*6.2*	**202.149**	**237.1**
Industry	**243.876**	*203.029*		*22.171*			*18.677*		**92.176**	*75.8*	*16.4*	**138.927**	**475.0**
Total	**1810.1**	*883.5*	*162.8*	*192.6*	*99.6*	*0.0*	*199.9*	*271.7*	**765.7**	*624.1*	*136.9*	**1401.5**	**3977.2**

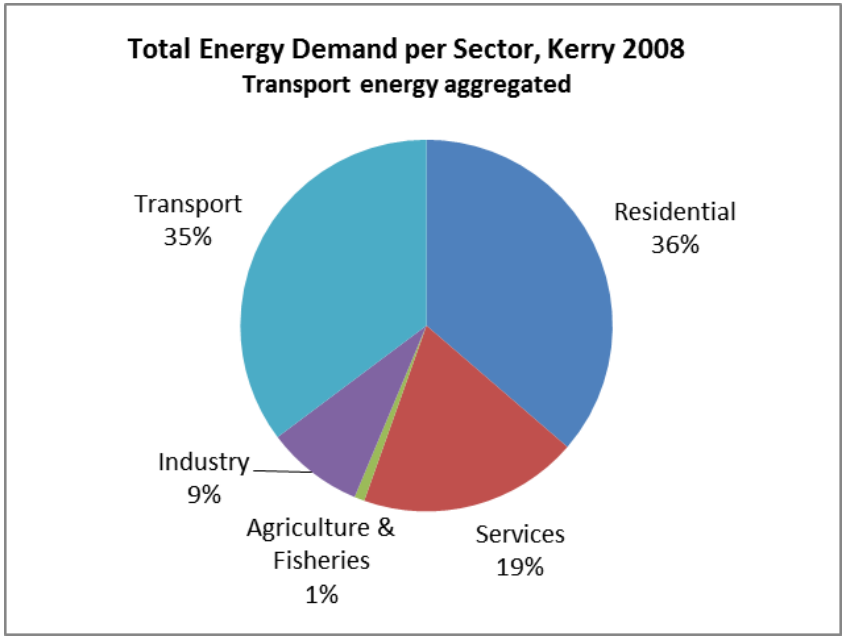


Figure 3: Share of socio-economic sectors in final energy demand in Kerry, transport energy aggregated.

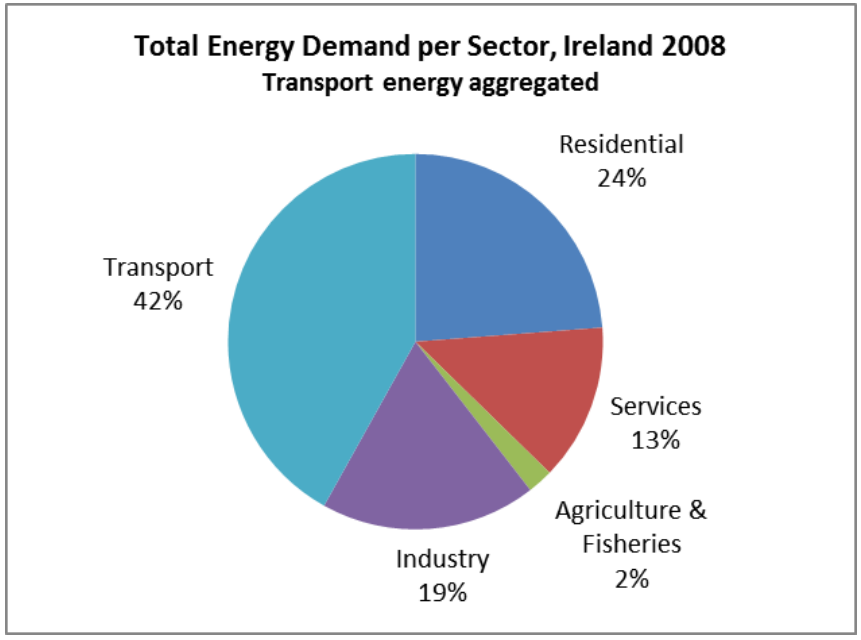


Figure 4 Share of socio-economic sectors in final energy demand in Ireland, transport energy aggregated.

The nature of the electricity mix[2] at county level was determined on the basis of the Covenant of Mayor convention for its Sustainable Energy Action Plan guidelines (European Union, 2010) whereby local generating plant below 20 MW are considered to contribute entirely to the local energy demand. Larger generating plants, typically connected to the transmission network, are assumed to contribute to the national electricity mix.

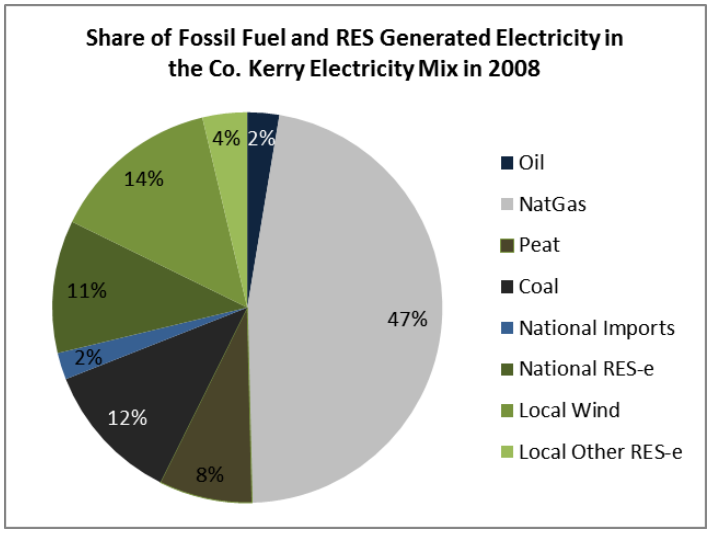


Figure 5 County Kerry electricity fuel mix, 2008.

Out of a total installed capacity of wind energy of 163.6 MW in 2008, 53.3 MW correspond to that definition and contribute 145.8 GWh/yr (31% capacity factor) to the local electricity mix. Adding this to an estimated 38.4 GWh/yr generated by local hydropower plant, it is considered that locally produced renewable electricity contributes to c.18% of the county's electricity consumption.

Considering the national primary fuel mix of electricity consumed in Kerry that is not produced locally (including its own share of renewable electricity) in 2008, the carbon factor for the Kerry electricity mix is estimated at 0.47 kgCO2/kWh compared to 0.55 kgCO2/kWh at national level.

2.3 Energy related CO_2 emissions in County Kerry

Table 2 below presents the estimated energy-related CO2 emissions of the different socio-economic sectors of the county in 2008 as well as the emissions distribution between the different fuels used. In total, it is estimated that the county's energy usage is responsible for 1.22 million tonnes of CO2 emissions3, approximately 2.5% of the national energy-related CO2 emissions. This represents 8.7 tonnes of CO2 emitted per person in Kerry. Assuming an external cost of carbon of €30 per tonne of CO2 emitted, the county's emissions create a social cost of 27.8 million euro.

Table 2 Energy related CO2 emissions per sector, Kerry 2008.

Annual energy-related CO2 emissions in Co. Kerry 2008 (,000 tCO2/yr)								
	Oil	*LPG*	*Coal*	*Peat*	*Nat. Gas*	Electricity	*Transport fuels*	***Total***
Residential	*148.509*	*13.771*	*57.544*	*36.364*	*0.000*	*169.139*	182.355	***607.7***
Public services	*5.893*	*0.091*				*17.544*	2.588	***26.1***
Commercial services	*21.174*	*23.469*	*0.505*			*243.558*	88.205	***376.9***
Agriculture & Fisheries						*16.537*	52.707	***69.2***
Industry	*53.579*		*7.551*			*43.571*	36.223	***140.9***
Total	***229.2***	***37.3***	***65.6***	***36.4***	***0.0***	***490.3***	**362.1**	***1220.9***

[2] Electricity mix is a term often used to designate the mix of primary fuels used for the generation of electricity at regional or national level.
[3] CO2 accounts for 96% of the energy-related greenhouse gas emissions.

Households and services are the main contributors to energy-related CO2 emissions in Kerry, on account of their thermal energy usage but more importantly their electricity consumption, see **Error! Reference source not found.**below.

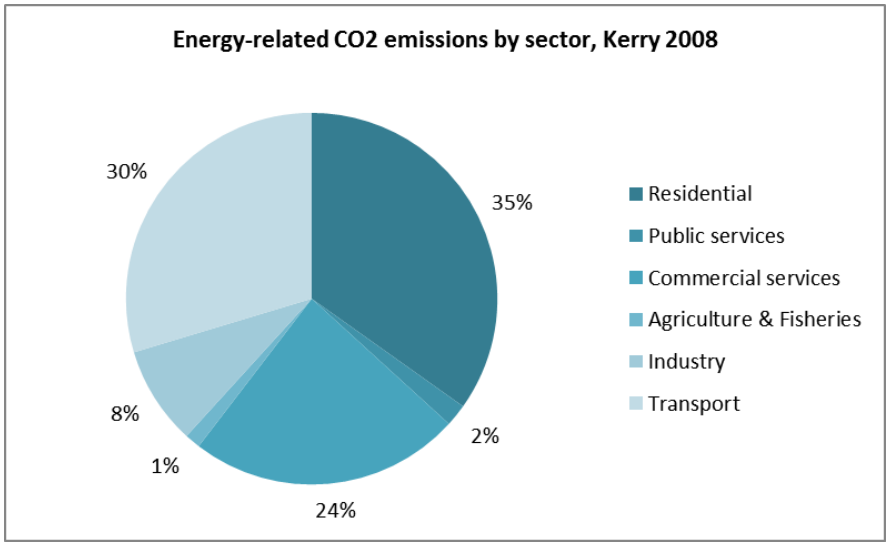


Figure 6 Share of energy-related CO2 emissions per end-use and per sector, Kerry 2008.

Electricity is the main greenhouse gas emissions contributor in the county, which accounts for the fact that the grid electricity in Ireland has a high primary energy to delivered energy factor (2.25 in 2008) and is generated by fossil fuels for a large part. Transport is also a very substantial CO2 contributor at 30% (considering a 5% penetration of biofuels in transport fuels).

At national level, energy represents approximately 66% of total greenhouse gas emissions, after agriculture (26%), industry (5%) and waste (3%) (SEAI EPSSU, 2009) – see Figure 7 below.

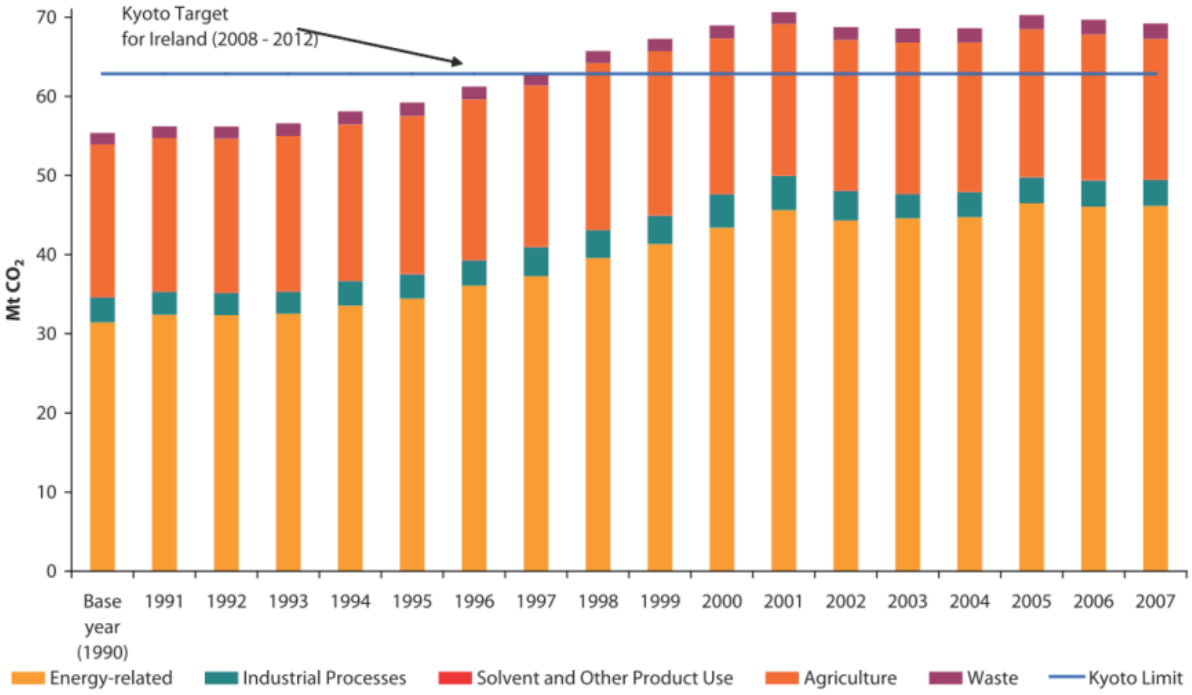


Figure 7 Greenhouse gas emissions by source 1990-2007. Source: SEAI, 2009.

2.4 Energy Expenditure in County Kerry

The annual energy costs presented in Table 3 below were calculated on the basis of historical energy costs comparison provided by SEAI (SEAI, 2013) and the energy usage figures in Table 1.

Table 3 Annual energy costs in Kerry, 2008.

	Annual energy costs in Co. Kerry 2008 (M€/yr)								
	Oil	*LPG*	*Coal*	*Peat*	*Nat. Gas*	*RES-heat*	Electricity	*Transport fuels*	***Total***
Residential	*46.694*	*6.798*	*8.365*	*5.202*	*0.000*	*12.025*	*60.472*	87.685	***227.2***
Public services	*1.937*	*0.036*				*0.000*	*6.031*	0.998	***9.0***
Commercial services	*6.959*	*9.239*	*0.015*			*0.029*	*83.730*	34.015	***134.0***
Agriculture & Fisheries							*34.985*	20.311	***55.3***
Industry	*13.272*		*0.226*			*0.613*	*12.167*	15.802	***42.1***
Total	***68.9***	***16.1***	***8.6***	***5.2***	***0.0***	***12.7***	***197.4***	**158.8**	***467.6***

Error! Reference source not found.indicates how the county energy bill is shared between the different sectors of activity and figure 10 shows how energy expenditure is split between end-use in the county.

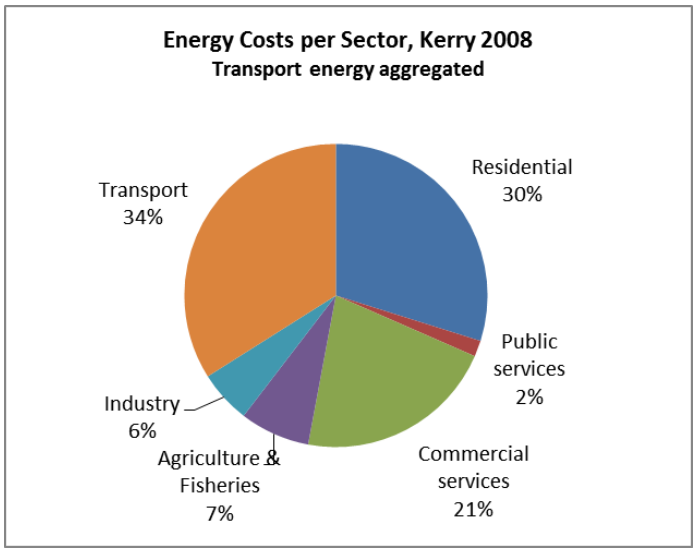


Figure 8 Share of energy costs per sector, Kerry 2008

According to our estimates, the annual energy bill in county Kerry was c.468 million euro in 2008, or approximately €8,800 per household. Transport is the main contributor (34%) after the residential sector (30%), while services represent about a quarter of energy costs.

In terms of end-use, electricity usage accounts for the largest expenditure at almost 200 million euro a year.

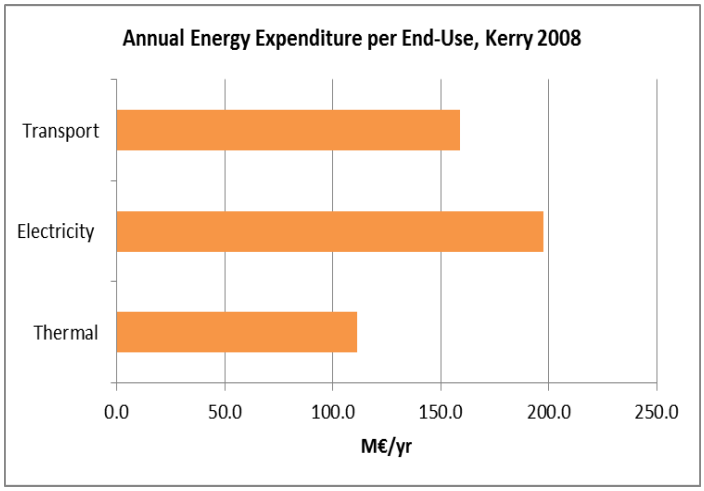


Figure 9 Annual energy expenditure per end-use, Kerry 2008.

2.5 Historical Energy Demand and Forecast for 2020 in County Kerry

The evolution of energy demand between 1990 and 2010 in the county has been modelled on the basis of historical final energy demand figures at national level compiled from SEAI's statistics by David Connolly of Aalborg University in Denmark (Connolly D. , 2012). In the absence of historical energy data for the county, we assume that energy demand follows the same evolution pattern as national energy usage.

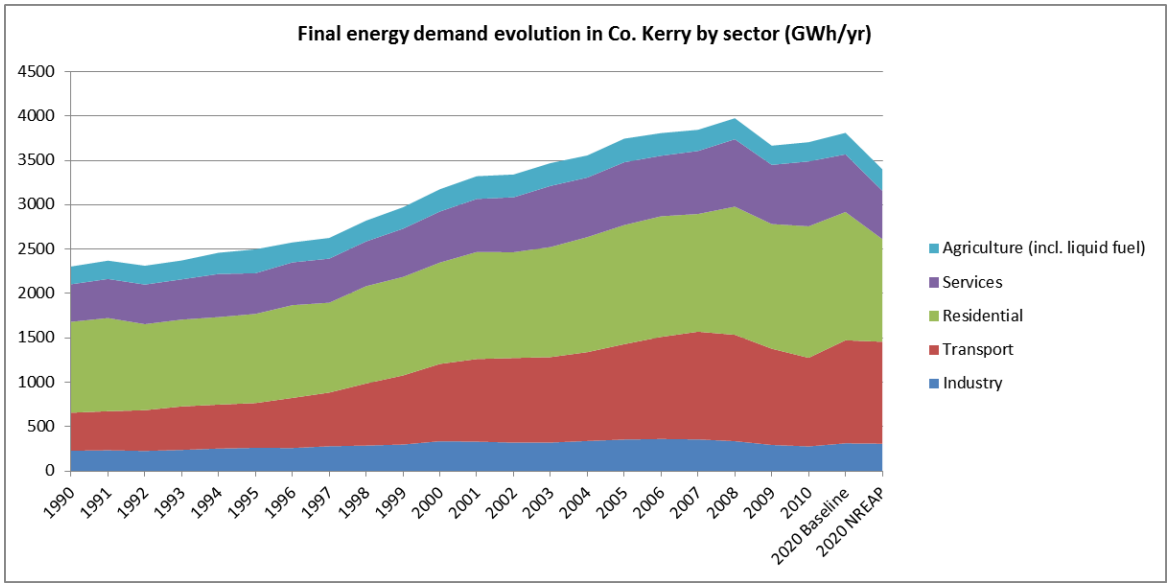


Figure 10 Evolution of final energy demand in Kerry 1990-2010.

As observed on Figure 10, final energy consumption in the county almost doubled between 1990 and 2008, in line with the rapid expansion of the economy and population, especially from the late nineties. With the economic crisis manifesting itself from 2008, there has been a significant decline in energy usage. Transport has been the primary cause for the overall increase in energy consumed in Ireland, which was 133% more in 2010 than in 1990. The commercial sector has experienced the second largest relative increase since 1990, with 2010 consumption 73% higher. The residential sector grew by 45%, industry by 22%, and agriculture by 9%.

In addition, we simulated the projected energy balance for the year 2020 based on the 'Baseline' and 'NEEAP/NREAP' scenarios created in the 2010 version of SEAI's forecasts (SEAI, 2009). The Baseline scenario includes all energy-related government policies and measures legislated for up to the end of 2010. It is a hypothetical scenario developed by SEAI to represent the consequences of no further action. The 'NEEAP/NREAP' scenario represents the energy consumption in Ireland assuming a 'low growth' economic recovery along with the implementation of both the National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy Action Plan (NREAP) for 2020.

Looking forward, it is also evident from Figure 10 that the agriculture sector is set to experience the largest relative increase between 2010 and 2020. In both the Baseline and the NEEAP/NREAP scenarios there is a 39% increase in energy consumption in agriculture. In the Baseline there is a 6% increase in the commercial sector, a 10% increase in industry, a 17% increase in transport, and a 3% drop in residential energy consumption. For the NEEAP/NREAP scenario both commercial and

residential energy consumption decrease by 14% and 22%, while the industry and transport sectors increase by 9% and 13% respectively. This represents the significant contribution from buildings to the energy savings required by 2020. The Baseline scenario represents a demand reduction of 4% compared to 2008 levels and the NEEAP/NREAP a reduction of 14.5% respectively.

3 Energy Infrastructure in Co. Kerry

3.1 Electricity Generation

3.1.1 Fossil-fuel Generation

Tarbert is the only generating station connected to the transmission grid in County Kerry. The power station, which runs on heavy fuel oil, has been recently acquired by Southern Scottish Energy (SSE) from Endesa. SSE plans to gradually decommission the existing heavy fuel oil plant and replace it with a 450 MW CCGT (combined cycle gas turbine) plant, increasing the efficiency (58%) and the flexibility of the Tarbert power station.

In addition to Tarbert, there is a diesel generator at Klinge Pharma of 1.74 MW Maximum Export Capacity (MEC) connected to the Oughtragh substation.

3.1.2 Wind Energy Generation

Table 4 indicates the level of wind energy capacity connected to the transmission (TSO) and distribution (DSO) grid in County Kerry to date (ESB Networks, 28 November 2012). In total, there are approximately 230 MW of Maximum Export Capacity (MEC) of wind generation operational in Kerry, placing the county in third position behind Donegal and Cork. This represents almost a quarter of the total wind generation capacity installed nationally (951.78 MW by December 2012).

Table 4 Connected or energised wind farms in Kerry (2012)

Wind Farm	System Operator	Installed Capacity (MW)	Maximum Export Capacity (MW)	Nearest Substation	Notified Connection Date
Clahane	TSO	40	38	Pallas	06/2008
Coomagearlahy	TSO	45	42.5	Coomagearlahy	03/2006
Coomagearlahy	TSO	8.5	8.5	Coomagearlahy	03/2009
Coomagearlahy	TSO	32.5	30	Coomagearlahy	06/2009
Glanlee	TSO	31.6	29.8	Glanlee	07/2007
Ballincollig Hill	DSO	13.3	15	Tralee	01/2010
Beale Hill 1	DSO	1.65	1.65	Trien	11/2000
Beale Hill 2	DSO	2.55	2.55	Trien	08/2003
Beenageeha	DSO	3.96	3.96	Tralee	10/2000
Mount Eagle	DSO	5.1	5.1	Tralee	03/2005
Mount Eagle	DSO	1.7	1.7	Tralee	11/2008
Muingnaminanne	DSO	14.8	15.3	Tralee	11/2008
Tursillagh	DSO	15.18	15	Tralee	11/2000
Tursillagh	DSO	6.8	6.8	Tralee	09/2004
Knockaneden	DSO	9	9	Oughtragh	09/2012 (energised)
Clidaghroe	DSO	5	5	Garrow	30/03/2012 (energised)
Total Connected or Energised		**236.64**	**229.86**		

Please note that the last 2 wind farms have electrical connection to the network but which are not yet permitted to export.

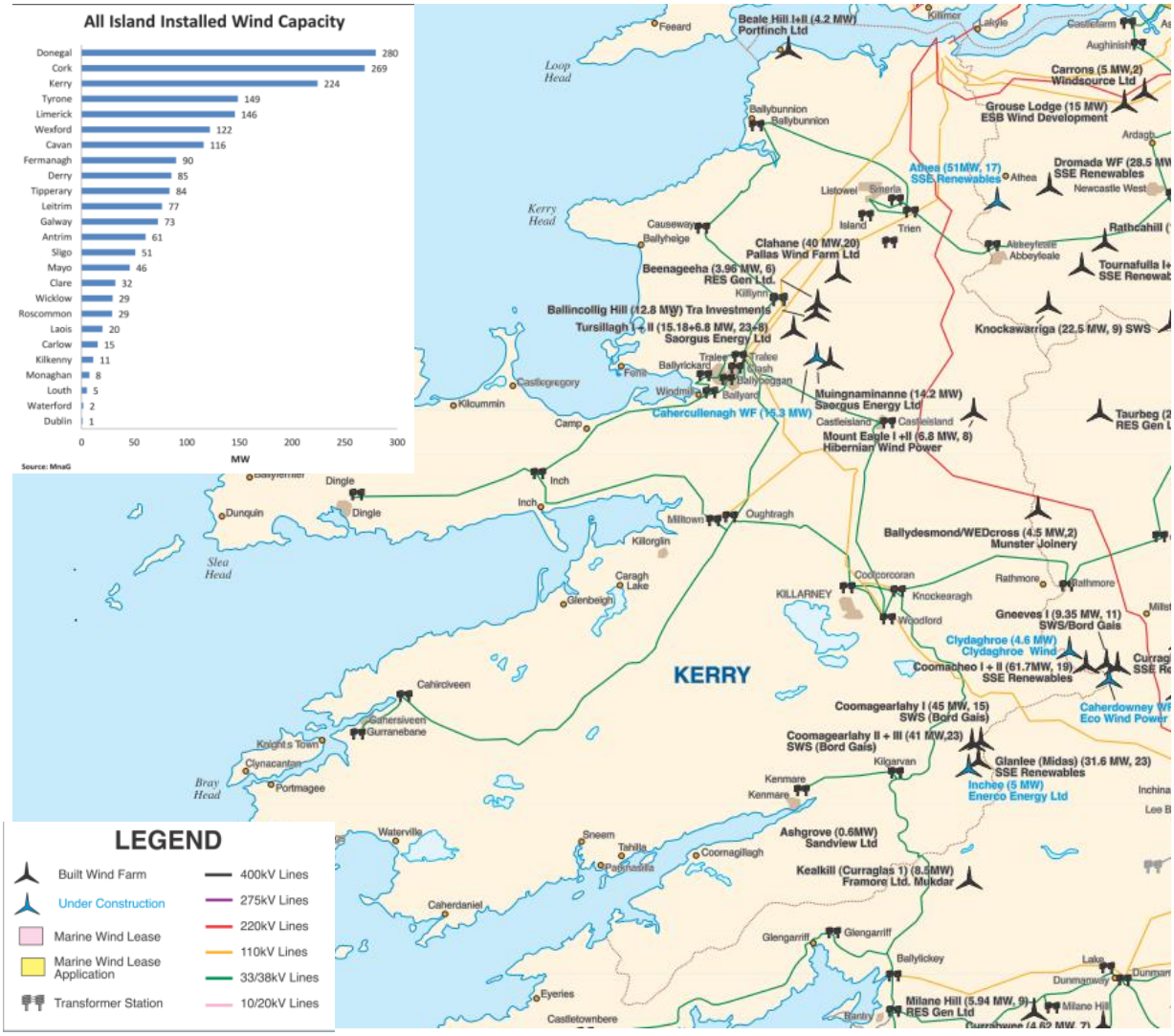


Figure 11: Wind Farm Map of Ireland 2012 (Source: MEITHEAL NA GAOITHE)

The following table lists the wind farms that have signed a connection agreement with the DSO and are committed to exporting electricity to the distribution network at a future date. Please note the first 4 wind farms listed have received a REFIT power purchase agreement (PPA) as per the Statutory Instrument No. 438 of 2012. However, it is not clear at present if they are connected or contracted to be connected to the distribution network.

Table 5 Contracted wind farms in Kerry (2013)

Wind Farm	MEC (MW)	Nearest Substation	Status
Foilgreana	5	Unknown	REFIT PPA (installed)
Coom	6.8	Unknown	REFIT PPA
Caherciveen	9	Unknown	REFIT PPA
Sillahertane, Inchincooch	41	Unknown	REFIT PPA
Knocknagoum	42.55	Reamore	Contracted (09/2013)
Knocknagoum 2	1.8	Reamore	Contracted (09/2013)
Beale Hill (3)	1.3	Trien	Contracted (06/2014)
Mount Eagle (3)	1.7	Tralee	Contracted (06/2014)

Coolgrean Dromadda Beg Dromadda More Cloghanaleskirt	18.5 2.55 20 10	Cordal Knocknagashel Knocknagashe Knocknagashe	Contracted (04/2014) Contracted (01/2015) Contracted (01/2015) Contracted (01/2015)
Scartaglen	23.95	Cordal	Contracted (03/2014)
Cordal (Knockanefune)	35.85	Cordal	Contracted 03/2014
Total Contracted	**220**		

In addition, a 46 MW wind farm at Cloghboola is expected to be connected to the 110 kV transmission network at the Knocknagashel substation by February 2014 (Eirgrid, 2011). In total, it is expected that a further 266 MW of wind generation will come on stream in County Kerry within the next 2 years, more than doubling the current installed capacity.

The Gate 3 Offer Project refers to the third round of connection offers that are currently being issued to generators under the Group Processing Approach (GPA). The GPA allows for strategic processing of generation applications for grid connection and was introduced by the Commission for Energy Regulation (CER) in 2004. It allows applications to be processed by the System Operators (EirGrid and ESB Networks) in groups or batches known as 'Gates'.

The following table indicates wind farms that have been allocated scheduled firm access by Eirgrid (Eirgrid, 2012) for their full MEC by 2020. According to this table, there is a potential for another 276.1 MW of wind generation to be connected to the grid by 2020 in County Kerry. This compares to 3989.8 MW total wind farms with firm access nationally.

Table 6 Wind farms under the Gate 3 process with Firm Access status.

Wind Farm	MEC (MW)	Nearest Substation	Status
Cordal 2	34	Cordal	Gate 3 (2020)
Cordal 3	31	Cordal	Gate 3 (2020)
Muignatee 2	1.8	New Reamore	Gate 3 (2020)
Muingnaminanne 2	13.5	New Reamore	Gate 3 (2020)
Clahane 2	13.8	Clahane	Gate 3 (2020)
Dromadda More 2	12	New Knocknagashel	Gate 3 (2020)
Stack's Mountain WF	13.8	New Reamore	Gate 3 (2019)
Muingatlaunlush	11.5	New Reamore	Gate 3 (2019)
CurraghDerrig.	4.5	Trien	Gate 3 (2019)
Scartaglen WF Ext.	2.4	New Cordal	Gate 3 (2019)
Sillahertane WF	10	New Coomataggart	Gate 3 (2019)
Lettercannon (1)	21.6	New Coomataggart	Gate 3 (2019)
Clooghboola 2	10	New Knocknagashel	Gate 3 (2019)
Barnastooka WF	34	New Coomataggart	Gate 3 (2019)
Kilgarvan 1	62.2	New Coomataggart	Gate 3 (2018-2019)
Total Gate 3 Firm Offers	**276.1**		

Between the wind farms connected (or energised), contracted and with firm access under Gate 3, the potential wind generation capacity installed by 2020 is approximately 772 MW, or more than 3 times the current installed capacity and over 80% of the current national installed wind capacity.

3.1.3 Other renewable generation

The table below lists non-wind generation plants, mostly hydro, that are connected or contracted according to ESB Networks. This represents a total installed capacity of circa 9 MW.

Table 7 Non-wind renewable energy generation connected in Kerry up to 2012.

Generator name	Type	MEC (MW)	Nearest Substation	Status
Adambridge Manufacturers Ltd	Biogas	3	Knockearagh	Connected
Owenbeg	Hydro	0.8	Knockearagh	Connected
Ashgrove	Hydro	0.6	Knockearagh	
Trewell Hydro Cottoners	Hydro	1.2	Oughtrach	Connected
Millstream Hydro	Hydro	0.18	Trien	Connected
Slaheny River	Hydro	0.485	Ballylickey	Connected
Brandon Hydro	Hydro	0.45	Oughtragh	Contracted (on hold)
Nancy Falls Hydro	Hydro	1.25	Knockearagh	Contracted (date unavailable)
Muingnaminnane	Landfill gas	1	Reamore	Unknown
Total non-wind contracted		**8.97**		

Figure 12: Ashgrove 600 kW hydropower station, Kenmare

3.2 Transmission Network

For the purpose of Grid25 (Eirgrid, 2010), Eirgrid[4]'s Grid Development Plan, the country is divided up into seven geographical regions. North Kerry is located in the West Region while Mid to South Kerry is located in the South West Region. Over the lifetime of Grid 25 it is proposed to invest € 325 million into the West Region and € 730 million into the South West Region. Eirgrid also proposes to significantly strengthen grid capacity between the South West and the South East. Through this investment Eirgrid intends to undertake grid reinforcements to connect significant amounts of wind generation to the grid and reinforce security of supply.

The existing transmission network in the County consists of 220kV and 110kV substations and lines. There is an existing 220 kV station at Tarbert; this provides a high voltage supply into the south-west. This station is connected by 220 kV overhead lines to Killonan 220kV station in County Limerick and Clashavoon 220kV station in County Cork. In addition to Tarbert, there are nine 110 kV transmission substations in County Kerry, namely Trien, Clahane, Tralee, Oughtragh, Knockeragh, Clonkeen, Coomagearlahy, Glanlee and Garrow. These stations are interconnected to the power system by a number of 110kV lines (Kerry County Council Planning Policy Unit, 2012).

