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Geothermal Energy Utilisation - Ireland Country Update

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ABSTRACT

The exploitation of low enthalpy geothermal resources in Ireland using ground source heat pumps for heating and cooling applications dominates utilisation at present. A modest rate of increase of 1.2% per annum in the number of heat pump units installed in Ireland between 2015 and 2019 accounts for a total of 193 MWt installed capacity at the time of reporting (tables 4 and 5). The decrease in uptake of GSHP systems in Ireland is attributed to the slow recovery of the building sector, increased competition from air source heat pumps and dedicated financial support for ground source systems being made available in Ireland only in the last year of the reporting period. This has resulted in limited numbers of small-scale domestic heat pumps, with larger-scale open and closed loop systems more prevalent. Extensive research aimed at furthering our understanding of deep geothermal resources in different geological settings in Ireland is being undertaken. The conclusion of the "IRETHERM" project in 2016 identified potential geothermal targets in low-medium enthalpy sedimentary aquifers and radiogenic granite plays in Ireland and Northern Ireland. Targets of interest included radiogenic granites, fractured Carboniferous limestones and associated thermal springs, uranium-bearing shales, and Permo-Triassic sandstone reservoirs. Follow-on research projects to assess the potential of deep, fractured carbonates and palaeokarst targets have been undertaken as part of the "Irish Carboniferous Palaeokarst" and "HotLime" projects, with focus mainly on the Dublin, Clare and Lough Allen Carboniferous sedimentary Basins, as well as the Kilmurry prospect in the Adare play, Co. Limerick. The "GEO-URBAN" Project, focused on the Dublin Basin, aims to explore the potential for low enthalpy geothermal energy in urban environments using novel multidisciplinary geophysical methods to increase our understanding of deep geological conditions and facilitate the commercialisation of deep resources. A number of projects funded by the European H2020 programme are being implemented with the aim of further developing the shallow geothermal energy sector in Ireland. Also considering the urban environment, the "MUSE" project, using Cork city as a pilot, aims to tackle some of the existing barriers related to the development, management and monitoring of shallow resources, and their integration in urban environments in efficient and sustainable ways. The development of innovative drilling, ground heat exchangers and heat pumps are being tested and installed as part of the "Cheap-GSHPs", "GEO4CIVHIC" and "GeoFIT" projects. These innovations seek to demonstrate the potential for increasing the deployment of ground source heat pumps in complex urban settings, in the context of major retrofitting of buildings and in historical buildings. New training and certification initiatives for industry stakeholders involved in design drilling and installation of systems are currently being undertaken.

1. INTRODUCTION

The demand for heat energy was the largest source of energy use in 2018, accounting for 37% of all primary energy and 31.2% of CO2 emissions. The contribution of the RES-H sector in Ireland increased from 6.2% in 2015 to 6.9% in 2018, with a national target of 12% set for 2020 (SEAI, 2018).

The National Renewable Energy Action Plan (NREAP) for Ireland fourth progress report (DCCAE, 2017) show the energy produced from heat pumps (including geothermal, aerothermal and hydrothermal) of 45 ktoe in 2015 increasing to 55 ktoe in 2016. This demonstrates a deficit of 6 ktoe in 2015 and 9 ktoe respectively to the targets set in the NREAP (DCENR, 2010). No contributions to the RES-H sector from district heating and cooling are reported despite the presence of small scale district heating systems.

A Spatial Energy Demand Analysis for Dublin City (Gartland, 2015) has highlighted that over 75% of Dublin City areas and particularly the North Docks area, have heat densities high enough to be considered feasible for connection to DH systems. These are deemed ideal first-phase developments of a city-wide large scale DH system plan with potential anchor loads and waste heat resources. The Dublin District Heating System (DDHS) is currently being developed by Dublin City Council and will include the implementation of a network that will distribute 90MW of waste heat from industrial facilities at Poolbeg throughout the City (Cull, 2018).

The Tallaght District Heating Scheme (TDHS) is developing a sustainable district heating solution in the Tallaght area to provide low-carbon heat to public sector, residential and commercial customers. The energy source planned for the scheme is a data centre under completion that will provide waste heat to the facility (SDCC, 2018).

The Energy White Paper 2015-2020 (DCCAE, 2015) identified geothermal energy, heat pumps and district heating as technologies for addressing the heat energy demand in Ireland and meeting renewable energy targets.

The Initial Public Consultation National Energy & Climate Plan (NECP) which aims to set targets for renewable energy source deployment between 2021-2030 to comply with the EU Renewable Energy Directive will set targets for rom renewable technologies in Ireland to be achieved by 2030. The current proposal makes reference to the use of geothermal energy and ground source heat pumps for heating & cooling applications but deep geothermal is currently not included. .

2. GEOTHERMAL RESOURCES IN IRELAND

Ireland is characterised by Precambrian to Lower Palaeozoic crystalline basement formations overlain for most of the central part of Ireland by Upper Palaeozoic formations of Upper Devonian and Lower Carboniferous age and comprising shales, limestones and sandstone lithologies (figure 1). Karstification of the Lower Carboniferous lithologies is extensive and for the most part buried due to a relatively thick Quaternary aged overburden cover.

The structural geological conditions in Ireland are controlled by the Caledonian and Variscan orogenies. These controlled the development and trend of the main fault structures of the Irish landmass. The presence of 42 warm springs across Ireland is largely associated with the occurrence of these regional fault structures and with the presence of Lower Carboniferous aged lithologies.

