An Economic Review of the Irish Geoscience Sector

prepared by

Indecon International Economic Consultants

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Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
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Sectoral Economic Review of Irish Geoscience Sector

Report

Submitted to

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Prepared by

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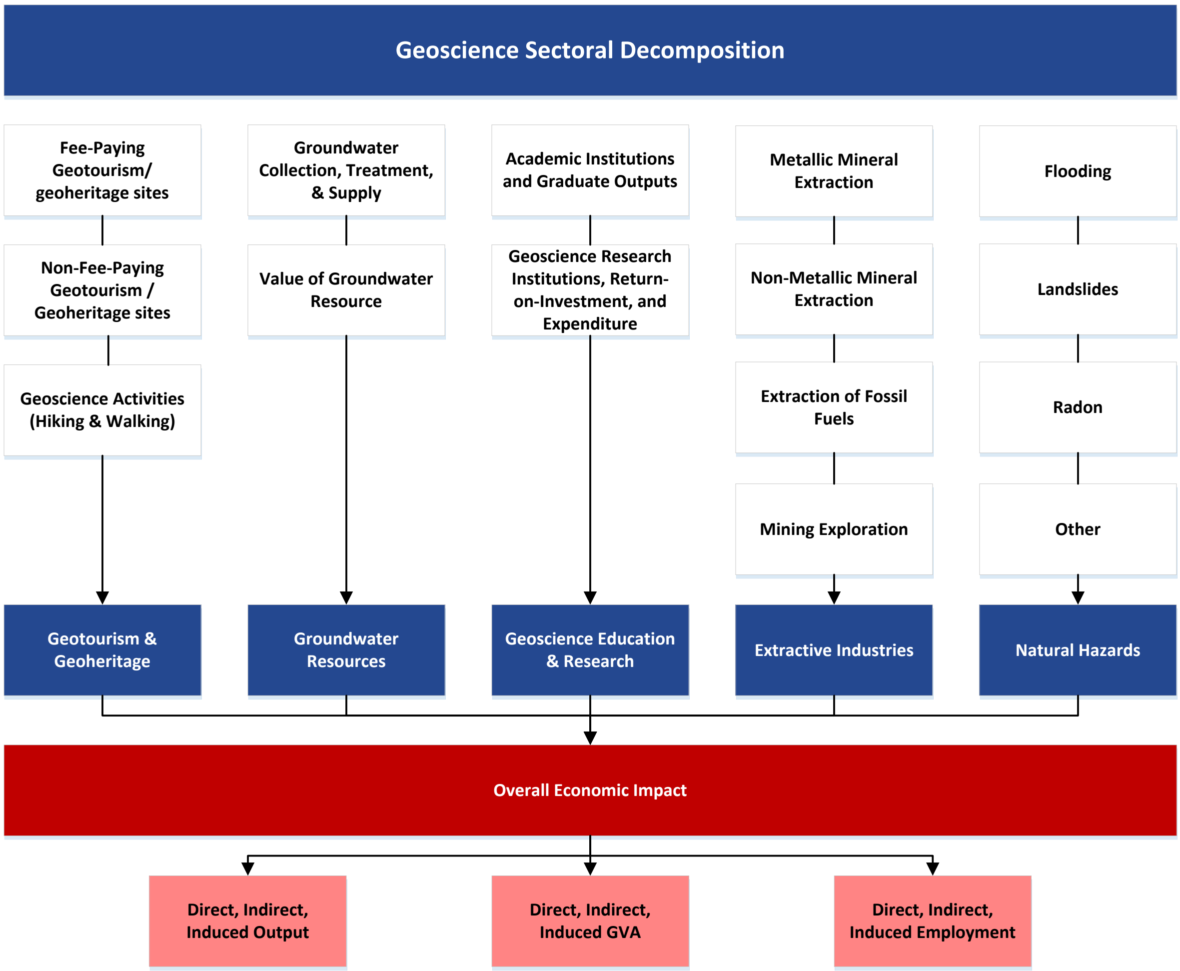
Introduction and Background

This report was prepared for the Department of Communications, Climate Action and Environment (DCCAE) and Geological Survey Ireland (GSI) by Indecon International Economic Consultants. The report represents an independent economic impact assessment of the important Irish geoscience sector.

'Geoscience' relates to what is internationally referred to as 'Earth sciences' and supports a range of economic services and activities, including geotourism and geoheritage, groundwater resources, education and research, and the extractive industries. Geoscience also helps to minimise the economic and social costs of natural hazards, and supports geoscience business clusters. Supporting continued development of the sector can provide long-term sustainable economic and social opportunities for Ireland, particularly as the world faces the challenge of climate change.

This study presents a rigorous, quantitative estimation of the economic impact of the geoscience sector in Ireland. Indecon believes it is important that care is taken in evaluating the economic impact of all sectors in the economy and we have utilised an evidence-based approach, based on prudent assumptions. Our research, however, indicates that the sector is of significant economic importance to the Irish economy and to society. The assessment examines a number of specific sub-sectors/activities. An overview description of these components, and of the economic impacts thereof, is presented below.



Geotourism and Geoheritage

Overseas tourism has expanded significantly in recent years and the total number of overseas visits to Ireland in 2016 amounted to almost 19 million. Ireland's green landscapes and heritage make it a major geotourism and geoheritage destination. GSI supports the Geotourism and Geoheritage sector in a number of ways, largely through their Irish Geoheritage Programme. Activities include developing UNESCO Geoparks in Ireland and managing the Irish Geopark Forum, providing co-funding for geologists within the existing and aspiring Geoparks, collaborating in major EU project initiatives on Geotourism such as Breifne (InterReg cross border project from the early 2000s) and BurrenLIFE projects. GSI also have a statutory role in this area and prepare inventories of Geoheritage sites for Local Authorities, which are then included in County Development Plans and often targeted for tourism development.

The evidence shows that the sector is a major contributor to the Irish economy, with total revenues (visitor expenditures) directly attributable to this sub-sector amounting to over €370 million in 2016, while the sector directly contributes almost €240 million to Irish economy GVA/GDP. The sector supports 8,767 FTEs on an economy-wide basis, as well as €415 million in GVA and over €660 million in output.

Economic Impact of Geotourism, 2012 – 2016 (€ Million)					
Revenue From	**2012**	**2013**	**2014**	**2015**	**2016**
Top Fee-Paying Sites	17.0	19.7	22.8	28.2	33.6
Top Free Sites	1.2	2.4	5.2	6.8	7.3
Hiking and Cross-Country Walking	149.8	189.8	225.1	286.3	329.8
Total Revenue	***167.9***	***211.9***	***253.1***	***321.3***	**370.7**
Gross Value Added	***108.6***	***137.0***	***163.6***	***207.7***	***239.6***
Source: Indecon analysis					

Groundwater Resources

Groundwater represents a significant source of water services for users not connected to public supplies. GSI contributes to the groundwater resources sector by producing a variety of data and mapping resources, including at-risk groundwater maps as well as databases on soil types, water resources and groundwater wells.

Our estimates suggest a direct economic contribution of groundwater resources amounting to €35m in turnover terms, €18m in Gross Value Added (GVA) terms and 205 FTEs. The table below summarises the economic impacts of the groundwater sector.