EirGrid's Forecast Statement 2010-2017 proposes 5 upgrade projects which are depicted on Map 4 and listed below:

- Kilpaddoge - Moneypoint 220 kV Cable: this project involves a new submarine cable being constructed across the Shannon Estuary from Moneypoint 400kV station in County Clare to the proposed Kilpaddoge 220kV station close to Tarbert. The project will provide an alternative route for power into the southwest and a path for power out of the southwest to the 400kV network.
- Kilpaddogue 220 kV Development: Kilpaddogue 220 kV station, when constructed, will be connected into the existing Clashavoon-Tarbert and Killonan-Tarbert 220 kV lines. A number of 110 kV lines will be connected into the new station, making Kilpaddogue a new hub for power flows into the south-west. This project is due for completion in 2013.
- Knockanure 220 kV Station: Knockanure 220 kV station will be looped into the existing Clashavoon-Tarbert 220 kV line and into the existing Trien-Tarbert 110 kV circuit and the planned Dromada-Trien 110 kV circuit. This project is due for completion in 2014.
- Kishkeam 220 kV Station: This station will be looped into the existing Clashavoon-Tarbert 220 kV line. The station will be linked to the existing Glenlara 110 kV station by a new 110 kV overhead line. Kishkeam 220/110 kV project is needed to accommodate the planned generation in the southwest. This project is due for completion in 2014.
- Ballyvouskill 220 kV Station: Ballyvouskill 220 kV station, close to Millstreet in Co. Cork, will be linked to the existing Garrow 110 kV station in County Kerry by two new 110 kV overhead lines. This project is due for completion in 2014.
- The Kilpaddoge - Tarbert 220 kV submarine cable will provide an additional high capacity path from the 400 kV systems into the South West. This cable will allow

[4] EirGrid is the independent electricity Transmission System Operator (TSO) in Ireland and the Market Operator (MO) of the wholesale electricity trading system.

planned increases in wind generation in the south of the country to connect with the high voltage system thereby enabling wind generated electricity to be exported. The new 110kV lines will transmit energy generated in wind developments across the county to where it will be collected by the new 220kV substations and onto 220kV lines for export.

On completion of the capacity upgrade projects included in EirGrid's Transmission Forecast Statement 2010-2017 it is estimated that there will be sufficient grid capacity to accommodate all offers made under the gate process. This includes the proposed connection offers under Gate 3 and Post Gate 3.

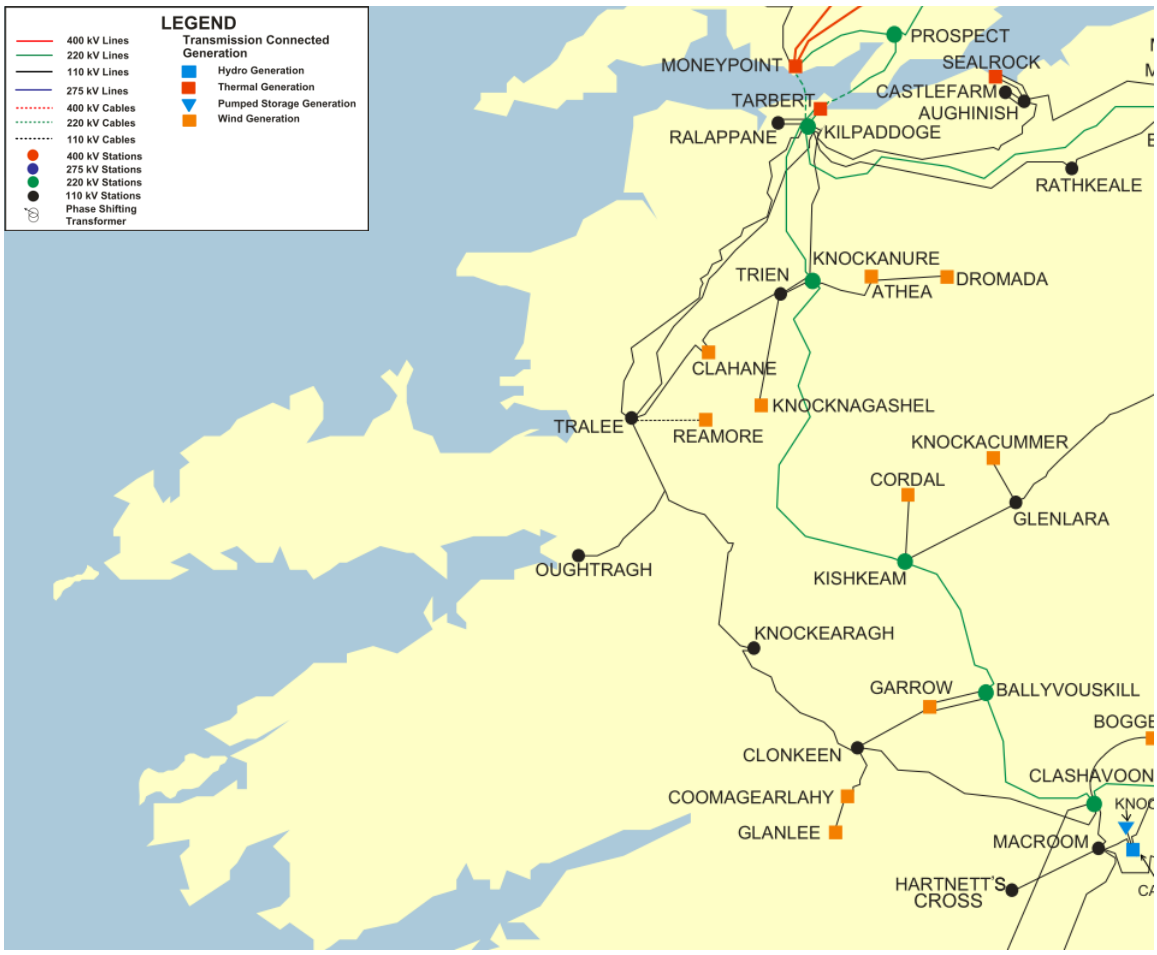


Figure 13: Grid 25 view of the transmission grid in Kerry by 2020.

However, Kerry County Council's Draft Renewable Energy Strategy 2012 identifies "a disconnect between land use planning and grid transmission planning which will make it difficult to achieve this level of connection. There are a significant number of permitted wind developments which have not been offered a grid connection, while connection offers are being made where no application has yet been submitted for a wind development. Unlike land use planning, connection offers are made to an individual or to a company and are not attached to a particular site. Furthermore, due to lack of connection details, planning applications for the transmission lines and wind developments are generally made separately."

The Draft Renewable Energy Strategy also states that significant parts of South Kerry (Dingle, Iveragh and Beara peninsulas) will have a transmission infrastructure deficit which will impair the capacity of

the region to harness and export its wind energy potential. This area of the county is served by an 110kV line from Tralee to Cahersiveen which has been operating at 38kV but needs to be upgraded.

3.3 Natural gas infrastructure

The natural gas network does not service county Kerry and there are no proposed extension from the existing network planned for the future. The map below gives an overview of the gas pipeline (Bord Gais Networks, 2013). The closest point of the pipeline to Kerry is near Shannon.

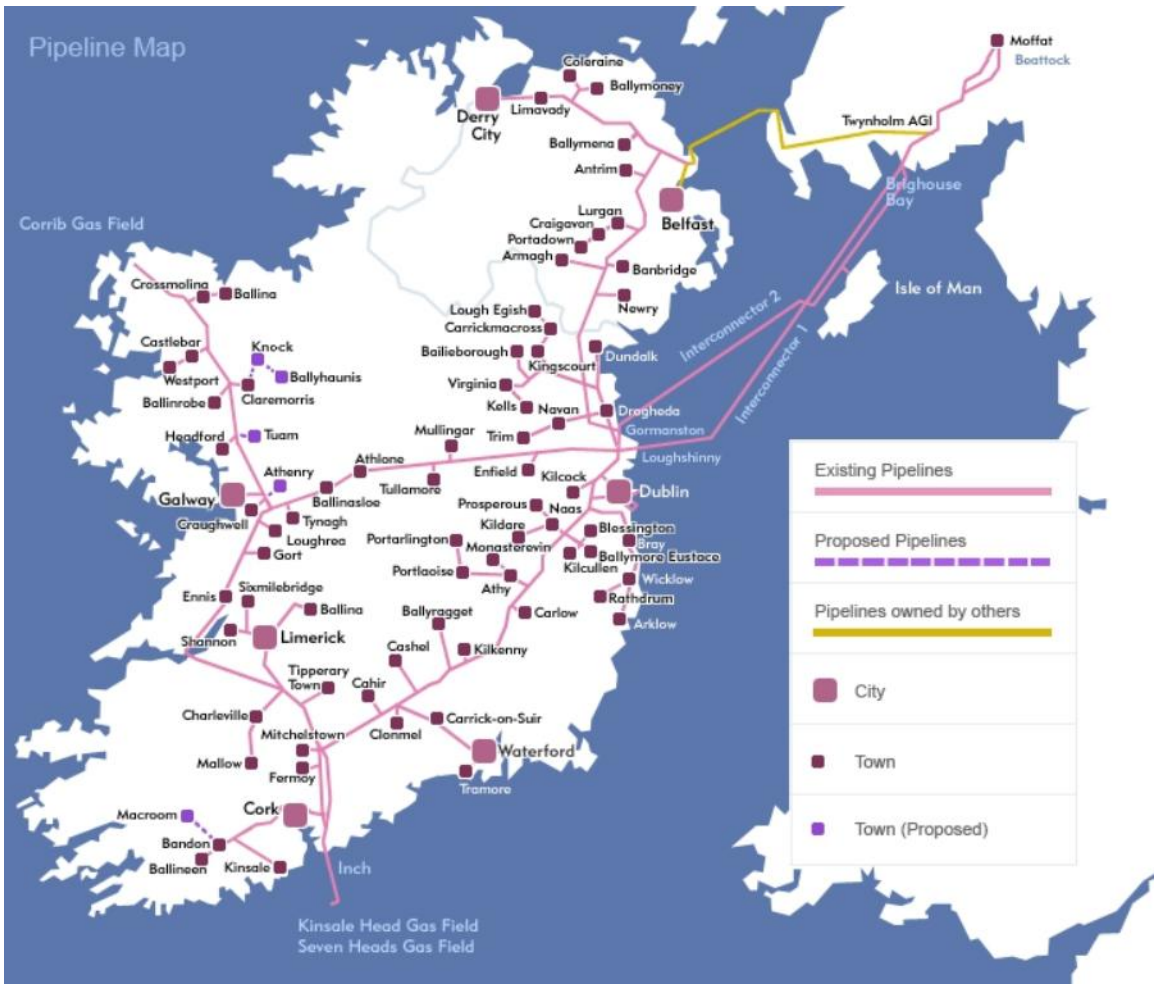


Figure 14: Natural Gas Network Pipeline (Source: Bord Gais Network)

The absence of natural gas supply presents opportunities and challenges for the sustainable energy development of the region. First of all, natural gas is cleaner and cheaper than most other fossil fuels, at least for heating and electricity generation. Large and small energy users in Kerry are therefore at a disadvantage compared to consumers connected to the network. In addition, compressed natural gas (CNG) is a serious contender to replace oil as a transport fuel due to its lower emissions, costs and the availability of proven technology in a wide range of vehicle types.

From a renewable energy point of view, the price of natural gas is generally so low that it is difficult to compete against it where it is available e.g. with wood fuels. This presents a unique opportunity for renewable fuels at county level. Having said that, the absence of natural gas network creates a barrier for the deployment of decentralised biogas production from anaerobic digestion. As we will see in Phase II of the study, one model of biogas development is to inject it where it is produced into

the natural gas network for distribution to final users where it can be converted to heat, power or used as transport fuel in CNG vehicles. Without a natural gas network pre-existing, this biogas option would be severely handicapped by the capital investment required for the distribution network as well as for storage and quality management solutions.

3.4 Shannon Liquefied Natural Gas (LNG)

Shannon LNG is a proposed Liquefied natural gas receiving terminal on the Shannon Estuary near Ballylongford and Tarbert in County Kerry to be built and operated by Shannon LNG Ltd, a company owned 50/50 by Hess LNG a subsidiary of the US multinational Hess Corporation and US hydrocarbons trading and transportation company Poten & Partners Inc (Wikipedia, 2013). LNG is natural gas that has been cooled to approximately minus 160 degrees Celsius to convert it into a liquid state. The volume as a liquid is approximately 600 times less than the volume as a gas, which makes it feasible for transportation in ships around the world. The LNG is stored and transported in insulated tanks; it is the very low temperature which maintains the LNG in a liquid state - it is not pressurised when it is in the ships or stored in the tanks at the terminal (Shannon LNG, 2007).

The figure below gives an overview of the proposed development at the terminal.

Figure 15: Proposed LNG terminal layout. Source: Shannon LNG

The project has been delayed for the last 6 years by a series of regulatory procedures. Most recently, Shannon LNG has challenged the State, the Attorney General and the Commission for Energy Regulation at an initial judicial review hearing scheduled in October 2012 on a regulatory decision whereby it must help pay for the costs of building the State's vital gas interconnectors with Britain if it wants to enter the Irish market. In January 2013, Shannon LNG has been given the go ahead to apply directly to An Bord Pleanala for the development of a combined heat and power plant at the site.

At this moment in time, it is not clear if the project will ever receive the go ahead. In any case, it is unlikely to result in the availability of natural gas supply in county Kerry in the absence of a distribution network. However, it is worth noting that LNG stored in high pressure containers can play a role as back-up fuel in independent biogas microgrids established to service an area without connection to the natural gas network.

3.5 District Heating

The concept of a biomass district heating system is a simple one – the centralised production of heat and the distribution of that heat through a network of insulated pipes, usually underground. Fuelled by locally grown and harvested wood fuels, community biomass district heating systems are commonplace across Europe (SEAI, 2012). Tralee hosts one of the few district heating systems in Ireland at the Mitchel's / Boherbee regeneration project where Tralee Town Council is developing a sustainable energy community based on home grown energy. The site (10 ha) is serviced by a 1 MW biomass heating plant supplying heat via a local insulated pipe network to 42 new apartments, 42 renovated housing units, the Council Library, a day-care centre and primary school. The boiler is fuelled by locally produced wood chips, generating an annual saving to the council of €100,000 on fuel bills.

The council is currently planning Phase II of the project which aims supplying heat to a third of the town population via a centralised biomass heating plant servicing:

- 2,000 houses
- Kerry General Hospital / Health Board head office
- Dairy processing unit
- County Buildings / Clash Industrial Estate
- Hotels / Sports Complex / Aquadome
- Primary & Secondary Schools, ITT South
- Campus

A similar project for the town of Killarney is also at feasibility study stage.

4 Conclusions

This first phase of the Kerry Sustainable Energy Roadmap study aimed at establishing the energy and emissions balance of county Kerry for the year 2008, selected as the baseline year against which targets for energy reduction and renewable energy supply will be benchmarked.

The data for the analysis was assembled by the consultant with the help of Kerry County Council's team of interns, using a mixture of bottom-up data collected 'on the ground' in Kerry and 'top-down' data extrapolated from national statistics. The analysis breaks down energy demand by socio-

economic sector and by fuel, and translates energy demand in related CO2 emissions and energy expenditure. The total energy demand was estimated at almost 4 TWh/year in 2008, with the residential sector corresponding to 36% of that total demand, transport 35% and services 20%. Industry's share is small (9%) in Kerry compared to at national level (19%), reflecting the relatively low industrialisation of county Kerry.

In terms of fuels, Kerry is highly dependent on oil (57% or 884 GWh/yr), showing its prime importance as a heating fuel (22% of total demand) and transport fuel (35%). Solid fuel occupy a significantly higher share of energy demand in Kerry (12%) compared to national usage (7%), reflecting the strong tradition of solid fuel heating in the county. It is estimated that local generation of wind energy and hydropower generation contributes to 18% of the Kerry electricity mix, bringing down considerably its carbon content (0.47 kgCO2/kWh) compared to the national electricity mix (0.55 kgCO2/kWh).

Overall energy usage in the county is responsible for the emission of 1.22 million tonnes of CO2 per year, equivalent to 8.8 tonne per person. The social cost of energy-related CO2 emissions in the county is estimated at c.28 million euro. The residential sector is the main contributor at 35%, after transport (30%) and services (25%). Energy represents 66% of the total greenhouse gas emissions at national level, after agriculture at 26%.

Energy expenditure is almost 470 million euro per year in Kerry, equivalent to approx. 8,800 euro per household. The county's economy spends most on electricity (c.200 million euro) after transport fuels (c.160 million euro) and heat (110 million euro). Households spend 227 million euro on energy or an average of 4,300 euro per year per unit on car fuels, heating and electricity.

The electricity network in Kerry is undergoing significant upgrade, in particular on the transmission network, to accommodate the connection of a large number of new wind farms and the export of electricity to the rest of the country. The wind generation capacity is likely to almost double in the next 3 to 5 years, to c.450 MW connected capacity, making the county a net exporter of electricity by then. Tarbert heavy fuel oil generation plant is the only local conventional power station in Kerry and is considered to contribute to the national electricity mix only.

There is no natural gas network in Kerry at present and it is unlikely there will be an extension of the national grid to service the county in the future. The Shannon liquefied natural gas terminal planned near Tarbert is unlikely to change that situation if it ever materialises.

Tralee Town Council in partnership with the County Council has been pioneering the introduction of biomass district heating in Ireland, with further plans for the roll-out of district heating to a large section of Tralee town as well as Killarney town.

The next phase of the study will be the assessment of the renewable energy resource in the county and the modelling of future energy systems and comparative analysis of local energy plans leading to a high penetration of renewable energy in the county.

Chapter II.
County Kerry's Renewable Energy Resource Assessment

1 Introduction

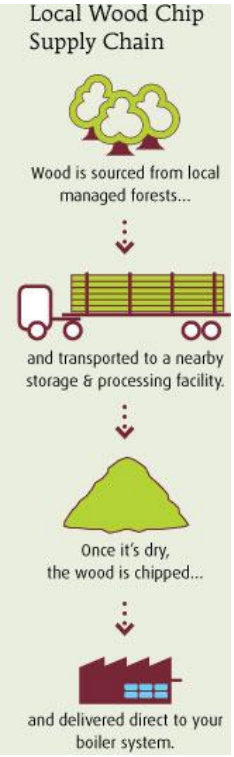
This chapter of the Kerry Sustainable Energy Community Roadmap builds on the Energy and Emissions Balance analysis of the county (chapter I). The objective of this part of the study is to assess the potential renewable energy resource available within County Kerry. Renewable energy is derived from natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, which are replenished constantly.

Where the renewable energy resource is available as a primary fuel in liquid, solid or gaseous form, our assessment will quantify the estimated resource on the basis of its energy content. This will be the case for bioenergy resources e.g. wood fuel, biogas, etc. For resources such as wind, solar, tidal and other forms of renewable energy which are converted directly into final energy, we will quantify the estimated resource in the form of potential thermal or electrical output from the relevant energy systems e.g. wind turbines, solar photovoltaic panels, etc.

This analysis drew primarily on published data from national agencies (Central Statistics Office, SEAI, Environmental Protection Agency, etc.) and regional organisations (Kerry County Council, Regional Waste Management Office, etc.). The methodology applied in the analysis also draws from the experience and models developed in the framework of two local energy planning studies:

- A Renewable Energy Roadmap for the Clonakilty District (Dubuisson, Stuart, & Kupova, 2011);
- Limerick Clare Energy Plan: Climate Change Strategy (Connolly , et al., 2012).

2 Biomass



Biomass is a very broad term which is used to describe material of recent biological origin that can be used either as a source of energy or for its chemical components. As such, it includes trees, crops, algae and other plants, as well as agricultural and forest residues. It also includes many materials that are considered as wastes including manufacturing effluents, sludges, manures, industrial (organic) by-products and the organic fraction of household waste. In many ways biomass is a form of stored solar energy through the process of photosynthesis in growing plants. The term 'bioenergy' is used for biomass energy systems that produce heat and/or electricity and 'biofuels' for liquid fuels for transportation. The following website of the International Energy Agency provides a wealth of information on bioenergy: http://www.aboutbioenergy.info/index.html

2.1 Forestry

County Kerry is the most forested county in Ireland with 55,000 ha planted (11.5% of land area). Wood fuel produced by the forestry sector at different stages of the lifecycle of a forest probably represents the largest bioenergy

resource available in the study area. Thinning and felling by-products which have no wood processing outlet (construction timber, boards, etc.) are an ideal source for wood fuel production, typically as logs or chips.

Forestry thinning in the small diameter assortment (7-13 mm, generally referred to as pulpwood or stakewood) represents the main potential for wood energy purposes. A certain amount of the larger diameter assortment (14-19 mm, also referred to as pallet wood) could become available as downgrade material or in areas where transport cost becomes prohibitive to bring it to relevant wood processing centres. Additional raw material is potentially available through the harvesting of tree tips (tip–7 cm) and through the collection of harvesting residues and some harvest loss material on suitable sites.

2.1.1 Assessment of the energy potential from forestry

The forecast of potential net realisable volume forestry production for Kerry was taken from Coford's report *'All Ireland Roundwood Production Forecast 2011-2028'* (Philips, 2011). In total, the forecast estimates that the private and public (Coillte) forestry sector in Kerry can potentially produce 357 and 427 thousand m3 of roundwood in 2020 and 2030 respectively, or an average of 300,000 m3 per year between 2011 and 2028 (around 14% of the total national production forecast). This represents a theoretical (unconstrained) wood energy resource of 575 GWh/yr in average over that period or 14% of the total final energy demand in Kerry in 2008.

Table 8 Forecast of potential net realisable volume production

	2011	**2020**	**2028**	**2011-2028**
Tip-7 cm cm assortment (,000 m3/yr)	7	14	10	10.2
7-13 cm assortment (,000 m3/yr)	56	104	61	67.5
14-19 cm assortment (,000 m3/yr)	61	129	134	98.8
20+ assortment (,000 m3/yr)	89	110	222	123.2
Total potential (,000 m3/yr)	213	357	427	299.7
Theoretical energy potential from forestry (GWh/yr)	408.5	684.6	818.9	574.8

(*) A conversion factor of 6.9 GJ/m3 of round wood was used (Philips, 2011).

We have used Coford's national estimates on the wood fibre potentially available for energy purpose to constrain the total realisable production volumes in Kerry identified above and determine a practical forestry energy potential taking into consideration other competing uses. The ratio between total production forecast and wood energy estimates (averaged over the 2011-2028 period) for the different roundwood assortments are presented in **Error! Reference source not found.** below. The total wood fibre potentially available for energy is estimated at 123,200 m3 per year in Kerry, representing a practical wood fuel potential of 174.6 GWh/yr or 4% of the county's final energy demand in 2008. There is no significant wood processing plant in the county. Estimates of the potential for wood processing residues and post-consumer recycled wood are integrated in Table 9.

Table 9: Estimate of potential availability of wood fibre for energy.

	2011	2020	2028	2011-2028	% of total production
Tip-7 cm cm assortment (,000 m3/yr)	3.4	6.0	4.1	4.4	44%
7-13 cm assortment (,000 m3/yr)	14.7	36.9	22.9	22.2	33%
Downgrade + Wood Residues (from 14cm+) (,000 m3/yr)	42.7	73.1	77.8	57.6	58%
PCRW (2-3% of total assortments)	5.3	8.4	7.5	6.8	6%
Total available for energy (,000 m3)	66.1	124.4	112.3	91.1	30%
Practical energy potential from forestry (GWh/yr)	126.7	238.5	215.4	174.6	

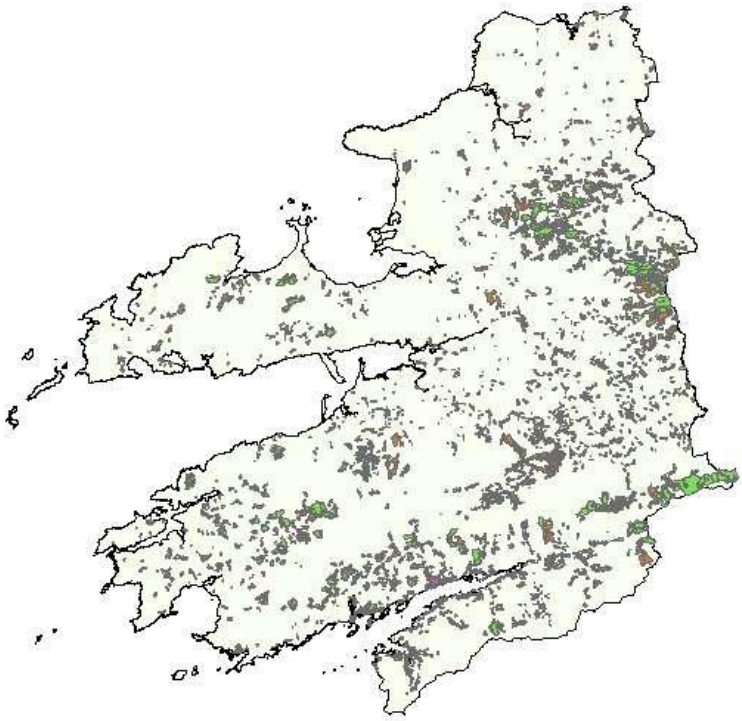


Figure 16: Afforested area in County Kerry. Source: DAFF, 2010

2.2 Energy Crops

Commercial energy crops are typically densely planted, high yielding crop species cultivated to produce liquid fuels (biofuels from corn, oil seed rape, etc.), solid fuels (short rotation coppice (SRC), elephant grass, etc.) or biogas (maize or grass silage).

2.2.1 Short Rotation Coppice (SRC)

Short rotation coppice (SRC) refers to a perennial, fast-growing, high-yielding woody crop that is harvested every two to five years and managed under a coppice system. The most popular coppice crops in northern Europe are willow and poplar.

Average commercial yields between 8-10 oven-dry tonnes (ODT) per hectare per annum are attainable (J. Wickham, 2010), but it is expected that new clones will yield 12-14 OD tonnes/ha,year (B CASLIN, 2010). 370 ha have been planted under the Bioenergy Scheme in Ireland, but none in Kerry according to SEAI's Bioenergy Maps.

The application of wastewater or wastewater treatment sludge to a short rotation coppice stand can increase average yields by up to 30%, due to the higher availability of nutrients and water to the plantation – two growth factors to which willow responds very well. This is referred to as biofiltration or bioremediation. It has attracted a lot of attention in recent years as an effective system to treat wastewater and other effluents, which provides additional income to growers through gate fees and increase yields.

2.2.2 Grass silage

Silage is forage biomass harvested and fermented for use as winter fodder for cattle and sheep. Grass silage is stored anaerobically in a silage clamp under plastic sheeting, or in a silo. Although silage is primarily produced as a feed, excess production can also be suitable as feedstock for bioenergy. Moisture content is high, typically 60-75%, and so it is not efficient to burn it, however it may be used as feedstock for anaerobic digestion. Fresh grass silage can yield between 250 – 350 Nm3 (volume at Normal temperature & pressure conditions[5]) of biogas per tonne.

2.2.3 Oil seed rape

Oil seed rape is an annual plant whose seeds are pressed to produce oil. Oil seed rape is grown on a rotational basis, typically one year in four. Current yields of rapeseed are about 3.5 tonnes per ha per year for spring sown rape up to 4 tonnes/ha,year for winter sown rape (SEAI, 2004). Approximately 450 litres of oil are extractable from a tonne of rapeseeds (D. Rutz, 2008).

Rape seed oil for energy is generally used for the production of liquid fuel for transport, with minimal processing as pure plant oil (PPO) in modified diesel engines, or as biodiesel after esterification. According to SEAI's Bionergy Maps, there is an existing 7250 ha planted with of oil seed rape in Ireland, none of those in Co Kerry. This is not surprising given the very low level of tillage farming in the county.

2.2.4 Straw

Straw, a by-product of cereal production, is successfully used as a fuel in biomass boilers. Straw is a significant fuel for district heating in Denmark for example. However, the agricultural land in the study area is primarily under pasture and the CSO 2010 Agriculture Census lists only 1696 ha of cereals, or less than 1%. The potential for straw as a fuel is therefore considered negligible.

---

[55] Nm3: normal pressure is generally assumed to be 1 atm while normal temperature may vary between industries, we will assume it is a 20 ºC.

2.2.5 Assessment of the potential for energy crops

2.2.5.1 Changes in land use

The total land area in County Kerry is 474,600 hectares (ha) with 286,386 ha farmed (60% of total). Grassland, including rough grazing, represents 99% of the farmed land cover. According to the CSO Farm Census 2010, the predominant farm specialisation in Co. Kerry is specialist beef production (46.6%) in addition to specialist dairying (18%) and specialist sheep rearing (16.7%). Generally, it is considered that specialist dairying is a profitable farm enterprise and there would be little scope in substitution of grazing in these farms towards energy crops. By comparison, only 10% of cattle rearing farms are economically viable.

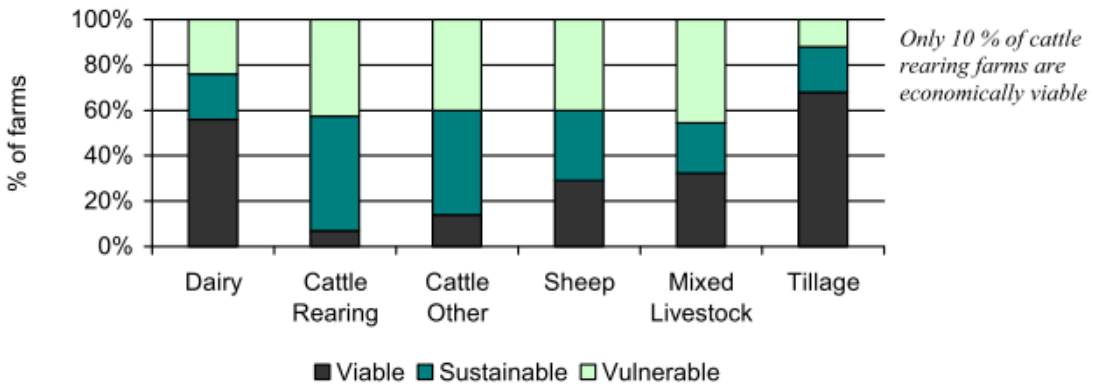


Figure 17: Classification of the 2010 Farm Population by System (Teagasc, 2011)

2.2.5.2 Woody Biomass Potential

On the basis of the above analysis, we assume that the strongest need for diversification and potential for energy crops uptake exists on specialist beef production farms, particularly among farmers at retirement age or part-time farmers. This represents a land pool of approximately 99,900 ha in County Kerry (47% of farms x 214,340 ha of grassland including rough grazing). Assuming the annual energy yield data published by Teagasc for willow SRC of 45.8 MWh/ha,year (Caslin, "Policy Targets & Bioenergy Scheme", 12/02/2008), the theoretical (100% substitution) potential of energy crops in Kerry is 4575 GWh/yr (115% of total final energy demand in Kerry in 2008).

Considering that 23% of farm holders in Kerry are at retirement age (65 y.o.) and that farming is a subsidiary occupation for 31% of all farm holders, a 20% substitution rate in the land pool above can be reasonably assumed for energy crop cultivation. Using the same energy yield for SRC as above, this represents a practical bioenergy potential of 915 GWh/yr or 23% of the county's final energy demand in 2008.

Table 10 below gives data extracted from the SEAI's Bioenergy Maps (see Figure 18 below also) in terms of agricultural land suitable for bioenergy production with high yield potential for energy crops. The statistics generated by the GIS database underlying the maps provide estimates of the total energy potential associated with each energy crop type. Both suitable land and energy potential estimates are broadly in line with the estimates resulting from our own analysis as outlined above.

Table 10: Energy Crop Potential

Energy Crop Type:	Ha of high yielding land:	% of farming land:	Yield (wet, tonne/ha)	Calorific Value (wet fuel) MWh/tonne	Total energy potential (GWh/yr)
Willow:	99,052	35%	28	2.44	6,774

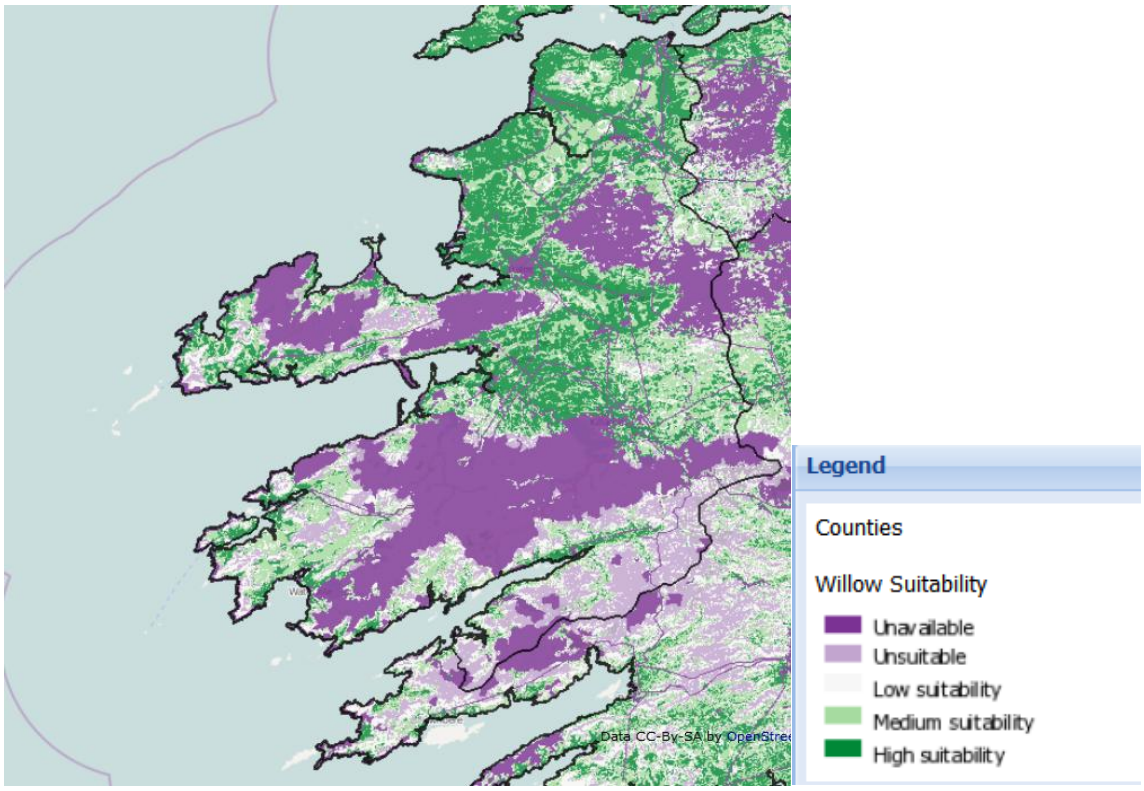


Figure 18: Willow suitability, extract from SEAI Bionergy Maps.