Temperatures of between 13°C and 24.7°C from the warm springs have been recorded as part of extensive research since the early 1980s and more recently as part of the IRETHERM project. Hydrochemical and isotope studies have demonstrated that whilst there is evidence of deeper than average circulation of groundwater occurring as a result of up to ten geological settings of the warm springs (Aldwell & Burden, 1986), these deep circulation pathways remain poorly despite extensive research on the hydrochemistry, hydrogeological conditions and imaging of the associated fault structures using magnetotelluric surveys (Blake, 2016).

Ireland's intraplate geological setting is such that geothermal resources are classified as low enthalpy with lower average geothermal gradients of approximately 10°C/km recorded in the south to higher gradients (figure 2) in the north east and in Northern Ireland where values of up to 35°C/km are observed (Goodman et al., 2004).

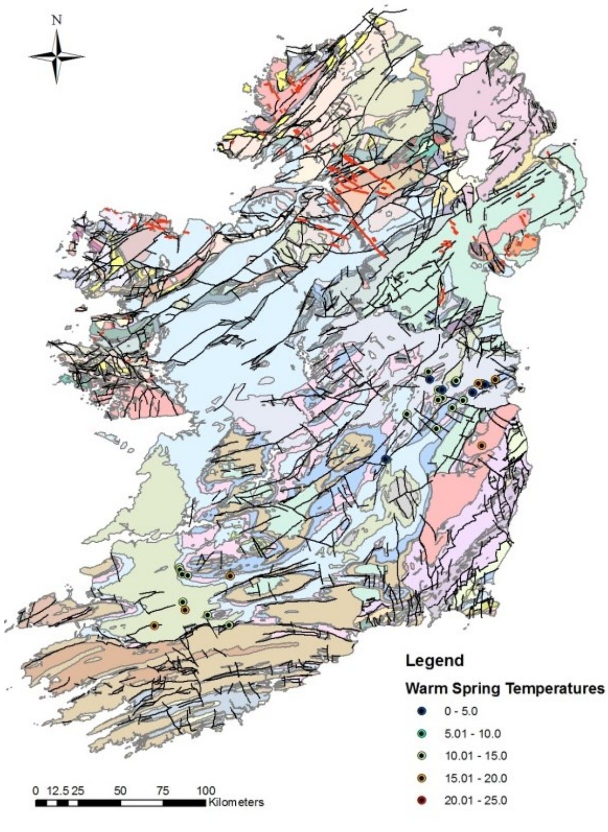

Figure 1: Bedrock Geological Map of Ireland (GSI, 2006) & location of warm springs.

Northern Ireland has a number of sedimentary basins. The Mesozoic Rathlin, Larne and Lough Neagh Basins have been explored in the past because of their potential to contain oil and gas reserves and as part of early geothermal energy research projects by the UK Department of Energy. These three basins contain in excess of 3,000 m of Permo-Triassic sediments (McCann, 1991) where the highest measured temperatures at depth have been recorded.

Shallow geothermal energy resources are favoured by the Irish climate that is dominated by warm and mild maritime conditions. Relatively consistent, year round soil temperatures and frequent rainfall keeping moisture in the ground maintains soil as an excellent conductor, allowing heat to move towards a thermal collector system. These conditions are particularly suited for closed loop systems (figure 2). The presence of gravel aquifers throughout Ireland and in particular in Cork, Dublin and Athlone, favours the use of open loop systems more commonly exploited for larger installations requiring heating and cooling (figure 3).

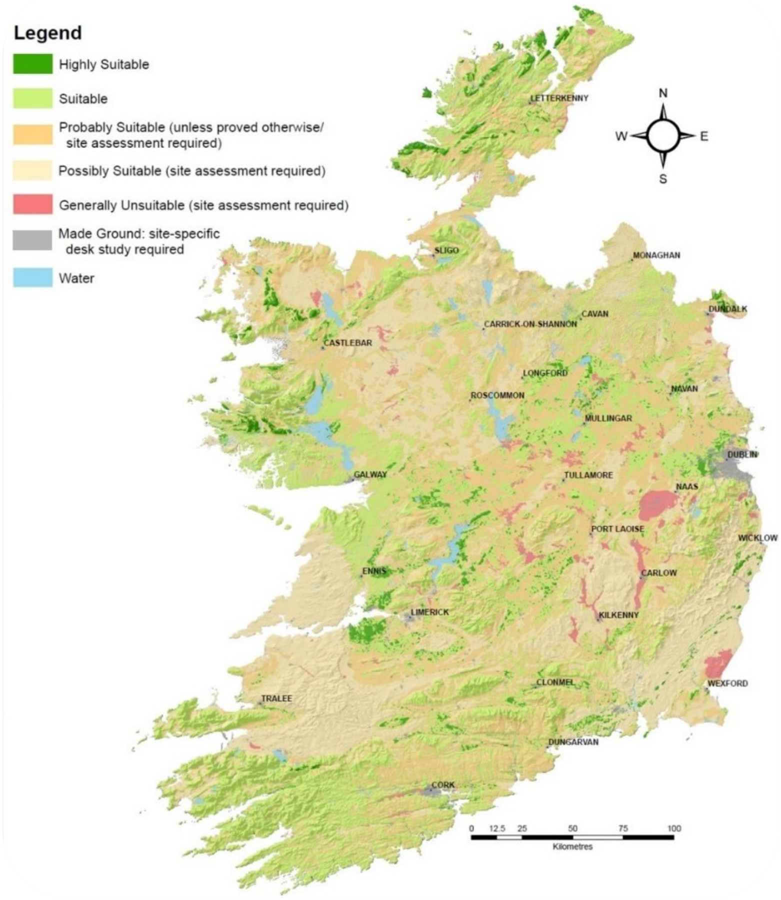

Figure 2: Vertical Closed Loop Collector Suitability Map (GSI, 2016).