Economic Impacts of Groundwater Collection, Treatment, and Supply – 2016			
Groundwater Collection, Treatment and Supply	**Output (€million)**	**GVA (€million)**	**Employment (FTE)**
Direct Economic Impacts	35.2	18.3	205
Indirect and Induced Impacts	29.5	17.8	539
Economy-Wide Impacts	**64.7**	**36.0**	**745**
Source: Indecon analysis			

These estimates exclude any social and other benefits to users associated with having a source of groundwater resources, and is therefore likely to underestimate the overall value of the sector. Water is an essential requirement for householders, as well as for the farming sector and for other businesses, and any disruption to water supplies can have significant economic consequences.

Indecon has undertaken innovative new econometric modelling to estimate the value of groundwater resources. Using the GSI's groundwater well database, a predictive model was used to estimate the potential

yield of total groundwater resources in Ireland. To estimate the total potential value of groundwater resources, we examined the total number, yields and types of groundwater wells in Ireland. Indecon has estimated an indicative value range for groundwater resources of between €392 million and €512 million in 2016.

Geoscience Education and Research

Geoscience education and research employs highly skilled individuals and contributes to Ireland's knowledge base. There are a number of contributors to geoscience education and research in Ireland, including academic institutions (iCRAG, TCD, UCD, NUIG etc.) and public institutions (GSI, Marine Institute, Teagasc etc.).

GSI supports the geoscience research sector through national coordination of research resources, direct funding programmes and collaboration with other national and international organisations and research institutes. The GSI Research Roadmap published in 2016 highlights coordinated effort in the sector and identifies a number of key areas for future development. The establishment of the Irish Centre for Research in Applied Geosciences (iCRAG) in 2015 has consolidated and increased resources in areas of applied geoscience. During this time, GSI has also developed formal collaboration with organisations such as the Irish Research Council and Science Foundation Ireland and other public institutions to further develop the basic and applied geoscience research area.

Indecon estimate that the direct impacts of geoscience research contribute €24.3m in Gross Value Added (GVA) and 465 Full Time Equivalents (FTEs).

Direct Impacts of Geoscience Research, 2016			
	Output* (€ million)	**GVA (€ million)**	**Employment (FTEs)**
DCCAE	10.9	8.5	97
iCRAG	5.5	4.3	136
Other Academic Institutions (incl. University Departments)	10.8	8.4	167
Public Institutions	3.8	3.1	65
Total	**30.9**	**24.3**	**465**

Source: Indecon analysis
**** For the purposes of measuring the economy-wide expenditure impact, output is taken as being equivalent to expenditure***

Estimates of the direct, indirect and induced impacts of geoscience research indicate that this activity supported output valued at €52.5m and GVA of €41.0m, while geoscience research supported employment amounting to 724 full-time equivalent persons.

Wider Economic Impacts of Geoscience Research, 2016			
	Output (€ million)	**GVA (€ million)**	**Employment (FTEs)**
DCCAE	18.5	14.4	150
iCRAG	9.2	7.2	212
Other Academic Institutions (incl. University Departments)	18.3	14.3	261
Public Institutions	6.5	5.1	101
Total	**52.5**	**41.0**	**724**

Source: Indecon analysis

Extractive Industries

Ireland has important extractive industries, including metallic minerals, non-metallic minerals and fossil fuels. Zinc and lead production are significant economic sectors in Ireland. The total turnover and GVA for these two components is shown in the next table. The scale of these activities is evident from the fact that these

components of the extractive industries supported the employment of 1,262 full-time equivalent persons and had an output of over €550m. GSI provide datasets to support exploration and development for the extractive industry, from basic geological mapping to the Tellus Programme of airborne geophysical and ground geochemistry surveys.

Economy Wide Impacts of Metallic Extraction - 2016			
Area	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Lead Extraction	60.1	25.1	1,262
Zinc Extraction	490.1	205.2	

Source: Indecon analysis

Natural gas extraction is also an important sector in Ireland, driven by the fields at Corrib and Kinsale. The Kinsale Head gas field was discovered in 1973 and began operation in 1978. Peak production was reached in 1995. The Corrib Gas Field was discovered in 1996 and began production in January 2016. A summary of the output from these fields is presented below. The fields had an estimated annual output of over €550 million in 2016.

Value of Natural Gas Fields in Ireland		
Field	**Kilotonnes of Oil Equivalent**	**Value of Gas (€ million)**
Kinsale	131	25
Corrib	7,662	533.5

Source: Indecon analysis

Note: Corrib KTOE based on expected peak rate. Value of gas in Kinsale based on front month futures contracts averaged over the previous five years and published turnovers in national press. Value of gas in Corrib based on Vermillion Annual Report 2016.

Another component of the extractive industries is peat production. This sector supported economy-wide employment of over 2,500 FTEs in 2016 (see below). It should be noted that this data relates to the operations of Bord na Móna, which is the largest peat producer in Ireland.

Economic Impacts of Peat - 2016			
Peat	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Direct Impacts	85.8	27.9	1,200
Indirect and Induced Impacts	65.4	35.4	1,384
Economy-Wide Impacts	151.2	63.3	2,584

Source: Indecon analysis

Note: Figure of 1,200 direct FTEs is based on the number of employees in Bord na Mona's peat business unit in 2015.

The extraction of non-metallic minerals also supports the construction of buildings and roads. The overall economy-wide impacts of these areas are €557.4m in terms of output, €233.3m GVA and 2,632 FTEs, and this includes the direct, indirect and induced impacts. Given the extent of housing and other construction requirements in Ireland, employment in this sector, which currently amounts to over 2,600, is likely to expand.

The economic impact of all mining and quarrying industries in terms of turnover is shown overleaf, with turnover estimated to be €940m in 2016.

Turnover in Extractive Industries, GVA, and Persons Engaged, 2008 - 2016									
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016***
Turnover (€m)	1,637.4	1,660.8	1,456.8	1,485.1	1,421.7	1,092.6	1,054.3	972.2	939.9
GVA (€m)	612.6	473.4	557.9	593.8	543.8	529.4	504.5	292.6	282.9
Persons Engaged	5,134	6,176	4,384	4,269	4,180	4,146	4,058	4,164	4,026

Source: CSO
***Note: 2016 forecasted using CSO Index**

The economic impacts of all extractive industries in terms of total turnover and GVA and employment (FTEs) is shown below. The total economy-wide output of all extractive industry activities in Ireland is estimated to account for €1.65 billion to the Irish economy. It is estimated that these activities directly and indirectly support a total of 7,822 full-time equivalent jobs.

Economic Impacts of the Extractive Industry - 2016			
All Mining and Quarrying	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Direct Impacts	939.9	282.9	3,633
Indirect and Induced Impacts	716.3	359.2	4,189
Economy-Wide Impacts	1,656.2	642.1	7,822

Source: Indecon analysis

Economic Impact of Natural Hazards

Natural hazards can have major negative impacts on economies and on human life. Moreover, natural hazards are an increasingly significant risk in the context of climate change. The economic costs of natural hazards can be reduced or mitigated through research and information provided by geoscience. This can also reduce the human costs, in terms of lives saved and reduced injuries or illness due to flooding, landslides, radon or other hazards. GSI are engaged in work to mitigate natural hazards including production of the National Landslide Susceptibility Map, Radon mapping initiatives and research via the Tellus Programme, karst and sinkhole mapping, subsidence mapping using satellite data and a discrete Turlough/Groundwater flood mapping programme initiated under the current Programme for Government

The total amount of direct costs associated with remediation arising from the flood in December 2015/2016 alone was €206.8 million. This is likely to represent only a small element of economic costs arising from this flooding event and, in our estimates, we assume that this amounts to only 50% of the economic costs, but we accept that the costs may be much higher.