2.2.5.3 Grass Silage for Biogas Potential

According to the agricultural census 2010, there are 213,965 ha of grassland (excluding rough grazing considered unsuitable land for grass biogas production) in Co Kerry, out of which 60344 ha are harvested for silage a year.

It is assumed that an annual yield of 12.5 tonne DS (dry solid) per ha per year can be achieved based on two silage cuts per year on regularly reseeded grassland (BM Smyth, 2010). The energy value of grass silage was estimated on the basis of its biomethanisation at a rate of 300 Nm3 of CH4 (normalised cubic meter of methane[6]) per tVDS (tonne of volatile solid), at 90% VS per dry matter weight.

If all the silage currently harvested was used for energy purposes, the theoretical potential biogas resource would be 209 million Nm3 of methane (CH4) per year, with an energy content of 2091 GWh in total (equivalent to 53% of the current annual final energy demand of the county). Assuming a

[6] Methane is the combustible compound in biogas, generally present in biogas at a concentration of 50-60%. 1 Nm3 of methane has a net calorific value of c.10 kWh.

20% practical substitution potential from beef to biogas production, this represents an energy resource of 418 GWh/yr, equivalent to 11% of the county's final energy demand.

2.2.5.4 Liquid biofuels

As discussed above, the amount of tillage land is negligible in Kerry and the potential for rapeseed oil and biofuel production is considered insignificant in the county.

2.3 Animal By-products (ABP)

There is a total of 324 thousand head of cattle in the study area (CSO, 2010). Cattle slurry is captured when the cattle are housed during the winter and is generally stored under the cattle shed or in adjacent above or below ground tanks. There is a marginal amount of slurry captured from the milking parlour. Cattle and cows in particular, are typically housed for 12 to 16 weeks during the winter. The estimated total cattle slurry captured and stored is estimated at 1.06 million tonnes of fresh feedstock per year.

Pigs are housed all year round and slurry is therefore captured and harvestable on an ongoing basis. There is an ongoing stock of c. 22 thousand pigs in three licenced pig farms in the study area (EPA's IPPC reports read on June 2013) releasing over 31 thousand tonnes of fresh slurry per year.

Cattle and pig slurry has a low dry matter content at 5-10% depending on the level of dilution with rainwater or washing water. This slurry is generally spread on land within the study area. Anaerobic digestion of this feedstock offers the possibility to produce heat and power as an intermediate step in slurry management, with significant benefits in environmental and agricultural terms.

There is a relatively small amount of poultry in Co. Kerry, with one licenced poultry farm producing c. 1 million broilers per year (according to the facilities IPPC report for 2012). Poultry litter is mostly made of fresh manure and bedding (straw or wood shavings) and is generally quite dry (between 50% and 80% dry matter). Poultry litter is generally spread on land, but can also be used to produce mushroom composting. As an alternative, poultry litter can be used as feedstock for anaerobic digestion or combustion.

2.3.1 Assessment of the energy potential of ABP

The table below summarises the result of the energy potential assessment of animal by-products (slurry and manure) based on the livestock numbers identified above, specific slurry/manure output per head, and specific methane yield figures taken from literature (] Murphy, 2005; E. Salminen, 2002; RPS MCOS, date unspecified). In total, the theoretical potential annual biomethane output is estimated at 14.3 million Nm3 with an energy content of 143.2 GWh/yr, equivalent to c. 4% of the total energy demand of the area.

Table 11: Biogas potential from animal by-products in Co. Kerry

	Qty fresh feedstock (t FM/yr)	Biogas potential (m3 CH4/yr)
Cattle	1,060,899	13,796,997
Pigs	31,410	407,073
Poultry	1050	115,500
Total		14,319,570

2.4 Non-agricultural Organic By-products

An estimate of organic by-products suitable as feedstock for energy generation was compiled for abattoirs in the study area, as well as harvestable domestic and commercial waste sources. In terms of slaughter waste, it was considered that the practical potential lied essentially with belly grass for anaerobic digestion because of the strict interpretation of the Animal By-Product Regulations in Ireland (Smyth, Smyth, & Murphy, 2011) . The wet organic fraction of household wastes (food) as well as garden waste collectable within the study area was also included in our estimates, including the fraction of organic waste currently collected in black bins (unsegregated) or brown bins (segregated), home composted or brought to civic amenities. A similar approach was taken for wet organic waste from commercial or industrial premises in the study area. In addition, paper, cardboard and recycled wood were taken as potential fuels. Finally, sludges from wastewater treatment plants (WWTP) were quantified and included as a potential feedstock for anaerobic digestion.

Table 12: Bioenergy potential from industrial and municipal organic by-products.

	Kerry	
Wet	Qty (tonnes/yr)	Energy (m3CH4/yr)
Organic waste (tWM/yr)	21810	1,648,818
Garden waste (tWM/yr)	4,715	579,230
Sludges (tODS/yr):	3,231	684,049
Abattoirs (tWM/yr)	1,415	45,287
Total wet organics for AD		***2,957,384***
Dry	Qty (tonnes/yr)	Energy (MWh/yr)
Paper and carboard (tWM/yr):	42,403	198,552
Recovered wood (tWM/yr):	20,558	103,735
Total dry organics		***302,287***

The belly grass feedstock from beef (c.10,800 units) and sheep (40,400 units) kills has been quantified on the basis of data for 26 local abattoirs in the county (no licenced slaughterhouses) provided by M. Poliafico (EPA, 2004). Organic wastes from domestic and commercial sources in the study area were estimated on the basis of the Replacement Waste Management Plan for the

Limerick/Clare/Kerry region 2010-2011 (King & Sweetman, 2011) and the EPA National Waste Report 2009 and Waste Characterisation report (2008).

We have assumed that all wet organic by-products would be treated by anaerobic digestion to determine their energy potential. We have taken specific potential methane yields figures for each type of by-product according to E. Salminen (2002), R. Alvareza (2008), (Dubrovskis, 2010). We have taken the calorific value of dry by-products such as paper, cardboard and recycled wood as expression of their energy value. The table below presents the results of this analysis.

The organic by-products quantified above represent a potential renewable energy resources estimated at 332 GWh/yr for Kerry, equivalent to c. 8.3% of the total final energy demand in the study area.

3 Onshore Wind Energy

Wind energy is the most successful renewable energy technology in Ireland, with approximately 1600 MW of installed capacity by August 2011 in the country (Eirgrid, 2011), and 230 MW of connected capacity in Co. Kerry by 2012 (ESB Networks, 2012).

Figure 19: Kilgarvan Wind Farm, Co. Kerry. © Gracjan Fil - Photography

The on-shore wind energy development potential considered in this study relates to commercial wind farms in the multi-megawatts scale. This type of wind farm ranges from 4 and 42 MW in Co. Kerry, with the average size around 14 MW. Existing wind farms are composed of turbines between 800 kW (rotor diameter 50 m) up to 2.5 MW (rotor diameter c. 95 m), with hub heights from 45 m to 110 m.

3.1 Potential Onsore Wind Energy Resource Assessment:

The screenshot of SEAI's Wind Maps below presents an overview of wind speeds at 100 m hub height in the study area. The map on the right shows constrained areas designated as the Special Conservation or Protection Areas (orange or green), Natural Heritage Areas (lilac). Round dots indicate the position of some of existing wind farms.

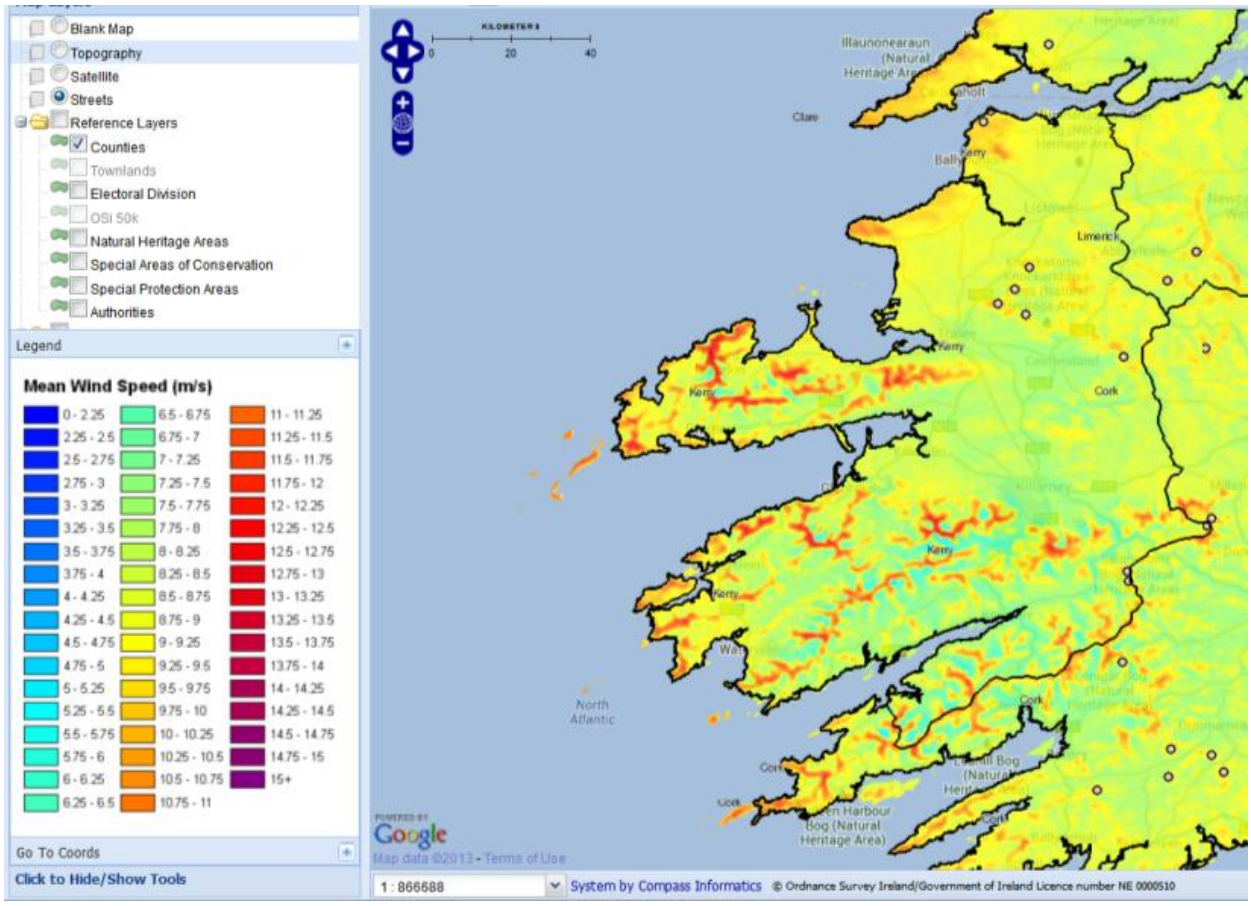


Figure 20: Screenshot of SEAI's Wind Maps for Co. Kerry.

Wind speeds vary from 6 m/s to 11.75 m/s at 100 m hub height, and are typically highest in coastal and elevated locations.

A detailed GIS analysis of the study area would be required to develop an appropriate estimate of the wind energy potential, taking into consideration wind speeds, proximity to dwellings, designated environmental or heritage areas, accessibility to transmission and distribution grid, environmental impact, etc. This type of analysis is beyond the scope of this study.

However, the Kerry County Development Plan's Renewable Energy Strategy 2012-2015[7] provides a good basis to approach the wind energy potential in the county. It specifies a total of 150 km2 of land as 'strategic for wind' and 544 km2 of land as 'open for consideration' for wind energy. Using a power density factor of 3 MW per km2 of land area (Denholm, Hand, Jackson, & Ong, 2009), there is a theoretical potential of wind generation capacity of 450 MW in strategic areas and 1632 MW in 'open to consideration' areas. Assuming a capacity factor[8] of 30.6% (Eirgrid, 2011), the theoretical potential for renewable electricity generation in strategic areas is estimated at 1206 GWh/yr and 4375 GWh/yr in acceptable areas, totalling 5581 GWh/yr.

---

[7] For more details, visit:

http://www.kerrycoco.ie/en/allservices/planning/codevplanvariations/renewableenergystrategy8thvariationtocdp/thefile,7512,en.pdf

[8] Capacity factor: the percentage of potential generation that is actually achieved considering that wind turbines do not work at full capacity all of the time.

Another approach to assess the wind energy potential in the county is to look at the wind generating capacity in the gate process of approval for grid connection by the distribution operator (DSO, ESB Networks) and the transmission grid operator (Eirgrid). In Kerry, there are 266 MW of wind farm projects that have signed a connection agreement with the network operators and are committed to exporting electricity to the electricity network at a future date. Another 276 MW have been allocated scheduled firm access by Eirgrid (Eirgrid, 2012). Wind farm projects in the pipeline of the gate process (542 MW) already exceed the theoretical wind potential in the 'strategic site search areas' of the county's renewable energy strategy.

Together with the capacity already connected of 230 MW, this represent a total wind generating capacity of 772 MW potentially operational by 2020. Considering a capacity factor of 31%, the average wind power output will stand at circa 240 MW by then, or 2.5 times the estimated average electricity demand in the county of 96 MW (Kerry County Council Planning Policy Unit, 2012). As a matter of fact, given the wind energy projects expected to be connected in 2013, it is likely that county Kerry will become a net exporter of wind energy this year.

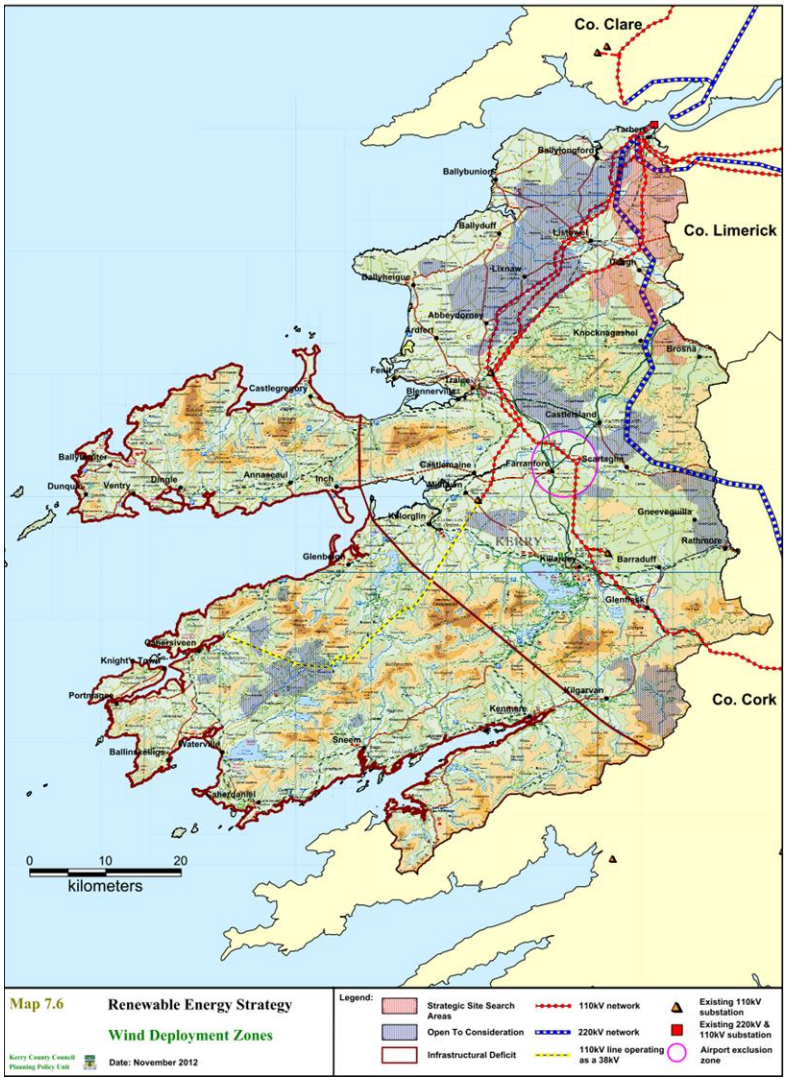


Figure 21: Wind Deployment Zones of Kerry CDP (Kerry County Council Planning Policy Unit, 2012)

Table 6 below summarises our analysis of the wind energy potential in county Kerry.

Table 13: Wind Energy Potential in the study area.

Total Wind Energy Potential	Total	
	Capacity (MW)	Output (GWh/yr)
On land designated as strategic search areas or 'open to consideration' in Kerry CDP Renewable Energy Strategy 2012-2015	2082	5585
Based on existing generating capacity and wind farm projects in the 'gate' connection approval process:	772	2069

Each approach gives very different estimates for the wind energy potential. The Kerry CDP land designation for wind provides an estimate of the theoretical, long-term wind energy potential in the county. This potential is equivalent to 5.4 times its 2008 electricity consumption. The estimate based on wind farm projects, existing and in the 'gate' pipeline, can be taken as practical potential for the 2020 horizon, equivalent to 2 times the county's 2008 electricity consumption.

4 Ocean Energy

Ocean energy, sometimes referred to marine energy, refers to off-shore renewable energy resources contained in the ocean's wind, waves and tidal currents. These resources are largely untapped today but they are clearly part of the long-term energy strategy of the Irish government and industry, in line with European ambitions in that regard. The National Renewable Energy Action Plan sets a target of 500 MW of wave and tidal energy capacity connected by 2020; the plan contains no target for offshore wind energy but makes reference to 800 MW of projects in the Gate 3 pipeline to the 2020 horizon.

4.1 Offshore Wind Energy Resource Assessment

With its long coastline, County Kerry has a substantial offshore energy potential. The screenshot of the SEAI Wind Energy Maps in Figure 22 below presents wind speeds within the 12 nautical miles (c.25 km) limit at 100 m hub height, which range from 9.25 m/s to 10.75 m/s. Sea bed depth, distance from the shore, navigational channels, designation for protection or conservation (orange and green areas in Figure 22: Offshore wind speed. Source: http://maps.seai.ie/wind/) are key constraints for the siting of offshore wind farms. In terms of sea depth, current or known future piled foundation technology for 'fixed' offshore wind turbines are compatible with sea depths up to 60 m. 'Floating' wind turbines are in development and will allow for siting at greater sea depth in the future. Accordingly, the Strategic Environmental Assessment (SEA) of the Offshore Renewable Energy Development Plan (OREDP) divides the offshore wind potential between 'fixed' (10-60 m depth) and 'floating' (60-200 m depth).

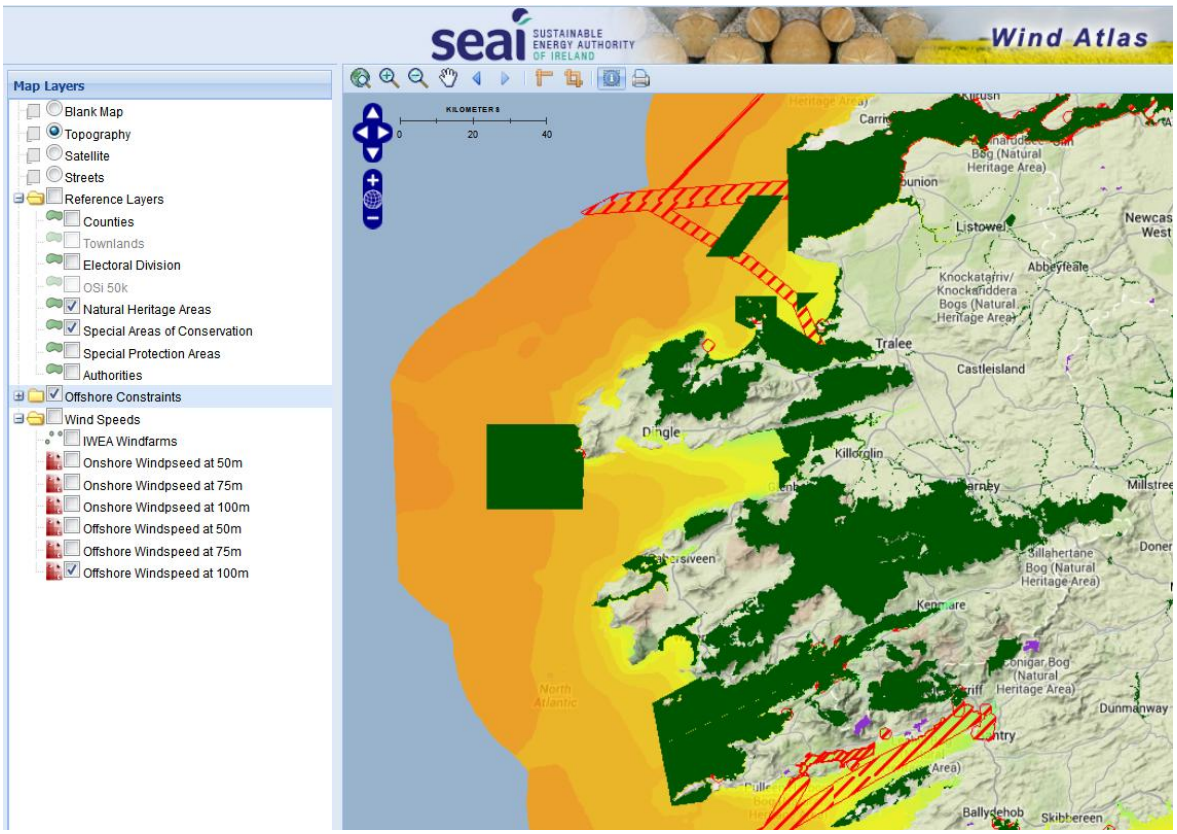


Figure 22: Offshore wind speed. Source: http://maps.seai.ie/wind/

In terms of distance from the shore, 100 km reflects the upper length limit of Alternating Current (AC) cable technology. For greater distances (beyond 100km), Direct Current (DC) cables would be required with convertor stations on land to convert to AC (AECOM Ltd, 2011). Offshore wind farm costs also increase significantly with the distance from the shore, generally accompanied by deeper waters. Table 14: Cost increase factors for offshore wind farm - distance to shore and water depth below gives scale factors of the cost increases of offshore wind farms as a function of distance to the shore and water depth.

Table 14: Cost increase factors for offshore wind farm - distance to shore and water depth (EEA, 2009)

		Distance to coast (km)							
		0–10	10–20	20–30	30–40	40–50	50–100	100–200	> 200
Depth (m)	10–20	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598
	20–30	1.067	1.090	1.113	1.136	1.159	1.262	1.501	1.705
	30–40	1.237	1.264	1.290	1.317	1.344	1.464	1.741	1.977
	40–50	1.396	1.427	1.457	1.487	1.517	1.653	1.966	2.232

The sea floor drops quickly along the Kerry Coast and brings the 60 m limit within 5 to 15 km from the coast. It is generally considered that the visual impact of offshore wind farms within 10 km is significant. In the UK, offshore developments outside the 12 NM limit (c.22 km) will be given preference.

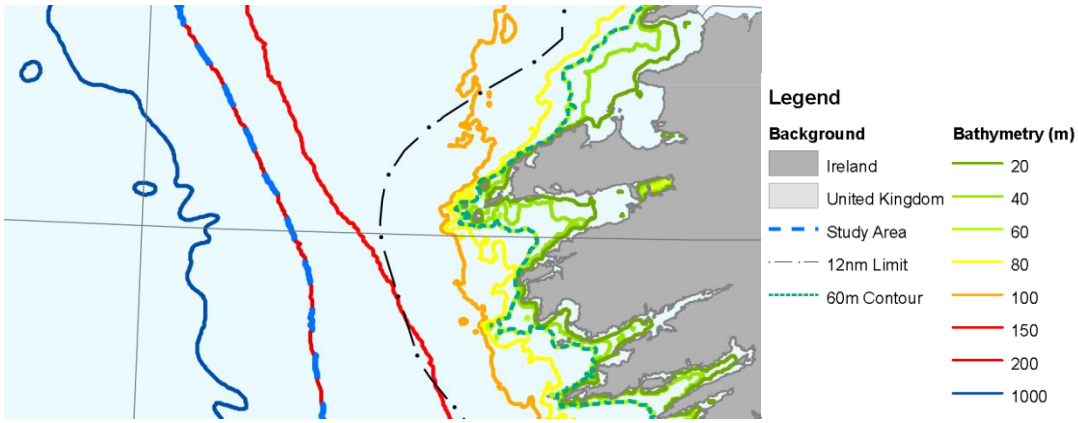
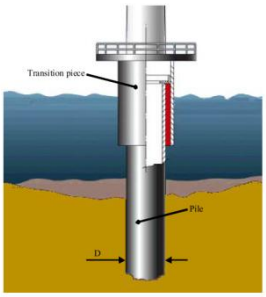


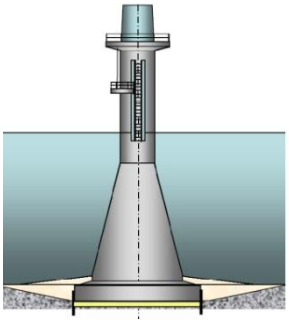
Figure 23: Bathymetry off West Clare (AECOM Ltd, 2011).

In the OREDEP's strategic environmental assessment, a number of constraints are applied to the theoretical potential of offshore wind based on issues such as impacts on soil and water, biodiversity, population and human health, material assets, heritage, seascape/landscape, material assets, climate, etc. The effect of mitigation measures is also applied and a generation capacity potential is determined.

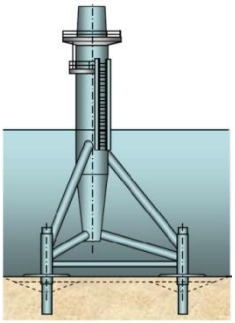
According to our analysis of the OREDEP's assessment of the potential for 'fixed' off-shore wind along the Kerry coastline[9], the total amount of development that could potentially occur without likely significant adverse effects on the environment (taking into account mitigation) can be estimated at 522 MW. Assuming a capacity factor of 42% (EEA, 2009), this 'fixed' wind capacity could generate c. 1910 GWh per year (equivalent to 40% of the total final energy demand in the county). However, the OREDEP Strategic Environmental Assessment states that given the narrowness of the coastal area suitable for siting wind developments within the 10-60 m depth zone, there is very limited potential to site devices away from sensitive receptors (fauna and flora). In addition, any offshore development within 15 km of the coastline is likely to have a substantial impact on the seascape character. While the Dingle bay has a relatively shallow floor, there would be substantial adverse effect on tourism and recreation in the bay area.



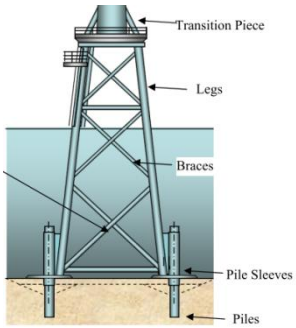
Typical monopole foundation design



Typical Gravity Base Structure design



Typical Tripod design

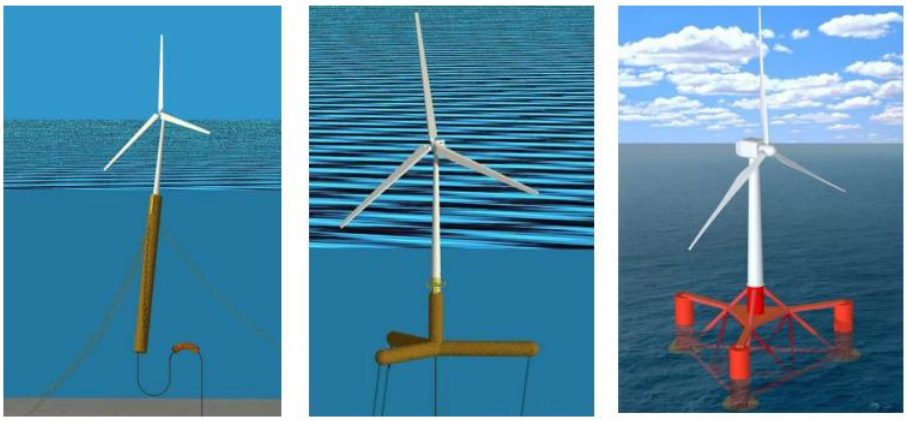


Typical Jacket design

[9] The coastline of Co. Kerry falls within two study areas of the OREDEP – Zone 4 (West Coast – South) and Zone 5 (West Coast – Centre). The off-shore energy potential along the Kerry coast was derived from the potential generation capacity of each zone (4&5) on the basis of the ratio between its total surface and the surface in that zone considered to be attached to the Kerry coastline.

Figure 24: Examples of typical 'fixed' wind turbine foundation designs. (Garrad Hassan & Partners Ltd. , 2011).

The potential for 'floating' offshore wind (beyond 60 m water depth and 100 km distance from shore) was estimated at 4563 MW without significant adverse effects on the environment (taking into account mitigation). Assuming the same capacity factor as above, this would potentially generate up to 16,710 GWh/yr (equivalent to 4.2 times Co. Kerry's final energy demand in 2008).



Spar Class TLP Class Jacket Class

Figure 25: Support structure classes for 'floating' wind turbines (Garrad Hassan & Partners Ltd. , 2011).

According to the OREDEP Strategic Environmental Assessment, the impacts of floating offshore wind development up to the level above are negligible to negative, however if larger areas are exploited there can be significant impact on commercial fisheries and marine wildlife. Impact on seascape can be minimised if developments are sited beyond a distance of 24 km from the shore.

4.2 Wave and Tidal Energy Resource Assessment

Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work, in particular electricity generation. Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves.

Figure 26: Wavebob, Irish wave power device. Source: Wavebob Ltd

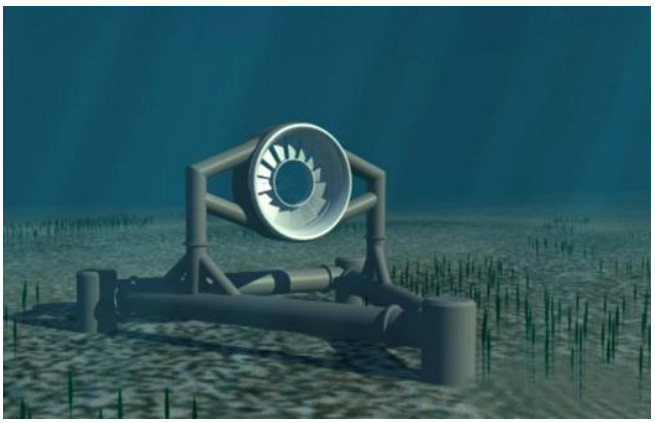


Figure 27: Illustration of Open Hydro's open centre turbine deployed directly onto the seabed.

There are currently a number of wave power devices being developed in Ireland, including:

- Wavebob (www.wavebob.com, ceased trading in April 2013);
- Ocean Energy Buoy (www.oceanenergy.ie)
- Hydam – McCabe Wave Pump

Tidal power, also called **tidal energy**, is a form of hydropower that converts the energy of tides into electricity or other useful forms of power. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design and turbine technology, are suggesting that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels. Open Hydro Ltd's Open-Centre Turbine is developed in Ireland and is one of the world's first tidal energy technologies to reach the development stage of permanent deployment at sea. See http://www.openhydro.com/home.html for details.

The following references were used in determining the potential for wave and tidal energy off the Kerry coast and Shannon estuary:

- Wave Energy Resource Atlas of Ireland (ESBI, 2005);
- Tidal & Current Energy Resources in Ireland (SEAI, 2005);
- The Offshore Renewable Energy Development Plan – Strategic Environmental Assessment (AECOM Ltd, 2011).

4.2.1 Wave Energy Resource Assessment:

The following maps show the practical potential for wave energy for Ireland (AECOM Ltd, 2011), and below a zoom-in on the potential off the Kerry coastline taken from the Irish Wave Atlas.