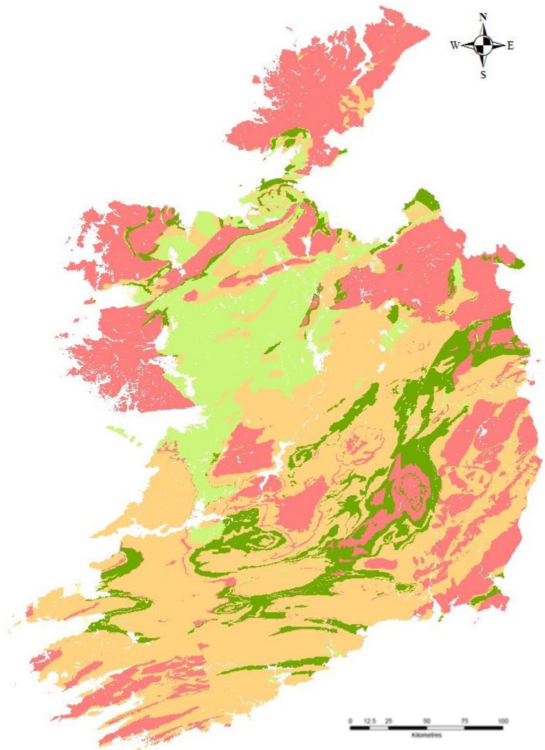

Figure 3: Open Loop Collector Suitability Map (GSI, 2016).

. 3. SHALLOW GEOTHERMAL ENERGY UTILISATION:

The shallow geothermal energy utilisation in Ireland had a very high growth rate until 2009. The total estimated installed capacity for ground source heat pumps in 2018 is estimated at 200 MWth, with a thermal energy produced for heating of 937 TJ/yr and 37 TJ/y for cooling (Table 4).

The lack of a dedicated database for reporting the number and characteristics for the installation of shallow geothermal energy systems in Ireland, has made it difficult to determine exactly both the market conditions in terms of the contribution of ground source heat pumps to renewable heating and cooling at a national level. Geothermal heating and cooling is estimated to contribute to of 3.3% to the percentage renewable energy contribution to gross final energy consumption in 2017 and 1.2% of total energy renewable energy contribution to thermal energy combined with air source heat pumps (figure 4). However, the assessment methodology for this contribution is based on BER datasets and not on monitored data (SEAI, 2018).

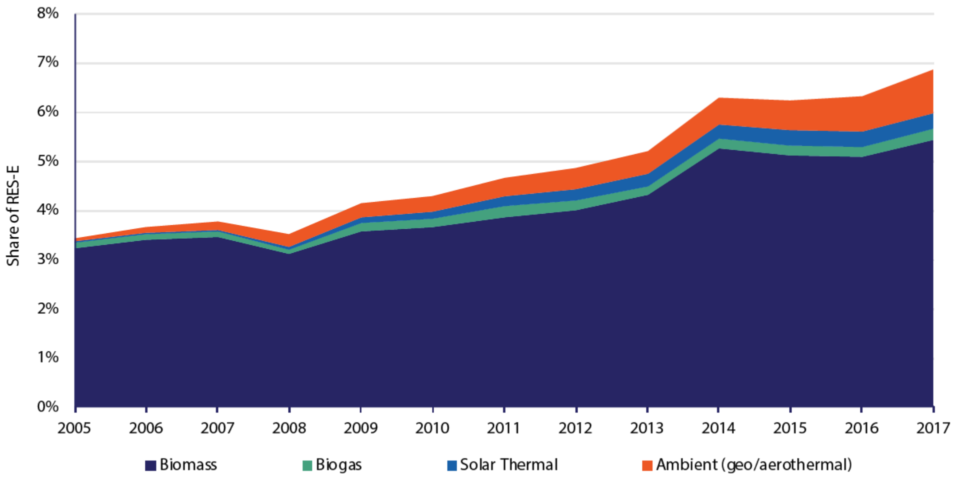

Figure 4: Renewable energy contribution to thermal energy (RES-H) (SEAI, 2018).

Information on large scale commercial systems operating in Ireland is available through the Geothermal Association of Ireland records however many installations (particularly new ones) remain poorly or not documented at all (see table 4).

Ground source heat pump installation figures from the Heat Pump Association for Ireland in 2018 show a decline in the total number of ground source system installed to approximately 150 units, representing approximately an average 1.2% increase from the last report in 2015. (HPAI, *pers. comm.*). This growth rate could be now expected to increase since the introduction of financial support schemes in 2018. The total number of heat pumps installed in Ireland in 2018 estimated at approximately 181,000 units, of which just under 10% are estimated to be ground source units.

The shallow geothermal energy market in Ireland remains dominated by the installations in the residential sector (c. 85%) with lower uptake in the commercial and industrial processes sector (14% and 4% respectively) with systems of intermediate installed capacity between 10kW and 24kW installed remain the most widespread but are experiencing a reduction in growth.

Large scale, ground source systems are dominated by the installation of open loop collectors with an increased number of large scale closed loop collectors. The majority of systems being installed ranging between 60kW to 250kW in size for heating and cooling applications (Table 4).

