Decarbonisation of Domestic Heating Systems

Ed O'Connor, Brendan O'Donnell, Joseph Walsh
Institute of Technology Tralee (ITT), Ireland

Abstract

Decarbonisation of Irelands heating system would mean a shift away from traditional fossil fuels, and a step towards more renewable and sustainable thermal energy systems. Climate change and the related consequences associated with it have become a key component of the political agenda at local, national and international levels. It has become clear that further action is needed to tackle global warming and alleviate the dangers associated with the continued warming of our planet. Reduced energy consumption, increased energy efficiency, increased use of renewable energy sources, and the reduction in Green House Gas (GHG) emissions may yet become one of this generation's defining moments.

1. Introduction

Climate change and the related consequences associated with it have become a key component of the political agenda at local, national and international levels. At the Conference of Parties 21 (COP21) in Paris in 2015, it was declared that the current measures to combat climate change are insufficient to keep global temperatures' below the proposed 2°C increase [1].

It has become clear that further action is needed to tackle global warming and alleviate the dangers associated with the continued warming of our planet. Reduced energy consumption, increased energy efficiency, increased use of renewable energy sources, and the reduction in Green House Gas (GHG) emissions may yet become one of this generation's defining moments.

At present a large proportion of domestic heating systems in Ireland are fossil fuel based. Green House Gas (GHG) emissions for Ireland represented 60 $MtCO_2e$ in 2012. In 2013 thermal energy accounted for 41% of Irelands Final Energy Demand (FED) [2].

Decarbonisation of Irelands heating system would mean a shift away from traditional fossil fuels, and a step towards more renewable and sustainable thermal energy systems. Decarbonisation consists of a removal of or a reduction in fuel stock with high carbon emission values. Current national and international policies suggest advancement to a low or zero carbon economy is necessary. The Intergovernmental Panel on Climate Change (IPCC) in their latest publicised report, The Synthesis Report (SYR) states "The IPCC is now 95 percent certain that humans are the main cause of current global warming" [3]. A report published by the European Commission (EC) through the Joint Research Centre (JRC) and the Institute for Energy and Transport (IET) in 2012 states "Space and domestic water heating for buildings is currently one of the largest sectional energy uses; about 43% of the total EU FEC...and is the most problematic to decarbonizes" [4]. The European Union (EU) directives expect Irelands Renewable Energy Source Heating and Cooling (RES-H) to reach 12% by 2020 [5].

If this target is to be achieved by the allotted time frame action will be needed.

2. Research Rationale

If Ireland is to achieve the expected RES-H target of 12% set by the EU within the proposed timeframe significant progress will need to be seen over the coming years. The Sustainable Energy Authority of Ireland (SEAI) estimates a 7% yearly increase from now until 2020 is required in the renewable heat sector if this target is to be achieved [6]. Import dependency for Ireland in 2014 stood at 85%, a reduction of 4% on 2013 levels, with 97% of imports relating to fossil fuels. Ireland has the fourth highest oil dependency in the EU at 49% of all energy use [2]. Ireland's lack of fossil fuel resources means it will need to look more towards alternative energy options if it is to tackle the issues of security of supply, reduction in GHG emissions and renewable energy targets. The Irish government has agreed to meet the energy targets set down by the European Union.

3. Methodology

To evaluate the possible carbon savings associated with the decarbonisation of domestic heating systems, this case study will calculate the CO_2 reductions which could be achieved from changing existing domestic heating systems to biomass fuelled heating systems. The case study takes the town of Tralee as a typical example. Tralee is the capital town of Co Kerry and is situated in the south west of Ireland. It is the third largest town in Munster and has a population of 23,639. The climate for the area is classed as maritime temperate climate; it is mild and changeable and has a lack of temperature extremes. Tralee has 9122 residential dwellings, 60% of the thermal demand of the residential sector is met through oil fired central heating, while another 20% of households use electricity to meet thermal demand. 10% of dwellings use coal as the main fuel for domestic heating and hot water. The remaining 10% of households use a variety of fuels including peat or turf 1%, Liquid Petroleum Gas (LPG) 1%, Natural Bottled Gas (NBG) 2% and biomass 1% [7].

There are a myriad of options available when considering an alternative to the traditional fossil fuel heating systems; from individual biomass boilers to solar thermal systems to a larger scale District Heating System (DHS). This paper will attempt to assess three options available; the base case, Scenario 1; will consist of the existing heating systems with all present systems upgraded to the expected efficiency levels and rating. Scenario 2; will represent a change for all existing systems to individual biomass fuelled heating systems. Scenario 3; will consider the development of a biomass driven District Heating System (DHS) to cater for the thermal needs of the residential sector of the town.