Economic Costs of Dec 2015-Jan 2016 Flood (€ Million)	
Clean-up Areas	**Clean-up costs**
Local Authority (emergency related overtime expenses, emergency material and equipment)	18.0
Transport Infrastructure	110.0
OPW Annual Budget for flood relief (€430 million for 2016-2021)	72.0
Small Businesses	5.0
Humanitarian Relief Expense	1.8
Total	**206.8**

Source: National Directorate of Fire and Emergency Management (2016). Report on Flooding

Radon is another potential hazard that has economic and social costs and which can be reduced by geoscience information and research. Radon is produced through the radioactive decay of radium, which is found in uranium ores, phosphate rock and several other minerals. It is a noble gas, which has the capability to seep through the ground and diffuse into the air. There are several economic costs associated with radon, including health costs and remediation costs. The National Radon Survey (NRS) has produced detailed radon profiles for all counties in Ireland. The Environmental Protection Agency (EPA) states that there are up to 250 cases of lung cancer annually which can be linked to radon. In order to estimate the economic cost of radon-induced lung cancer, Indecon has estimated the value of a statistical life, as well as the value of lost earnings due to cancer. This is provided in the table overleaf. The estimates suggest an economic cost of over €340 million per annum, but this does not include the significant human costs or the impacts on the health service.

Monetary Impact of Radon Cancer Cases, 2016	
Variable	**Value**
Number of Lung Cancer Cases Due to Radon	250
1 Year Survival Rate Lung Cancer	32.1%
Lung Cancer Deaths Due to Radon	170
Lung Cancer Survivors	80
Value of Statistical Life Year	€2 Million
Average Loss of Earnings for Cancer Diagnosis	€16,750
Cost of Lung Cancer Death Due to Radon 2016	€339.5 Million
Loss of Earnings Due to Radon-Induced Lung Cancer	€1,3 Million
Economic Impact of Radon-Induced Lung Cancer	**€340.8 Million**
Source: Indecon analysis of EPA, Department of Health, Cancer Research UK, Irish Cancer Society	

Geoscience Ireland

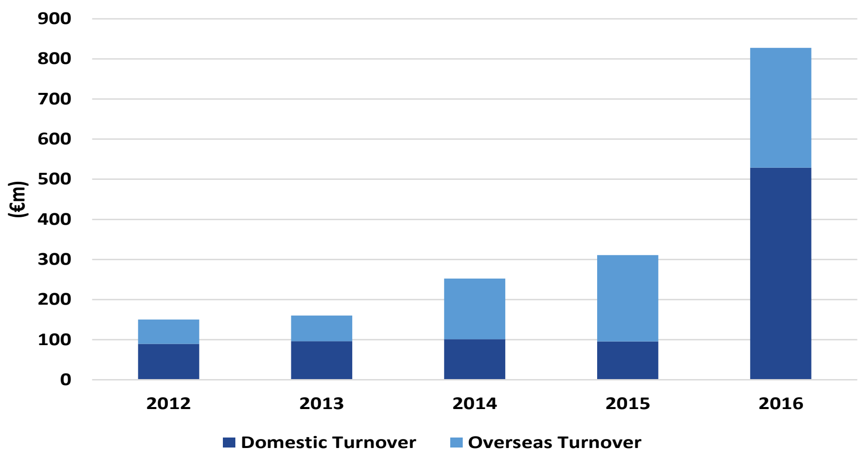
In addition to considering some of the main sectors of economic impacts of geoscience, it is also instructive to highlight the role and economic impacts of geoscience-related business clusters. This can be illustrated by reference to the activities of the Geoscience Ireland business cluster.

Geoscience Ireland (GI) is a network of geoscience-related organisations in Ireland which was set up and is funded by the Geological Survey Ireland and is supported by Enterprise Ireland with participation in steering committee by the Department of Foreign Affairs. The network was established as an initiative for creation and retention of Geoscience jobs by increasing collaboration of Irish companies in the sector in order to win more work in overseas markets and provides common branding, promotion, access to tender opportunities and support.

The Geoscience Ireland Network is comprised of 33 companies. The network of firms provides design, consultancy and contracting services to multilateral agencies, governments and the private sector. The network has consultative capacity in areas such as geology, engineering, environment, institutional capacity building, geophysical/geochemical surveying, and in project management. The network can also contract in drilling, lining, infrastructure, mining/quarrying, and building materials. The number of businesses participating in the Geoscience Ireland network has grown from 5 in 2011 to 33 in 2017.

Indecon has examined the economic impact of the Geoscience Ireland network through an analysis of turnover of member organisations, as shown in the figure below. This shows an overall annual turnover of over €800 million across the 33 member firms in 2016, with an increasing contribution evident from export sales.

Geoscience Ireland Member Companies – Overall Turnover, 2012 - 2016



Source: Geoscience Ireland

Summary of Geoscience Economic Impacts

Indecon's analysis indicates that the geoscience sector in Ireland had an **overall economic impact, in terms of the economy-wide value of output supported, of €3.28 billion in 2016**. The sector contributed approximately €676 million directly to Irish economy GVA/GDP. Taking account of both indirect and induced activity, the overall GVA contribution increases to €1.47 billion.

Overall Economic Impacts - Output 2016, (€ Million)

Area	Direct	Indirect and Induced	Overall Economic Impact
Geotourism and Geoheritage	370.7	290.3	660.9
Groundwater Collection, Treatment, Supply	35.2	29.5	64.7
Extractive Industries	939.9	716.3	1,656.2
Geoscience Research	30.9	21.5	52.5
Natural Hazards	414.0	429.6	843.6
Total	**1,790.7**	**1,487.2**	**3,277.9**
Non-additive Areas			
Geoscience Ireland	*827.2*	-	-
Groundwater Yield Value	*392-512*	-	-
INFOMAR contribution to Marine	*24.6*		

Source: Indecon analysis

The geoscience sector is estimated to directly support approximately 15,000 jobs in full-time equivalent terms. When the indirect and induced multiplier impacts are taken into account, this increases to **almost 25,000 in full-time equivalent jobs**.

Overall Economic Impacts – Employment (FTEs) 2016			
Area	**Direct**	**Indirect and Induced**	**Overall Economic Impact**
Geotourism and Geoheritage	6,888	1,879	8,767
Groundwater Collection, Treatment, Supply	205	539	745
Extractive Industries	3,633	4,189	7,822
Geoscience Research	465	259	724
Natural Hazards	3,919	2,763	6,681
Total	**15,110**	**9,628**	**24,739**
Source: Indecon analysis			

Future Trends in Geoscience Sector

There are a number of emerging future trends that are likely to impact on the geoscience sector. While there is inevitable uncertainty regarding these developments, changes in societal demands, in policies to handle climate change and natural hazards, as well as the application of technology in mapping and data analytics, will impact on the geoscience sector.