4. DEEP GEOTHERMAL ENERGY DEPLOYMENT:

Deployment of deep geothermal energy resources in remains slow. An extensive research programme under the IRETHERM project that highlighted the potential from low enthalpy geothermal energy setting in Ireland of deep sedimentary aquifers and radiogenic granites. IRETHERM generated valuable new data on Ireland's deep geology and geothermal potential and highlighted areas of promising subsurface temperatures and permeability for district heating projects. This was achieved through extensive geophysical exploration and the use of deep electromagnetic geophysical methods (primarily magnetotellurics) to image electrically conductive fluid bearing horizons, and electrically resistive granite bodies in various locations across Ireland. The geophysical results identified areas in the Lough Neagh and Rathlin Basins in Northern Ireland with high potential for geothermal district heating, and identified specific geological structures that are likely to control hydrothermal fluid flow in the subsurface. New geochemical data from Irish rocks were also collected, which identified buried granites and shales as the most likely targets for enhanced geothermal systems (Blake, 2018).

This IRETHERM research paved the way for further projects investigating deep geothermal resources in Ireland to develop as part of SFI funded projects through the iCRAG centre and EU-funded projects. These are further discussed in section 7 below.

7. GEOTHERMAL PROJECTS:

The G.O.THERM.3D used a novel approach to quantify and map temperature in Ireland's crust in an integrated approach that simultaneously accounts for multiple geophysical and petrological datasets. Based on this integrative approach a new 3D temperature atlas for Ireland's crust was created and provided an insight into the thermal regime within Ireland's subsurface, offering a robust constraint on future quantitative modelling of both shallow and deep geothermal prospects across the country. The temperature model and its associated data will be made publicly trough an interactive online platform. The outcomes of this project were aimed at assisting in the development of public policy on geothermal energy exploration, mapping, planning and exploitation (Mather, 2018).

The Geo-URBAN project aims to evaluate novel geophysical exploration and modelling techniques for urban areas (figure 5), which is being applied at two test locations, Vallès, Catalonia, Spain and Dublin, Ireland. Geophysical data collected during GEO-URBAN will feed into a commercialisation strategy for the exploitation of deep geothermal resources in challenging urban environments, which will draw upon existing knowledge and experience from partners in Denmark, where the deep geothermal heat industry is more established. Significant stakeholder involvement of local planning authorities and companies ensure that GEO-URBAN exploration activities align with local sustainable energy plans and district heating strategies. Furthermore, policy recommendations to assist the sustainable exploitation of deep geothermal energy resources in each region will be outlined. The overall objective of the GEOURBAN project is to identify the geothermal resources available in two challenging urban locations and to demonstrate a commercialisation strategy for such an environment that has the potential to be adapted in other similar locations (McAteer, 2018).

Figure 5: Initial Geophysical Data Collection for the Geo-Urban Project - Dublin (Photo courtesy of DIAS).

The COSEISMIQ project integrates seismic monitoring and imaging techniques, geomechanical models and risk analysis methods with the ultimate goal of implementing innovative tools recently developed but yet untested. These adaptive, data driven approaches for reservoir optimisation and for the control and management of induced seismicity represent a major contribution to safe and sustainable geothermal energy exploitation. COSEISMIQ aims to demonstrate Real-Time Induced Seismicity Controller (RISC) in a commercial scale application in Iceland. Understanding how to prevent or reduce large induced earthquakes plays a pivotal role in the development of future, innovative, and clean forms of natural deep underground energy resources. The Dublin Institute for Advanced Studies is focusing of the development of the geomechanical models, the deployment of seismic monitoring stations and characterisation of seismicity and Hengill volcano test site in Iceland (Bean, 2018).

An investigation in the Geothermal Potential in the Irish Carboniferous Palaeokarst based on oil and gas industry evidence from analogues of coalesced collapsed paleocave carbonate reservoirs exist in the Ordovician Ellenburger Ramp Carbonate play of West Texas. The 'Coalesced Collapsed Paleocave' play, characterised by moderate porosities and permeabilities in the Ellenburger is considered to be a good analogue for geothermal resource potential of the Waulsortian Mudbanks. Published records of Irish Carboniferous Geology provide substantial evidence to support the hypothesis of the presence of preserved karst within the Waulsortian at depth. The Carboniferous Shannon Trough is considered as a good prospect to intercept the Waulsortian coalesced mudmounds at depths of >1000m. A focused seismic interpretation was carried out on four recently acquired 2D seismic lines where 'karst indicators' (sag features, polygonal faults etc) towards the base of the Waulsortian Formation were inferred to be related to preserved collapsed structures, like those observed in the Ellenburger Group. The data obtained from the Kilmurry prospect provides a new methodology for assessing geothermal tragets in Waulsortian karst systems in Ireland (Vaz, 2018).

The HotLime project is assessing low-enthalpy deep limestone geothermal reservoirs. Hydrothermal systems in deep carbonate bedrock among most promising low-enthalpy geothermal plays across Europe. However, these prospects have received little attention, and are perceived as 'tight'. The HotLime project aims to improve mapping and assessment of geothermal plays in deep carbonate rocks in Europe in order to de-risk geothermal exploration in such plays. The project will do this through identifying the generic structural and geological controls on fractures and karst conduit development in deep carbonate formation. This will be achieved by comparing geological situations and their structural inventory, and through collating deep borehole data and their petro- and hydro-physical characteristics. Outcomes from HotLime include: spatial resource assessments in focussed areas (the study areas within Ireland are: the Dublin Basin, the Clare Basin, and Lough Allen Basin), best practice workflow and guidelines for characterisation and mapping of deep carbonate hydrothermal plays; web-based classification system for plays and prospects; assessment tool for doublet performance (Hunter Williams, 2018)

A study by UCD Business School and iCRAG on Public acceptance and risk perception of Geothermal Energy in Ireland has highlighted public risk perceptions towards geothermal energy in the Irish context are lower in comparison to other energy sources. Based on a nationwide survey, public acceptance of geothermal energy was generally high with risk to the environment, society and the economy perceived as being low. Environmental and societal risks were deemed as the most important factors that influence overall public acceptance of geothermal energy in Ireland. The research also demonstrated the importance of communities being involved in the process of geothermal energy development from the beginning and are well communicated with in order to stabilise and generate acceptance (Hook, 2018).