Consideration needs to be given to several issues regarding any assessment of this nature; Any renewable alternative needs to be both truly renewable and sustainable. Fuel stocks need to be locally available and locally produced. The realisation that any money spent on locally produced fuel stock will remain within the locality. Security of fuel supply can be strengthened when it is locally grown, produced and utilised. Social gains would include but are not limited to, improved air quality, job creation and a constant cash flow for the local economy.

The increased cash flow within the community could also help to stimulate further spinoff employment in areas such as hospitality, leisure and tourism. According to the 2011 Census the unemployment level for Tralee was 27.4% compared to the national average of 19% [7].

Tralee was hit hard by the economic downturn and lost a large number of key industrial jobs during the recession. With Tralee's unemployment figures a clear 8 points above the national average any job creation in the area would be an extremely welcome addition.

4. Case Study

According to a report published by the Sustainable Energy Authority of Ireland (SEAI) in 2015 the average Irish dwelling consumed 17,927 kWh of energy per year taking climate corrected data into account. This can be broken down to 4,610 kWh of electrical energy per year and 13,318 kWh of thermal energy per year [2]. Using the average figure given for residential buildings, Table 1 below shows the overall thermal energy requirements for Tralee on a yearly basis. All housing data used was taken from the 2011 census [7].

4.1. Base Case

Table 1. Household average thermal energy

Average Thermal kWh/Year/House	Dwelling Number	kWh/Year	MWh/Year
13,834	9,122	126,193,748	126,194

Table 2 below shows the breakdown of housing for Tralee by heating system type. These figures will allow for the assessment of carbon dioxide (CO_2) displacement possibilities.

Table 1. Household by heating system type

Housing by Heating System Type	Number	%
Oil	5,516	60.5
Electricity	1,749	19.2
Coal	933	10.2
Natural Bottled Gas	248	2.7
No Central Heating	250	2.7
Not Stated	124	1.4
Peat (Including Turf)	97	1.1
Liquid Petroleum Gas (LPG)	85	0.9
Other	34	0.4
Wood (Including Pellets)	86	0.9
Totals	9,122	100

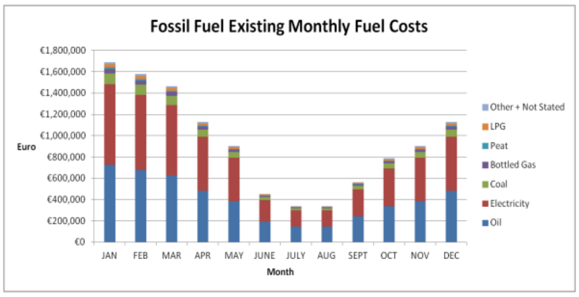
All fossil fuel prices used were obtained from a publication by the Sustainable Energy Authority of Ireland (SEAI) [8]. All fossil fuel prices were converted to price per kWh.

All carbon emissions values were taken from the publication by the Environmental Protection Agency (EPA) titled "Irelands Greenhouse Gas Emissions 2012" [9].

All fossil fuel boiler prices were sourced through Hevac, and can be accessed through their website hevac.ie [10].

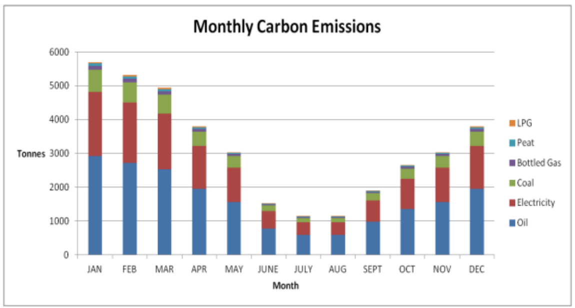
Graph 1 below shows a monthly breakdown of the existing fuel costs incurred to meet the thermal needs of the residential sector of the town. The graph also shows the fuel cost breakdown by chosen heating fuel type.

Graph 1. Base case monthly fuel costs



Graph 1 above shows the total yearly spent to meet the thermal energy needs of the town of Tralee, the total spend comes to €13,960,422. The heating costs for the town are shown monthly to better express the seasonality of heating needs. The thermal energy costs are also broken down by existing heating fuel type.