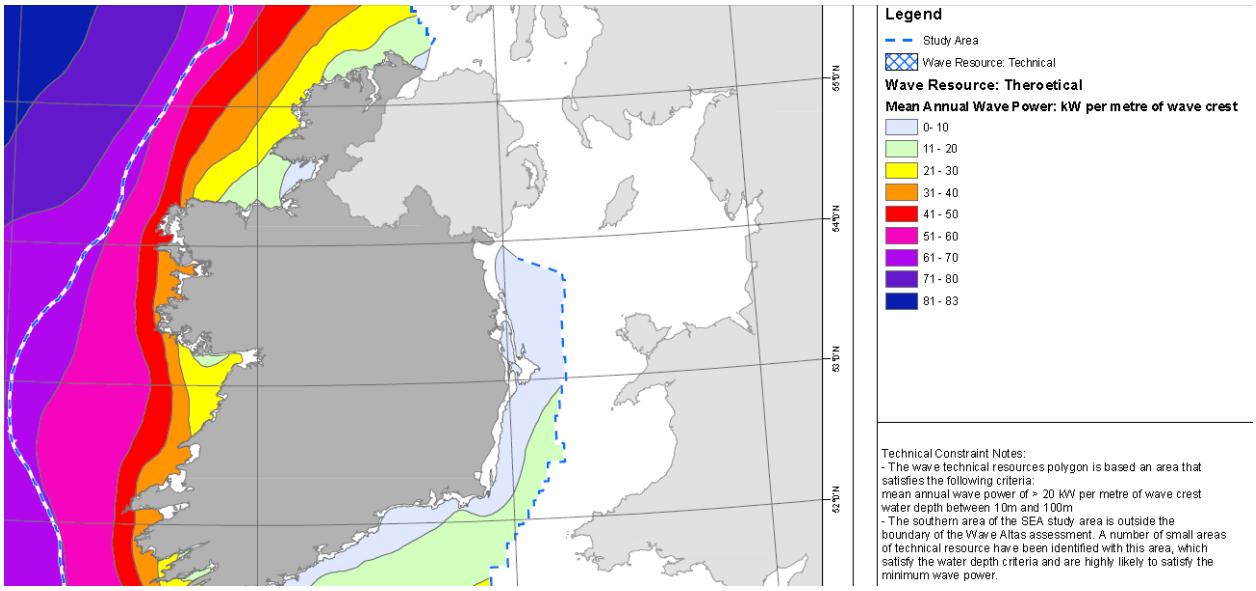


Figure 28: Wave Power Potential off the Irish coast, kW/m of wave crest (AECOM Ltd)

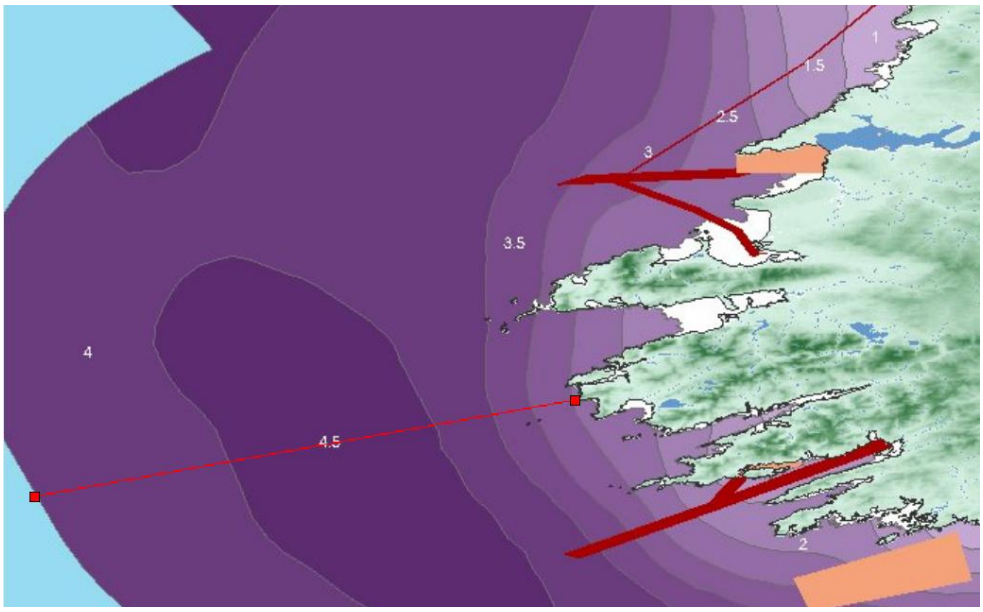


Figure 29: Average practicable wave power in MWe/km of wave crest, navigation channels (red), traffic separation exclusion zones (orange), 100 km distance from shore (thin red lines) (Wave Energy Atlas, ESBI, 2005).

Several observations can be made from these:

- A minimum of 20 kW of annual mean power per m of wave crest, considered the lower limit for technical feasibility, is available immediately off the Kerry coast.
- The practical wave power varies from 2 to 4.5 MWe per km between the 20 m sea depth boundary and the 100 km limit (maximum distance recognised as economically feasible for grid-connection from a wave farm). For illustration purposes, a 22 km of wave crest equipped with wave energy devices at a 50 km distance from the coast would be sufficient to cover the winter electrical peak demand of the study area (96 MW in 2011 according to the Kerry Co. Development Plan 2009-2015).
- The average practicable annual wave energy was modelled at about 40 GWh per km of wave front from the Kerry coast, and 24 GWh/km at proximity of the coast, based on modelling the output of the Pelamis wave energy device (ESBI, 2005). For illustration purposes, a 25 km of wave crest equipped with wave energy devices at a 50 km distance from the coast would be sufficient to cover the total annual electricity demand (1037 GWh/yr) of the study area.

The OREDEP assumes two levels of sea water depth for the development of wave energy corresponding to the technical constraints of different devices under development, one between 10 & 100 m deep and one between 100 & 200 m. According to our analysis of the OREDEP's assessment of the potential for wave energy along the Kerry coastline, the total amount of development that could potentially occur without likely significant adverse effects on the environment (taking into account mitigation) can be estimated as follows:

Type of device (see below for details)	**Pelamis**		**Ocean Energy**	
Sea water depth:	10-100 m	100–200 m	10-100 m	100–200 m
Generation capacity (MW):	1400	3220	1400	3220
Theoretical capacity factor	33%		44%	
Potential electricity generation (GWh/yr)	4000	9160	5400	12400
% of total electricity demand in Kerry, 2008	390%	880%	520%	1200%

The Ocean Energy Buoy (see Figure 30 below) is an Oscillating Water Colum device developed by the Cork-based Ocean Energy company and currently being full-scale tested at the Wave Hub in Cornwall. As waves enter a subsea chamber they force air through a turbine on the surface, generating electricity. As the waves recede they cause a vacuum, drawing air back through the turbine. This means the turbine rotates continuously regardless of the direction of the airflow. Its capacity factor is estimated to be 44% (Dalton & Lewis, 2011).

The Pelamis is an 'attenuator' type of device composed of cylindrical sections linked by hinged joints (see Figure 31 below). The wave induced motion of these joints is resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors. The hydraulic motors then drive electrical generators to produce electricity. Pelamis Wave Power has produced six full-scale models and the P2 version has completed a one-year accelerated real-sea testing programme at the European Marine Energy Centre in Orkney. The company claims a capacity factor between 25-40%.

Figure 30: Ocean Energy Buoy (www.oceanenergy.ie)

Figure 31: Pelamis Wave Power (www.pelamiswave.com)

Based on a power density of 15 MW/km2 for the Pelamis device, it is estimated that a wave energy farm of 25 km2 would cover the entire electricity needs of county Kerry.

4.2.2 Tidal Energy Resource Assessment

A review of the SEAI's report on the potential of tidal energy in Ireland indicates that:

- Peak tidal current velocities above 2.5 m/s are necessary for the viability of tidal energy devices based on current technologies (2005). The report speculated that it might be 2015 before technical breakthroughs enable the economical extraction of tidal currents at 1.5 m/s or more;
- The practical tidal energy resource lies within the bathymetry (depth of sea floor) zone between 20 and 40 m, outside of shipping lanes, military zones, disposal sites, areas with pipelines and cables;

On the basis of the above, 11 sites (see

- Figure 32) offering a practical potential for tidal energy have been selected;
- The tidal resource on the West Coast is concentrated in the Shannon estuary and the 'practical resource' is estimated at 367 GWh/year, some of that resource can be assigned to the Kerry shores of the estuary.

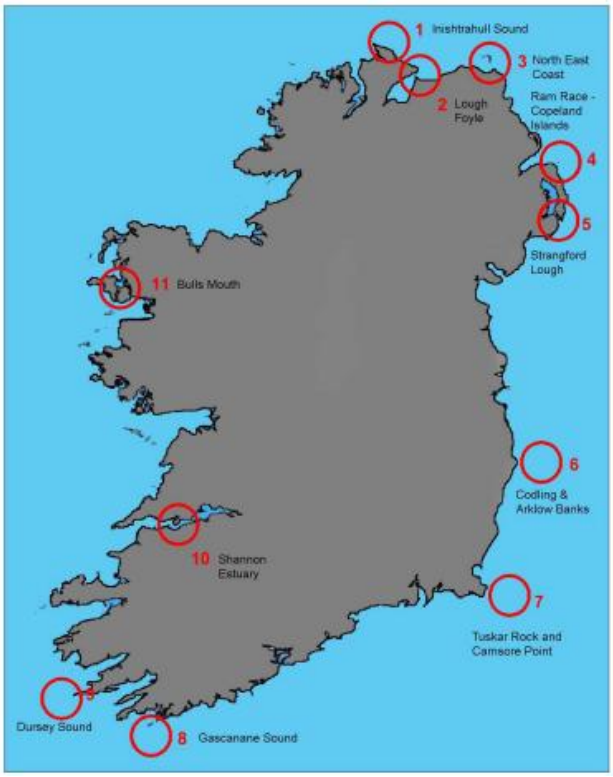


Figure 32: Tidal energy sites selected for offering a practical potential. Source: SEAI

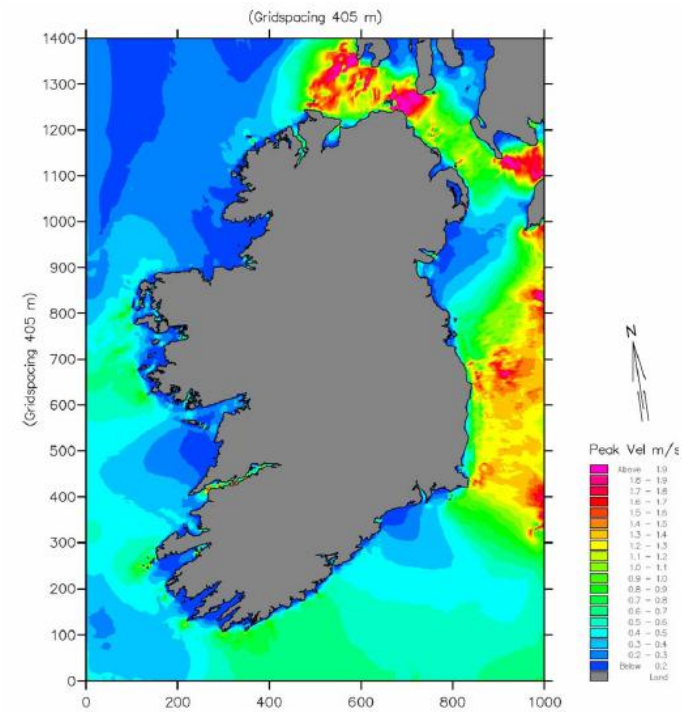


Figure 33: Hotspots for tidal currents. Source: SEAI

Although the OREDP-SEA (AECOM Ltd, 2011) and SEAI estimates that there is an unconstrained tidal energy potential in the Shannon Estuary of 100 MW, any commercial scale tidal development in the estuary is likely to have significant adverse effect on the Lower Shannon Estuary Special Areas of Conservation and Special Protection Area sites. There is also likely to be significant adverse effects on shipping and navigation due to the high intensity of vessels within the estuary. However, there

may be opportunities for the area to be used as a location to test tidal devices or for the deployment of a full size demonstration projects (AECOM Ltd, 2011).

5 Geothermal Energy and Ambient Heat

5.1 Deep Geothermal Energy Resource Assessment

Geothermal energy is extracted from the heat stored in the earth to produce power and/or heat. In Ireland, geothermal applications are limited to low temperature for direct heating. The map below (Figure 34) shows earth temperature at 5000 m below ground in Ireland:

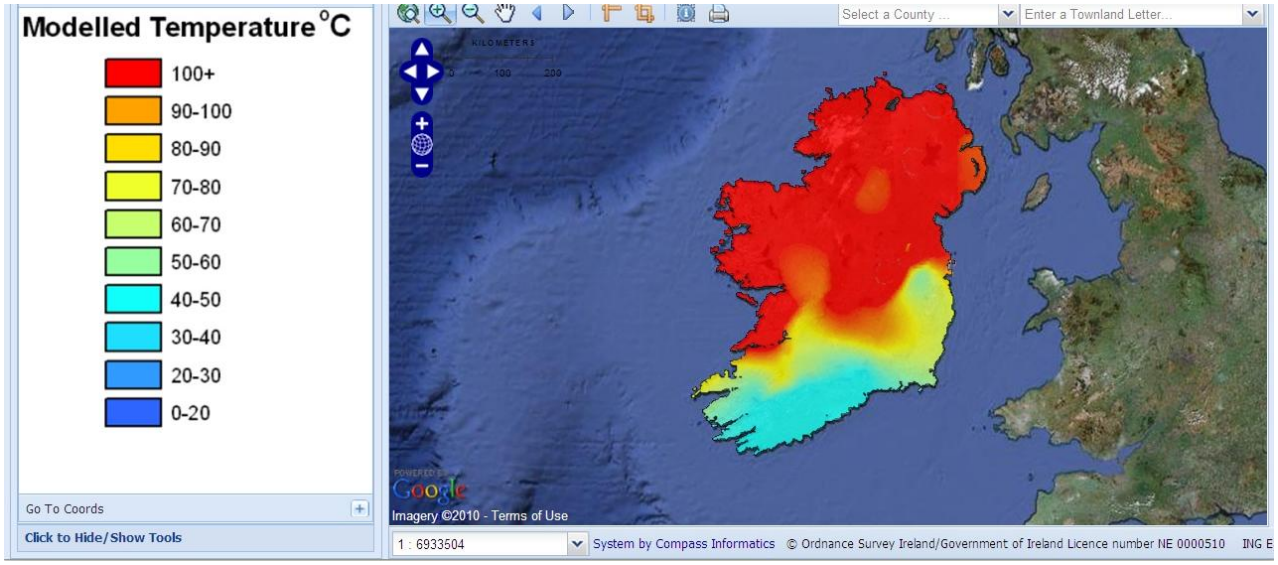


Figure 34: Screenshot of SEAI's Geothermal Mapping System, temperature at 5000 m depth (maps.sei.ie/geothermal/)

According to Alan G. Jones et al (2011), "little is currently known of the potential of Ireland's subsurface geology to provide geothermal energy for district-scale space-heating and electricity generation. Both applications require identification and assessment of deep, permeable aquifers or large-volume, hot, radiogenic granitic intrusions. Ongoing technological advances in utilizing medium-temperature (110–160 °C) groundwaters provide real potential for electricity generation within the upper range of thermal gradients observed in Ireland (28 °C/km). However, such potential can only be realised in the future if deep (4–5 km) geothermal source rocks can be identified within the country's subsurface."

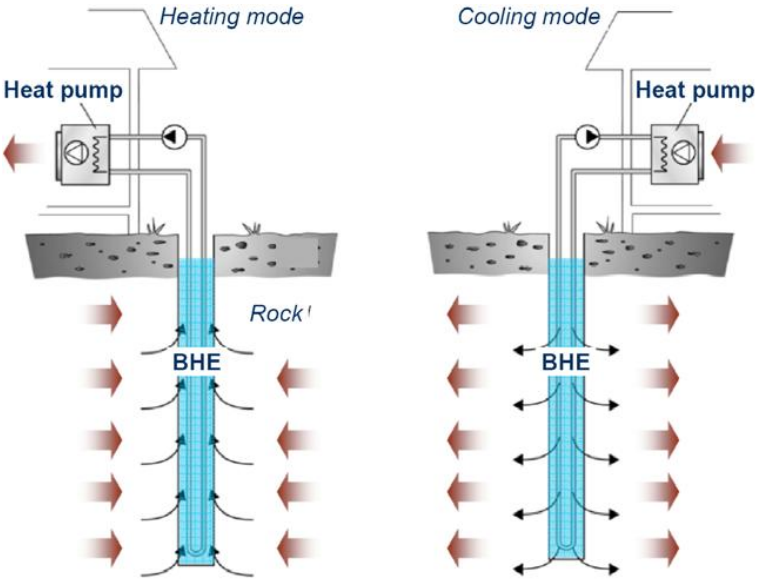
The SEAI's Geothermal Energy Maps indicates a lack of potential for deep geothermal in Co. Kerry except maybe in the northern part of the county along the Shannon estuary where theoretically temperatures of 122 °C can be found 5000 m deep. However, there are no urban centre of significance in that area and therefore no potential for geothermal district heating.

5.2 Ambient Heat Pumps Resource Assessment

'Ambient' heat pumps is a term encompassing the use of heat pumping technology to exploit low-grade heat sources (such as the ground, water or air) and upgrade them via a thermodynamic cycle to higher, usable temperatures. With ground-source heat pumps, closed-loop heat collectors are used to extract heat from the ground either close to the surface (approximately 1 m deep, average ground temperature of 6 °C) in horizontal collectors, or deeper in vertical boreholes (typically 100 m deep) where higher more stable temperatures are harnessed (10-12 °C). Heat pumps use a

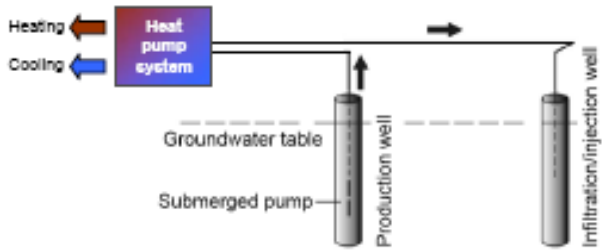
refrigeration circuit typically driven by an electrical compressor, however the ratio between heat output and electricity input of the system (referred to as Coefficient of Performance or COP) is generally favourable i.e. superior to 3.

The heat pump cycle can be reversed to provide cooling, whereby heat extracted for cooling purposes is rejected into the ground through the borehole system, with the advantage of recharging the borehole geothermal potential during the summer for winter use.



Source: Sintef, 2008 [1].

Where groundwater is available in sufficient quantities, it can also be used as a heat source with similar intake temperatures.



Depending on the level of the water table, dry sediment only yields 20-25 W of heat per linear m of borehole (EN 15450) while saturated sediment can yield up to 60 W/m. Consolidated rock can provide a heat extraction rate of 84 W/m (considering 1800 hrs of heat pump operation per year).

Air source heat pumps are an increasingly popular alternative to geothermal heat pumps as they are considerably cheaper and easier to install. However, the quality of this heat source is lower since its temperature varies widely between seasonally and diurnally, and is typically at its lowest when the heat demand is at its highest. However, significant improvements in efficiency have increased the prospect of air source heat pumps to become a credible renewable energy technology.

With the recent development of heat pumps capable of delivering heat at temperatures superior to 60 C efficiently, it is conceivable that heat pumps can be applied to a large percentage of the

building stock in Co. Kerry, especially in rural or sub-urban areas where there is better accessibility to the ambient heat sources. For illustration purposes, if we assumed that 50% of the thermal energy demand in the building stock in 2020 (2008 heat usage – 30%) was met with heat pumps, this would represent a thermal energy potential of 391.4 GWh/yr from renewable heat sources[10].

In addition, the potential of using individual geothermal heat pumps as part of a demand management and thermal storage system, in combination with intermittent renewable generators such as wind, might be worth exploring. Geothermal heat pumps are one of the technologies being considered for electrical energy storage along with batteries, pumped hydro, flywheels, etc. with the difference that electricity is stored as heat instead of chemical energy, kinetic energy, etc.

6 Hydropower

As discussed in the energy infrastructure assessment of Kerry, there is approximately 5.1 MW of hydropower plants in place in the county and an additional 0.65 MW capacity in the pipeline with the Hags Glen project, see Table 15 below. Where available, actual electricity generation output figures were used; otherwise we assumed an average capacity factor of 54% based on the Department of Energy study of the Small-scale Hydro-electric Potential (1985). Together, known projects have an estimated annual energy output of 27.7 GWh/yr or less than 1% of the total final energy consumption of the county.

Table 15: Hydropower plants in Co. Kerry.

Generator name	Generation Capacity (MEC, MW)	Project Status	Annual energy output (GWh/yr)
Owenbeg	0.8	Connected	3.82
Ashgrove Mill	0.65	Connected	1.80
Trewell Hydro Cottoners	1.03	Connected	6.50
Millstream Hydro	0.18	Connected	0.86
Slaheny River	0.485	Connected	2.31
Brandon Hydro	0.45	Contracted	2.15
Nancy Falls Hydro	1.25	Contracted	5.97
Lough Guitane	0.25	Energised	1.19
Hags Glen	0.65	EIA	3.10
Total hydro projects	**5.745**		27.70

The Department of Energy study mentioned above identifies 60 potential hydropower sites in county Kerry and estimates a potential installed capacity of 6.1 MW, with a potential annual energy output of 28 GWh/yr. It is difficult to determine how the sites identified in this study overlap with the projects listed above, however these figures would tend to indicate that a large share of the small hydropower potential in the county has already been harnessed.

[10] This takes into account the fact that part of the heat supplied by a heat pump is generated by the compressor and is therefore not considered renewable. As per the Irish Building Regulations Part L 2011, we assume that the heat pumps' coefficient of performance is at least 3.5 – or for each unit of electricity used to drive the heat pump, at least 2.5 are from a renewable source.

Figure 35: Cottoners Power Station near Killorglin. Source: Rainpower Ltd.

7 Solar Energy

There are two broad types of technologies to harness solar energy:

- Solar thermal systems using solar collectors to transform solar radiation into heat. That heat can be used for space heating, water heating, thermal processes, etc. Solar thermal systems can vary widely in scale, from individual home systems to large solar district heating systems.
- Solar photovoltaic systems using solar modules to generate electricity which can be grid-connected or off-grid (typically in conjunction with batteries). Again, PV systems can vary from home-scale to utility multi-megawatt scale.

Since solar energy is available everywhere and is inexhaustible, its potential is virtually unlimited. However, there are 3 main factors affecting the technical potential:

- Area of suitable hosting surfaces and impact of orientation and inclination on the capture of solar energy;
- The intermittency of solar energy and variation of solar irradiation according to diurnal and seasonal cycles;
- The match between the profiles of energy demand and solar energy supply, notably in terms of timeline (e.g. solar energy is at its peak in the summer while heat demand peaks in the winter).

7.1 Solar Thermal Energy Potential

In order to illustrate the potential of solar thermal energy, we have calculated the amount of solar collectors that would be required to achieve two levels of solar fraction[11] of the heat demand in Kerry (buildings and low-temperature thermal processes) and associated specific solar performance[12] figures. These figures are arising from a literature review of state-of-the art solar thermal applications in the framework of demonstration projects and research projects (Sunstore, IEA SHC, Solar Combi+, etc.).

The figures below indicate that there is a theoretical potential for c. 1.84 million m2 of solar collectors in Kerry on the basis of state-of-the art solar thermal technology, providing 52% of the total heat demand in Kerry.

[11] Solar Fraction: fraction of heat demand fulfilled by solar energy.
[12] Solar energy output per sq. m of solar collector per year.

Applications	Thermal energy demand (GWh/yr)	Solar Fraction	Solar output (kWh/m2)	Solar collector area (,000 m2)	Solar energy output (GWh/yr)
Residential	1207	60%	500	1449	724
Services	359	50%	550	326	179
Process heat	244	14%	500	66	33
Total	**1810**	52%		1841	937

This would literally mean that:

- all dwellings in Kerry use solar thermal systems to cover a large share of their space and water heating;
- all commercial & public buildings do the same;
- all factories using process heat at less than 150 °C use solar thermal systems to produce a substantial part of their thermal energy use (30% in 'good' practice and 50% in 'state-of-the art').

If we assume that only 25% of this theoretical potential is feasible due to physical, environmental and regulatory constraints, the 'practical' potential for solar thermal energy can be estimated at 460 thousand m2 covering 13% of the thermal energy demand in Kerry. For illustration purposes, we estimate that the roof area of all houses in Kerry is 2.3 million m2.

7.2 Solar Power Potential

We took a similar approach to illustrate the potential of solar power in Kerry. Key constraints in that regard include hosting surface (land, roofs, etc.) availability, grid integration limitations, environmental impacts, etc. While the analysis of all these factors specifically for the Kerry context is beyond the scope of this study, we have used the scenarios developed in the framework of the SunShot[13] Vision study by the U.S. Department of Energy (DOE) as a reference. This study considers the German model of large scale solar power integration and its long-term scenario assumed a continued reduction in solar power prices in line with developments of the last 5 years. The study determines that the potential for solar to meet the US electricity needs is 14% by 2030 and 27% by 2050 **Invalid source specified.**.

Assuming a similar level of long-term penetration for Kerry (27% of electricity demand), the potential for solar generated electricity in the county is estimated at 280 GWh/yr. Assuming a solar electricity output of 1000 kWh per kilowatt of solar power capacity installed, it would require the installation of 280 MW of solar power systems to generate this electricity. Assuming a power density of 5 m2 of solar panel area for each kilowatt of solar power system installed, the total panel area required would be c. 1.4 million m2. This is based on a solar panel efficiency of 25% at standard testing conditions. Again, for illustration purposes, this is 60% of the estimated roof area of houses in Kerry, or it would require 420 ha of land if these panels were ground mounted.

[13] http://www.eere.energy.gov/solar/sunshot/

8 Conclusions

The following table presents a summary of the results of the analysis conducted to determine the potential of different renewable energy resources in Kerry and compare it to the final energy demand in the county at the reference year 2008.

Table 16: Summary of results of the renewable energy resource assessment.

Potential Renewable Energy Resource (GWh/year)		
Resource	**Total RES (GWh/yr)**	**% of 2008 final energy**
Fixed Offshore Wind Energy	1,911	48%
Floating Offshore Wind Energy	16,709	420%
Wave Energy (10-100 m water depth)	5,417	136%
Wave Energy (100-200 m water depth)	12,404	312%
On-shore Wind Energy	2,069	52%
Wood Energy from Forestry	175	4%
Wood Energy from Energy Crops	915	23%
Biogas from Grass Silage	418	11%
Biogas from Agricultural, Municipal & Industrial Waste	475	12%
Small-scale Hydropower	28	1%
Geothermal Heat Pumps	391	10%
Solar Thermal Energy	937	24%
Solar Power	280	7%
Total	**42,131**	**1059%**

It is evident that the bulk of the renewable energy resource in Kerry lies with on-shore and offshore wind energy as well as wave energy, which together can potentially generate an amount of electricity equivalent to over 5 times the total final energy demand.

The theoretical potential of biomass in the study area has been estimated at circa 2 TWh/yr or 50% of the final energy consumption in the area. The potential consists primarily in woody biomass from forestry and energy crops (55% of total biomass) which can be combusted for the production of heat and/or electricity. Against initial expectations, our analysis indicates that wood fuel from forestry as a limited potential and that a very large substitution of grassland with energy crops such as miscanthus or willow would be required to make a significant contribution to producing the heat and electricity demand of the area from indigenous resource.

Grass silage together with other wet organic by-products of agriculture, municipalities and industry can be used effectively and without major alterations to the existing productive systems in place in the region for producing biogas through anaerobic digestion. The theoretical potential of biogas production was estimated to 893 GWh/yr or 22% of the final energy demand in the study area.

Please note that comparing the bioenergy resource to the final energy demand is only done to illustrate the scale of the resource, and a realistic picture of the actual energetic value of this resource can only be obtained when efficiency factors for its conversion in final energy are applied.

Together, solar technologies have an energy potential of 1217 GWh/yr, or over 31% of the county's final energy demand, of which solar thermal represents the biggest share. Geothermal heat pumps could also provide a substantial part of the thermal energy demand in the county and could play an important role as an energy storage technology.

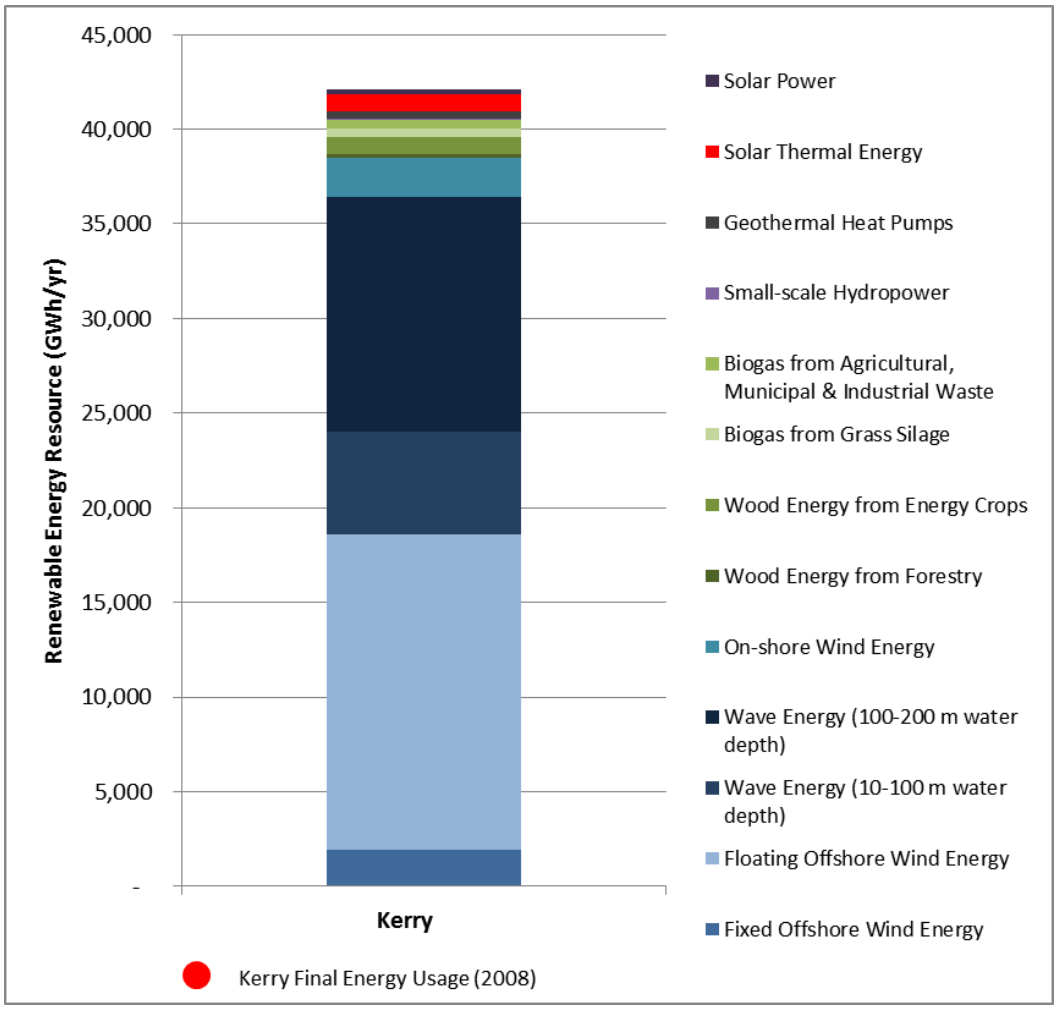


Figure 36: Renewable Energy Resource and Final Energy Demand in Co. Kerry

The total figure of 42 TWh of renewable energy resource potentially available in the study area, including its adjacent offshore area, is encouraging when compared to the final energy demand of the region (10.6 times more). Figure 36 gives a graphical representation of the scale of the renewable energy resource potentially available in the study area and compares it to the current final energy demand. It must be emphasised that the estimates obtained from this analysis are theoretical in that in many cases they haven't been constrained by economic, environmental or socio-cultural considerations. They give an indication of the upper limit of what is technically feasible.

The next steps of the analysis which will look at how this resource will fit within an overall energy system optimised on the basis of parameters such as cost-effectiveness, reliability of supply, environmental impact and considering socio-economic effects.

Chapter III.
Technological Pathways to 100% Renewable Energy Systems in Kerry

1 Introduction

This chapter of the Kerry Sustainable Energy Community (SEC) Roadmap builds on the Energy and Emissions Balance analysis of the county (chapter I) and the follows the Renewable Energy Resource Analysis (chapter II). The objective of this part of the study is to model different scenarios for the evolution of the energy system in Kerry towards 100% renewable energy supply and conduct a comparative analysis of these scenarios in terms of their economic, social and environmental impacts.

This transition will require a radical change not only in technological terms but also in institutional, economic and policy terms. Planning the future energy system therefore requires a long-term view and we have taken 2030 as a prospective target date for achieving the 100% renewable energy status for the county. Leading 100% renewable energy communities in Europe such as Güssing (Austria) and Samsø (Denmark) have demonstrated how this is achievable within a 20 year timeframe, having started their journey in the early 1990s.

Since the transition will take place through gradual, incremental changes in the energy system, it is essential to make sure that steps taken along the way do not compromise the end goal. We have therefore taken 2020 as a mid-point in the transition scenarios, and we have investigated different energy system options for the county that would fit within the overall pathway to the 100% renewable energy supply by 2030. For both the 2020 and 2030 cut-off dates, we have defined reference energy systems based on 'business as usual' scenarios, against which the proposed advanced energy systems are benchmarked.

For each scenario investigated, we have compiled indicators that will help comparing their impacts in:

- Economic terms: investment, fuel costs, operation and maintenance (O&M) costs, CO2 costs;
- Social terms: trade balance, job creation, security of energy supply;
- Environmental: greenhouse gas emissions, land use and resource depletion.

Having considered other aspects of the transition not readily quantifiable, we have made recommendations as to the consultants' preferred scenario for development. In the following part of the study (chapter IV), we will review and discuss different approaches for community participation in the renewable energy transition of county Kerry.