A four year Irish Research Council postgraduate research project that is being done in University College Cork in collaboration with University of Liverpool, University of Leeds, and GNS Science (NZ) into the controls on geothermal reservoir mineral scaling is currently funded by the Irish Research Council. This work makes use of microanalytical techniques such as electron backscatter diffraction and mineral chemical mapping to determine crystallographic controls on calcite and quartz mineralisation and growth in geothermal fractures (McNamara et al., 2016). Research is focused on natural examples of geothermal and hydrothermal veins from Iceland, Uganda, and New Zealand, but has implications for understanding geothermal fluid-rock interaction processes in global geothermal systems. It is the aim of this IRC research project to determine the mechanisms by which fracture scaling happens and the environmental controls such as temperature, pressure, and fluid properties hinder or enhance them.

The "CHeap and Efficient APplication of reliable Ground Source Heat exchangers and PumpS" CHEAP-GSHPs project has adopted a practical demonstration approach to new technologies in ground source heat exchangers (GSHE). The project is focussed on the development of more efficient and safe shallow geothermal systems and the reduction of the installation costs. An existing, innovative vertical borehole installation technology of coaxial steel GSHE was developed along with a helix type GSHE with new, innovative installation methodologies. A trial of these technologies was implemented at a test site at University College Dublin. A decision support tools available on the project website has been developed to identify the best GSHE system based on climatic conditions and the building energy requirements.

The GEO4CIVHIC project aims to develop and demonstrate easier to install and more efficient ground source heat exchangers, using innovative compact drilling machines tailored for the built environment. The project also aims to develop or adapt heat pumps and other hybrid solutions in combination with renewable energy sources for retrofits through a holistic engineering and controls approach, for improving the return of investments. GEO4CIVC aims to accelerate the deployment of geothermal systems for heating and cooling in retrofitting existing and historical buildings based on the innovations developed by the project that consider both ground heat exchangers and hybrid heat pumps for high and low temperature terminals. A case study in Ireland will demonstrate these technologies at a historical building in Co. Wicklow. The project will also consider the legislative, environmental and European standard conditions for the application of the project technologies (Pasquali, 2019).

The MUSE (Managing Urban Shallow geothermal Energy) project aims to provide tools and services to assist uptake and sustainable and efficient use of shallow geothermal energy in European urban areas. The MUSE project will identify, summarise and develop state-of-the-art methods for SGE assessment, management and monitoring; develop strategies for efficient and sustainable use in urban areas; and, transfer methods and integrate strategies into specific urban pilot areas. The current pilot area in Ireland is the city of Cork (Hunter Williams, 2018).

5. LEGISLATIVE AND REGULATORY FRAMEWORK:

The Draft Geothermal Development Bill (the Bill) defines geothermal energy in Ireland and vests ownership of geothermal energy in the State, giving practical effect to the assertion of ownership of natural resources in the

Constitution (King, 2011). The Bill covers the exploration and development of deep geothermal energy resources in Ireland (excluding aspects such as district heating, market regulation and health and safety).

An extensive consultative process started in 2008 in advance of the drafting of the general scheme of the Bill and included web-based consultations, two national workshops and meetings with industry stakeholders. Draft Heads of the Bill completed in July 2010 have been submitted to the Government for approval and referred to the Attorney General and the Parliamentary Counsel for detailed drafting. This process is expected to be completed following the enactment of the Minerals Development Bill in 2017 and the on-going work on the associated regulations.

The DCCAE White Paper 'Ireland's Transition to a Low Carbon Energy Future 2015-2030' makes provisions for the establishment of a regulatory framework to facilitate the exploration for, and development of, geothermal energy resources, although the timing of consultation process for these regulations and their implementation is not yet known.

6. FINANCIAL SUPPORT:

New financial support measures for GSHPs have been made available in 2018 through the Sustainable Energy Authority of Ireland for both domestic and non-domestic applications.

The Heat Pump System grant provides home owners with €3,500 towards the cost of a heat pump system (irrespective of the type) subject to adequate energy efficiency upgrades being implemented that reduce heat loss in the building fabric below $2W/K/m^2$.

The Support Scheme for Renewable Heat supports the adoption of renewable heating systems by commercial, industrial, agricultural, district heating, public sector and other non-domestic heat users not covered by the emissions trading system. The grant based scheme provides funding of up to 30% of eligible costs to air source, ground source and water source heat pumps based on the buildings and heat using processes adhering to verified energy efficiency criteria, Building Regulations, Construction Products Regulations, EN Standards, efficiency, technology standards and air quality standards in relation to emissions. Under the same scheme an operational support tariff for high efficiency biomass CHP and biogas heating systems for a period of 15 years is offered.

The Renewable Electricity Support Scheme (RESS) makes provision for a renewable electricity (RES-E) ambition of up to a maximum of 55% by 2030. This is to be achieved through a series of auctions throughout the scheme that begins in 2019 and that will promote the increasing technology diversity by broadening the renewable electricity technology mix allowing Ireland to achieve these ambitious goals. Deep geothermal energy could be considered as a future technology under this scheme.