Graph 2. Monthly CO_2 emissions



Graph 2 above shows the existing monthly CO_2 emissions associated with supplying the thermal need for the town. The monthly carbon values are broken down by existing heating fuel type. The value of carbon that could be displaced with 100% switch to biomass driven systems is 38,561 tCO_2/year.

4.2. Alternative Options

As with any improvement or upgrade there are several options available when considering a change from existing fossil fuel thermal heating systems. This paper will assess three alternative options to help alleviate some of the carbon emissions associated with fulfilling the thermal energy need of the town of Tralee.

Scenario 1; will consist of the existing heating systems with all present systems upgraded to the expected efficiency levels and rating. Scenario 2; will represent a change for all existing systems to individual biomass fuelled heating systems. Scenario 3; will consider the development of a biomass driven District Heating System (DHS) to cater for the thermal needs of the residential sector of the town.

4.3. Scenario 1

Scenario 1; upgrade of all existing heating systems to comply with most recent efficiency levels and ratings. All fuel types would remain the same as existing.

Table 3 below shows a capital investment of €16,653,500 to upgrade all existing heating systems. Considering recent improvements regarding building regulations and standards, all newly installed fossil fuel driven thermal heating systems must have a seasonal efficiency of not less than 90% [11].

Table 2. Scenario 1 installation costs

Scenario	Description	Boiler Numbers	Capital Costs €
Scenario 1	Fossil Fuel Boilers	9,122	€16,653,500

This scenario would show an improvement on the current conditions of roughly 10%.

Table 3. Scenario 1 yearly operational costs

Scenario	Fuel Costs/Year €	O & M Costs/Year €	Total Costs/Year €
Scenario 1	€11,275,000	€684,150	€11,959,150

Table 4 above shows an improvement regard operation and maintenance cost/year of €2,001,272. This improvement is driven by the increased efficiency of the systems and could prove to be a worthwhile procedure.

Table 4. Scenario 1 possible yearly CO_2 displacement

Scenario	Description	CO_2 Displacement/Year Tonnes
Scenario 1	Fossil Fuel Boilers Upgrade	3,856

Table 5 above shows a possible saving that could be achieved from an upgrade to the existing thermal systems of 3,856 tCO_2/year. This shows the savings associated with the improved efficiency of the new systems.

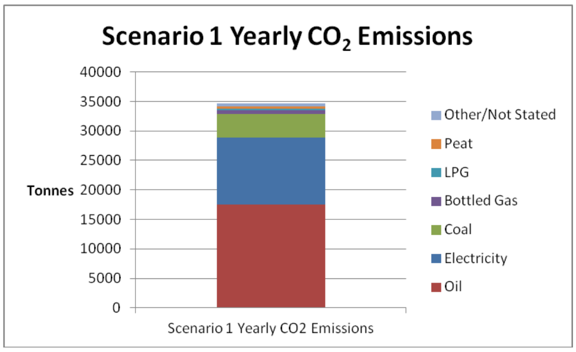
Table 5. Scenario 1 cost overview project life cycle 20 years

Scenario	Capital Costs €	20 year O & M Costs €	Total Project Cost €
Base Case	0	€273,808,440	€273,808,440
Scenario 1	€16,653,500	€239,183,000	€255,836,500

Taking a project life cycle of 20 years we can show the possible savings that could be associated with Scenario 1 over the chosen life cycle. Table 6 above shows the cost associated with Scenario 1 compared to that of the existing base case situation in the town over the chosen 20 year project life cycle.

Graph 3 below shows the yearly CO_2 emissions relating to scenario 1 and represents a CO_2 displacement of 3,856 tCO_2/year when compared to the existing base case.

Graph 3. Scenario 1 yearly CO2 emissions



4.4. Scenario 2

Scenario 2; will represent a change from all existing systems to individual biomass fuelled heating systems.

All wood pellet boiler prices were sourced from Kerry Biofules [12].

The assumption being made in both Scenario 2 and 3 is that the biomass fuel stock is being supplied from a sustainably managed forest, meaning that all fuel stock would be replanted allowing for the sustainable growth of the forest. This allows the biomass fuel stock to remain carbon neutral, ensuring the combusted fuel will have zero impact on GHG emissions. In this instance the biomass fuel is given credit for the carbon it extracted from the atmosphere during its growing cycle. This also ensures the replenishment of the fuel stock for the future. For a project of this nature to be successful a comprehensive analysis of local available fuel stocks would need to be carried out. The recommended maximum transportation distance for biomass fuel stock is said to be 50km, above this distance the cost becomes uneconomical.