2 Methodology

2.1 Key Guiding Principles

This part of the Kerry SEC Roadmap study looks into the future to forecast what energy systems could or should look like in 20 years' time, an exercise that carries significant levels of uncertainty. Since it would be futile to try and remove completely this uncertainty, a number of key guiding principles were adopted as a basis for the methodology applied in this study. These principles are informed by best practice in renewable energy system modelling and planning (Lund, Renewable Energy Systems - The Choice and Modelling of 100% Renewable Energy Solutions, 2010) as well as by

other local energy planning studies conducted in Ireland (Dubuisson, Stuart, & Kupova, 2011; Connolly , et al., 2012). These key guiding principles are:

- The analysis shall consider all segments of the energy system: **electricity, heat and transport**, both from an energy consumption and energy supply point-of-view. Rather than looking at these segments in a 'silo' view, analysing their interactions enables developing integrated solutions that seek to optimise energy flux and efficiency within the overall system. As we will see in scenarios for 2030, integrating transport energy usage and electricity supply from intermittent renewable energy (IRES) sources such as wind is critical to achieving 100% renewable energy supply;
- It shall embrace **radical technological change** that goes beyond the limits of the current institutional and market framework currently in place, as well as reasonably anticipate technical innovation beyond the constraints of what is currently considered 'economical'. Concrete technological alternatives shall be designed in such a way that they can be compared with 'business-as-usual/status quo' proposals and enable choice awareness[14];
- **It shall consider short-term fluctuations of intermittent renewable energy sources across long-term time horizon.** In energy systems with a high penetration of IRES such as wind or solar energy, rapid changes in availability of energy supply against variable energy demand need to be managed in order to maintain security of supply. In addition, taking a long-term horizon is important from a technico-economic perspective since the energy technologies considered have a long lifetime (superior to 20 years). Investments made within the next ten years in Kerry will need to be compatible with the energy system of 2030 and beyond;
- The analysis shall take a **socio-economic perspective** in order to assess the feasibility of technical alternatives for society as a whole rather than looking at project feasibility purely from a business perspective. This principle recognises the fact that markets typically do not reflects benefits such as reductions in GHG emissions, job creation in rural areas, resource depletion and land-use changes, etc. In addition, long-term investments necessary to develop future energy systems will be typically borne by society and its public institutions, rather than market actors with short-term perspectives.
- **The methodology applied shall aim at balancing energy demand and renewable energy supply within the boundary of the region.** This promotes the idea of self-sufficiency rather than dependency on the national energy system to deal with the challenges of high renewable energy penetration locally. Energy can be exported or imported to/from the county, but without impacting negatively on the rest of the country's energy system.

2.2 EnergyPLAN – the modelling tool

EnergyPLAN is an energy system analysis tool developed by the Sustainable Energy Planning Research group at Aalborg University in Denmark, expanded continually since 1999. This computer model is designed to assist the development of national and regional energy planning strategies on

[14] According to Lund (2010), the basic idea of Choice Awareness is to "understand that existing institutional perceptions and organisational interests will often seek to eliminate certain choices from the political decision-making process when the introduction of radical technological change is discussed. The counterstrategy is to raise public awareness of the fact that concrete alternatives do exist and that it is possible to make a choice." Choice awareness is a central tenet of this study.

the basis of analysing the technical, economic and environmental impacts of implementing different energy systems and investments. The tool is complex in that it encompasses a wide variety of technical, economic and regulatory parameters; however the deterministic nature of the model allows testing and comparing different energy systems quickly and accurately. The EnergyPLAN model has been used to support energy planning for the transition to 100% renewable energy supply in different cities, regions and countries across Europe. It played an important role in the development of the Danish national plan for 100% renewable energy supply by 2050[15].

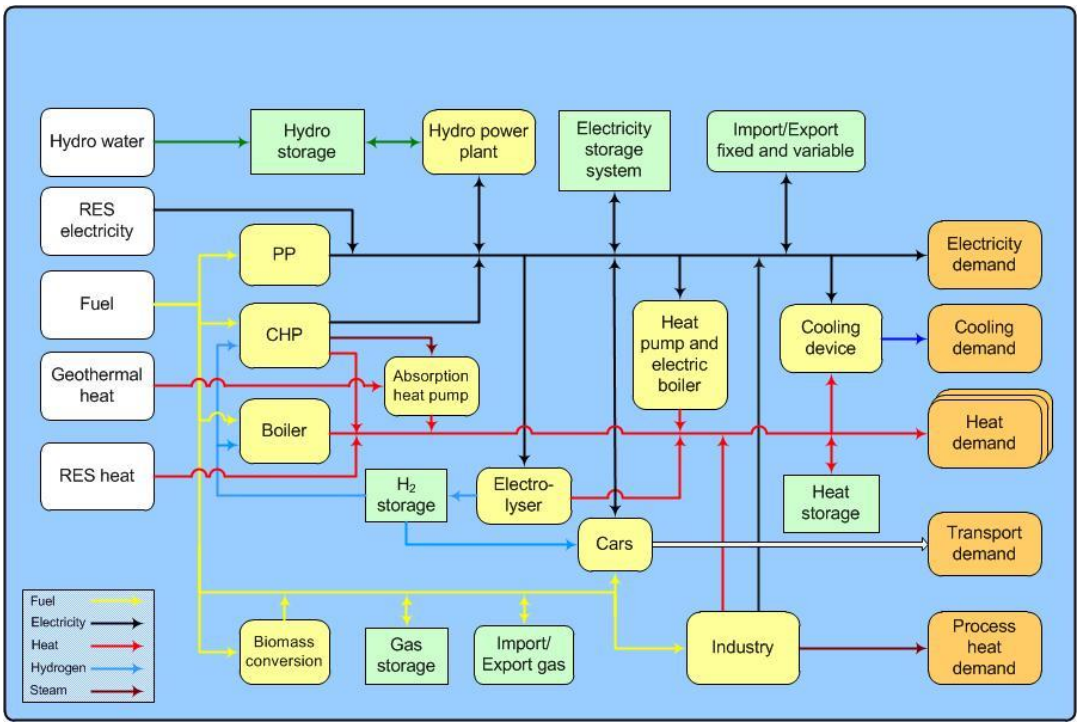


Figure 37: Flow chart of resources, conversion technologies, and demands considered in EnergyPLAN. Source: www.energyplan.eu

EnergyPLAN meets the requirements of the key guiding principles outlined above:

- It considers **all components of the energy system,** see Figure 37, in terms of energy uses (electricity, transport and thermal energy), energy generation, conversion and storage. It is also capable of modelling radical technological change in that it includes emerging energy technologies (e.g. electrolysis, wave energy, synthetic fuels, etc.);
- The model **simulates the energy system on an hourly basis over a one year period** in order to account for fluctuations in energy supply (in particular from IRES), energy demand and market prices (when modelling open energy systems with gas and/or electricity exchange). This is particularly important for the electricity system operation which require balancing supply and demand on very short time steps, and securing frequency and voltage stability;
- The model's algorithms are designed **to optimise the technical operation of the overall energy system** as opposed to optimising investments in individual components of the system. This enables designing future energy systems that maximise the benefits of the

[15] We recommend watching the video posted by the IIEA to get an overview of the Danish 100% RES plan and how Samsø island is pioneering this transition: http://www.iiea.com/events/denmarks-renewable-energy-strategy-and-the-energy-positive-island-lessons-for-ireland

system integration (e.g. excess electricity from wind is used to charge electrical vehicles' batteries which in turn can supply electricity to the grid during low wind periods);

- It also enables testing different regulation strategies for the energy system in particular with regard to ensuring grid stability and controlling excess electricity production. The energy system operation and regulation strategies can be tested free of the constraints imposed by existing institutional and regulatory frameworks, **allowing to explore radical technical and institutional changes;**
- The modelling outputs provide socio-economic indicators that allow measuring and comparing the impact of different energy system options including in terms of primary energy supply, renewable energy penetration, GHG emissions, costs, job creation, etc.;
- The model **allows simulating an energy system in island mode** (no transmission) to test its ability to balance supply and demand internally.

The model is a deterministic input/output model. General inputs are demands, renewable energy sources, energy station capacities, costs and a number of optional different regulation strategies emphasising import/export and excess electricity production. Outputs are energy balances and resulting annual productions, fuel consumption, import/export of electricity, and total costs including income from the exchange of electricity. The structure of EnergyPLAN is illustrated in the schematic below:

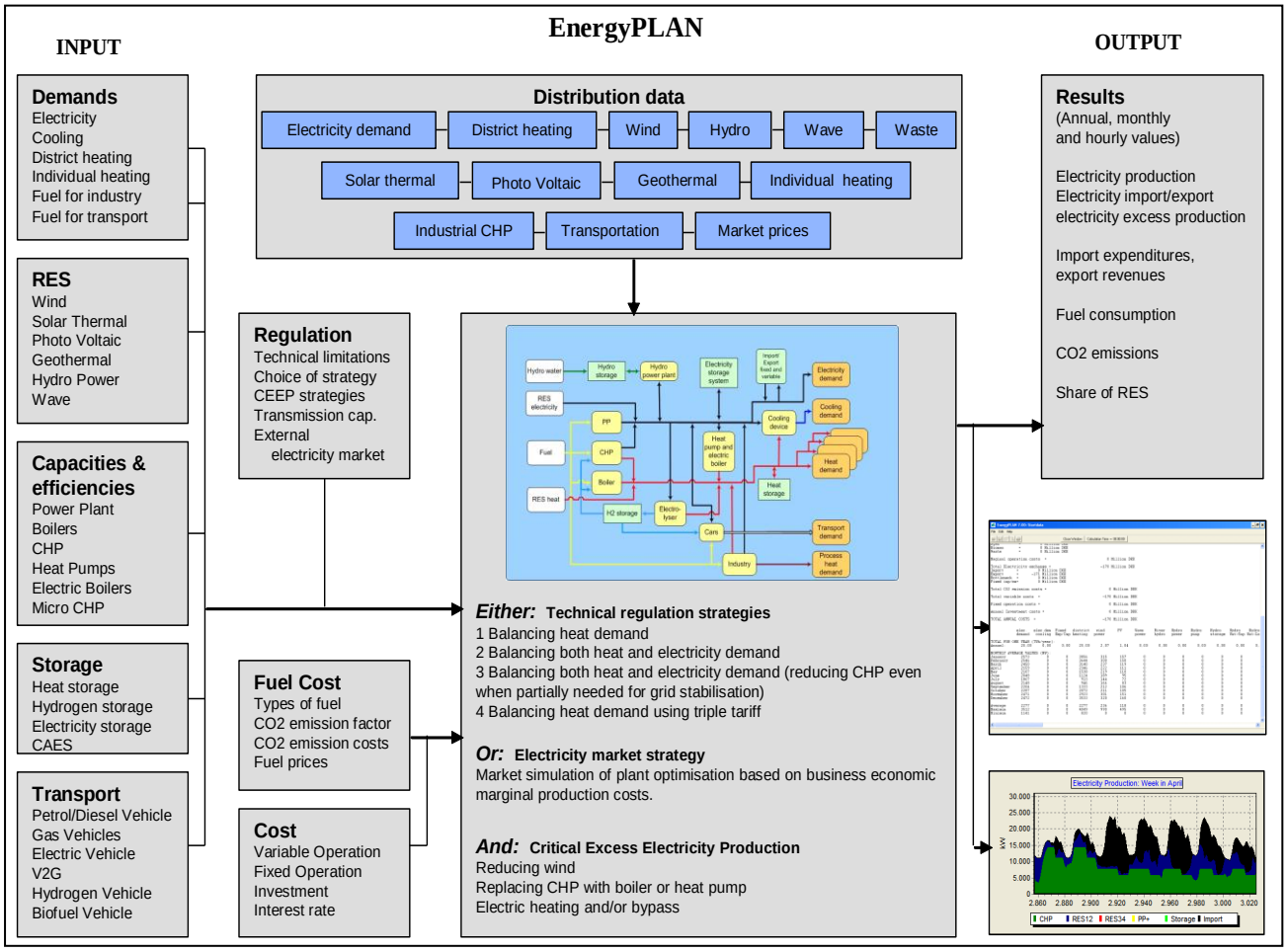


Figure 38: Structure of the EnergyPLAN model. Source: Connolly et al., 2012.

For more information on EnergyPLAN, visit http://energy.plan.aau.dk .

2.3 Approach used for the energy system analysis

We have used EnergyPLAN to model different future energy systems for County Kerry that can ben integrated into scenarios of 100% renewable energy transition. We have taken the following step approach for our analysis:

- 2020 was selected as our first cut-off date to represent a phase of large-scale integration of renewable energy in the system and of significant energy efficiency gains, at least in compliance with the national and European energy policies. In this phase, further increases in renewable energy penetration will have direct impacts on the overall energy system which must be modelled on an hourly basis;
- 2030 was selected as our second cut-off date to represent a situation in which the transition to 100% renewable energy supply is being achieved. In this phase, changes and investments in the energy systems are not compared to conventional fossil-fuel based technologies but to alternative renewable-based energy systems;
- For each cut-off date, a reference energy system is established representing a 'business-as-usual scenario' based on the current energy policy framework for 2020 and its extrapolation to 2030. NREAP 2020 and NREAP 2030 scenarios continue relying on fossil fuels for the supply of a significant proportion of the county's energy demand;
- Alternative energy systems are defined according to best practice and current knowledge of emerging energy technologies, in order to explore different scenarios of high levels of renewable energy penetration (approaching 50% of PES in 2020 and 100% in 2030). These alternative energy systems are modelled individually with EnergyPLAN and benchmarked against the business as usual scenarios;
- Key technical, environmental and cost indicators are taken from the modelling results for each energy system scenarios and the socio-economic consequences of each choice of energy system are compared;
- The energy systems were modelled for technical optimisation using a technical regulation strategy that seeks to balance both thermal energy demand and electricity demand within the energy system[16];
- The mix of renewable energy sources selected for each energy system options was carefully checked against the potential resource in the county with a view to contain primary energy supply within the county boundaries, again with self-sufficiency as a key consideration;
- In EnergyPLAN, all costs are annualised according to the following equation:

  which consists of the specific investment costs *I* and installed capacity *C* of each technology used (aggregated per technology type), their lifetime *n*, an common interest rate *i*, and the annual fixed O&M costs as a percentage of the total investment cost of each technology. In addition, fuel costs and variable O&M costs are calculated to determine the overall annual energy cost of the energy system modelled. In this way, various scenarios consisting of

[16] This is of particular relevance for the operation of decentralised combined heat and power (CHP) plants in situations of excess electricity generation due to high levels of IRES such as wind. With this strategy, the export of electricity is minimised mainly by replacing CHP heat production with boilers or heat pumps; thereby simultaneously increasing electricity consumption and reducing its production.

different technology mixes can be compared with one another in a consistent manner (Connolly et al., 2012).

- Costs data was provided by David Connolly of Aalborg University and calibrated against the data available from previous studies (Dubuisson, Stuart, & Kupova, 2011) as well as the Danish Energy Authority's references for energy system modelling (Energistyrelsen, April 2011)[17]. In addition, we have used SEAI's bioenergy supply curves for projections of future biomass fuels costs (SEAI, 2012). Please note that the costs accounted for are economic costs to society and do not include taxes (VAT, excise duties, etc.), subsidies, profit margins, etc.

3 Findings of the energy system analysis

3.1 Energy Demands for 2020 and 2030

Energy demands by 2020 were forecasted from the 2008 energy balance for the county established as part of the first part of this study (see chapter 1), considering SEAI's assumptions for the national energy forecast for 2020 (SEAI, 2011). Key trends forecasted between 2008 and 2020 from energy demand point of view include:

- The impact of the recent economic crisis as well as increase in fuel prices, will result in stabilising and even reduction of energy demand in line with a slow economic recovery to 2020, compared to rapidly growing energy demand prior to that;
- This will be compounded by the impact of energy reduction policies and programmes planned as part of the National Energy Efficiency Action Plan and locally-led energy efficiency campaigns. Energy savings will be particularly significant in residential and services sector buildings;
- Overall, the final energy demand of the county has decreased by 17%, with particular reductions in the residential and services sectors (-20% and 28% respectively) and to a lesser degree industry (-10%);
- Transport energy reduction is estimated at -14% while agriculture's energy demand increases by 13% due to intensification and increased outputs in the sector;
- Electricity consumption reductions are less dramatic, in part due to lower efficiency gains in that area but also intensified power usage in the industrial sector as well as some electrification of the transport sector. Similarly electricity usage for heating in the residential and services sectors, mainly as a result of further electric heat pumps penetration in these sectors.

It must be noted that in line with national trends, the relatively high energy reductions forecasted above have been frontloaded in the early years of the economic crisis. We estimate there was a 7% total final energy use drop between 2008 and 2010 in Kerry, in line with a circa 10% drop at national level.

[17] The DEA's 'technology catalogue' provides a useful forecast on the evolution of investment and O&M costs as well as efficiency of relevant energy technologies. This allowed taking into consideration future technological improvement and cost reduction following commercial deployment of new technologies. Available at http://www.ens.dk/info/tal-kort/fremskrivninger-analyser-modeller/teknologikataloger

Figure 39: Forecasted evolution of final energy demand in Co. Kerry

There are no readily available authoritative references for forecasting energy demand beyond 2020. Our estimates for 2030 are based on projecting the 2008-2020 trends further, reflecting a continued proactive policy of energy efficiency improvements at local level. In total an additional 8% energy reduction in total final energy consumption is achieved between 2020 and 2030, compared to the reference year of 2008. These are largely due to further thermal energy savings in buildings, significant gains in electricity efficiency and a deeper penetration of electric vehicles.

Please note that:

- we have assumed that final energy requirements remain constant between the different energy system scenarios we have analysed for a given cut-off date; in other words the amount of heat, transport and non-thermal electricity required do not vary. The focus of the modelling effort and the overall study is on renewable energy supply rather than energy demand;
- on the same basis, the costs of energy demand reduction and energy efficiency increase are not accounted for in the economic analysis of future energy scenarios. It is generally considered that the cost of energy efficiency measures is negative to society (SEAI, 2011).

4 Energy System Scenarios 2020

4.1 The scenarios investigated

Given the range of variables involved (energy technologies, fuel types, regulation strategies, etc.), it is not possible to study all potential scenarios within the scope of this analysis. Instead, a limited number of credible scenarios were selected on the basis of:

- previous research in this area that is particularly relevant to Ireland (Connolly, 2012; Connolly et al., 2012; Dubuisson et al., 2011);
- best practice in advanced energy systems with high renewable energy penetration, in particular from Denmark (Lund, Renewable Energy Systems - The Choice and Modelling of 100% Renewable Energy Solutions, 2010);

- the nature of energy demand in the county (chapter I) and renewable energy resource potentially available within its boundaries (chapter II).

The following energy system scenarios were analysed for 2020:

a) NREAP 2020:

This is our reference scenario in which Kerry complies with the national energy policies as stated in the National Renewable Energy Action Plan (NREAP) in line with the EU 2020 targets i.e. 16% of primary energy supply coming from renewables. As in the national plan, a strong emphasis is given to renewable energy electricity to meet the overall renewable energy target. Renewable heat penetration remains modest and exclusively via individual heating systems in buildings and industry. In transport, biofuels substitute 10% of all liquid fuels (diesel and petrol) used for passenger vehicles, freight and the agriculture/fishing fleet. Electrical vehicles have a 10% penetration among passenger vehicles (approximately 6,600 vehicles or 115 million km travelled).

b) District heating with biomass CHP + Individual RES (CHP DH & Ind. RES):

This scenario improves on the NREAP scenario by introducing district heating in major urban centres to meet a total heat demand of 144 GWh/year (equivalent to approximately 75% of the estimated heat demand in Tralee and Killarney). The heat for these district heating systems is generated by a combination of biomass CHP units and oil boilers for peak loads. Outside of district heating areas, solid biomass (wood fuels) meets over 25% of individual buildings heat demand and 17% of industrial fuel consumption. Solar thermal systems meet 5% and electrical heat pumps circa 10% of the total heat demand in buildings.

c) District heating with centralised heat pumps, biomass peak boilers and solar thermal + Individual RES (WB + HP+ST DH & Ind. RES):

In this scenario, large centralised heat pumps and solar thermal systems provide the bulk of the heat supply mix for district heating with the addition of biomass boilers for peak loads and back-up (no biomass CHP). Also, the district heating schemes are equipped with limited heat storage capacity (about 30% of an average winter's day heat demand). Solar thermal energy further reduces the demand for primary fuels (biomass) for district heating. Centralised heat pumps and heat storage enable to capture excess electricity supply from wind to produce heat and store it, if necessary, momentarily. These 'demand side' measures add flexibility in the system and help balancing supply and demand.

d) Individual RES only and low biomass (Incl. RES low biomass):

This scenario's focuses on renewable heat development through a higher penetration of heat pumps and solar thermal systems in individual buildings, including in urban areas. No district heating is introduced and the reliance on biomass fuels is limited to 10% individual heating, industry (17%) and biofuels (10%). This scenario has been defined to illustrate the impacts of a strategy that minimise reliance on biomass.

In all 2020 scenarios, we have included for wind electricity generated by a total of 496 MW reflecting wind farm projects in Kerry that are currently live or have received firm connection offers (see

chapter II for details). We also included for 6 MW of hydropower capacity, representing a small increase on the current installed capacity to reach close to the estimated potential resource in the county.

Please note that in this analysis of the 2020 scenarios, we have accounted for a large 'virtual' power plant in our models. That virtual power plant reflects the role played by large generation plants part of the national electrical infrastructure to balance supply & demand and ensure grid stability in Kerry via the transmission network[18]. This enables us to account for the fuel used, the cost and CO2 emissions associated with generating this electricity. Equally we have accounted for the coal and natural gas substituted on the national grid by the excess renewable electricity exported from the county.

4.2 Modelling results

Figure 40 below presents the primary energy balance in the county for the different energy system scenarios modelled. Primary energy includes primary fuels (fossil fuels and biomass) supplied to the county's energy system as well as energy delivered without undergoing a conversion process (solar heat, wind or solar electricity, hydroelectricity, etc.). The coal and natural gas energy values account for the fossil fuels used to generate the electricity imported (positive values) and substituted by the renewable electricity exported from the county ('export correction' negative values). Coal consumption also includes domestic, services and industrial use.

Biomass includes solid fuels used in individual boilers or stoves, biomass used to produce biofuels for transport, and biomass used by CHP units or wood boilers connected to district heating. Oil includes oil used for transport, individual heating and by peak boilers in district heating, as well as an industrial fuel.

In Figure 41, we illustrate the weight of the different RES in the overall renewable energy mix, as well as the penetration of RES in the overall primary energy supply and in the electricity supply of the county.

[18] We assumed that the electricity imported via the transmission grid is generated in conventional thermal plants using a mix of coal (41%) and natural gas (59%) with a combined efficiency of 48%.

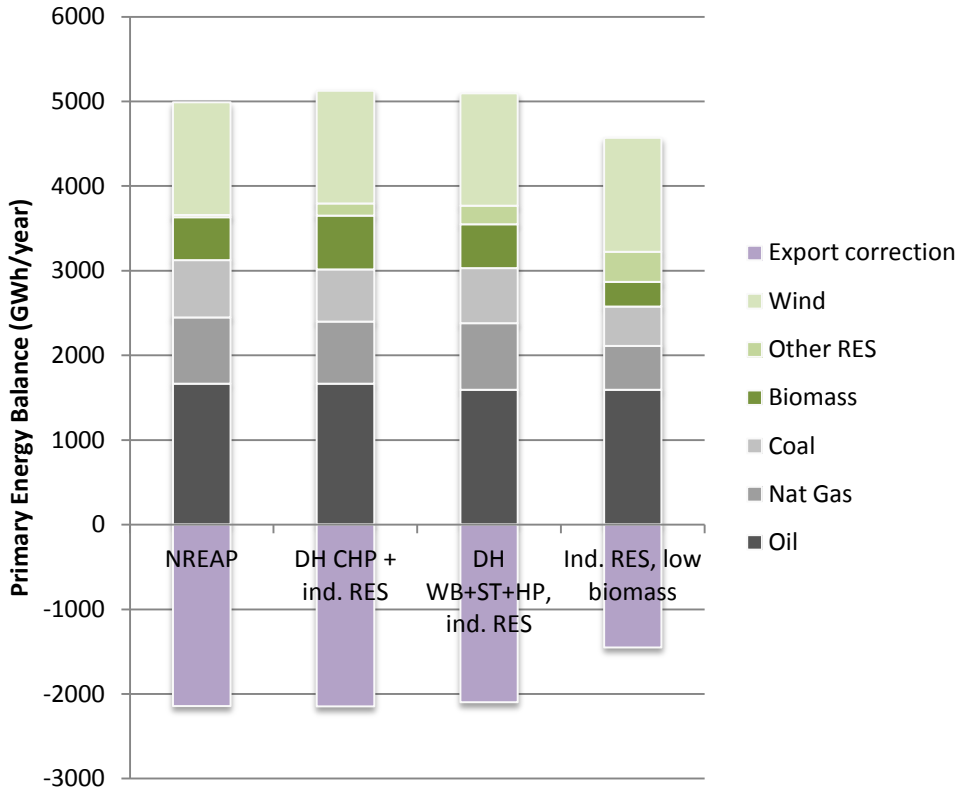


Figure 40: Primary energy balance in the county for 2020 scenarios.

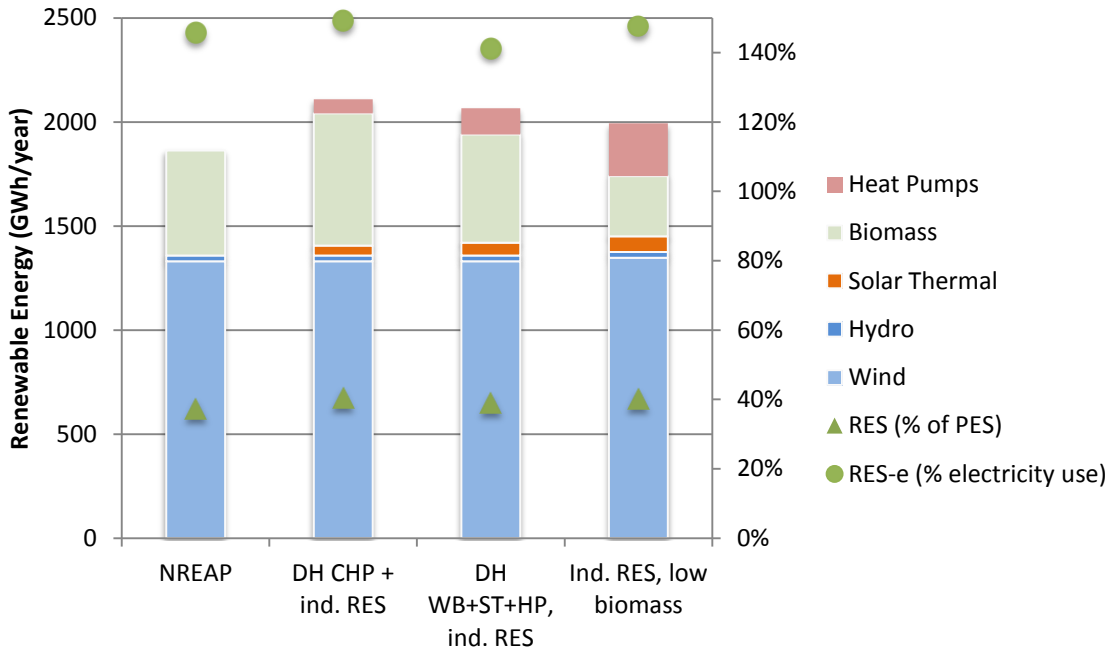


Figure 41: Renewable energy mix and penetration in the energy supply of the county, per 2020 scenario.

Figure 42 below compares the overall annual costs of each energy system scenarios. The fuel costs used reflect an international oil price of $117/bbl and a CO2 cost of €25.8/tonne forecasted for 2020. The negative costs in green represent the value of the excess electricity available for export.

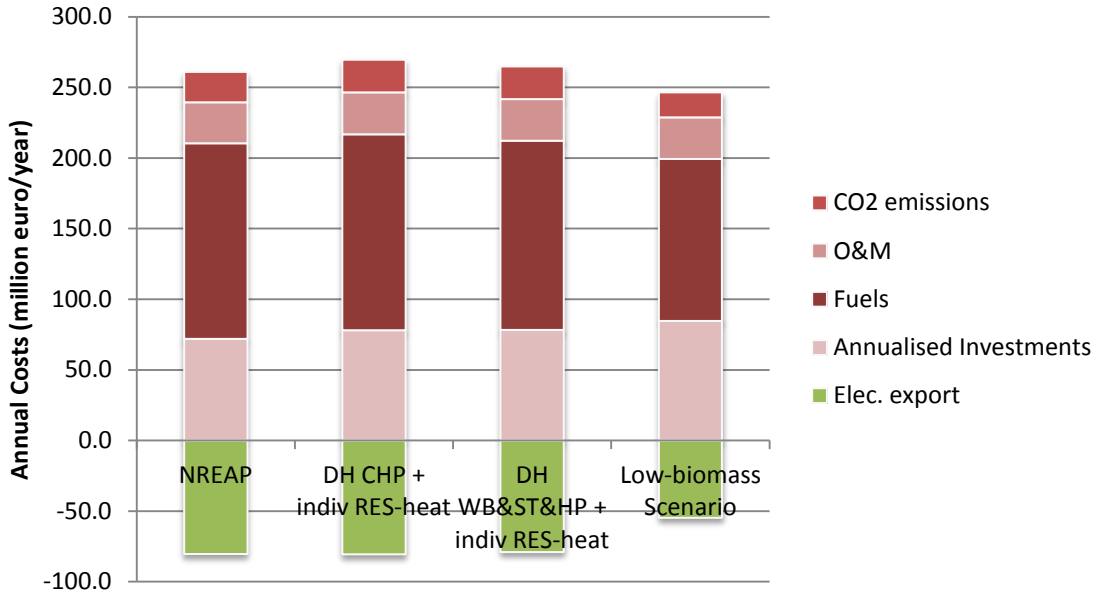


Figure 42: Total annual costs of the 2020 energy system scenarios.

Figure 43 below illustrates the additional jobs created locally in the energy sector by 2020 over those already in place in the energy sector in 2008. These were calculated on the basis of 'local labour cost share' factors for the main costs of the 2020 energy system scenarios modelled. The 'local labour cost share' factors are: 40% for investment, 10% for fossil fuels, 90% for biomass fuels, 80% for operation and maintenance (Connolly et al., 2012).

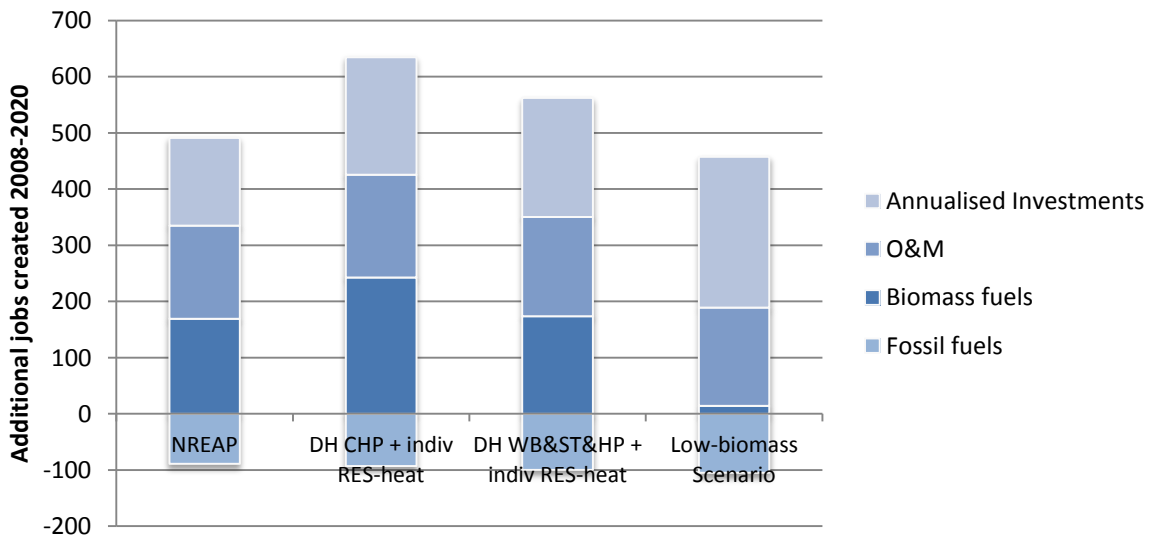


Figure 43: Additional jobs created in the energy sector in Kerry between 2008 and 2020.

Finally, Figure 44 below compares the CO2 emissions resulting from the 2020 energy system scenarios operation compared to those modelled for the 2008 energy system. The 'total' value includes CO2 emissions resulting from coal and gas use for electricity generated by centralised power plants and imported; the 'corrected' value accounts for the CO2 emission reductions associated with fossil fuel substitution by renewable electricity exported from Kerry.

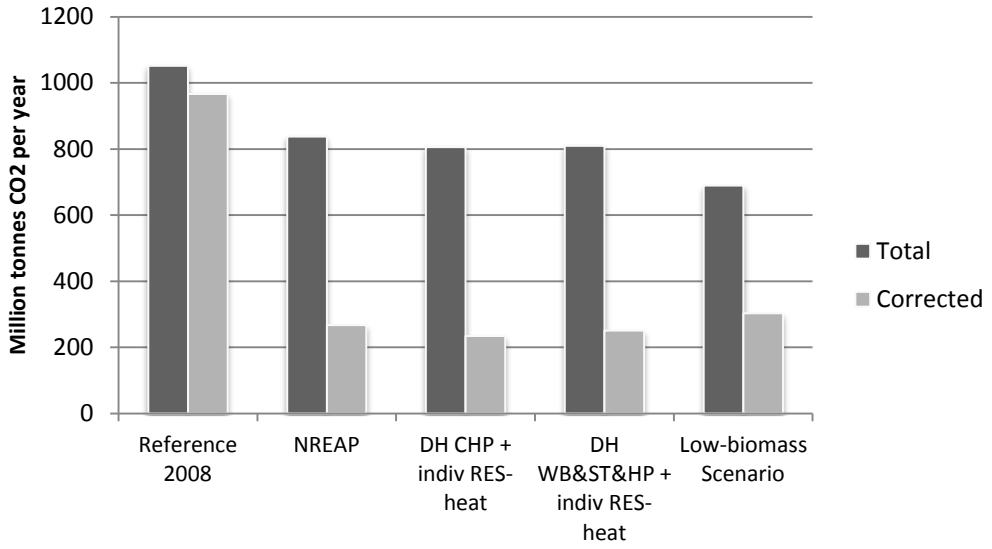


Figure 44: Total and corrected CO2 emissions of energy system scenarios for 2020 compared to those modelled for 2008.