6. BARRIERS TO DEPLOYMENT:

The introduction of the carbon tax which places an extra cost on fossil fuels such as gas or oil has facilitated the reduction of payback periods to less than 10 years for systems that replace oil or LPG fuelled heating (Burgess 2011). The changes in the Primary Energy Factor (PEF) proposed as part of the Energy Efficiency Directive are also likely to influence the ground source marked in Ireland.

The main barrier to the development of deep geothermal energy resources in Ireland remains the lack of deep geological information for potential deep geothermal plays and understanding the contributions these could have to renewable heating and cooling. Current research project in Ireland are actively seeking to de-risk deep geothermal prospects in areas as high heat demand and where district heating networks are planned.

The lack of specific legislation allowing developers to obtain licenses for resource exploration, development and drilling under third party lands still remains a barrier. In addition, financial support for geothermal electricity generation has still not been considered by government through the RESS scheme despite a target of 5 MWe installed capacity by 2020 being set as part of the NREAP for Ireland.

The lack business models to inform policy strategy on the development of deep geothermal resources and the implication for the heating and cooling markets are still lacking. The potential contribution of geothermal to district heating to Ireland's RES-H sector are still not clear despite research in to the integration of geothermal to Dublin City Centre and Tallaght district heating schemes.

The recent development of technical best practice guidelines for the installation of shallow geothermal energy collectors in Ireland by the Geothermal Association and the implementation of the EN Standard 17628:2015 as an Irish standard has the improved awareness in the need for best practice completion of ground source heat exchangers. Both documents are referenced in the contractor code practice implemented by SEAI for the installation of ground source heat pumps. This will facilitate the sustainable development of shallow geothermal energy resources in Ireland.

Public awareness and information including the lack of information on the potential economic benefits of installing ground source heat pumps and potential for harnessing deep geothermal energy to meet a part of Ireland's heat demand has been identified as a significant barrier to development. Despite the development of the Geological Survey Ireland collector suitability maps for the country and guidance documents from SEAI being made available to explain the use of the technology, not many data are available on the operational and economic aspects of operating plants. These would help to promote successful deployment strategies and target specific areas of Ireland's heat sector that could be best addressed with geothermal energy.

This information would be essential in showcasing the benefits of ground source heat pumps versus the lower capital investment cost of air source heat pumps that currently similar grant aid funding despite significantly different performance.

Dedicated training and certification for key contractors involved in the installation of heat pump systems is currently being undertaken through a certification scheme. This allows trades such as plumbers, electricians and refrigeration engineers to be trained and certified to install shallow geothermal energy systems. Dedicated training or certification courses for contractors responsible for the design, completion of ground works and drilling associated with the completion of thermal energy collectors are being developed with new courses for drillers expected to commence during 2019.

Dedicated courses on project management and ground source heat pump system design are only available through dedicated university courses at Galway Mayo Institute of Technology, University College Cork, University College Dublin and Trinity College Dublin. However professional certification for trades, often tasked with designing systems or involved in the construction aspects of ground source heat pump systems, is currently not available. A new national certification training initiative combined with the second Geotrainet programme is being considered to promote a sustainable development of the shallow geothermal energy sector in Ireland.

7. DISCUSSION:

The geothermal energy sector in Ireland remains dominated by the utilization of ground source heat pump systems. Despite very modest increases in GSHP system installation in the last 5 year reporting period, the recent publication of the draft National Energy Climate Plan for Ireland which presents possible deployment scenarios for renewable energy technologies, the prospects for increased capacity in delivering renewable heat through the use of geothermal is improved. The scenarios for comparing renewable heat targets to 2030 (figure 6) demonstrate the potential for future deployment of geothermal in Ireland. However, given that statistical data has been so far reported in the context of heat pumps in general in Ireland (without differentiating between air source and ground source) an improvement in differentiating the two technologies and the provision of figures for calculating energy produced should be developed.

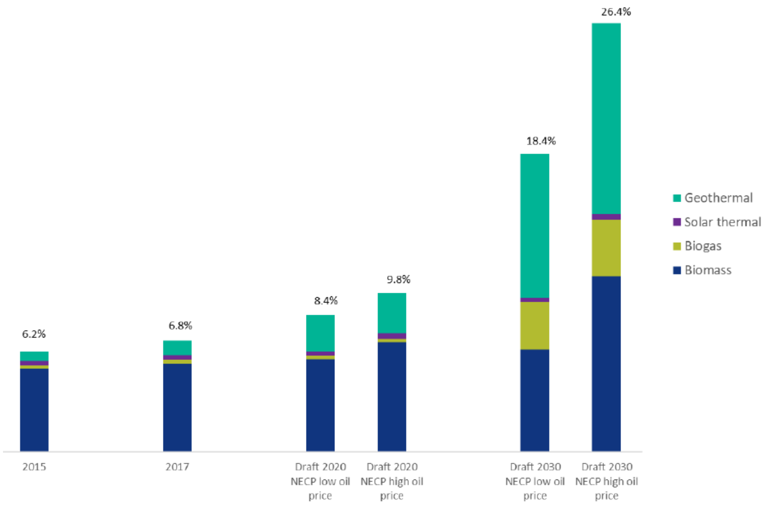

Figure 6: Scenario comparison of progress towards renewable heat targets (SEAI, 2019).