One example of future changes which will impact on the geoscience sector is the predicted expansion in biomass and renewables. According to EirGrid, the energy production capacity of biomass in 2030 will range from 270-750 MW. The future use of biomass is relevant to the geoscience sector as it may have an impact on the important peat extraction industry.

In addition, a major development is likely to relate to new opportunities provided by Ireland’s marine territory. In terms of exploration, only a small proportion of Ireland’s territorial waters has been explored to date. Ireland’s marine territory covers an area of 880,000 km^2. As well as any potential for oil and gas finds, our marine territory also offers very significant potential for the marine sector and for marine related research and development, as well as offshore renewable energy, aggregates, biodiscovery and marine tourism. DCCAE through GSI fund and co-manage the national marine mapping programme INFOMAR which underpins these developments.

There is also expected to be potential for expansion of the geotourism and geoheritage sector, as tourists become increasingly aware of the importance and uniqueness of Ireland’s natural landscape and other geotourism/geoheritage assets.

In addition, the potential for geoscience to reduce the economic and social costs of natural hazards is likely to be of growing importance, both to the sector and to wider society. There is likely to be an increasing requirement to develop high resolution assessments for natural hazards arising from the need to respond to climate change, and geoscience databases will be an essential component of such responses.

There is also likely to be a significant increase in construction activity in the coming years, which will require an expansion of the activity of extractive industries to meet the need for construction inputs. In an ESRI report, it was suggested that housing supply could reach up to 30,000 units per annum by 2024. A more recent study of the housing market and the Help to Buy incentive undertaken by Indecon for the Minister of Finance suggested that there is likely to be a significant increase in housing supply over the next three years, and this will provide opportunities for the geoscience sector, in areas such as aggregate extraction, geotechnical investigation and geothermal energy.

One of the most significant future trends impacting on the geoscience sector will be changes in the use of technology to help the sector address economic and societal challenges. This will include more extensive use of sensors, UAVs, AUVs and satellites. The impact of geoscience will also be enhanced for users through utilisation of enhanced imaging and telemetering, and sophisticated data analytics.

Conclusion

Indecon's independent analysis indicates that the scale of the existing and future economic impacts of geoscience may be much more significant than initially perceived. While all sectors of the economy have an impact, it is evident that geoscience includes a number of areas of activity which contribute significant employment and output in the Irish economy. The sector is also likely to have wider societal impacts and offers potential for future expansion.

1 Introduction, Background and Approach

1.1 Introduction

This report was prepared for the Department of Communications, Climate Action and Environment (DCCAE) and Geological Survey Ireland (GSI) by Indecon International Economic Consultants. The report represents an independent economic impact assessment of the important Irish geoscience sector.

1.2 Background and Scope

'Geoscience' relates to what is internationally referred to as 'Earth sciences' and supports a range of economic services and activities including geotourism and geoheritage, groundwater resources, education and research and the extractive industries. It also helps minimise the economic and social costs of natural hazards, and supports geoscience business clusters. Supporting continued development of the sector can provide long-term sustainable growth opportunities for Ireland as the world faces the challenge of climate change.

The Geological Survey Ireland was founded in 1845. It is the national geoscience agency of Ireland and is a division of the DCCAE. The GSI is tasked with providing geological advice and information to the public and these services are considered by the organisation to be a corporate priority. Other services offered by the GSI include data acquisition of Irish geological data, mainly through major mapping programmes onshore such as Tellus and offshore (INFOMAR), management and distribution of data through the National Geoscience Data Centre (NGDC), project partnering with agencies and EU, environmental protection particularly groundwater mapping, planning advice in relation to geoscience heritage, research support and business development through the Geoscience Ireland business cluster. The organisation has up to 100 staff, evenly split between permanent and contracted specialists and maintains a fleet of vehicles, five inshore mapping vessels, two drilling rigs and a Geological Core repository to carry out its work.

This repot concerns a quantitative estimation of the economic impact of the geoscience sector in Ireland. Various subsectors of geoscience are explored on a thematic basis throughout this report. The report also assesses at an aggregate level the overall economic impact of the sector to the Irish economy, and also sets out potential future trends in the sector.

This study presents a rigorous, quantitative estimation of the economic impact of the geoscience sector in Ireland. Indecon believes it is important that care is taken in evaluating the economic impact of economic sectors and we have utilised an evidence based approach with prudent assumptions. Our research, however, indicates that the sector is of significant economic importance to the Irish economy and to society. The assessment examines a number of specific sub-sectors/activities. An overview description of these components, and of the economic impacts thereof, is presented below.

1.3 Methodology for Study

Figure 1.1 presents a schematic summary of the methodology and work programme applied in completing this study. The rigorous methodology applied in this assessment is consistent with international best practice, incorporating a conceptual and measurement framework.

Figure 1.1: Phases of Methodological Approach/Work Programme

Source: Indecon

During the completion of this report Indecon has utilised a variety of methodological approaches, including:

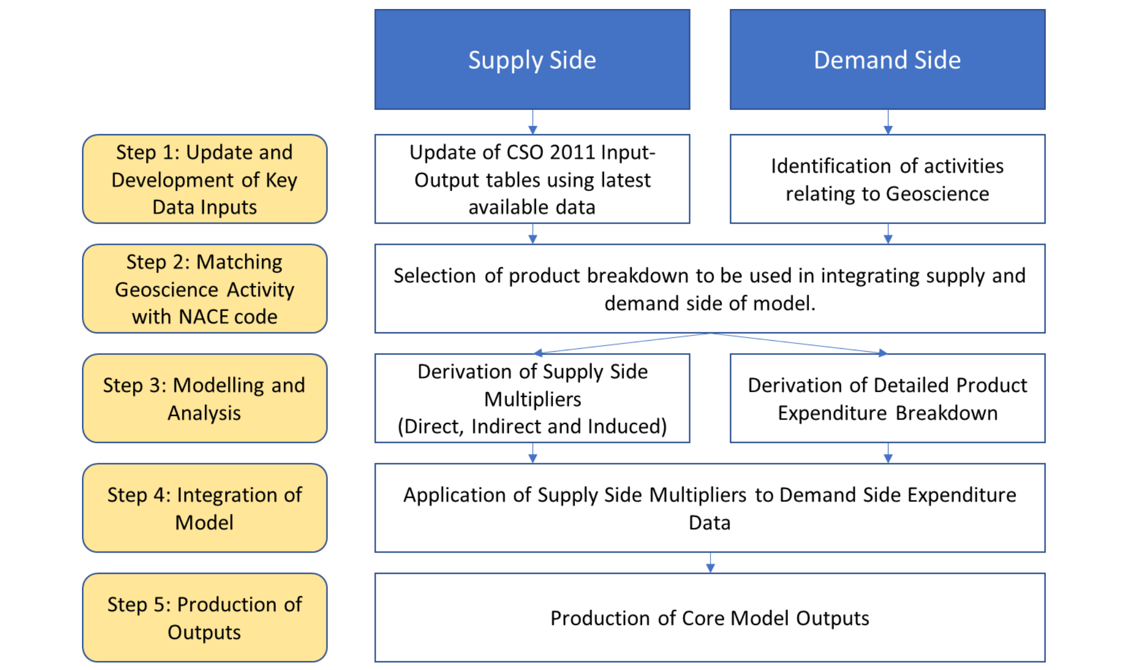
- Desktop research based on variety of data sources, including:
  - Geological Survey Ireland;
  - CSO;
  - Department of Communications, Climate Action, and Environment;

- ➢ Environmental Protection Agency;
- ➢ EirGrid;
- ➢ Geoscience Ireland;
- ➢ Fáilte Ireland;
- ➢ Irish Water;
- ➢ Higher Education Authority;
- ➢ Third-Level Institutions and Research Centres; and,
- ➢ Newspaper articles and press releases.