Table 6. Scenario 2 installation costs

Scenario	Boiler Type	Boiler Numbers	Capital Cost €
Scenario 2	Wood Pellet Boilers	9122	€34,244,000

Table 7 shown above represents the installation cost for replacing all existing fossil fuel boilers with biomass wood pellet boilers. The capital investment required is €32,244,000.

Table 7. Scenario 2 yearly operational costs

Scenario	Fuel Costs/Year €	O & M Costs/Year €	Total Costs/Year €
Scenario 2	€9,338,000	€684,150	€10,022,150

Table 8 above shows the yearly fuel and maintenance cost associated with the installation of individual biomass boilers to replace the existing fossil fuel systems. This shows a yearly cost of €10,022,150. The wood pellet price used for the analysis is 7.4 cent/kWh delivered thermal energy [8].

Table 8. Scenario 2 possible yearly CO_2 displacement

Scenario	Description	CO_2 Displacement/Year Tonnes
Scenario 2	Wood Pellet Boilers	38,561

Table 9 shown above gives the possible CO2 displacement value for scenario 2 as 38,561 tCO2/year. This represents a significant reduction in the carbon emissions associated with the existing thermal energy system.

Table 9. Scenario 2 cost overview 20 year project life cycle

Scenario	Capital Cost €	20 Year Project LC Cost €	Total Project Cost €
Base Case	0	€273,808,440	€273,808,440
Scenario 1	€16,653,500	€239,183,000	€255,836,500
Scenario 2	€34,244,000	€200,443,000	€234,687,000

Table 10 above shows a comparsion between two of the proposed alternative scenarios and the origonal base case. Both the suggested alternatives yeald a financial gain as well as a carbon saving over the proposed 20 year project life cycle.

4.5 Scenario 3

Scenario 3; will consider the development of a biomass driven District Heating System (DHS) to cater for the thermal needs of the residential sector of the town.

District Heating and Cooling (DH) is based on a central heat plant that through a network of pipes and substations distributes heat energy to individual buildings. The thermal heat can be delivered by several modes, but the most common are; water or steam. Thermal energy can be generated from many sources such as; biomass boilers, combined heat and power generation (CHP), heat from waste incineration, waste industrial heat, solar collectors, geothermal sources or heat pumps. DH systems have proven more energy efficient than individual central heating systems. One central boiler allows for a more thorough and comprehensive operational and maintenance (O & M) control schedule. It also allows more control over fuel price concerning the bulk buying of fuel stocks. A DH system that generates thermal energy using biomass fuel stock or/and captures otherwise wasted heat can assist in delivering national and international energy efficiency and GHG reduction targets.

The chosen fuel stock for the DHN would be locally produced wood chip.

Table 10. Scenario 3 installation costs

Scenario	Description	Boiler Numbers	Capital Costs €
Scenario 3	DHN	5 (5 X 5MW)	€52,500,000

Table 11 shown above represents the installation cost for replacing all existing fossil fuel boilers with a biomass driven DHN. The capital investment required is €52,500,000. The heat plant size is estimated at 25MW. The investment cost relates to the biomass heat plant and the district heating distribution network.

Table 11. Scenario 3 yearly operational costs

Scenario	Fuel Costs/Year €	O & M Costs/Year €	Total Costs/Year €
Scenario 3	€5,678,730	€1,575,000	€7,253,730

Table 12 above shows the yearly operational cost for the proposed DHN. The fuel cost is again sourced from SEAI and are given as per kWh delivered energy price [8]. The O & M costs are taken as a yearly estimate set at 3% of capital investment. The total yearly operational cost for the DHN stands at €7,253,730.

Table 12. Scenario 3 possible CO_2 displacement

Scenario	Description	CO_2 Displacement/Year Tonnes
Scenario 3	DHN	38,561

Table 13 expresses the possible CO_2 displacement associated with the installation of the suggested biomass DHN.

Table 13. Scenario 3 cost overview 20 year project life cycle

Scenario	Capital Cost €	20 Year Project LC Cost €	Total Project Cost €
Base Case	0	€273,808,440	€273,808,440
Scenario 1	€16,653,500	€239,183,000	€255,836,500
Scenario 2	€34,244,000	€200,443,000	€234,687,000
Scenario 3	€52,500,000	€113,574,600	€166,074,600

Table 14 above shows the comparison between the base case and all scenarios assessed. As can be seen from the total project costs over a 20 year project life cycle, financially all three suggested options are viable options when compared to the existing systems.