4.3 Discussion of results

The following observations can be made about the results of the modelling of 2020 energy system scenarios with EnergyPLAN:

- The county's wind energy project pipeline is such that, in all the scenarios modelled, the national 2020 targets for renewable electricity would be met, with an overall RES share in the primary energy supply of around 40%;
- However, the wind generation capacity of circa 500 MW used in our 2020 scenarios will produce significant excess electricity above the county's annual electricity demand (at least 140%). This presents opportunities and challenges:
  - This excess electricity can be exported to the rest of the country, generate revenue for the county and reduce CO2 emissions elsewhere on the grid. Alternatively, as we will explore in 2050 scenarios, it can be converted to meet heat or transport energy needs;
  - Exporting excess power from the county requires significant investments[19] in grid transmission capacity (see Grid25 plan - Eirgrid, 2010) and fossil-fuel based generation capacity to balance supply & demand and ensure grid stability;
  - Gains in renewable electricity are partly compensated by increased import of fossil-based electricity to maintain supply:demand balance and grid stability;
  - Excess electricity generated from wind and other IRES in the county will happen roughly at the same time as in surrounding counties, typically coinciding with high IRES penetration at national level. In these situations, electricity exported from Kerry will have to compete with cheap electricity on the national electricity trading (spot) market, with the potential of reducing considerably its value.
- In terms of primary energy use (see Figure 40), there are no significant changes between the NREAP reference scenario and the district heating scenarios in absolute terms. In energy mix terms, a proportion of fossil fuels used for heating in scenario NREAP are replaced with

[19] These grid transmission investment costs were not factored in our cost analysis for the 2020 scenarios.

biomass, solar thermal energy and ambient heat[20]. In the 'low biomass' scenario without district heating, primary energy use in the county is significantly reduced (-8% compared to the NREAP scenarios) and electricity export is reduced too since the heat pumps harness part of the excess electricity from wind.

- Wood fuels use varies from 500 GWh/year in the 'DH CHP + ind. RES' scenario and 150 GWh/year in the 'low-biomass' scenario. This must be benchmarked against an available forestry energy resource estimated at 240 GWh/year by 2020 in Kerry (see chapter 2). This highlights the fact that any energy system development relying significantly on biomass solid fuels must be based on a robust, continuous effort to mobilise the wood energy resource of the county's forestry and plan for the expansion of that resource with an ambitious programme of forestry plantation and energy crop cultivation. Potential pressure from competitive use of wood fibre and external markets, as well as using agricultural land for energy production instead of food, must be carefully considered;
- In terms of total annual costs, there are no massive variations between the different scenarios, which average at around 260 million euro per year. This figure is very close to the one obtained when modelling the total costs for 2008 on a similar basis. This indicates that there would be negligible change in the cost of energy for society despite significant investment to achieve a renewable energy penetration increase from 17% to over 40% in that period;
- The potential value of the electricity exported on the Irish electricity market based on an average cost of circa 80 euro/MWh was estimated at 80 million euro (55 million in the 'low biomass scenario);
- In terms of CO2 emissions, the 2020 scenarios result in a reduction of 20% (NREAP) to 34% (low-biomass) compared to the 2008 reference. The fact that the 'low-biomass' scenario provides a 10% additional gain compared to the district heating scenarios can be explained by the fact that there is less demand on gas/coal power plants for supply:demand balance and grid stability due to the regulating role of heat pumps. A higher penetration of heat pumps in the 'low-biomass' scenario also results in a significant reduction in excess electricity generation from wind when compared to the district heating scenarios.
- Finally, our analysis of job creation potential indicates that the biomass fuel supply plays a predominant role in that regard, with the 'DH CHP + ind. RES-heat' scenario resulting in 542 additional jobs compared to 353 in the 'low-biomass' scenario (above the 2008 reference). These figures account for the jobs displaced in the fossil fuel sector. Investment also plays an important role with the creation of engineering and installation jobs, in particular in the 'low-biomass' scenario which requires a higher level of investment (multiple individual installations instead of large centralised systems in district heating scenarios).

[20] We use 'ambient heat' to designate ground, water, air heat sources harnessed by heat pumps. We use a seasonal coefficient of performance of 3 for large heat pumps used in district heating and 3.3 in individual heat pumps.

5 Energy System Scenarios 2030

5.1 The scenarios investigated

The energy system scenarios investigated for 2030 were designed to achieve even deeper penetration of renewable energy supply, striving to 100% in advanced energy systems.

a) NREAP 2030:

This reference scenario is designed as a continuation of the NREAP 2020 scenario, with continued energy reduction as discussed in section 3.1 and unchanged focus on wind energy development on the renewable electricity front. In this scenario:

- an additional 200 MW wind farms are operational in the county in 2030[21] compared to 2020.
- There is a substantial penetration of biomass in individual buildings (35% of heat demand) and in industry (22% of fuel usage);
- Solar thermal systems cover about 10% of the heat demand in buildings;
- Biofuels cover 12.5% of transport liquid fuels demand;
- There is a significant penetration (50%) of electrical vehicles in the passenger vehicle and light freight fleet in line with SEAI's forecast for EVs (SEAI, 2011).It is assumed that EVs have smart battery charging/discharging capability, whereby electricity is stored in their batteries during excess supply from IRES, or electricity is injected into the grid during periods of low supply;
- Overall, there remains a substantial reliance on fossil fuels for heating, transport and electricity generation; and there is no strategic objective to balance energy supply and demand within the county.

b) 100% RES with DH and biomass CHP, hydrogen, synthetic fuels and individual RES-heat (Bio+DH+H2+indiv. RES):

This scenario illustrates the next stage of development of the 2020 district heating scenarios to achieve 100% RES and strive to balance supply and demand (minimal excess exported), while fulfilling the requirement of grid stability. It includes the following additional energy system features:

- Solar PV (150 MW) have been added to the electricity generation system, with a slight increase in wind generation capacity (550 MW) and no change in hydropower (6 MW) capacity. We considered adding wave energy to the renewable energy mix with a view to combine IRES with different patterns of fluctuations and obtain a smoother pattern of generation, resulting in lowered excess electricity. However, the significant increase in investment was considered disproportionate;
- District heating supplies 300 GWh/yr of heat, covering the heat demand of the main urban centres (equivalent to the heating requirement of Tralee, Killarney, Listowel and Kenmare and some smaller towns). Heat is generated by a combination of biomass CHP

[21] This corresponds to about 70% of the Gate 3 pipeline of wind farms that have been allocated scheduled firm access, bringing the total wind generation capacity to 700 MW.

(25 MWe, 50 MWth) with large-scale solar thermal (equivalent to 50,000 m2), centralised ambient heat pumps (18 MWth) and 0.5 GWh of thermal storage capacity (1/2 of mid-winter heat demand) to store excess heat produced by the heat pumps and the CHP units. We also included for the supply of waste heat from industry and from hydrogen production (10% waste heat from electrolysers) into the district heating system;

- In rural areas, we have assumed that most of the heating requirement is supplied by heat pumps (COP of 3.3) and direct electric heating, in combination with solar thermal systems (20% of total heat demand). Wood fuels also make a small contribution (7% of heat demand);
- Centralised and individual heat pumps have intelligent controls and can respond to signals from the grid operators to capture excess electricity generated by IRES;
- Hydrogen plays an important role in balancing the energy system by converting excess electricity from IRES into fuel (H2) via electrolysers with a total capacity of 290 MW. This hydrogen can be stored and used to produce liquid transport fuel from biomass (see next point) and gaseous fuel for power generation;
- Fuel for transport in non-electric vehicles is produced in two forms:
    - Biomethane used in compressed natural gas (CNG) vehicles, and manufactured by upgrading biogas supplied by anaerobic digestion plants. This represents 28% of non-EV transport energy demand;
    - Synthetic fuels[22] produced by the chemical reaction of hydrogen with biogas and gasified solid biomass (see Figure 45). In our model, we have assumed a mix of 40% biogas and 60% solid biomass as feedstock to produce the synthetic fuels.
- We have made provision for an extra 190 MW of power generation capacity in our model to balance supply and demand and to ensure grid stability when operating in island mode. This power generation capacity is assumed to have an efficiency of 62% and to be fuelled by a combination of biogas and hydrogen. Alternatively, supply:demand balance and grid stability can be delivered by the transmission grid in an open electricity system (non-island mode). The costs and fuel requirements have been accounted for in our simulation on the basis of a 'virtual power plant' as in the 2020 scenarios.

c) No district heating, hydrogen, individual heat pumps & solar thermal (no DH, ind. HP&ST):

This scenario represents a continuation of the 'low-biomass' 2020 scenario. Its key features are:

- There is no district heating and, instead, rural and urban dwellers rely for the majority on individual heat pumps to meet their heat demand (annual COP of 3.3) together with solar thermal systems (20% of total heat demand). A small amount of wood fuels and direct electrical heating is used to meet the heat demand (5% and 8% respectively);
- Upgraded biogas is not used for transport in CNG vehicles. Instead the penetration of EV is doubled compared to other 2030 scenarios. The additional battery capacity provides increased ability to support the grid; The same amount of synthetic liquid fuels is produced as in the previous scenario, from biogas and solid biomass;

[22] This would be methanol and Dimethyl ether (DME), which can be used in adapted petrol and diesel vehicles respectively. To find out more about DME, check http://www.aboutdme.org

- There is no solar PV in the IRES mix, but a small increase in wind capacity to 560 MW;
- There is the same capacity to produce and store H2 as in the previous scenario.

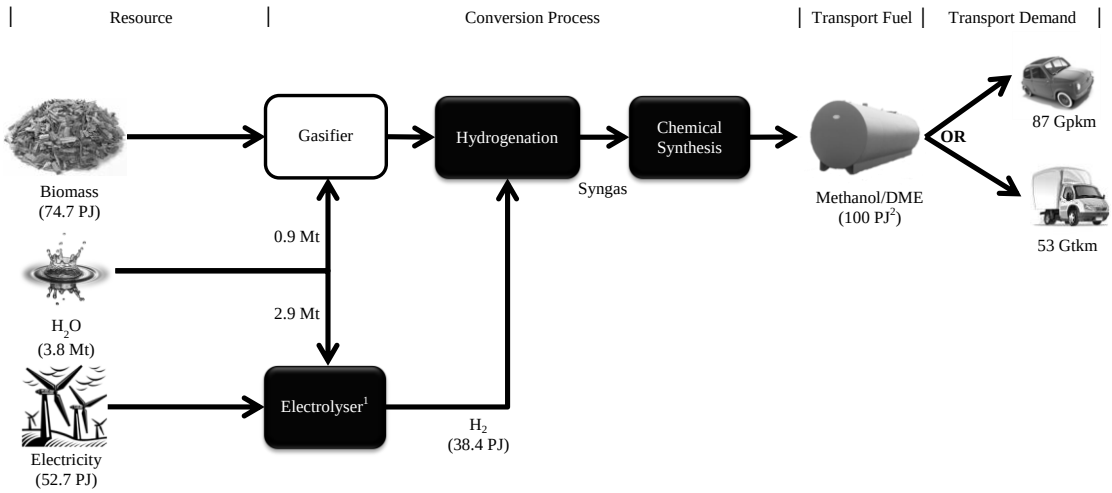


Figure 45: Gasification of biomass which is subsequently hydrogenated. (1) Assumed an electrolyser efficiency of 73% for the steam electrolysis. (2) A loss of 5% was applied to the fuel produced to account for losses in the electrolyser, chemical synthesis, and fuel storage. Source: (Connolly , et al., 2012)

5.2 Modelling results

The graphs below present key modelling results of the 2030 scenarios and allow comparing them to results for the reference year 2008, illustrating the evolution of the energy systems considered for Kerry over the next two decades.

Figure 46 below presents the primary energy balance in the county for the different energy system scenarios modelled.

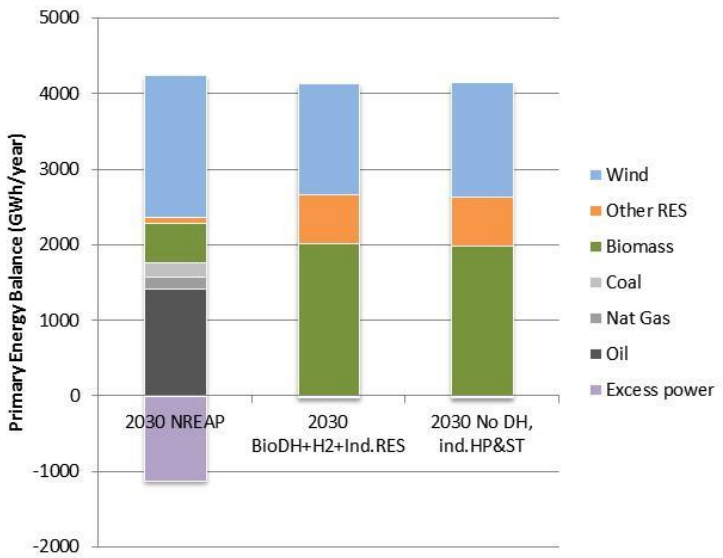


Figure 46: Primary energy balance in the county for 2030 scenarios.

In Figure 47, we illustrate the weight of the different RES in the overall renewable energy mix, as well as the penetration of RES in the overall primary energy supply.

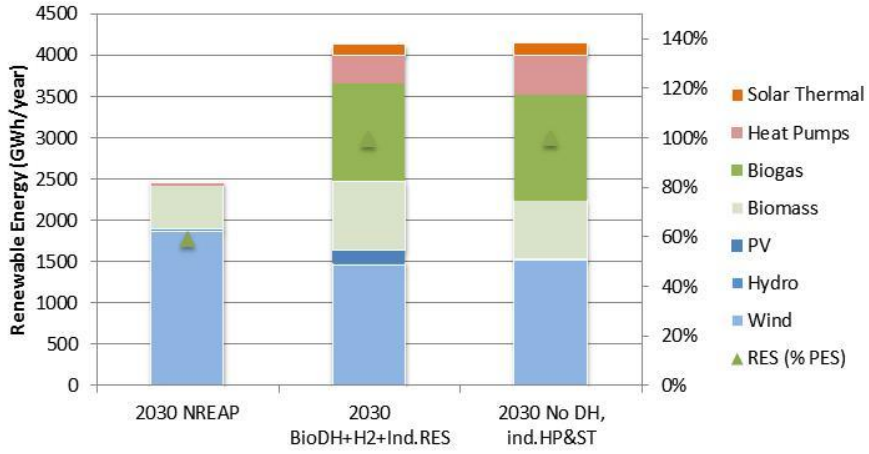


Figure 47: Renewable Energy mix and RES penetration in 2030 scenarios.

Figure 48 below compares the overall annual costs of each energy system scenarios. The fuel costs used reflect an international oil price of $130 per Brent barrel and a CO_2 cost of €55/tonne forecasted for 2030[23]. The negative costs in the 2030 NREAP represent the value of the excess electricity available for export if valued at the average cost of electricity on the spot market. However, it is very unlikely that this export can be valued at that level since excess electricity will typically occur during periods of high wind (possibly combined with low demand) when electricity generation costs on the wholesale market could almost fall to zero. In 100% RES scenarios, there is no electricity export since energy supply and demand are balanced within the county.

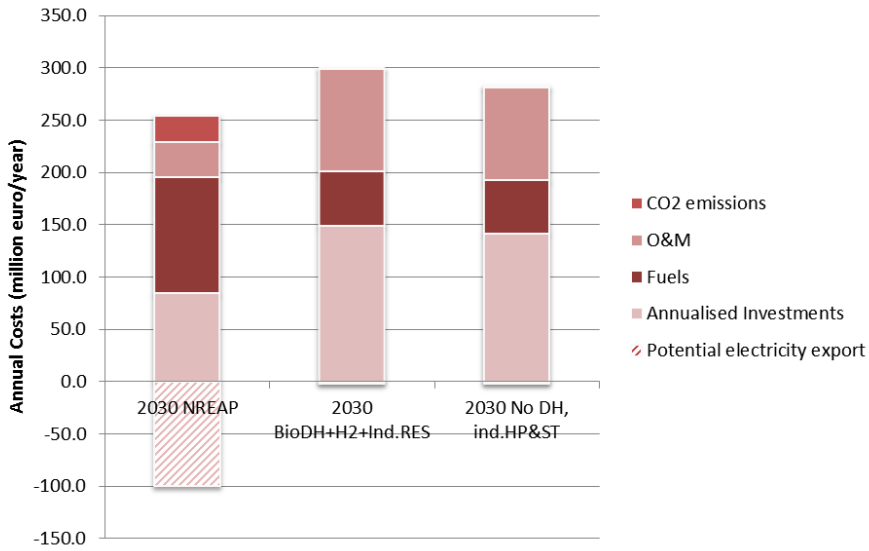


Figure 48: Annualised costs of energy system scenarios 2030.

In Figure 49 below, the additional jobs created locally in the energy sector by 2030 over 2008 levels.

[23] This CO2 cost of €55 per tonne is based on forward projection of SEAI forecast of €33/t by 2020 (SEAI, 2011) and ESRI's forecast of for €41/t by 2020 (Di Cosmo, 2013). Fuel costs, investment costs and O&M costs have been forecasted in line with the Danish Energy Authority's (Energistyrelsen, 2011) modelling assumptions for fossil fuels and SEAI's for biomass fuels (SEAI, 2012).

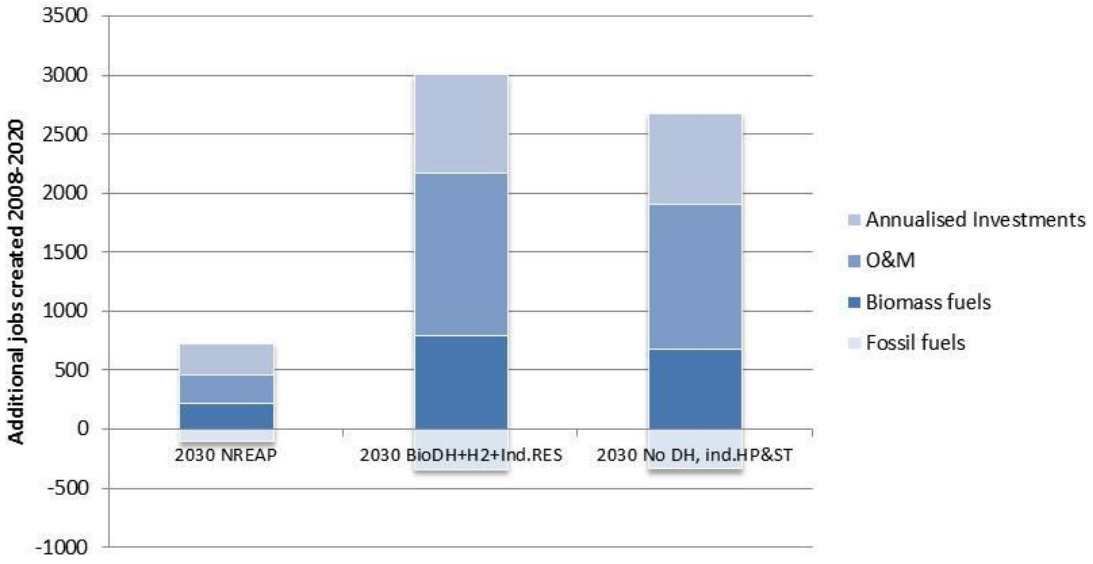


Figure 49: Additional job creation potential of 2030 scenarios compared to the 2008 reference.

Finally, Figure 50 below presents compares the CO2 emissions resulting from the 2030 energy system scenarios operation compared to those modelled for the 2008 energy system.

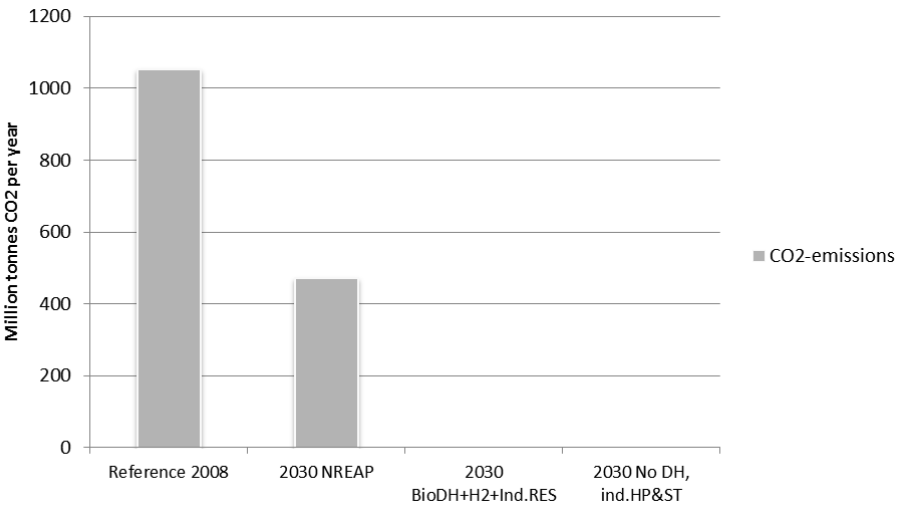


Figure 50: Comparison of CO2 emissions between 2008 and 2030 energy systems.

5.3 Discussion of results

The following observations can be made about the results of the modelling of the 2030 energy system scenarios:

- The 'BioDH+H2+ind.RES' and 'No DH, incl.HP&ST' scenarios demonstrate that it is technically feasible to achieve 100% RE supply in the county. Not only that, but it can be done while in island mode i.e. the system can balance supply and demand, and maintain grid stability, without reliance energy import from outside the county;
- The NREAP 2030 scenario indicates that the 'business as usual' approach in line with the current national 2020 policies can result in significant renewable energy penetration (60% of PES) but won't be sufficient to achieve the 100% RES objective. In addition, the energy

system of this reference scenario does not have the capability of balancing the system and generates significant excess electricity. The value of that excess electricity will depend on the evolution of the national electricity market and the price that can be obtained for it on the spot market;

- Wind energy and biomass are critical sources of primary energy from which the county's final energy requirements can be derived to fulfil its needs in terms of power, heat and transport[24] in 2030. In the 100% renewable energy systems, biomass will cover circa 50% of the total primary energy needs, and wind circa 35%. Solar PV and hydropower will make a minor contribution to the overall PES (between 1% and 4%).
- Solar thermal and heat pump systems will play a non-negligible role in the overall primary energy supply, in particular for individual heat supply (10% of PES in the scenario with district heating and 15% in the scenarios without);
- Hydrogen will play a key role in balancing the system, by overcoming the constraints imposed by IRES as well as leveraging limited biomass resources to their maximum potential;
- In addition, a high penetration of heat pumps and electric vehicles introduce a significant amount of flexibility in the energy system by enabling storing excess electricity in the form of heat for heat pumps, and in batteries for EVs. EVs have the additional advantage that, when plugged-in, their batteries can be discharged onto the electricity grid to support it in case of low supply from IRES[25];
- The 'BioDH+H2+Ind.RES' energy systems modelled also take advantage of large scale heat storage facilities operating in combination with district heating. These thermal stores also provide flexibility to the energy system by:
    - Enabling the CHP units to continue producing electricity (and participate to grid stability) in situations where the heat by-product is not required;
    - Using heat pumps to capture excess electricity and convert it to heat;
    - Storing excess solar thermal heat (typically during the summer);
- Biomass, as discussed before, is a constrained resource. In both 100% renewable energy scenarios, meeting the biomass needs will not only require mobilising all of the resource available from forestry and organic waste streams, but also using agricultural land to cultivate energy crops (including grass) instead of food. We estimate that diverting 40% of the grass silage production (equivalent to 12,000 ha output) would be required to complement biogas production from all the agricultural, industrial and municipal organic waste sources available. In addition, close to 14,000 ha of agricultural land (typically substituted from beef farming) would be required for energy crops cultivation in order to supply the woody biomass needed in addition to the wood fuel forecasted to become available from forestry by 2030 (see chapter II).
- In terms of overall costs, the move to 100% renewable energy supply would lead to an increase of around 17% in the scenario with district heating and 11% in the scenario with individual heating systems. The cost analysis presented in Figure 48 shows that the capital cost and operation and maintenance costs will represent circa 80% of the total costs

[24] Excluding air transport, not considered in the county's energy balance as per the European Covenant of Mayors guidelines.

[25] These intelligent control mechanisms presuppose that the energy system is equipped with smart grid technology combining the ability to monitor and control energy flows with communication between end-users and the energy system

compared to 46% in the NREAP (business as usual) scenario. There is therefore a large substitution of fuel costs with capital and labour costs as the shift is made to the 100% renewable energy system;

- The good news is that instead of spending money on importing fossil fuels as in the business as usual scenario, the county's economy would benefit widely from harnessing local renewable energy resources and investing in its own energy infrastructure. As can be seen in Figure 49, up to 2700 new jobs could be created by the transition to the 'bioDH+H2+Ind.RES' (with district heating) scenario and 2300 jobs in the case of the 'No DH, Ind.HP&ST' scenario. That is respectively 2000 and 1700 more jobs than in the 'business as usual' scenarios;
- With the move to 100% renewable energy supply, CO_2 emissions have been reduced by over 1 billion tonne per year compared to 2008 emissions.

6 Conclusions

The analysis conducted in this chapter of the Kerry SEC Roadmap aimed at modelling different energy system scenarios for the county, illustrating how energy demand and supply could evolve towards 100% renewable energy supply over the next 20 years. To that effect, we projected future energy demand from the 2008 baseline established in Chapter I, assuming significant reductions in the overall energy demand (-9% by 2020 and -18% by 2030) due to rational use of energy. Considering SEAI's national energy forecast and other local energy planning studies, we created reference scenarios for 2020 and 2030 illustrating a 'business as usual' evolution of the energy supply mix in the county in line with the current policy framework for renewables at national level. We also considered existing and expected renewable energy generation projects identified in Chapter II, in particular in terms of wind generation. In these NREAP scenarios, renewable energy will cover 40% and 60% of the primary energy consumption in the county by 2020 and 2030 respectively.

We then developed alternative energy system scenarios for both cut-off dates, illustrating different strategies of renewable energy development tending towards 100% renewable energy supply by 2030. We modelled the reference and alternative energy system scenarios with EnergyPLAN in order to compare their technical, socio-economic and environmental impacts. The scenarios definition and their modelling considered a number of key guiding principles such as the benefits of building in capacity for balancing supply and demand in the framework of the overall energy system, including heat, transport and electricity.

The alternative energy system scenarios analysed revolved around two different technological pathways: one with district heating systems in urban centres and individual heating systems in rural areas; one with individual heating systems only. The scenarios with district heating had a strong component of biomass energy supply, while individual heating systems rely increasingly on heat pumps and solar thermal. In terms of electricity supply, wind energy is predominant (35% to 44% of total energy requirements in 2030 scenarios) and generates electricity significantly above the county's demand for electricity in all scenarios. Harnessing this excess electricity to store it and/or use it for transport and thermal energy needs is critical for balancing energy supply and demand in the region. Hydrogen production by electrolysis has been selected as a key component of the 2030 energy system scenarios to enable this, together with electric vehicles and heat pumps. Biomass is the other pillar of future renewable-based energy system scenarios, as a primary fuel to supply heat,

electricity and transport fuels (50% of the overall primary energy requirement). However, meeting the biomass fuel needs of future energy systems will be challenging and will require a robust programme of supply chain development to mobilise existing feedstock and create new sources with energy crop cultivation.

Key results obtained from the modelling of future energy scenarios indicate that:

- It is feasible to achieve 100% renewable energy supply in Kerry with advanced energy systems that can be autonomous in terms of ensuring security and stability of supply. Additional renewable energy capacity above the energy mix selected in these future scenarios would essentially provide cheap, clean energy that can be exported to other regions;
- The first step in increasing RES supply (40% by 2020) shouldn't result in significant changes in the overall costs (circa €260 million/year) of future energy systems compared to 2008 or the 'business as usual' scenarios. However, the transition to 100% RES energy systems will require significant additional investments and operation & maintenance costs that could push overall costs by an estimated 15% in the 2030 scenario with district heating compared to 2008. As fossil fuels prices continue to go up and renewable energy technology costs goes down due to innovation and mass deployment, there is a strong potential for the additional price tag of 100% RE supply to become negligible;
- Nevertheless, the substitution of imported fossil fuels with locally produced biomass fuels, the investment in new energy infrastructure and its operation and maintenance will result in the creation of up to 2700 new jobs locally compared to 2008. This does not consider indirect jobs created as a result of increased economic activity in the region. Therefore, the investment in the local economy will generate socio-economic benefits well above the additional direct costs of future energy systems discussed earlier;
- Finally, the transition to renewable energy naturally results in incremental CO2 emission reductions, totalling 1 billion tonne per year in 100% RES scenarios compared to 2008 emissions. This will be worth €27 million euro per year in carbon credits by 2030.

In terms of technological pathways to 100% renewable energy supply, the option of developing district heating in urban centres provides a number of advantages despite limited additional costs compared to individual renewable heating solutions. These include:

- It can improve the overall efficiency of the energy system by allowing the use of waste heat e.g. from power generation (CHP), electrolysers, industrial processes, etc;
- It provides greater resilience and security of supply in urban centres as source of heat supply can be adapted in response to changes in fuel prices, the availability of waste heat, disruption in fuel supply, etc;
- In addition, longer-term (including seasonal) heat storage becomes economically feasible in particular with solar thermal energy;
- The extra-cost of retrofitting district heating in existing urban centres is partly compensated by the lower cost of centralised heat generation capacity compared to individual heating appliances;
- In terms of local energy planning and policy-making, the conversion of a large number of buildings to renewable heat supply can be achieved with a limited number of investment decisions as opposed to multiple individual investment decisions. The overall investment

cost in the district heating infrastructure can also be mutualised and absorbed by society over a longer period (district heating systems have a lifetime of up to 50 years).

Chapter IV.
Community Participation in Renewable Energy Development

1 Introduction

This chapter builds on the Renewable Energy Resource Analysis (chapter II) and the Energy System Analysis (Chapter III). The objectives of this part of the study are to:

- review key aspects of the SEC Roadmap development and implementation in the form of a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis, and map out important stakeholders in the roadmap;
- study how RE co-operatives can be a successful model for community participation in renewable energy development in Kerry, reviewing best practice and case studies from Ireland and Europe;
- define a roadmap for community based, co-operative RE development in Kerry and outline how it would fit within the overall framework of transition towards 100% RE supply by 2030, as considered in the scenarios analysed in chapter II.

2 SWOT Analysis of the Community Energy Transition Framework

In this chapter, we look at key aspects of the transition to renewable energy from the perspective of community participation, including policy and regulation, organisational and financial issues, as well as infrastructural development.

2.1 Policy & regulation

Strengths

- Renewable energy, energy efficiency and decarbonisation of the energy system are at the core of European and national energy policies.
- Community-based initiatives have the potential to increase social acceptance of RE.
- Community groups can play a key role in behaviour change, promoting a bottom-up approach to sustainable energy.

Weaknesses

- RE development is governed by multiple agencies and regulatory bodies, creating a complex institutional framework to deal with.
- Community groups typically have a low familiarity with the bureaucratic processes.
- They are relatively inexperienced in the energy market and in a weak position when dealing with large energy players such as utilities.

Opportunities

- Governmental authorities and energy companies are starting to realise the benefit of community participation.
- Community based initiatives have the opportunity of creating more transparency and openness in RE sector.
- The community sector has almost a blank page when it comes to creating a favourable framework to support community participation to RE development.
- SEAI has initiated the Sustainable Energy Community programme (with limited outreach).

Threats

- Bureaucracy associated with RE development (planning, grid-connection) is complicated and expensive to overcome
- Changing policy on RE support systems (e.g. feed-in tariffs, subsidies, etc.)
- Misconception and misinformation fuelling local resistance to RE projects.
- Large energy companies and utilities can perceive community initiative as a threat to their interests and resist them powerfully.
- EU rules on State Aid for energy investment can impede certain forms of capital investment support.

2.2 Organisational

Strengths

- Community groups can tap into the skills and resources of its members to get things done at no or low cost.
- Community groups have extensive local, informal networks to promote their projects.
- A culture of self-help is evident in many communities in Ireland.
- A shared identity and trust are important resources for collective action and overcoming costs and risks.
- There is a strong capability for organisation and project management in the volunteering sector.
- The Kerry local authorities have an excellent track record in sustainable energy project development, providing a local base of know-how and capability in this area.

Weaknesses

- Volunteers have limited amounts of time to give.
- Difficulty in maintaining volunteering effort over time.
- Conflict of interest and cultural differences in collaborations with large energy companies or public institutions.
- Community volunteers in RE projects can be technically focused and competent, but lacking in communication and organisational skills.

Opportunities

- Community-based initiatives are a good democratic and open platform to bring all RE project stakeholders together.
- Open and democratic structures are prone to innovation and collaboration.
- Other community groups and initiatives in Ireland and abroad are keen to help and share experience.
- Community pride, strength and empowerment can be key outcomes of community RE projects.
- The quest for community autonomy (reduce dependency on outside influence) can be a powerful motivator for community-based RE projects.

Threats

- Volunteering fatigue among core group sets in and lack of new energy stalls initiatives.
- Lack of clarity on mission, weak strategic planning and poor organisational skills lead to wasteful use of resources.
- Lack of communication and engagement with the wider community creates resistance to change.
- Lack of confidence in community groups' organisational capacity among other stakeholders (banks, utilities, etc.) prevents productive engagement.

2.3 Funding/finance

Strengths

- Community groups will consider social and environmental benefits of RE project, in addition to financial profitability.
- Investment in RE projects has a multiplier effect in the local economy and supports social services.
- Low-cost, volunteer based organisations are more financially resilient even under unfavourable conditions.
- The possibility of partnering with local

Weaknesses

- Community groups might lack financial credibility among lenders and funding agencies.
- They might lack the financial management skills required to conduct RE projects.

authorities and other public institutions would facilitate access to public funding.

Opportunities

- Community RE initiatives are best placed to address rising energy costs and fuel poverty issues, especially in rural areas.
- Community groups can privilege RE projects that maximise job creation and investment in the local economy.
- Large energy companies are starting to realise that lack of participation of local communities in RE projects can become very expensive.
- Win-win situations can be created between energy companies and community groups, notably around ancillary services such as billing and administration, balancing of energy supply/demand, etc.