- ❑ Review of national and international research into the economic impacts of geoscience subsectors;
- ❑ Consultation programme with relevant stakeholders;
- ❑ Input-Output modelling techniques to estimate sectoral economic multipliers (outlined below); and
- ❑ Econometric modelling of the value of groundwater (outlined in Section 3 of this report).

Indecon has utilised our Input-Output model of the Irish economy extensively throughout this report. In this section, we provide a brief explanatory note on its functionality. The Input-Output model assesses the cross-sector flow of economic activity using the CSO's 2011 Input-Output tables. Indecon has updated these tables to 2014. There are several steps in the estimation of the final economic multipliers, as outlined below.

Figure 1.2: Steps to Estimate Input-Output Multipliers

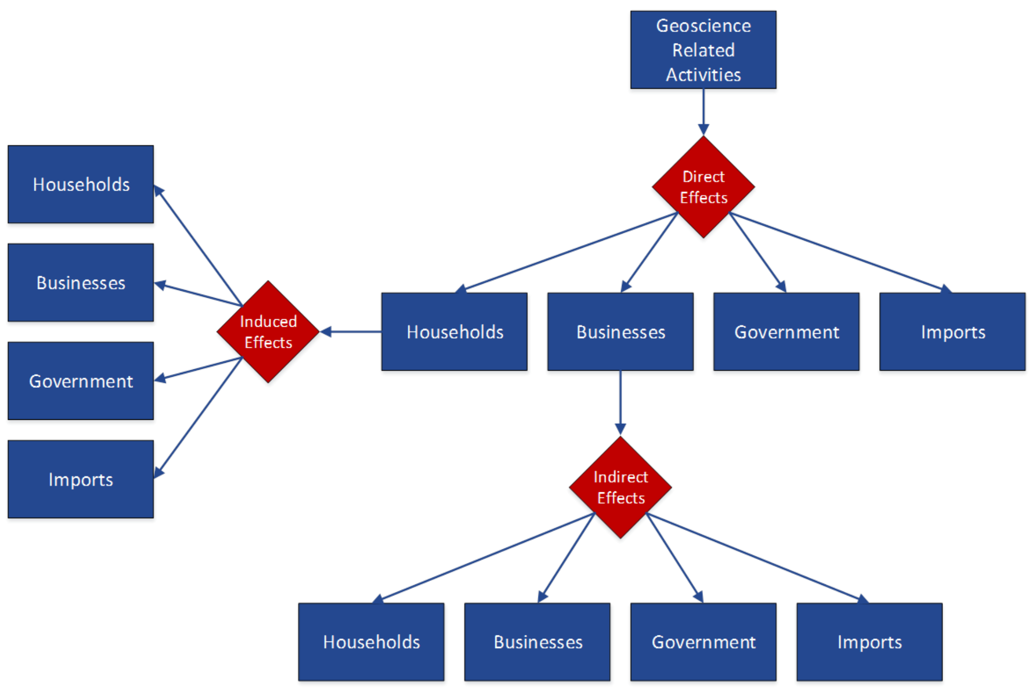


Source: Indecon

The supply side of the model was modelled using the RAS technique[1] to assess the economic linkages across sectors. This allowed the team to calculate the Leontief Inverse and calculate the sectoral multipliers using matrix algebra. On the demand-side, the team first determined which specific geoscience activities would be included, and then developed a mapping of estimates of demand and output onto appropriate NACE categories. These sectors include the Mining, Quarrying and Extraction sector, as well as a weighted average of other sectors reflecting demand for geotourism and geoheritage, and the scientific research and development sectors.

Direct, Type I, and Type II multipliers have been derived for use in this study. Direct multipliers allow for the estimation of the direct effects of economic activity in terms of Gross Value Added and employment. Type I multipliers estimate the indirect impacts of economic activity. Indirect impacts include the knock-on business activity that is supported through direct economic activity, e.g., the positive economic impacts of upstream suppliers would be captured by this multiplier. Type I multipliers are concerned with knock-on *business-related* activity. Type II multipliers include both indirect and induced effects. Induced effects are concerned with the knock-on impact of household consumption due to direct economic activity. This will include the impact of additional employment wages directly supported through geoscience activity. As such, Type II impacts are concerned with *business and household-related* activity. The figure below presents these impacts graphically.

Figure 1.3: Graphical Description of Economic Multipliers



Source: Indecon

[1] https://ec.europa.eu/eurostat/cros/content/ras-method_en

1.4 Structure of the Report

The remainder of this report is structured as follow:

- Section 2 contains an examination of geotourism and geoheritage;
- Section 3 analyses groundwater resources in Ireland;
- Section 4 examines geoscience research in academic and other public institutions;
- Section 5 discusses the economic impact of extractive industries in Ireland;
- Section 6 contains a review of the impact of natural geoscientific hazards;
- Section 7 analyses the Geoscience Ireland organisation;
- Section 8 provides an aggregated summary of the impact of the sector as a whole; and
- Section 9 looks into the future trends in the geoscience sector and provides recommendations.

1.5 Acknowledgements and Disclaimer

Indecon would like to acknowledge the inputs and assistance provided by Koen Verbruggen, Garry Dunphy, Ray Scanlon and Monica Lee at Geological Survey Ireland in the compilation of this report. Further, Indecon would also like to thank other stakeholders, including Clare Morgan, Eibhlin Doyle, Stephen Walsh and Evin McMahon (Department of Communications, Climate Action and Environment; Stephen Dineen (Department of Housing, Planning and Local Government); Martin White and Stephen Hynes, (NUI Galway); Sarah Culloty and Andrew Wheeler (School of Biological, Earth & Environmental Sciences, UCC); Ken Byrne (Department of Biological Sciences, University of Limerick); Chris Bean (Dublin Institute for Advanced Studies); David Chew (Department of Geology, Trinity College Dublin); Frank McDermott (School of Earth Sciences, UCD); Gerry Kearns (Department of Geography, Maynooth University); Ciaran Kelly (Marine Institute); Stephanie Long (Environmental Protection Agency); Carol Gleeson (Burren & Cliffs of Moher UNESCO Global Geopark); Gerry Farrell (Irish Concrete Federation); John Walsh, Balz Kamber and Jennifer Craig (iCRAG Research Centre); Richard Watson (Marble Arch Caves Global Geopark); Aoife Braiden RML Ltd.; Patrick Shannon (Irish Offshore Operators' Association) and Brian Downes (Lagan Asphalt Group).

The usual disclaimer applies and the analysis and findings in this independent report are the sole responsibility of Indecon.