The development of geothermal power generation has also development renewed interest in Ireland with private sector companies interested in the development of proven offshore resources of hot water. To sustain the future planned development of geothermal resources, the Sustainable Energy Authority of Ireland and Geological Survey Ireland are supporting a series of new initiatives along with several post graduate positions in iCRAG. The results of the these initiatives is to increase awareness of geothermal resources and their opportunities for development in the future of Ireland's energy mix. The support of Sustainable Energy Communities across Ireland in the development of local, community led initiatives for the development and use of renewable energy resources provides significant potential for the development of geothermal in Ireland.

New regulations applicable to the building sector in the context of the implementation of the Clean Energy Package EU Directives, are promoting design of nZEB buildings in case of both new build and retrofit buildings. These design strategies offer an improved opportunity for ground source heat pump technologies to deliver high efficiency heating and cooling solutions over competing air source technologies.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables WIND - Onshore/Offshore		Other Renewables PV		Total
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe
In operation in December 2019	0	0	7,616	44,357	212	716	0	0	3,318	7,568	20	10	11,823
Under construction in December 2019	0	0					0	0					
Funds committed, but not yet under construction in December 2019	0	0					0	0					
Estimated total projected use by 2020	0	0	7,720		237	732	0	0	4,100	10,530	70	77	12,317

TABLE 4. **GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019**

Locality	Ground or Water Temp. (ºC)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
Domestic Installations Nationwide (Average Installed Capacity)	10	10.4	18005	H/W/V/O	3.5	1800	866.71	0.00
Dolmen Centre, co. Donegal	10	45	1	H	3.5	1363	0.16	0.00
Tralee Motor Tax Office, Co Kerry	10	120	1	H	3.5	1922	0.59	0.24
SHARE Hostel, Cork	15	120	1	W	3.5	1363	0.42	0.00
UCC Glucksman Gallery, Cork	15	200	1	W	3.65	1922	1.00	0.40
Fexco HQ, Killorglin, Co Kerry	11	310	1	W	3.65	1922	1.56	0.62
Glenstal Abbey, Co Limerick	10	150	1	W	3.5	1363	0.53	0.00
Musgrave HQ, Cork	10	160	1	V	3.65	1922	0.80	0.32
Killarney International Hotel, Co Kerry	11	60	1	W	3.5	1363	0.21	0.00
Cork Co Council Environmental Labs	11	90	1	W	3.5	1363	0.32	0.00
Cliffs of Moher Visitor Centre, Co. Clare	10	160	1	H	3.5	1363	0.56	0.00
Killorglin Town Centre, Co Kerry	11	160	1	W	3.65	1922	0.80	0.32
Fermoy Leisure Centre, Co Cork	11	160	1	W	3.5	2725	1.12	0.00
Tory Top Road Library, Cork	13	80	1	W	3.5	1363	0.28	0.00
Coraville, Blackrock, Cork	13	36	1	W	3.5	1363	0.13	0.00
Castleisland, Co Kerry	11	135	1	W	3.5	1363	0.47	0.00
ESB Administration Offices, Cork	13	250	1	W	3.65	1922	1.26	0.50
Cork County Library, Cork	13	450	1	W	4	560	0.68	0.91
Swedish Ambassador's Residence, Dublin	12	21	1	V	3.5	1363	0.07	0.00
Cowper Care, Kilternan, Dublin	8	100	1	V	3.5	1363	0.35	0.00
Cowper Care, Rathmines, Dublin	8	66	1	V	3.5	1363	0.23	0.00
Cowper Care, Dublin	11	86	1	V	3.5	1363	0.30	0.00
Vista Health Care, Naas, Co Kildare	10	400	1	W	3.65	1922	2.01	0.81
UCC Western Gateway IT Building, Cork	15	1000	1	W	3.65	1922	5.02	2.01
Athlone City Centre Retail Complex, Westmeath	10	2786	1	W	3.65	1922	14.00	5.61
Lifetime Lab, Cork	12	70	1	W	3.5	1363	0.25	0.00
Bagenalstown Swimming Pool, Co. Carlow	11	18	1	W	3.5	1363	0.06	0.00
Croi Anu Creative Centre, Co. Kildare	10	8	1	H	3.5	1363	0.03	0.00
Rathmore Community Childcare, Co. Kerry	11	12	1	V	3.5	1363	0.04	0.00
Treacys Hotel Co. Wexford	11	450	1	V	3.65	1922	2.26	0.91
Fairy Bush Childcare Centre, Co Roscommon	11	23.5	1	V	3.5	1363	0.08	0.00
Tinnypark Nursing Home, Co. Kilkenny	10	32	1	H	3.5	1363	0.11	0.00
Goretti Quinn Creche, Co. Kildare	11	12	1	V	3.5	1363	0.04	0.00
CloCeardlann na gCnoc, Co. Donegal	10	18.3	1	H	3.5	1363	0.06	0.00
St John's National School, Co. Mayo	10	14.2	1	H	3.5	1363	0.05	0.00
Dubin Dockland Development Authority	12	17.5	1	H	3.5	1363	0.06	0.00
Dunmore House Hotel, Co. Cork	11	18	1	W	3.5	1363	0.06	0.00
Comhaltas Cosanta Gaeltachts Chuil Aodha, Cork	11	16	1	V	3.5	1363	0.06	0.00
David Cuddy, Rathbranagh, Co. Limerick	11	11.5	1	V	3.5	1363	0.04	0.00
Skeaghanore Farm Fresh Duck, Co. Cork	11	12	1	V	3.5	1363	0.04	0.00
Kanturk Sheltered Housing, Co. Cork	11	8.3	1	V	3.5	1363	0.03	0.00
Comhlacht Forbartha an Tearmainn, Co. Donegal	11	33.6	1	V	3.5	1363	0.12	0.00