Threats

- Mobilising personal finance from members can be a real challenge in times of economic crisis.
- Accessing finance from lenders is very difficult for any organisation in this time of credit crisis.
- Dependency on public funding exposes the groups and their projects to bureaucratic and possibly political control.
- Idealistic motivations can cloud financial judgements and lead to bad investment decisions.

2.4 Infrastructure

Strengths

- County Kerry has a good electricity infrastructure at transmission level for wind farm development.
- Infrastructure development would have strong benefits for the local economy, in terms of investment, job creation, more sustainable energy supply.

Weaknesses

- Rural areas such as are prevalent in Kerry might not be seen as a priority for energy infrastructure development (smart grids, EV charging, gas network, etc.)
- The electricity distribution network in certain parts of Kerry could have face difficulties with a high degree of microgeneration penetration.
- Currently, the electricity infrastructure development in Kerry is essentially designed to facilitate the export of renewable energy to large demand areas (Cork, Dublin, Limerick) rather than to service the local energy demand.

Opportunities

- A better energy infrastructure could be a key attraction for manufacturing industries in Kerry, generating additional jobs.
- The development of 100% RES energy systems will be a significant opportunity to position Kerry as an international energy innovation hub.
- In doing so, Kerry could attract significant investments from public and private sources for R&D and demonstration projects in this area.
- The two biomass district heating projects currently being planned for Tralee and Killarney offer a unique opportunity to develop capability in this area, demonstrate

Threats

- Private developers engaging in land-rush for wind or solar projects, locking in land-owners in long-term commitments and precluding access to land for community groups.
- Private developers having inundated the grid connection application process, blocking access for new applications by community groups.
- The development of energy infrastructure could, if not carried out in a sustainable manner, have a significant environmental impact.
- General increase in opposition to energy infrastructure development (in particular

this technology and to kick-start the biomass supply chain in the county.

transmission grid) can be a strong impediment to RE development.

The previous SWOT analysis is meant to provide a basis to stimulate a more comprehensive assessment of the context in which the renewable energy transition will happen in Kerry. No doubt local knowledge and experience will help deepen and widen it.

3 Key stakeholders Mapping

In this section, we try and map out the key stakeholders in the transition to renewable energy, at a local and national level. We then provide a high level review of important roles they can play in it, and assessment of the threats and opportunities they might face.

3.1 Kerry 100% RES Transition Stakeholders Map

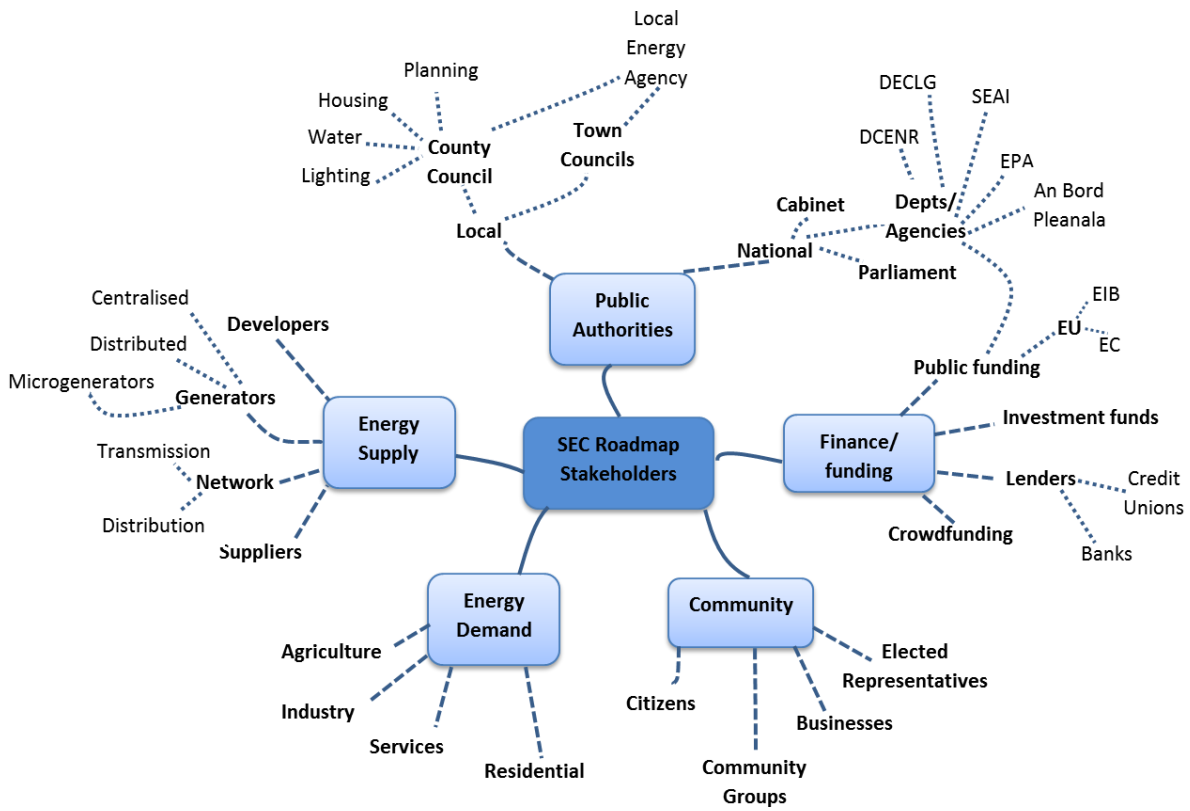


Figure 51: Key stakeholders in county Kerry's transition to 100% renewable energy.

3.2 Roles, opportunities and threats for key stakeholders

In this table, we outline the roles some of the key stakeholders mapped out above can take in the transition, as well as some of the threats and opportunities presented by their (potential) involvement in renewable energy development from the point-of-view of community participation.

Who?	Roles	Opportunities	Threats
Local Authorities Kerry County Council	• RE project developer • Social housing owner • Energy user • Planning authority	• Public Private Partnership with community in RE projects • Purchase of energy produced by community-owned RE projects • Leasing of public land • Support for spatial planning • Access to funding sources (public & private) • Technical & organisational support	• Lack of financial resources • Lack of human resources • Risk averse culture • Political interference
Commercial RE Developers Coillte, Airtricity, ESB, Bord Gais, …	• Project development • Financing • Operation & maintenance	• Community compensation fund • Engagement & consultation • Joint venture • Mentoring & support	• Access to land • Community objection • Spatial planning • Grid connection • Access to finance
Community Groups Transition Kerry, An Taisce, **Transition Corca Dhuibhne**, Community Centres, …	• Awareness-raising • Lobbying • Project development • Investing • Sale of self-generated or third-party energy	• Social & cultural connection with local community • Pooling of personal savings and/or borrowing capacity • Pooling of energy spending power • Volunteer resource • Pioneer innovation • Demand response management	• Access to finance • Long lead times • Organisational capability • Technical capability • Lack of volunteering time

Who?	Roles	Opportunities	Threats
Network Operators Eirgrid (transmission), ESB Networks (distribution)	• Grid-connection • Energy network development	• Fast-track access to grid-connection • Technical support & mentoring • Consultation • Smart grid development	• Local opposition to grid infrastructure projects • Grid stability & security • Administrative & technical capability
Education and Research Institutions	• Education and training • Research and Development	• Support capacity building in the RE sector • Support policy-making & cultural change • Foster innovation at a local level	• Lack of human & capital capability • Lack of strategic vision & thinking
Development agencies NEKD, SKDP, Kerry County Development Board, IDA, SEAI	• Funding • Mentoring & Support • Energy purchase	• CAPEX co-funding • Feasibility studies funding • Mentoring support • Hosting (office facilities) • Purchase of community energy • Innovation support	• Excessive red-tape • Long decision-making • Uncertainty in funding streams • Lack of alignment of priorities • Changing policy framework
Energy Users Households, Businesses, Public services, Industry	• Energy buyers • Prosumers[26] • Investors • Resource owners (land, forestry, etc.)	• Investing in RESCoop projects • Volunteering & moral support • Buying RES Coop energy • Leasing of resource • Security of energy supply	• Rising energy prices • Fuel poverty • Lack of competitiveness

[26] A prosumer in the context of energy systems refer to a consumer of energy who is also a producer.

4 Introduction to the Renewable Energy Co-operative model

4.1 What is a RESCoop?

According to ICOS[27], "a co-operative is an enterprise which is owned and controlled by its user members and operates for the benefit of its user members." As well as giving members an equal say and share of the profits, co-operatives act together to build a better society. Co-operatives are a flexible alternative business model which can be set up in a variety of ways, using different legal structures, depending on the needs and circumstances of the members. Co-operatives want to trade successfully and their members strive to do better by working together, sharing the profit between the members and/or the local community in a fair way rather than rewarding outside investors.

While there is no standard definition for a Renewable Energy Co-operative (referred to 'RESCoop' hereafter), we assume that a RESCoop:

- Is established along the principles of co-operative businesses introduced above;
- Its main purpose is to produce and/or sell renewable energy (although generating energy savings can be an associated service);
- Its members are investors and share-holders in the co-operative, and typically buy energy services from the co-operative;
- Supports the socio-economic development of its local community and the preservation of its environment.

4.2 Why a Kerry RE Co-op?

Our recommendation is to encourage the development of RESCoops as business entities driving community-based renewable energy projects in county Kerry. This business model has been adopted across Europe and we will discuss some case studies hereafter. Promoting the RESCoop model for renewable energy development in Kerry should accrue significant benefits for the members, their community and the nation:

- More local ownership of renewable energy means more benefits for the local community;
- Generate revenue for the members and/or reduce energy expenditure;
- Part of this revenue is naturally reinvested in the local economy through members' spending on local goods and services;
- The RESCoop can decide to plough back some of its profit into projects benefitting the wider community e.g. improve sports facilities, care for the elderly and children, etc.;
- RESCoops would typically strive to use local materials, equipment and contractors to implement their projects, generating local jobs. At some stage in their growth, they could employ people to operate the business and manage its projects;

[27] ICOS is the Irish Co-operative Organisation Society, a co-operative umbrella organisation that serves and promotes commercial co-operative businesses and enterprise, across multiple sections of the Irish economy. To find out more, visit www.icos.ie

- People working together for a common cause reinforce social cohesion at local level. RESCoop would also provide learning opportunities for its members through training and experience;
- The know-how (technical, financial, organisational) and skillset (negotiation, consultation, flexibility, etc.) emerging from RE project development can then be applied in other community projects as well as in other sectors of the economy;
- RESCoop can decide to take on renewable energy projects that wouldn't necessarily be considered sufficiently profitable by conventional commercial companies, but which would generate additional socio-economic and environmental benefits for their community e.g. solar water heating in local sports club;
- Community participation in renewable energy development is recognised as an effective measure for higher social acceptance by empowering people to harness their natural resources for their own benefit and that of their community[28];
- While typically smaller in scale, community-based RE projects have similar positive environmental impacts in terms of GHG emissions, environmental pollution, etc. This is often a key motivator for community groups.
- By linking energy demand with renewable energy generation at a local level, and providing innovation pathways (e.g. smart grid, demand-side management, etc.) to balance supply and demand locally, community RE can reduce electricity transmission losses;
- By creating and maintaining jobs locally, providing constructive volunteering and learning opportunities, as well as contributing to the local economy, RESCoop help their community becoming more resilient.

4.3 REScoop Case studies

In this section, we will review case studies of REScoops and community-based renewable energy projects in Europe. A number of these case studies have been extracted from the RESCoop 20-20-20 project documentation (see www.rescoop.eu for full details).

4.3.1 Ecopower

Ecopower is a Belgium REScoop established in 1991 and with 43,000 members by 2012. It owns and operates 38 MW of wind, 3.5 MW of PV, 90 kW hydropower and 420 kW bio-oil generation, for a total investment of over 34 million euro. It also invests in other like-minded projects (other co-ops, social enterprises, etc.). It is also currently building a pellet manufacturing plant with a 40,000 tonnes/year capacity.

Individual shares are set at €250 each, and each shareholder has a vote at the co-op AGM. Members invested €8 million in the co-op last year, with the average dividend over the last 5 years being 5.5%. Dividends are limited to 6% by law, an opportunity for profits over and above that limit to be used for less profitable projects with a strong socio-economic impact for the local community.

[28] Social acceptance is becoming a critical issue for the industry and policy-makers who are facing growing discontent and NIMBYism among affected communities

Source: www.ecopower.be

The co-op breakthrough came when it won a tender for the development of a wind farm for the local authority of the city of Eeklo (Flanders), proposing 100% community ownership of the project. Ecopower developed a close partnership with the local authority and conducted an intense, open communication campaign among the local citizens, encouraging participation. As a result there was no significant public opposition to the project, the process for obtaining planning permission and grid connection was very fast, and the first turbines were built within 10 months of the contract being awarded. A third of Ecopower's new members were from the city, and Ecopower continues to co-operate closely with the local council on sustainable energy and environmental projects.

4.3.2 Torrs Hydro New Mills Limited

Torrs Hydro New Mills Ltd in Derbyshire, UK, was founded in 2007 and is incorporated as an Industrial and Provident Society (IPS), 'an organisation that conducts industry, business or trade either as a co-operative or for the benefit of the community'. The co-op has about 230 shareholders, two third of which are from New Mills (Peak District) and surroundings, who invested one third of the equity. One third of the shareholders came from elsewhere in the UK and invested two third of the equity. The co-op re-developed an old mill site in partnership with Water Power Enterprises.

The scheme uses a 9m long reverse Archimedes screw turbine weighing 10 tonnes, has a rated power of 69 kW and is designed to generate 240 MWh/yr of electricity. The local Co-operative supermarket purchases all the electricity. The scheme cost around £330 000. A community share issue raised over £125 000, with grant funding and loans providing another £165 000. The share issue (minimum £250 per investor) was completed within 2 months with the target achieved – an amazing result attributed to the clarity of the scheme and the media attention it received. A professional PR campaign using local, national and social media helped spread the word and

attracted investors from around the country. The co-op had a clear message that the project would generate money for the community and that parts of the profit would be reinvested in projects for New Mills (community fund estimated at £3-5,000 per year).

For more information: http://www.torrshydro.org/index.php

4.3.3 Templederry Community Wind Farm

Figure 52: Minister Pat Rabbitte officially opens the Templederry wind farm. Source: Tipperary Energy Agency.

The Templederry wind farm is a pioneering project in Ireland. It is located on the northern edge of the Slieve Felim mountains, an area suffering from population decline and lack of local employment opportunities. The project took 12 years from start to finish, a very long lead-time that is a testimony of the community's determination and perseverance in the face of adversity. The development process the project went through is outlined in Figure 53. Obtaining planning permission and grid connection were a source of major delay in the project. A grid connection moratorium that lasted for 3.5 years meant that the first planning permission obtained in 2003 ran out after 5 years and a second planning permission had to be applied for. This time objections led to the application being delayed for another 2 years while the appeal at An Bord Pleanala was being processed, before being finally granted in 2009.

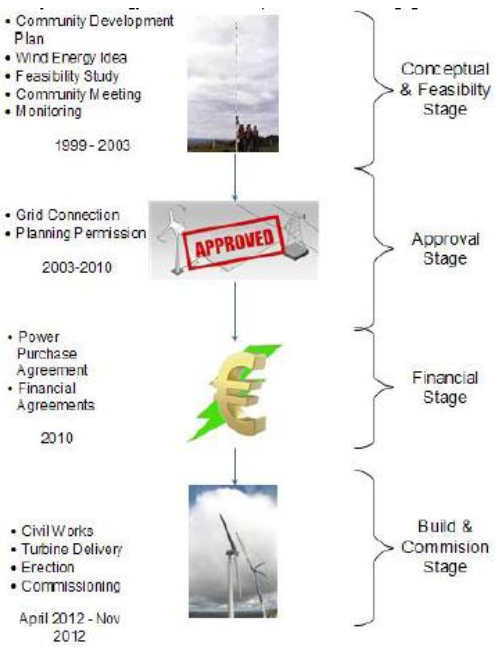


Figure 53: Templederry wind farm development process. Source: TEA.

The community group created a development company, with 30 shares being issued to individual members of the community and 2 shares were retained by the development company to support other community projects. This shareholder investment was used to finance the development process (planning applications, EIS, resource assessment, professional fees, etc.) together with a

bank loan and Leader funding (€200,000). With the approval process completed, a power purchase agreement (PPA) was signed with Bord Gais Energy, a guarantee necessary to obtain bank finance for the construction stage of the project. With the financial crisis, the original plans for Business Expansion Scheme finance (providing the equity) and a loan from an ethical bank (Triodos) fell through and it took a second round to complete the financing process. The equity in the project is held by the shareholders of the Templederry Energy Resources development company and the BES investors, while loans were provided by Enercon (the wind turbines manufacturers) and De-lage Landen (Rabobank).

Today, the 4.6 MW wind farm (2 x 2.3 MW Enercon turbines) is operating with a 50% capacity factor (exceptional when compared to a national average of 31%). Chairman of the Templederry group John Fogarty said "local ownership of wind farms is vital to the regeneration of rural Ireland. Exporting our energy will enable local children to attend third level colleges, generate investment, support local businesses and secure the long term viability of our community"[29]. His presentation at the SERVE conference (2012) provides an excellent summary of the project development (video/presentation).

4.3.4 WindCentrale

Raising €1.3 million in just thirteen hours, 1,700 Dutch households that came together to buy shares in a wind turbine located in Culemborg (Netherlands) have set a new world record for crowdfunding. All 6,648 shares in the electricity from the Vestas V80 2MW wind turbine were sold at a share price of €200. Each household bought single shares or blocks of shares, with each share corresponding to an output of around 500 kWh/share per year. The purchase was organised by Windcentrale, a company that facilitates cooperative wind turbine purchases. Windcentrale says it has enabled more than 6,900 Dutch citizens to buy shares in wind turbines, and according to co-founder Harm Reitsma there is a growing list of several thousand people who have expressed interest in future purchase options (Renewable Energy World, 24/09/2013).

[29] According to Paul Kenny of the Tipperary Energy Agency, who strongly supported the wind farm project development, it is expected that each share will generate a dividend of €30,000 when the project becomes profitable.

Source: Windcentrale.

Windcentrale buys turbines that are several years old – the Vestas turbines were made in 2005 – from energy companies, financial institutions and project developers, Reitsma said. “It’s not a big market and turbines are scarce,” he continued. “People who own a wind turbine are generally very happy with it, and not in the market to sell.” Windcentrale acquires its turbines through networking, Reitsma said: “We contact everybody in the wind energy market."

For each turbine Windcentrale sets up a cooperative, and each cooperative has a separate contract with Vestas, which maintains the turbines. The electricity is sold through energy company Greenchoice, which was founded in 2003 as one of the first green competitors to the major Dutch utilities and now has 350,000 customers, Reitsma said.

“What’s key is why people are enthusiastic about this,” he continued. “We think it’s because many people want to do something good, help the environment, and at the same time save money. It’s the best of both worlds for many people. Until now, if you wanted to ‘be green’, it was a lot more expensive.”

4.3.5 Samsø Energy Island

Samsø is a small island off the coast of Denmark, with 4000 inhabitants. In less than ten years, Samsø went from importing all its energy and producing 11 tonnes of carbon dioxide per person per year, to being a net exporter of renewable energy and producing just 4.4 tonnes. It has become a worldwide inspiration of community-based transition to 100% renewable energy. This transition started in 1997 under the impetus of a contest held by the Danish Ministry of Environment and Energy requiring islands to present a realistic plan to convert their entire energy systems to renewables within ten years. Samsø submitted a plan and, to the island residents’ surprise, won.

The island now heats 60 percent of its homes with three district heating plants running on straw, and one which runs on a combination of wood chips and solar panels. People outside of the district heating reach have replaced or supplemented their oil burner with solar heating, ground-source heat pumps or wood boilers. Eleven onshore wind turbines provide 11 megawatts of power, enough to power the entire electrical load of the island. And 10 offshore wind turbines produce 23 MW, enough to compensate for the carbon dioxide emissions generated by the island’s transport sector (Rocky Mountain Institute, October 2013).

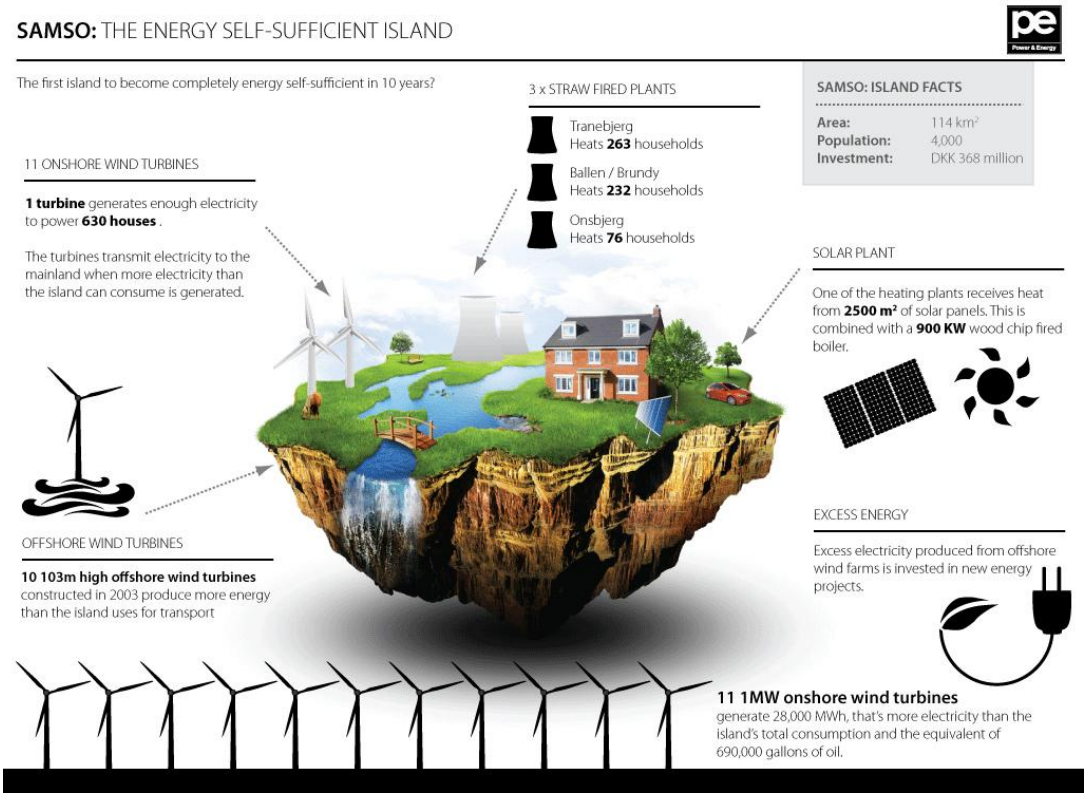


Figure 54: Renewable energy mix of Samsoe. Source: Samsoe Energy Academy.

While funding from the Danish government helped kick-start the project, the transition largely owns its success to a grassroots movement that rallied the island population and based renewable energy development on community participation. Convincing the island population to come on board wasn't easy at first and a lot of conservatism and NIMBYsm had to be overcome. It took months of community meetings and a broad effort of communication but eventually, the key to success was to convincing people to become shareholders in the project by demonstrating that it was a smart business choice which would also bring socio-economic benefit to the island. Creating jobs, new businesses and attracting more visitors to the island were important motivators. Local farmers own 9 of the 11 onshore turbines and the other two are owned by local wind cooperatives. One of the four district heating plants is also divided into shares and owned by local consumers. Samsingers export millions of kilowatt-hours of electricity from renewable sources to the rest of Denmark.

Soren Hermansen, a local farmer and environmental studies teacher, was at the core of the community participation process. He was also instrumental in setting up the Samsø Energy Academy in 2007, is a source of renewable energy research, education, and training. The academy arranges exhibitions and workshops that attract more than 5,000 politicians, journalists, and students from around the world every year. Hermansen has since been named one of TIME magazine's Heroes of the Environment, and travels around the world telling the story of Samsø's success (RMI, 2013). The motto "think locally, act locally" is one of the secrets behind the success of the project, Hermansen maintains. It's about acting on a small

scale to get the islanders to change their mindset. But, he says, the efforts they make must be reflected concretely in their wallets.

5 Roadmap for Community-Based RES Development to 2020

In the following sections, we lay out a vision and business model for the establishment of a REScoop movement in county Kerry as a key driver for community participation in renewable energy development. We then propose a roadmap for REScoop development over the next 7 years, designed to fit within the broader framework of the 2020 'DH CHP & Ind.RES' scenario of transition towards 100% RES supply by 2030[30].

5.1 The Vision, Mission & Objectives

The proposed vision is for county Kerry to become a model of community and citizen participation in the transition to 100% renewable energy supply, for the social, economic and environmental benefits of its citizens. The proposed mission is for Transition Kerry to drive this movement by promoting and supporting the creation of RE co-operatives or other similar community-enterprises.

The overall objectives of the Kerry RESCoops initiative would be:

- To raise awareness and foster buy-in by the different stakeholders in the Kerry 100% RE transition strategy;
- To promote bottom-up approaches and citizens' involvement in renewable energy development through awareness-raising, education and dissemination activities;
- To pilot RESCoop projects in pioneering communities and encourage replication in other communities;
- To foster partnerships with other stakeholders with a view to increase technical, financial and organisational capability, particularly for medium to large projects.

5.2 Business Model for REScoops

The following recommendations for planning the REScoop business model are derived from a review of best practice in this area undertaken by the European project REScoop 20-20-20. This best practice review has been summarised in Annex 1 Review of REScoop Best Practice.

5.2.1 Governance and Organisational Structure

The table next page compares key legal aspects between the co-operative form and the private limited company form. By acquiring shares, members of a RESCoop can have different involvement in their coop combining ownership, investment and use, each one with associated specific roles and responsibilities (J. Rijpens, 2013):

[30] This scenario is built around the development of district heating fired with biomass (CHP) in the main urban centres of the county (75% of heat demand in Tralee and Killarney) and individual RES solutions in rural areas and would result in 40% renewable energy penetration in the primary energy supply of the county.

- They own the coop and participate in the control of the organisation (one member, one vote);
- They become investors and therefore expect a return on investment, being financial and social/environmental;
- They become users of the coop and its services, being one or a combination of economic functions (consumption, production, work).

There can be flexibility in the choice and level of involvement in the coop, or in some cases it can impose restrictions. For example, some REScoops can impose their members to become investors as well as users, thereby increasing capital and turnover.

Item	Co-operative	Private Company
Limited liability	Yes (value of the share capital given by the individual members)	Yes
Membership	No Limit	100
Perpetual succession	Yes	Yes
Can issue share capital	Yes	Yes
Can reduce & expand share capital	Yes	Yes, but with strict criteria
Minimum number of members	7 individuals	1 or 2
Compliance burden	• Conduct an annual audit. • Submit annual / triennial returns.	• Conduct an annual audit. • Submit annual return. • Submit returns in regard to changes of directors and officers.
Back-up services	See below - Section 8. ICOS Back-up services and co-operative development	Separate legal fees and consultant costs
Power of nomination of shares	Yes, up to €15,000	No
Taxation status	Same for both co-operatives and private companies	Same for both co-operatives and private companies
Are model rules available?	Yes	No

Source: http://www.icos.ie/starting-a-co-op/what-is-a-co-op/

The REScoops engagement with other stakeholders often leads to a multi-governance structure. While citizens remain the primary category of stakeholder in the structure, others such as local authorities, other non-profits or NGOs (community groups, development companies), private companies (e.g. business energy users, grid operators, etc.), credit unions, etc.

Some restrictions on membership can be adopted e.g. on the type of members (see above), geographical association, number of shares ownership, etc. Typically, the democratic decision-making process is organised around the 'one member, one vote' principle. However, in rare cases, representation can be linked to the number of shares. In addition, different types of members can apply different types of membership with different voting rights.

Next to the general assembly made of its members, REScoops have a board of directors (typically between 7 and 10) elected by the general assembly to represent the members and participate in the management of the coop. Most REScoops function with a small number of employees (<5) or none at all, but rely on a good number of volunteers (typically up to 20) to engage in various activities during the development stage and operation of the REScoops. Volunteers bring major resources to the organisation (experience, expertise, free time, creativity, etc.) and constitute its social capital (connections, networks, democratic vitality, etc.).

5.2.2 REScoop Activities – Goods and Services

The nature of the activities undertaken by a REScoop will vary according to several factors:

- The needs of their members, challenges and opportunities they are facing at a particular time or place, etc.
- Their organisational development from creation to business development to diversification;
- Their business model e.g. investment in RE projects, exploitation and production of RE, retail of green energy only, etc.
- Their RE project development stage.

The following is a sample of possible activities for Kerry REScoops, inspired by the case studies reviewed previously and informed by the findings of our analysis of energy needs in Kerry (chapter I) as well as the potential opportunities arising from the RE resource assessment and RE Scenario analysis (chapter II). A REScoop can undertake single activities or combine several activities (e.g. production AND supply of electricity).

Production of renewable energy

- Development of a wood fuel supply chain, from growing the timber to processing into fuel (e.g. chips, briquettes, logs, etc.) to packaging and distribution;
- Production of renewable heat e.g. from wood fuels, solar thermal, heat pumps, etc.;
- Production of renewable electricity from wind energy, solar energy, hydropower or bioenergy.

Each type of project listed above can vary in scale, from a solar PV system servicing a single building/facility to a biomass district heating system servicing a neighbourhood or a town to a multi-MW wind farm integrated into the national grid. Larger RE projects normally achieve significant economies of scale (and better return on investment) but require stronger financial and technical capability, and entail a more complex, lengthy planning and permitting process.

Supply/retail of renewable energy

- Supply of renewable fuel e.g. wood fuel or biofuel;
- Supply of renewable heat directly to a single user, or via district heating to multiple users;
- Supply of renewable electricity directly to members or to the electricity market (non-members) via the distribution grid.

The renewable energy supplied can be produced by the REScoop's own production plants, plants owned privately by its members or bought from other producers or wholesale suppliers. In the

simplest form, the REScoop owns a RE production plant installed at the user site and supplies the energy generated (heat or power) directly to the user[31]. The REScoop can also act as an intermediary to a large electricity supply company from which it bulk buys electricity and retails it to multiple users (which can be members or not)[32]. In a much more complex business model, the REScoop acts as a licensed supplier which buys electricity from the wholesale market (Single Electricity Market) and retails it to consumers, in a similar way to well-known electricity suppliers such as Airtricity, Electric Ireland, etc.

Ancillary services

In addition, the REScoop can build on its experience and offer the following services:

- Awareness-raising, education, consultancy and support services to its members, other coops and third parties;
- Bringing risk capital for new RE initiatives;
- Collective buying of RE equipment or fuel for its customers;
- Energy efficiency initiatives, including a Pay As You Save scheme for its members/customers.

5.2.3 Financing

The requirement for financing varies according to type and scale of project, as well as which phase it is at. Venture capital is typically required during the planning and feasibility stage while construction requires capital and loans. A number of financial resources can be considered to finance a project:

- Self-finance, using the investment made by shareholders or loans from members;
- Bank loans from traditional and/or ethical or cooperative banks;
- Public subsidy in the form of capital, cheap loans, tax rebates, etc.
- Capital/investment from private funds;
- Venture capital from other REScoop developers.

Typically, large RE projects such as wind farms require a combination of the above finance sources. The Business Expansion Scheme or its current equivalent the Employment and Investment Incentive Scheme (EIIS) has been a successful investment fund vehicle for renewable energy projects in Ireland, offering income tax relief to investors[33].

Crowd-funding is an emerging alternative source of finance for projects, leveraging the power of social media and internet-based financial transaction systems to raise funds from a diffuse pool of individuals, often with motivations wider than pure financial gain, for projects/companies that might not have access to formal sources of finance. As we have seen in the case study above, Dutch

[31] In the case of electricity, without using the distribution grid. This can be done without acquiring a supplier licence.

[32] In this case, the RESCoop undertakes the operations of sales, billing and credit control in addition to bulk purchasing. It can offer a pay as you go service to simplify the payment and credit control service. The physical operation of electricity distribution and metering would be undertaken by a third-party (ESB networks). The sustainability of this business model depends largely on the ability of the REScoop to negotiate a sufficient margin from its wholesaler to recover administrative costs and remain profitable.

[33] See www.simple.ie for an example of green investment fund operating in the framework of the EIIS.

Windcentrale raised €1.3 million within 13 hours from 1700 households. The Solar Schools initiative in the UK (http://www.solarschools.org.uk/) offers a successful platform to help schools fund-raise for their solar power project.

5.2.4 Partnerships

A REScoop should be open and indeed actively seek to establish partnerships with other stakeholders with aligned interests/principles. Examples of potential partners can include:

- Public bodies: local authorities, agencies such as SEAI & IDA, Leader companies, etc. Local politicians can also help raise the public profile of the REScoop and open doors in public institutions;
- Private companies such as wind farm developers or wind turbine manufacturers, farming coops, energy companies, etc.
- Community groups and social enterprises which can help tap into the local social capital to further the REScoop project.

There is a growing realisation among renewable energy development stakeholders that meaningful community participation is an important measure to overcome social acceptance problems. This could create a favourable framework for engagement between the REScoop and RE project developers e.g. towards some form of joint venture. The REScoop offers an organised structure with which developers might feel more comfortable and safe to do business. It is interesting to note that the manufacturer/supplier of wind turbines for the Templederry wind farm provided bridge loans during the project development phase and was generally very supportive of the community aspect of the project.

Equally, local authorities, in this case Kerry County Council and the town councils, should be partners of choice. The two large scale district heating project planned for Tralee and Killarney should be looked at as unique opportunities for a co-operative model of development in the framework of a public-private partnership. In Denmark, 75% of district heating schemes are owned by users' co-operatives.