2 Geotourism and Geoheritage

2.1 Introduction

Geotourism, as defined by the National Geographic, is tourism that sustains or enhances the distinctive geographical character of a place—its environment, heritage, aesthetics, culture, and the well-being of its residents.[2] With respect to these characteristics of tourism, Ireland can be considered as one of the major locations for geotourism and geoheritage; being home to several landscape tourism sites, cultural centres, geo-activities and rich local heritage.

Based on Newsome and Dowling (2010), Indecon defines geotourism and geoheritage as:

> *"…a form of natural area tourism that specifically focuses on geology and landscape. It promotes tourism to geosites and the conservation of geo-diversity and an understanding of Earth sciences through appreciation and learning."*

GSI supports the Geotourism and Geoheritage activity in a number of ways, largely through their Irish Geoheritage Programme. Activities include developing UNESCO Geoparks in Ireland and managing the Irish Geopark Forum, providing co-funding for geologists within the existing and aspiring Geoparks, and collaborating in major EU project initiatives on Geotourism such as the Breifne Project. GSI also have a statutory role in this area and prepare inventories of Geoheritage sites for Local Authorities, which are then included in County Development Plans and often targeted for tourism development.

In this section we set out an estimate of the economic value of geotourism and geoheritage to the Irish economy.

2.2 Background

Overseas tourism has expanded significantly in recent years and the total number of visitors to Ireland in 2016 amounted to almost 19 million, up from a post-crisis low in 2010. Tourism generally, as an economic sector, has steadily increased in Ireland, as shown in Table 2.1 below. The green landscapes and local heritage in Ireland makes it a major geotourism and geoheritage destination.

Table 2.1: Number of Overseas and Domestic Tourists in Ireland (000s)

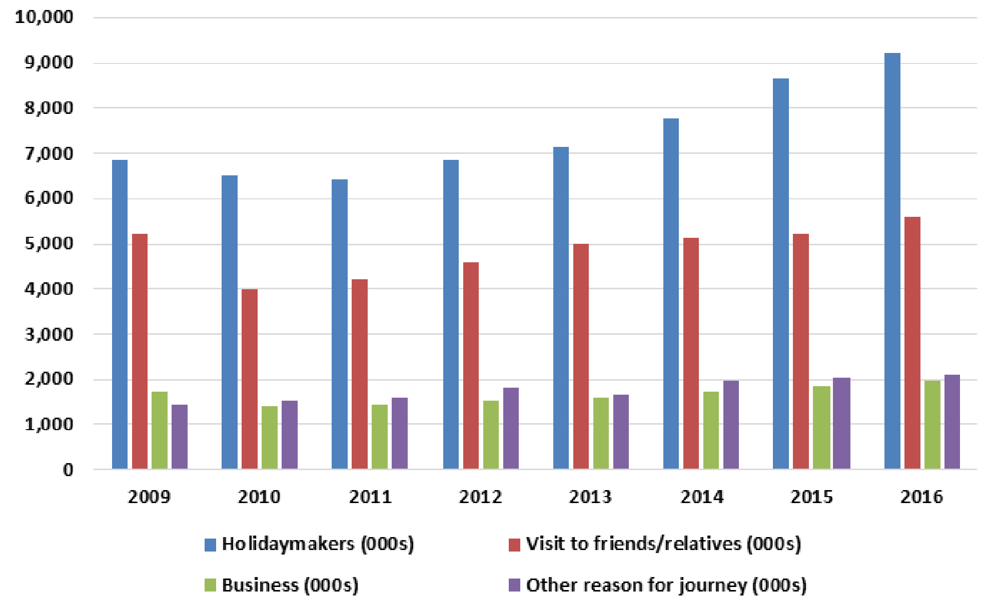
	2009	2010	2011	2012	2013	2014	2015	2016
Overseas Visitors	6,907	6,139	6,505	6,517	6,986	7,604	8,643	9,584
Domestic Visitors	8,340	7,300	7,169	8,291	8,413	8,991	9,125	9,282
Total	**15,247**	**13,439**	**13,674**	**14,808**	**15,399**	**16,595**	**17,768**	**18,866**

Source: Central Statistics Office, Ireland

[2] Source: The National Geographic. Retrieved on 8th October, 2017 from *http://www.nationalgeographic.com/maps/geotourism/*

The increase has been driven mainly by the tourists who visit Ireland for holiday and vacations, as shown in Figure 2.1. There have been increases in other visitor categories also.

Figure 2.1: Visitors Characterised by Reason to Travel (000s)



Source: Central Statistics Office, Ireland

In terms of its economic impact, tourism supports a substantial number of jobs and contributes significantly to national income. Table 2.2 reports the economic contribution of tourism with respect to tax receipts and direct employment in Ireland.

The figures in the table below indicate that approximately 225,000 jobs in Ireland are supported by the tourism sector. Tax revenue of €1.9 billion in 2016 is also attributed to the tourism sector by Fáilte Ireland.

Table 2.2: Tax Receipts and Direct Employment in Tourism Sector

	2011	2012	2013	2014	2015	2016
Tax Revenue (€ billion)	1.4	1.3	1.4	1.6	1.8	1.9
Direct Employment (000s)	180	185	200	205	220	225

Source: Fáilte Ireland Tourism Facts and Annual Reports

Figure 2.2 shows the 2016 Fáilte Ireland statistics for the importance given by overseas visitors of various characteristics in choosing a tourist destination. A high proportion of tourists regarded beautiful scenery, natural attractions and a natural unspoilt environment as important in their choice of destination, and that they were satisfied with their experience in Ireland.

Figure 2.2: Importance of Destination Issues Among Overseas Holidaymakers (%)

Source: Fáilte Ireland's Port Survey of Overseas Holidaymakers 2016

2.3 Fee Charging Geotourism and Geoheritage Sites

This section sets out the number of tourists visiting the most important fee-paying sites with a significant geotourism and geoheritage element in Ireland, and estimates the value of this activity. The next table presents the number of visitor for the most visiting of these sites, and shows that Cliffs of Moher, Fota Wildlife Park, and Powerscourt House and Gardens are the most visited fee-paying geo-tourism destinations in Ireland. These sites are relevant to the measure of economic impact of geoscience as they are part of Ireland's landscape heritage and are encompassed within a wide definition of geotourism.

Sites	2011	2012	2013	2014	2015	2016*
Aillwee Cave & Burren Birds of Prey Centre	-	-	0.11	0.12	0.14	0.15
Belvedere House Gardens and Park	-	-	-	-	0.13	0.13
Blarney Castle & Gardens	0.33	0.33	0.37	0.39	0.40	0.42
Brú na Boinne Newgrange	0.23	0.13	0.13	0.14	0.15	0.16
Cliffs of Moher Visitor Experience	0.81	0.87	0.96	1.08	1.25	1.43
Dún Aonghasa	-	-	0.11	0.12	0.12	0.13
Fota Wildlife Park	0.39	0.38	0.37	0.44	0.44	0.47
Glenveagh Castle and Grounds	-	-	0.12	0.15	0.17	0.18
Hill of Tara	-	-	-	-	0.16	0.17
Kylemore Abbey & Garden	-	-	-	-	0.30	0.46
Powerscourt House & Gardens	0.21	0.20	0.21	0.23	0.25	0.47
Rock of Cashel	0.23	0.24	0.26	0.37	0.30	0.34
Total (Millions)	**2.19**	**2.16**	**2.62**	**3.04**	**3.81**	**4.50**

Table 2.3: Number of Tourists visiting Top Fee-Paying Geotourism Sites (millions)

Source: Fáilte Ireland's Annual Visitor Attractions Survey

Note: Figures for 2016 that are not included in the 2016 Fáilte Ireland Fact Sheet are estimated using the growth in overall tourism numbers between 2015 and 2016.