Feohanagh Special Needs Housing, Co Limerick	11	17	1	V	3.5	1363	0.06	0.00
CLS Rosmuc, Co. Galway	10	19.8	1	H	3.5	1363	0.07	0.00
Vicarious Golf, Co. Wicklow	10	13	1	H	3.5	1363	0.05	0.00
Inis Oirr Health Centre, Co. Galway	10	12	1	H	3.5	1363	0.04	0.00
Children's and Adults Respite Centres, Co. Galway	11	21	1	V	3.5	1363	0.07	0.00
Kilcurry Community Development, Co. Louth	11	17	1	V	3.5	1363	0.06	0.00
Ardara Community Childcare, Co. Donegal	11	22.1	1	W	3.5	1363	0.08	0.00
Seawright Swimming School Co. Cork	11	31	1	W	3.5	1363	0.11	0.00
Cope Foundation, Bandon, Co. Cork	11	30	1	V	3.5	1363	0.11	0.00
Parklands Apartment Development, Co. Wicklow	11	40	1	V	3.5	1363	0.14	0.00
Ballyconnell Central National School, Co. Cavan	11	12	1	V	3.5	1363	0.04	0.00
James B Joyce & Co, Co. Galway	11	18.3	1	V	3.5	1363	0.06	0.00
Poor Clare Monastery, Co. Louth	11	18	1	W	3.5	1363	0.06	0.00
Tralee Community Nursing Unit, Co. Kerry	11	100	1	V	3.5	1363	0.35	0.00
Brook Lodge Hotel, Co Wicklow	10	134	1	H	3.5	1363	0.47	0.00
Hudson Bay Hotel, Athlone, Co. Westmeath	11	132	1	W	3.5	1363	0.46	0.00
Hotel Europe, Killarney, Co. Kerry	10	110	1	W	3.5	1363	0.39	0.00
Rathass Housing Estate, Tralee, Co. Kerry	8	70	1	H	3.5	1363	0.25	0.00
Whites Hotel, Wexford	10	21	1	H	3.5	1363	0.07	0.00
Belinter Hotel, Navan, Co. Meath	10	306	1	H	3.65	1922	1.54	0.62
Bellview Woods Childcare, Killarney, Kerry	8	30	1	H	3.65	1922	0.15	0.06
D&G Electrinics Ltd, Castleisland, Co Kerry	8	21	1	H	3.5	1363	0.07	0.00
Oilgate Nursing Home	8	100	1	V	3.5	1363	0.35	0.00
Youghal Town Hall, Co Cork	8	21	1	V	3.5	1363	0.07	0.00
Borris Nursing Home	14.65	74	1	W	3.8	3276	0.64	0.00
Moyross Estate, Co. Limerick	9	140	1	V	4.1	1872	0.71	0.00
Kilboy House, Tipperary	9	120	1	V	4.1	1872	0.61	0.00
Vistakon Irleand, Limerick	12	890	1	W	5	4800	12.30	23.74
IKEA, Dublin	10	2000	1	V	3.5	1800	9.26	0.00
Wonder Years Childcare Rossbrack, Manorcunningham Co. Donegal	8	43.6	1	H	4	1872	0.22	0.00
Ballyroan Library, South Dublin	9.8	60	1	V	4.1	1872	0.31	0.00
Cowper Care, Kilternan, Co Dublin	8	80	1	V	3.5	1872	0.39	0.00
Mallow Swimming Pool, Co. Cork	15	100	1	W	3.5	4250	1.09	0.00
Offaly Co. Council Ofices, Tullamore, Co. Offaly	10	105	1	W	3	1872	0.47	0.00
Kelly's Showroom, Mountcharles, Co Donegal	8.4	38	1	V			0.00	0.00
Lisdoonan Community Residential Scheme, Co. Monaghan		124	4 GSHP & 4 ASHP	H & ASHP			0.00	0.00
UL Limerick Presidents House (estimated)		20	1	v	3	1800	0.09	0.00
The Danes - Ashford Co. Wicklow (estimate)		45	2	v	3.5	1800	0.42	0.00
NUI Galway (estimated)		24	1	v	3	1800	0.10	0.00
Mount St. Anne's Retreat and Conference Centre (est.)		80	1	v	3	1800	0.35	0.00
Mount Juliet - Apartments (estimate)		125	1	v	3	1800	0.54	0.00
Mount Juliet - Walled Garden Lodges (estimate)		30	1	v	3	1800	0.13	0.00
Wexford Nursing Home (estimate)		75	1	v	3.5	1800	0.35	0.00
Solas Chroi Spa & Health Centre, Brandon House Hotel (estimate)		50	1	v	3	1800	0.22	0.00
Coolemore House & Gate Lodge Thomastown, Col. Kilkenny (estimate)		40	1	v	3	1800	0.17	0.00

Offaly Co. Council Offices, Tullamore, Co. Offaly	10	105	1	W	3	1872	0.47	0.00
TOTAL		200867	18092				936.94	37.05

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	200.87	974	0.153
TOTAL	200.87	974	0.153

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	2	0	12	5	0	10
2016	2	2	12	6	0	12
2017	2	2	15	6	0	13
2018	3	2	15	8	0	14
2019	3	2	16	8	0	14
Total	12	8	70	33	0	63

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.2		0.50		70	30
2000-2004	1		1.60		70	30
2005-2009	7.5		0.23		95	5
2010-2014	1.85		1.08		95	5
2015-2019	2.62		1.01		70	30