Below table 15 shows the CO_2 displacement possible if any of the three scenarios were implemented. Scenario 1 shows a slight carbon emissions saving of just over 77,000 tCO_2 over the life time of the project while both Scenario 2 and Scenario 3 would yield a significant carbon emissions saving of just over 771,000 tCO_2 during the 20 year project life cycle.

Table 14. Overview CO_2 displacement possibilities

Scenario	Description	CO_2 Displacement 20 Year Tonnes
Base Case	Existing Fossil Fuel Boilers	0
Scenario 1	Fossil Fuel Boilers Upgrade	77,120
Scenario 2	Wood Pellet Boilers	771,220
Scenario 3	DHN	771,220

Having evaluated each scenario for capital investment costs, operation and maintenance costs and carbon displacement possibilities, a project life cycle cost per unit can be developed. This would allow for a total cost per housing unit to be compared across each scenario.

Table 16 below shows the total project cost and the total CO_2 displacement possibilities per household over the 20 year project life cycle.

Table 15. Scenario overview per household 20 year project life cycle

CO_2 Displacement & Cost Per Unit		
Scenario	Total Cost/Household €	Total CO_2 Displacement/Household Tonnes
Base Case	€30,016	0
Scenario 1	€28,046	8
Scenario 2	€25,727	85
Scenario 3	€18,205	85

5. Conclusion

The base case represents the existing systems employed within the town to meet the required thermal energy needs. The town is heavily reliant on oil with just over 60% thermal energy market share, electric heating systems enjoy the next biggest market share covering 19% of the required need, while coal holds a 10% share and bottled gas with 3% of the market total. The remaining heating needs are met by LPG, peat and biomass.

The existing fuel cost per year per individual household is just over €1,500. The current carbon emissions per household per year are averaged out at 4 tCO_2/year.

The existing fuel types and percentages market share were used to evaluate cost and CO_2 emissions.

Scenario 1 represents an upgrade to the existing systems with no change to fuel type use. This would see all existing systems upgraded to required efficiency levels and would provide a small amount of CO_2 abatement. This would be due to the increase in efficiency of the systems and would represent roughly 10% savings. This could yield a CO_2 emissions saving of 3,8561 tCO_2 per year and taking a 20 year project life cycle the savings could be 77,120 tCO_2.

The fuel cost per year per individual household after the boiler upgrades would be just over €1,311. This would also see an improvement in carbon emissions per household per year again averaged out at 3.8 tCO_2/year.

Scenario 2 would see all existing systems changed to individual biomass boilers. Wood pellet would be the fuel of choice as it is more suitable for domestic situations and is readily available. The possible CO_2 savings associated with this scenario are reliant on the assumptions that; 1: All the fuel stock is locally available and locally produced. 2: The fuel stock comes from a sustainable run forest. 3: 100% project take-up. With all that considered the projected savings in CO_2 emissions of 38,561 tCO_2 per year is impressive. Over the 20 year project life cycle the total CO_2 emissions savings could be 771,220 tCO_2.

The fuel cost per year per individual household after the installation of the biomass boilers would be just under €1,100. The major shift regarding this scenario is the reduction to zero CO_2 emissions regarding the direct use of fuel.

Scenario 3 considers the development of a biomass District Heating System. Woodchip would be the fuel type chosen and as with scenario 2 the same assumptions would be in place. Again the CO_2 emissions displacement would represent 38,561 tCO_2 per year and shows a project life cycle saving of 771,220 tCO_2. Projects of this nature need to be investigated more comprehensively when the long term savings are considered.

The fuel cost per year per individual household after the installation of the biomass driven DHN would be just under €795. This scenario also sees a major shift with the reduction to zero CO_2 emissions regarding the direct use of fuel.

Climate change and the relating consequences and effects associated with it have become a firm component of the political agenda at local, national and international levels. The climate change issue has long been argued among scientists and is a debate that may well continue for some time; however most experts now agree that; climate change is real, our use of fossil fuels is the major contributor to the escalated levels of GHG emissions found in our atmosphere and action needs to be taken to mitigate any further damage to our planet and its ecosystems.

It has become clear that further action is needed to tackle global warming and alleviate the dangers associated with the further warming of our planet. The reduction of energy consumption, the efficient use of the energy we generate, the increased use of renewable and sustainable non pollutant energy generation, and the reduction in GHG emissions may yet become one of this generation's defining moments.

Emissions targets have been set at national and international levels and the political will seems to be progressing towards these goals. To mitigate the effects of climate change action is needed and needed now.

6. References

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