The total revenue that was generated from these sites with a significant geotourism and geoheritage element is shown in Table 2.4. The revenue generated from these tourist sites is calculated using the average ticket price charged per location.[3] The highest revenue-generating site is the Cliffs of Moher Visitor Experience, adding over €7 million in 2016, followed by the Fota Wildlife Park, generating €6 million. The total revenue from the fee-paying sites sums estimated to be over €33.5 million in 2016.

Table 2.4: Revenue from the Top Fee-Paying Geotourism Sites (€ Million)

Sites	Entry Fee (€)	2011	2012	2013	2014	2015	2016
Aillwee Cave & Burren Birds of Prey Centre	7.5	-	-	0.8	0.9	1.1	1.1
Belvedere House Gardens and Park	6.0	-	-	-	-	0.8	0.8
Blarney Castle & Gardens	10.5	3.4	3.5	3.8	4.1	4.2	4.4
Brú na Boinne Newgrange	8.9	2.0	1.2	1.2	1.2	1.3	1.4
Cliffs of Moher Visitor Experience	5.0	4.0	4.4	4.8	5.4	6.3	7.1
Dún Aonghasa	4.0	0.0	0.0	0.4	0.5	0.5	0.5
Fota Wildlife Park	13.0	5.1	4.9	4.8	5.7	5.7	6.0
Glenveagh Castle and Grounds	6.0	-	-	0.7	0.9	1.0	1.1
Hill of Tara	4.0	-	-	-	-	0.6	0.7
Kylemore Abbey & Garden	10.0	-	-	-	-	3.0	4.6
Powerscourt House & Gardens	8.0	1.7	1.6	1.7	1.9	2.0	3.7
Rock of Cashel	6.0	1.4	1.4	1.5	2.2	1.8	2.0
Total (€ Million)	**-**	**17.62**	**16.99**	**19.72**	**22.81**	**28.22**	**33.56**

Source: Indecon estimates based on visitor statistics from the Fáilte Ireland Visitor Attraction Surveys and Entry fees data from official websites of the locations.

[3] The average ticket price is calculated by taking the mean of entry tickets across all categories (child, adult, student) and age-groups, excluding the family ticket. The information is derived from the official websites.

2.4 Non-Fee Paying Geotourism and Geoheritage Sites

Non-fee charging geotourism and geoheritage sites also have an economic value. There is an inherent difficulty in measuring the economic value of a free-of-charge site, though the existing literature suggests methods such as stated preference and revealed preference as appropriate valuation methodologies for such attractions. Indecon has employed a contingent valuation methodology based on the willingness-to-pay (WTP) approach, in which a certain price is assumed as the appropriate contribution by visitors for the satisfaction and enjoyment that they derive by visiting these sites.

The next table summarises the number of tourists that visited the most popular free geotourism attractions. Doneraile Wildlife Park was the most popular in 2016 with just under 500,000 visitors.

Table 2.5: Number of Tourists Visiting Top Free Geotourism Sites (000s)

Sites	2011	2012	2013	2014	2015	2016
Ballyhoura Mountain Bike Trails	-	62	66	70	70	74
Burren Perfumery and Floral Centre	-	-	-	45	50	53
Connemara National Park	203	167	170	170	191	211
Doneraile Wildlife Park	-	-	-	460	432	480
Glencar Waterfall	-	-	-	-	84	89
Grianan of Aileach	-	-	-	-	108	115
Kilmacurragh Gardens	-	-	-	51	67	71
Malin Head Viewing Point	-	-	106	105	155	162
Sliabh Liag Cliffs	-	-	125	120	186	177
Total (Million)	**0.20**	**0.23**	**0.47**	**1.02**	**1.34**	**1.43**

Source: Fáilte Ireland's Annual Visitor Attractions Survey.
Note: Figures for 2016 that are not included in the 2016 Fáilte Ireland Fact Sheet are estimated using the growth in overall tourism numbers between 2015 and 2016.

Indecon utilised studies and academic research conducted in Ireland, the UK, and wider international markets such as the USA, Vietnam, Oman, and Costa Rica in our estimation of visitors' willingness-to-pay for geotourism and geoheritage sites. The summary of findings from these studies is shown in the next table. The average WTP is adopted for this study equalled €5.07.

The methodology used to estimate the economic impact of non-fee charging institutions is as an actual expenditure attribution measurement. Visits to a non-fee charging site can be expected to generate additional expenditure in the economy through channels such as travel costs, expenditure on souvenirs/guides, and even food and drink at these locations. While such expenditure could be expected to be greater than our conservative attribution of €5.07 per person per site, this is considered appropriate and prudent due to the need to measure the marginal or net impact of the site on the economy. Under the counterfactual in which the site does not exist, tourists may travel to a different site, and therefore estimating the marginal/incremental effect is required. Indecon consider the average cost of fee-paying sites as a fair estimation in this respect.

Table 2.6: Summary of WTP Studies and Average WTP					
Research Study	**Location**	**Year of Survey**	**Method**	**WTP (Local Currency)**	**WTP (€)**
Majumdar et al. (2011)[4]	Savannah, Georgia, USA	2009	CVM using Payment Card	11.25 USD	8.24
Tran et al. (2015)[5]	Phu My Protected Area, Viet Nam	2013	Choice Experiment	134000 VND	6.59
Zekri et al. (2012)[6]	Misfat- Al Abreen Mountain Oases, Oman	2009	CVM using bidding amounts	8.6 USD	6.30
Yadav et al. (2013)[7]	Western region of Ireland	2011	Payment cards for bidding	1.03 Euro	1.04
Willis et al. (2003)[8]	Sitka spruce forests, England, Scotland and Wales	2002	Single and Double bounded CVM	2.75 GBP	5.24
Bienabe et al. (2006)[9]	Costa Rica	2005	Choice Experiment	3.36 USD	2.99
Average WTP	**€5.07**				
Source: Indecon analysis. Note that the WTP is adjusted for foreign exchange and price level differences					

Indecon has applied this average WTP value to the numbers of tourists visiting non-fee paying geotourism and geoheritage sites in Ireland. This amounted to almost €7.3 million in 2016, as can be seen in Table 2.7.

Table 2.7: Estimated Value of Top Free Visitor Attractions (€ Million)							
Sites	**WTP (€)**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Ballyhoura Mountain Bike Trails	5.07	-	0.31	0.33	0.35	0.35	0.38
Burren Perfumery and Floral Centre	5.07	-	-	-	0.23	0.25	0.27
Connemara National Park	5.07	1.03	0.85	0.86	0.86	0.97	1.07
Doneraile Wildlife Park	5.07	-	-	-	2.33	2.19	2.43
Glencar Waterfall	5.07	-	-	-	-	0.42	0.45
Grianan of Aileach	5.07	-	-	-	-	0.55	0.58
Kilmacurragh Gardens	5.07	-	-	-	0.26	0.34	0.36
Malin Head Viewing Point	5.07	-	-	0.54	0.53	0.78	0.82
Sliabh Liag Cliffs	5.07	-	-	0.63	0.61	0.94	0.90
Total (€ Million)	**-**	**1.03**	**1.16**	**2.37**	**5.17**	**6.81**	**7.26**
Source: Indecon estimates based on visitor statistics from the Fáilte Ireland Visitor Attraction Surveys and mean WTP reported previously.							