Moreover, we believe there are opportunities for co-operation between REScoops and the energy R&D community in Ireland. From our discussion with various public and private research centres (Tyndall Institute, United Technologies Research Centre, CIT's Rubicon), there appears to be a growing understanding of the role of communities in renewable energy deployment. There are particular opportunities for collaborations in the area of smart grids, demand response management, 'near zero energy' buildings, etc.

5.3 Kerry SEC Roadmap 2020

The following steps outline a proposed 7-year action plan for establishing a REScoop movement in Kerry at the forefront of the county's transition to 100% renewable energy supply. It is envisaged that Transition Kerry will play an essential role for kick-starting this movement. The following action plan has been defined around a process of piloting one or two REScoop initiatives, starting with

small-scale projects[34] and building capacity along the way (phase I), to then expand into larger projects and diversify activities (phase II); and eventually fostering replication of the initial successes by supporting other REScoops in the county (phase III).

Project Inception:

- Set up your project by talking to people and inviting them to join a core group committed to working together towards a renewable energy project for their community;
- Work together to define a collective understanding of the project, its boundaries and founding principles. This understanding can be articulated around a vision, values and mission;
- Identify the assets (skills, time, connections, etc.) that can be mobilised by the group. Organise the group by defining the legal form[35] (if any) required by the project, its organisational statutes and governance principles.

Feasibility Studies:

- Explore different renewable energy project possibilities by carrying out a high-level SWOT analysis, and shortlist projects to bring to feasibility study stage;
- Build the technical plan of the project:
    - Initial RE system design: RE resources, energy demand, sizes, location, etc.;
    - Review practical aspects of construction, operation & maintenance;
    - Review the regulatory constraints, planning requirements, etc.
- Study the financial aspects of the project:
    - Estimate the lifetime costs of the project (capital, fuel costs, O&M costs, end-of-life costs, savings/revenues, etc.) and potential return on investment;
    - Research financing mechanisms (members resources, subsidies, loans, crowdfunding, etc.);
    - Carry out a risk analysis;
- Select the project(s) to take forward based on feasibility studies and communicate with your members with a view to obtain a mandate for the management team to proceed with the next steps.

Project Development

- Develop a business plan for the project based on feasibility studies information, with level of detail commensurate to complexity of the project. Define a "financial commitment" policy which clearly explains the rights and obligations for all the investors, a fortiori the members;

---

[34] It is recommended to initially focus on small projects with manageable time-frame and resource requirements in order to allow building capacity and confidence within the group - and demonstrate tangible benefits for the community. Such initial projects could include group purchasing, green electricity retailing, wood fuel production, installing solar systems in community buildings, etc.

[35] The Irish Co-operative Society provides advice and guidance on how to set up a co-op: http://www.icos.ie/starting-a-co-op/intro/

- Communicate and consult with key stakeholders in order to continue raising awareness, promote social acceptance for the project, increase the volunteer base and invite financial contributions from members and other stakeholders;
- Establish (formal) partnerships with other stakeholders if necessary (see section 5.2.4);
- Carry out permitting procedures, for example: planning permission, environmental impact assessments, grid connection, etc.;
- Construct a financing plan for the project and raise finance/funding through appropriate means, starting with members' contributions (shares purchase, loans);
- Realise the project. This step can encompass detailed design and engineering of the RE systems, tendering for their supply and installation, construction works and commissioning, handover and training, etc.

Please note that the project development steps laid out above would be typical of a RE production project e.g. a small hydropower plant, a wind farm, etc. A project aiming to trade green electricity or producing and retailing wood fuel would obviously require a different approach.

Business Management

In this step, the REScoop is in a position to operate its renewable energy system and trade the energy produced. This is essentially about conducting business in a sustainable manner and requires:

- Operating and maintaining the RE plants;
- Marketing and selling energy-related products and services, organising the underlying logistics/supply chain requirements;
- Managing the organisational, legal and financial aspects of the business.

Outreach and Dissemination

Information and transparency are key when engaging with stakeholders at all stages of the project. Learning from its initial RE projects, the REScoop should continue raising its profile and help other co-operative groups (citizens, farmers, workers, etc.) setting up their own projects. Outreach and dissemination efforts can include:

- Fostering learning and experience development by offering volunteering opportunities for members of the community and other groups;
- Share knowledge through open days, training courses, mentoring support, etc.
- Engage with other community groups and stakeholders to promote synergies and partnerships for local action;
- Communicate widely about the results of the RE projects, using conventional media and social networks;
- Network with other REScoops in the country and internationally, engage in common advocacy efforts.

Figure 55: Kerry REScoop action plan. summarises the REScoop development process steps and proposes an indicative timing leading to 2020:

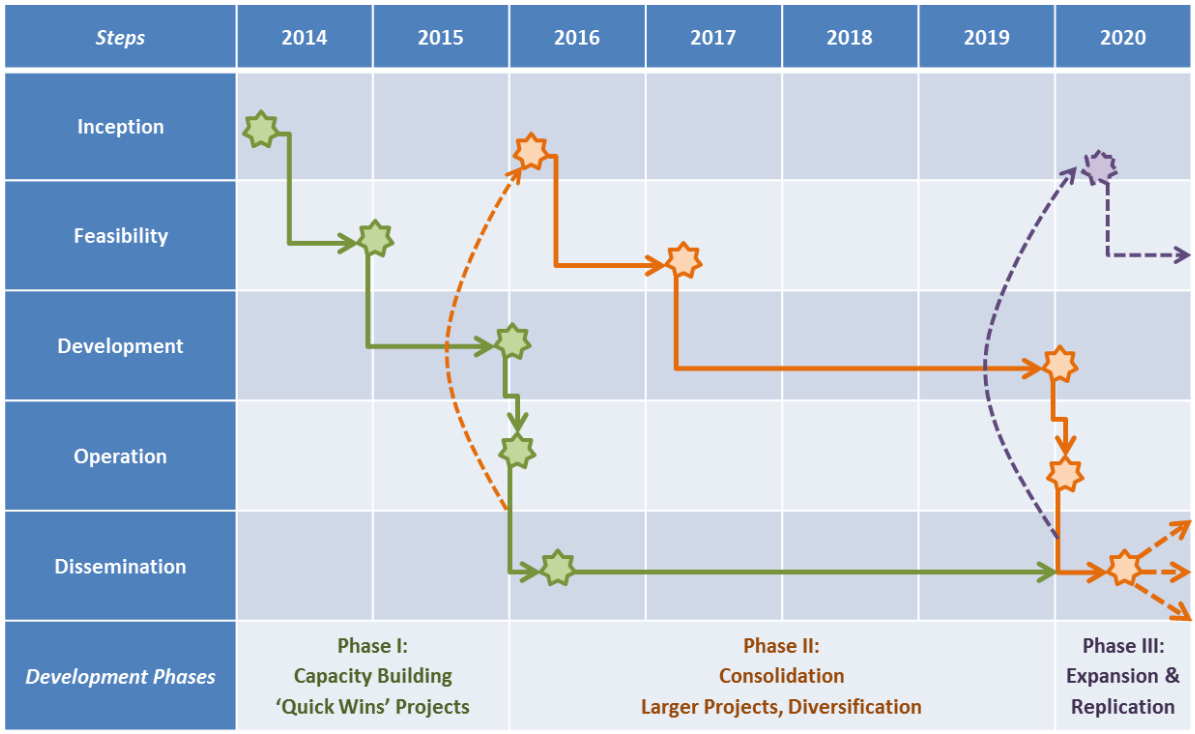


Figure 55: Kerry REScoop action plan.

5.4 The Wider RE Transition in Kerry

The Kerry SEC Roadmap should take place within the framework of the overall transition of the county towards renewable energy. While proposing an action plan for this overall transition is beyond the scope of this study, we can speculate about key developments that should take place in the county to fulfil the 2020 and 2030 scenarios towards 100% renewable energy supply:

- An intensive, multi-sectorial campaign to accelerate energy demand reduction (-15% by 2020 and -30% by 2030) through rational use of energy. This combines awareness-raising towards behavioural change, education and training, quality management, investment support and financing mechanisms, reinforced policy framework (planning, regulations, etc.), demonstration projects, etc. Here again community groups and local authorities play a key role in this regard;
- On-shore wind energy continues to be developed towards achieving 550 MW installed capacity by 2030. There are more than enough projects in the grid connection pipeline (Gate 3) to meet this target. An increasing number of wind farm projects include community participation in their finance and ownership, and approximately 50 MW of wind farms are owned by local REScoops by 2030. In addition, solar PV becomes competitive and makes a remarkable entry into the electricity mix both at micro-scale and utility scale (150 MW by 2030);
- District heating schemes supplied with renewable heat are being rolled out in the major urban centres of the county (300 GWh/year by 2030), piloted first in Tralee and Killarney by 2020. Kerry local authorities play a key role as instigators and developers of DH projects, and

adopt a co-operative form of co-ownership with users. These major infrastructural projects rely on national and European public investment funds as main financing mechanisms;

- A major drive to develop a reliable and cost-effective biomass supply chain takes place throughout the county to meet the demand from district heating and industrial users in particular. Harnessing existing forestry and organic waste resources efficiently and sustainably becomes a priority for the forestry, agricultural and waste management sectors. In parallel, an ambitious programme of forestry and energy crops plantation is undertaken by public and private land-owners, with the farming community taking a lead role. Here too the co-operative businesses play an important role in the biomass supply chain;
- A comprehensive and sustained programme aiming to accelerate the uptake of individual RES heating solutions among rural dwellers and businesses is undertaken by a co-ordinated consortium including local authorities, SEAI, NGOs, REScoops, lenders, etc. The county-wide programme includes awareness-raising, capacity building and support for investment. Local and national public institutions based in the county continue demonstrating best practice of sustainable energy in buildings.
- Similarly, the transport sector is gradually decarbonised, notably through the accelerated uptake of electrical vehicles to reach 10% penetration by 2020 and 50% by 2030. In addition, biomethane in CNG engines and synthetic liquid fuels produced from biomass and hydrogen become primary transport fuels. In parallel, the use of public transport, cycling and walking are promoted heavily in the framework of the demand reduction campaign outlined above, and the necessary infrastructure is put in place by relevant stakeholders;
- In parallel, a co-ordinated, multi-stakeholder programme of energy infrastructure development is put in place to drive key elements of future energy systems for the county such as: smart grids including demand-response management systems, hydrogen and synthetic fuel production and distribution, etc. The planning, development and operational phases of this programme should be conducted in the framework of partnerships involving private and public stakeholders, with community participation at the core. Kerry becomes a hot bed of innovation in community integrated renewable energy systems and is at the centre of R&D partnerships between local and international players in this area.

6 Conclusions

In this chapter, we have focussed on community participation in the renewable energy transition of county Kerry. In our SWOT analysis, we explored the challenges and opportunities for community groups aiming to take a proactive role in that regard. To a large extent, these are intrinsically linked with the centralised and monopolistic nature of the current energy system and the radical transformation of the associated institutional, policy and infrastructural framework required by the transition. Other challenges and opportunities are inherent to how community groups are organised, relying for the most part on volunteers, and how they compensate for limited financial resources with social capital. To a degree, many opportunities arise from the fact that the models of community participation and pathways for the transition are still to be defined in Ireland.

We then mapped out the different stakeholders involved directly or indirectly in the renewable energy transition from the point-of-view of community participation, and we looked at their role(s)

as well as the threats and opportunities presented by their involvement. It is quite clear from this review that community groups will need to thread carefully as they challenge the status quo, and promote a different set of values for the energy system. However, community groups can gain enormously by engaging proactively and creating win-win situations with other stakeholders when carving for themselves a rewarding role in the energy transition.

Our recommendation is for community groups to adopt a co-operative business model when organising themselves for renewable energy project development, joining a strong European movement of REScoops driving and taking advantage of the renewable energy transition. REScoops promote local ownership of renewable energy projects, democratic and transparent business principles, and put a strong emphasis on contributing to the socio-economic and environmental well-being of their community.

We have proposed an outline action plan for the Kerry Sustainable Energy Community Roadmap, articulated around a process of capacity building, starting with accessible projects, before tackling larger developments and diversifying their activities. Outreach will play an important role in promoting community buy-in and in disseminating the REScoop model to other communities in the county. Finally, a review of the wider transformation of the county energy system towards 100% renewable energy supply indicates that it will require a full-scale mobilisation of human resources and capital as well as radical technological and institutional innovation. REScoops and other community groups should be pivotal in this revolution to make sure that local communities take full advantage of the opportunities it will present.

Bibliography

AEA Technology. (2005). *Assessment of Methane Management and Recovery Options for Assessment of Methane Management and Recovery Options for.* DEFRA.

AECOM Ltd. (2011). *Strategic Environmental Assessment (SEA) of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland.* Cheshire: SEAI.

ARUP. (2011). *Review of the generation costs and deployment potential of renewable electricity technologies in the UK.* Department of Climate Change and Energy (UK).

B CASLIN, J. F. (2010). *Short Rotation Coppice Willow: Best Practice Guidelines* . Teagasc .

B.M. Smyth, J. M. (2009). What is the energy balance of grass biomethane in Ireland and other temperate northern European climates. *Elsevier, Renewable and Sustainable Energy Reviews*.

Battisti, R., Vannoni, C., & Drigo, S. (2008). *Potential for Solar Heat in Industrial Processes.* Madrid: SHC Executive Committee, IEA.

Bell, M., Hoyne, S., & Petersen, K. (2013). *SERVE Monitoring – Implementation & Analysis.* Thurles: Tipperary Rural & Business Development Institute.

BM Smyth, H. S. (2010). Modeling and Analysis: Grass biomethane – an economically viable biofuel? *Biofuels, Bioprod. Bioref.* , 10.1002/bbb.

Bomberg, E., & McEwen, N. (2012, Decemeber). Mobilizing Community Energy. *Energy Policy - Volume 51*, pp. 435-444.

Bord Gais. (2010). *The Future of Renewable Gas in Ireland.*

Bord Gais Networks. (2013). *Pipeline Map*. Retrieved March 2013, from http://www.bordgaisnetworks.ie/en-IE/About-Us/Our-network/Pipeline-Map/

BP. (2012). *Statistical Review of World Energy June 2012.* London: BP.

Brown, J. (2010). Biogas from Grass - A diversification opportunity for farmers in West Cork. *Transition to a Sustainable Energy Future - Empowering Rural Communities.* Sustainable Clonakilty .

Bruton, T., Luker, S., Donovan, P., & Tottenham, F. (2010). *Regional Wood Fuel Resources.* RAL-RES project.

Callum, R., & Bradley, F. (2012, August 4). Energy Autonomy in Sustainable Communities - A Review of Key Issues. *Renewable and Sustainable Energy Reviews 16*, pp. 6497-6506.

Census. (2012, 01 01). *Central Statistics Office.* Retrieved 03 15, 2013, from http://census.cso.ie/sapmap2011/Results.aspx?Geog_Type=LT&Geog_Code=18009

Coford. (2003). *Strategic Study - Maximising the Potential of Wood Use for Energy Generation in Ireland.*

Coford. (2007). *Harvesting and Processing Forest Biomass for Energy Production in Ireland The ForestEnergy 2006 Programme.*

Coford. (2009). *Roundwood production from private sector forests 2009-2028 – a geospatial forecast. .*

Connolly , D., Mathiesen, B., Dubuisson , X., Hansen, K., Lund H, H., Finn, P., et al. (2012). *Limerick Clare Energy Plan: Energy and Emissions Balance. .* Aalborg University and Limerick Clare Energy Agency. Available from: http://www.lcea.ie/.

Connolly, D. (2012). *Energy Balance Ireland 1990-2020*. Retrieved from Personal website: http://www.dconnolly.net/downloads/energybalance.html

County Clare Wood Energy Project. (2010). *Step by Step Guide to Selling Your Timber for Wood Energy Experiences from the County Clare Wood Energy Project.*

COWI for UNEP and Danish EPA. (Date unspecified). *Cleaner Production Assessment in Meat Processing.* UNEP DTIE.

CSO. (2011). *Population Census 2011 - Priliminary Results.* Cork: CSO.

CSO. (2012, 01 01). *Energy Statistics Databank Fuel Consumption.* Retrieved 03 15, 2013, from http://www.cso.ie/px/sei/Dialog/varval.asp?ma=SEI06&ti=Fuel+Consumption+(ktoe)+by+Sector,+Fuel+Type+and+Year&path=../DATABASE/SEI/Energy%20Balance%20Statistics/&lang=1

D. Rutz, R. J. (2008). *Biofuel Technology Handbook.* WIP.

Dalton, G., & Lewis, T. (2011). *Performance and economic feasibility analysis of 5 wave energy devices off the west coast of Ireland.* Cork: HMRC, UCC.

DCENR. (Date not specified). *Guidelines on the Planning, Design, Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisheries.* Department of Communication, Energy and Natural Resources.

DCMNR. (2010). Maximising Ireland's Energy Efficiency. The National Energy Efficiency Action Plan 2009 – 2020. .

Denholm, P. (2009). *Land-use requirements of modern wind power plants in the United States.* NREL.

Denholm, P., Hand, M., Jackson, M., & Ong, S. (2009). *Land-Use Requirements of Modern Wind Power Plants in the United States.* NREL.

Department of Energy of Ireland. (1985). *Small-scale Hydro-Electric Potential of Ireland. .*

Devine, P. (2005). Local Aspects of UK Renewable Energy Development: Exploring Public Beliefs and Policy Implications. *Local Environemtn: The International Journal of Justice and Sustainability, 10*(1), 57-69.

Dillard, J., & Layzell, D. (2009). Social Sustainability. In V. D. Jesse Dillard (Ed.), *Understanding the Social Dimension of Sustainability* (pp. 174-198). Oxford: Oxford University Press.

Dubrovskis, V. (2010). *Anaerobic digestion of sewage sludge.* Engineering for rural development.

Dubuisson, X., Stuart, J., & Kupova, D. (2011). *Renewable Energy Study 2011. A Roadmap to Energy Neutrality for Clonakilty Town and District.* Clonakilty: Sustainable Clonakilty.

E. Salminen, J. R. (2002). Anaerobic digestion of organic solid poultry slaughterhouse waste – review. *Bioresource Technology 83, Elsevier*, 13-26.

EEA. (2009). *Europe's onshore and offshore wind energy potential. An assessment of environmental and economic constraints.* Copenhagen: European Environment Agency.

Eirgrid. (2010). *Grid 25 - a Strategy for the Development of Ireland's Electricity Grid for a Sustainable and Competitive Future.* Dublin: Eirgrid.

Eirgrid. (2011). *All-Island Generation Capacity Statement 2011-2020.* Dublin: Eirgrid.

Eirgrid. (2011). *Transmission Forecast Statement 2012-2018.* Dublin: Eirgrid.

Eirgrid. (2012). *Gate 3 Scheduled Firm Access Quantities* . Dublin: Eirgrid.

EirGrid. (2013, 01 01). *All-Island Transmission Map.* Retrieved 03 24, 2013, from http://www.eirgrid.com/media/All-IslandTransmissionMap.pdf

Energistyrelsen. (April 2011). *Forudsætninger for samfundsøkonomiske analyser på energiområdet.* Copenhagen: Energistyrelsen. Available at http://www.ens.dk.

EPA. (2005). *Anaerobic Digestion: Benefits for Waste Management, Agriculture, Energy, and the Environment. Discussion Paper Prepared by the Strategic Policy Unit.*

EPA. (2008). *Irish waste characterisation report.*

EREC / Greenpeace International. (2010). Retrieved from Energy Blue Print: http://www.energyblueprint.info/

ESBI. (2005). *Accessible Wave Energy Atlas for Ireland. SEAI and Marine Institute.* SEAI.

European Union. (2010). *How to Develop a Sustainable Energy Action Plan (SEAP) - Guidebook.* Luxembourg: Publications Office of the European Union.

Garrad Hassan & Partners Ltd. . (2011). *Industrial Development Potential of Off-shore Wind in Ireland.* Dublin: SEAI.

Gavigan, N. (2011). Economics of Bioenergy. *SERVE Project Conference.* Thurles: Irish Bioenergy Association.

Geels, F. W., & Schot, J. (2008). Typology of Sociotechnical Transition Pahways. *Research Policy, 36*(3), 399-417.

Geis, D., & Kutzmark, T. (1998). *Developing Sustainable Communities: The Future is Now.* Washington: International City/County Management Association.

Hesikanan, E., Johnson, M., Robinson, S., Vadovics, E., & Saastamonien, M. (2010, December). Low-carbon communities as a context for individual behavioural change. *Energy Policy Vol 38*, pp. 7586-7595.

Hicks, J. (2013 a, 01 01). *United States - Ellensburg Community Solar Porject.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=2294086

Hicks, J. (2013 c, 01 01). *Denmark - Middelgrunden Wind Turbine Co-operative.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=2294076

Hicks, J. (2013 d, 01 01). *Germany - Hollich Citizen's Wind Farm.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=2294082

Hicks, J. (2013 e, 01 01). *United States - Minwind I - IX Wind Farms.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=2294986

Hicks, J. (2013 f, 01 01). *Sweden - Swedish Wind Power Co-operative.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=2294078

Hicks, J. (2013 g, 01 01). *Hepburn Community Wind Park Co-operative.* Retrieved 03 06, 2013, from http://www.embark.com.au/display/public/content/Hepburn+Community+Wind+Park+Co-operative

Hicks, J., & Ison, N. (2011). Community-owned Renewable Energy (CRE): Opportunities for Rural Australia. *Rural Society, 20*, 244-255.

IEA Bioenergy Task 37. (2011). Ireland Country Report. Turkey.

Innes, J. E., & Booher, D. E. (2010, 12 09). Indicators for Sustainable Communities: A Strategy Building on Complexity Theory and Distributed Intellignece. *Planning Theory & Practice*, pp. 173-186.

J. Rijpens, S. R. (2013). *Report on REScoop Buisiness Models.* www.rescoop.eu.

J. Wickham, B. R. (2010). *A review of past and current research on short rotation coppice in Ireland and abroad.* SEAI & Coford.

JHSBA. (2012, 01 01). *District Heating and Cooling.* Retrieved 03 27, 2013, from http://www.jdhc.or.jp/en/what02.html

Kerry County Council. (2013). *Sustainable Energy Action Plan 2012-2020 for the Covenant of Mayors.* . Tralee: Kerry Council Council.

Kerry County Council Planning Policy Unit. (2012). *Proposed 8th Variation to the Kerry County Development Plan 2009 - 2015. Draft Renewable Energy Strategy.* . Tralee: Kerry County Council.

King, P., & Sweetman, C. (2011). *Regional Waste Management Plan. Limerick/Clare/Kerry region. 5th annual report 2006-2011.* Limerick: Regional Waste Management Office.

Lund, H. (2010). *Renewable Energy Systems - The Choice and Modelling of 100% Renewable Energy Solutions.* San Diego: Academic Press, Elsevier.

Lund, H. (2012). *EnergyPLAN Advanced Energy Systems Analysis Computer Model Documentation Version 10.0.* Aalborg: Aalborg University.

Mangold, D. (2007, (1)). Seasonal storage – A German Success Story. *Sun and Wind Energy*, pp. 48-58.

Mangold, T. S. (2007). NEW STEPS IN SEASONAL THERMAL ENERGY STORAGE IN GERMANY. *Solites.* .

Murphy, J. D., & Thamsiriroj, T. (2013). Chapter 6: Fundamental Science and Engineering of the Anaerobic Digestion Process. Cork: UCC.

Ni Ruanaigh, A. (2011). *Developing Anaerobic Digestion Cooperatives in Ireland. Masters Dissertation.* Dublin: Dublin Institute of Technology.

Nielsen. (2003). *Offshore Wind Energy Projects Feasibility Study Guidelines SEAWIND.* www.emd.dk .

Philips, H. (2011). *All Ireland Roundwood Production Forecast 2011-2028.* Coford.

Poyry Energy Consulting. (2009). *Potential and Cost of District Heating Networks.* UK Department of Energy and Climate Change.

Reilly, J. (. (2010). The Co-Firing Market for Biomass. *National Forestry Conference.*

Renewable Energy Partnership. (2004). *To Catch the Wind.* Dublin: Sustainable Energy Ireland.

REScoop 20-20-20. (2013). *Best Practices Report.* Intelligent Energy Europe.

Risoe Laboratory. (2005). *Wind Energy the Facts.* Retrieved 2010, from http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_2.pdf

RPS MCOS. (2004). *An Assessment of the Renewable Energy Resource Potential of Dry Agricultural Residues in Ireland.* SEAI.

Seadi, T. A. (2008). *Biogas Handbook.* Big East – Biogas for Eastern Europe.

SEAI. (2004). *Biofuel strategy study.*

SEAI. (2005). *Tidal and Current Energy Resources in Ireland.* SEAI.

SEAI. (2008). *Energy in the Residential Sector.* Dublin: SEAI.

SEAI. (2009). *Energy Forecasts for Ireland to 2020.* Dublin: SEAI.

SEAI. (2010). *Residential Energy Roadmap.* Dublin: SEAI.

SEAI. (2011). *Electric Vehicles Roadmap.* Dublin: SEAI.

SEAI. (2011). *Energy Forecasts for Ireland to 2020.* Cork: SEAI.

SEAI. (2011, 01 01). *Energy Statistics Databank - Transport.* Retrieved 03 12, 2013, from http://www.cso.ie/px/sei/Dialog/varval.asp?ma=sei07&ti=Average+Fuel+Consumption+and+Distance+Travelled+for+Private+Cars+by+Engine+Capacity+cc,+Year,+Statistic+and+Type+of+Fuel&path=../DATABASE/SEI/Transport%20Statistics/&lang=1

SEAI. (2012). *Bioenergy Supply Curves for Ireland 2010-2030.* Dublin: SEAI.

SEAI. (2012). *Biomass District Heating - The Mitchels Boherbee Regeneration Project.* Retrieved from http://www.seai.ie/Publications/Renewables_Publications_/Bioenergy/The_Mitchels_Boherbee_Regeneration_Project.pdf

SEAI. (2012). *Sustainability*. Retrieved 12 17, 2012, from Sustainable Energy Authority of Ireland: http://www.seai.ie/About_Us/About_Energy/Sustainable_Energy/

SEAI. (2013, 01 01). *CHP and District Heating.* Retrieved 03 27, 2013, from http://www.seai.ie/About_Energy/Energy_Technologies/CHP/

SEAI. (2013). *Energy costs comparison (archive)*. Retrieved from http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/

SEAI EPSSU. (2009). *Energy in Ireland 1990-2008. .* Cork: SEAI.

Shahidehpour, M. (2011). Microgrid: A New Hub in Energy Infrastructure. *International Conference on Electric Utility Deregulation and Restructuring and Power Technologies (DRPT) 2011.* Chicago.

Shannon LNG. (2007). *Shannon LNG planning portal*. Retrieved from http://www.shannonlngplanning.ie/

Smyth, B. (2010). Can grass biomethane be economically viable biofuel for the farmer and consumer? *Biofuels, Bioprod, Bioref.*

Smyth, B., Smyth, H., & Murphy, J. (2011). Determining the regional potential for a grass biomethane industry. *Applied Energy (Elsevier)*.

Stene. (2008). *Design and operation of ground-source heat pump systems for heating and cooling of non-residential buildings.* www.sintef.no.

UC Davis. (2011, 01 01). *Biogas - Biogas As An Alternative Fuel.* Retrieved 03 27, 2013, from http://teenbiotechchallenge.ucdavis.edu/2012_TBC/JSingh-Sheldon/Biogas.html

V. Giordano, F. G.-I. (2011). *Smart Grid projects in Europe: lessons learned and current development.* EC JRC Institute for Energy.

Valeria Di Cosmo, M. H. (2013). *Carbon tax scenarios and their effects on the Irish energy sector.* Elsevier, Energy Policy Journal. Summary available at http://www.esri.ie/UserFiles/publications/RB20130207/RB20130207.pdf.

Walker, G., Hunter, S., Devine-Wright, P., Evans, B., & Fay, H. (2007). Harnessing Community Energies: Explaining and Evaluating Community-Based Localism in Renewable Energy Policy in the UK. *Global Environmental Politics, 7*(2), 64-82.

Webb, A. (2013, 01 01). *UK - Lewes Community Power Station.* Retrieved 03 06, 2013, from http://www.embark.com.au/pages/releaseview.action?pageId=4259990

WEO, W. E. (2012). *World Energy Outlook 2012.* Paris: International Energy Agency.

Wikipedia. (2013, January). *Shannon LNG*. Retrieved March 2013, from en.wikipedia.org/wiki/Shannon_LNG

WRAP. (2009). *Food waste collection guidance.*

Annexes

Annex 1 Review of REScoop Best Practice

The following section summarises a review of the Best Practices Report prepared in the framework of the European REScoop 20-20-20 project (2013). The project, funded by the Intelligent Energy Europe programme, aims to "accelerate renewable energy production, leveraged by the cooperative model with local citizen involvement". The report provides a valuable insight in best practices and lessons learned from pioneering RESCoops interviewed as part of the research conducted by the project team. Best practices are organised and described around key principles underlying the successful development and operation of RESCoops.

Organisation:

1. Adherence to clear and unambiguous ethical principles in line with those of the International Co-operative Alliance such as open membership, democratic and autonomous control by the members, equal contribution by members to the capital, co-operation among co-operatives, concern for the community, empowering members through education and training.
2. Start small (typically 40-50 members with a core of 5-6 active volunteers) and aim first for modest, rapidly achievable projects that build confidence among members and generate goodwill among the community.
3. Use the skills, free time and networks of your members as key assets of the co-operative, encouraging members to become active volunteers around the core group. Members' social power should be leveraged to quickly build membership for the co-op.
4. Transparency is key to build and maintain trust in the organisation. It is important to communicate clearly and continuously about its goals, values, organisational structures to the members. Demonstrating to members that they, as co-owners, can actively participate in the organisation.
5. REScoops are typically willing to share their knowledge and experience. New REScoops should aim to learn as much as possible from them and avoid reinventing the wheel, using and adapting proven business models.
6. REScoops can take advantage of their member base and open culture to participate in innovation projects. Innovation projects can be catalysts for energy infrastructure development and provide funding opportunities that can be of benefit to the co-operative. Its board should negotiate being included in the project team and be part of the learning process. In return, they can offer a co-ordinated group of people proactive in the R&D process and acting as the demand side in innovative energy technology or services testing.

Financial Management

1. Use the REScoop's membership skills and know-how to carry out voluntarily as much of the project development work as possible, thereby reducing investment requirements until there is an actual project to invest in.
2. During start-up phase, simple but profitable activities such as selling third-party electricity help generate revenue that can then be used to support more substantive and complex projects involving capital investment and professional fees. Founders can also provide seed capital before wider contribution from the membership is sought.

3. Transparency and communication on financial aspects of the co-op and its projects at regular intervals and critical times is important to build trust. Any share or loan offer to members must be backed by robust feasibility and due diligence studies providing transparent information on technical, legal and financial details of the project. Financial structures should be kept simples and financial reports should be freely available.
4. As REScoops often depend on energy systems (wind farms, solar PV plant, etc.) for their business model, downtime associated with failure and repair & maintenance need to be minimised. In addition to solid insurance cover, it is recommended to enter in good service contracts with specialist companies that will track the performance of the installation and carry out preventative maintenance. Such contracts should have an 'up-time' guarantee clause.
5. It is best to keep levels of financial transfer to members in the form of dividends on shares or interest payments on loans variable, to maintain the REScoop's flexibility to adapt payments to actual returns on investment (in case of a bad generation year for example).
6. The REScoop project research provides evidence that REScoops are flourishing in the economic crisis as citizens have grown suspicious of traditional placements for their savings. REScoops can tap in this sentiment by offering investment opportunities where investors, as members, have direct control and visibility on how their money is being used. Building trust with transparency on expected rewards and potential risks is critical in that regard.
7. While the overall organisation needs to stay financially healthy, members can often respond positively to other motives than purely financial profits from their investment, and decide to support project marginally financially viable but with high social and/or environmental benefits for their community.

Relations with stakeholders

1. REScoops' members have deep connections at many levels (social, cultural, economic) with their community. These connections are essential when engaging and developing a working relation with stakeholders in the co-ops' RE projects, and give them a definite advantage over external companies.
2. REScoops should have a clear knowledge of their vision and assets (capability, connections, projects, etc.) are before engaging with local stakeholders. In addition, they should try and understand what these stakeholders' interests and concerns are, using the local knowledge of their members.
3. Local authorities are key stakeholders for REScoops in that they have useful assets (e.g. energy usage, land, human resource, machinery, know-how, etc.), control over certain regulatory procedures (in particular planning) and access to a wide range of stakeholders (national government, local politicians, etc.). REScoops and local authorities can become partner and provide services to each other (green energy supply, research activities, etc.).

Grid connection and sale of energy

1. REScoops can have different business models, some focusing on the production of energy, others on the sale of green electricity bought from a third-party producer, some others on energy saving projects. It is recommended to diversify in different models to increase resilience and lines of cash-flow.

2. As indicated before, sale of third party generated energy enables to kick-start the REScoop trading relatively quickly and without major investment, as they move on to renewable energy projects development (often with long lead times).
3. In many cases, members feel strongly about using themselves the energy their co-op produce, either directly by trading their energy themselves or using service companies to administer the whole process. Often, REScoops deliver fee energy to their investor-members instead of giving dividends.
4. REScoops can adopt alternative business models to conventional energy suppliers that focus on growth and selling as much as possible energy, to the detriment of efficiency and economy. Some have set a single, simple and all-inclusive tariff that doesn't differentiate day/night usage or rewards higher consumers, and encourage savings.
5. The process and the cost of obtaining grid connection must be considered very early on in the project, and the network operator (Eirgrid for transmission, ESB Networks for distribution) must be engaged with very early on in the project. Autogeneration projects and small (<500 kW) grid connection projects have a much simpler, faster and cheaper access to the grid than large utility-scale projects such as multi-MW wind farms.
6. REScoops and their demand-side membership base can be natural partners for smart grid projects and associated R&D activities in this area, on the proviso that all parties have clear expectations and understanding of each other's needs.