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[4] Majumdar, S., Deng, J., Zhang, Y., & Pierskalla, C. (2011). Using contingent valuation to estimate the willingness of tourists to pay for urban forests: A study in Savannah, Georgia. *Urban Forestry & Urban Greening*, 10(4), 275-280.

[5] Tran, D., Nomura, H., & Yabe, M. (2015). Tourists' Preferences toward Ecotourism Development and Sustainable Biodiversity Conservation in Protected Areas of Vietnam - The Case of Phu My Protected Area. *Journal of Agricultural Science*, 7(8), p81.

[6] Zekri, S., Mbaga, M., & Fouzai, A. (2012). Complementarity between agriculture and tourism towards sustainability. *Int J Agric Res*, 7(10), 482

[7] Yadav, L. P., O'Neill, S., & Van Rensburg, T. (2013). Supporting the conservation of farm landscapes via the tourism sector. *The Economic and Social Review*, 44(2, Summer), 221-245.

[8] Willis, K. G., Garrod, G., Scarpa, R., Powe, N., Lovett, A., Bateman, I. J., ... & Macmillan, D. C. (2003). The social and environmental benefits of forests in Great Britain. *Forestry Commission, Edinburgh*.

[9] Bienabe, E., & Hearne, R. R. (2006). Public preferences for biodiversity conservation and scenic beauty within a framework of environmental services payments. *Forest Policy and Economics*, 9(4), 335-348.

UNESCO

It is important at this point to note the three UNESCO Global Geoparks in Ireland which are:

- the Copper Coast in Waterford (Ireland's first Geopark);
- the Marble Arch Caves, partially located in Cavan with the rest in Fermanagh; and,
- the Burren and Cliffs of Moher in Clare.

Research undertaken in the UK found that the UNESCO label added approximately £2.69 million to the UK economy per annum for each UNESCO geopark.[10] The Marble Arch Caves is the first cross-border geopark in the world, and is estimated to generate approximately £17.2 million per year to the surrounding economy. The company operating the Marble Arch Caves attribute the success over the previous three years of secured EU funding (€3.2m) entirely to their Global Geopark status.[11]

In total, the three Irish Global Geoparks and three further aspiring geopark projects attracted at least €19m net in EU funded projects between 2004 and 2014.[12] UNESCO Global Geoparks create additional employment, and also contribute to geoscience and geo-education programmes. In the Marble Arch Caves geopark area only, there are five full-time and five seasonal or part-time staff; in the Caves alone (as a key Geopark site), there are five full-time and 45+ seasonal staff. In addition, the manager is full-time shared between the Caves and wider Geopark area. Indecon captures their value as part of the walking and hiking section of this chapter. To calculate these separately and then add them may lead to double counting and an over-estimation of the value of geotourism.

The following sub-sections estimate various channels through which geoscience tourism contributes to the Irish economy. Our estimation is based on fee-paying and free geotourism sites, and geoscience activities such as walking and hiking.

2.5 Geotourism Activities

The outdoor activities that involve immediate involvement with the geological environment are considered by Indecon to constitute geoscience tourist activities. Therefore, the focus of this subsection is on hiking/cross-country walking, and cycling. The next table shows the number of overseas and domestic visitors involved in these activities.

[10] United Kingdom National Commission for UNESCO. *Wider Value of UNESCO to the UK 2012-2013.* https://www.unesco.org.uk/wp-content/uploads/2015/05/Wider-Value-of-UNESCO-to-UK-2012-13-full-report.pdf

[11] United Kingdom National Commission for UNESCO. *Wider Value of UNESCO to the UK 2014-2015.* https://www.unesco.org.uk/wp-content/uploads/2016/02/UK-National-Commission-for-UNESCO_Wider-Value-of-UNESCO-to-the-UK_UK-Organisations_January-2016.pdf

[12] Irish Geoparks Committee, 2014

Table 2.8: Number of Overseas and Domestic Visitors Engaging in Geoscience Activities							
	Activities	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Overseas Visitors	Hiking and Cross-country Walking (000s)	763	578	742	1,193	1,674	2,077
	Cycling (000s)	178	149	241	286	355	399
Domestic Visitors	Hiking and Cross-country Walking (000s)	1,505	1,824	2,019	1,978	2,099	2,321
	Cycling (000s)	430	746	673	719	639	743
Total Visitors	**Hiking and Cross-country Walking (000s)**	**2,268**	**2,402**	**2,761**	**3,171**	**3,773**	**4,398**
	Cycling (000s)	**608**	**895**	**914**	**1005**	**994**	**1,142**
Source: Indecon analysis Tourism Facts Reports, Fáilte Ireland.							

To avoid double-counting and in order to provide a conservative estimate of the number of visitors engaged in geoscience tourism activities, Indecon has assumed that cycling and hiking are not mutually exclusive. As such, the number of visitors involved in geoscience activities are considered as the total number of visitors who engage in hiking and cross-country walking alone, equating to 4.4 million in 2016.

In order to estimate expenditure on these activities, Indecon has prudently attributed a single day of spend to geoscience activity. As holidaymakers often spend multiple days exploring Ireland's landscape (Ring of Kerry, Cliffs of Moher, etc.), we consider this a conservative estimate. The total estimated number of days is then multiplied by an estimate of daily expenditure to arrive at a figure for the economic impact of hiking and cross-country walking.

Daily expenditure varies for visitors on holiday and visitors on other trips. Also, the amounts are different for international and domestic visitors. Thus, it is important to arrive at the final per-diem which is based on all these distinctions. Indecon has applied a weighted average to estimate the average daily spend of a visitor to Ireland, shown in the next table. The final daily expenditure value is estimated as €79.50 in 2016. For domestic visitors, the distinction of per-diems based on holiday visits and other visits was not available. Thus, for simplicity the average per-diem for all the purposes of trips is taken together.

Table 2.9: Weighted Per-Diem Expenditure by Tourist Type						
	Activity and Category of Visit	**2012**	**2013**	**2014**	**2015**	**2016**
Overseas Visitors	Hiking/Cross-country walking during Holiday trips (%)	0.55	0.55	0.54	0.55	0.55
	Hiking/Cross-country walking on Other trips (%)	0.45	0.45	0.46	0.45	0.45
	Per-diem Holiday visitors (€)	77	82	83	89	89
	Per-diem Other Visitors (€)	61	63	64	68	68
	Weighted per-diem (€)	69.8	73.5	74.3	79.5	79.5
Domestic Visitors	Per-diem (All visitors) (€)	60	67	69	73	71
Source: Activity Product Usage Annual Reports, Fáilte Ireland (Engagement in activities based on purpose of visits). Tourism Facts Annual Reports, Fáilte Ireland (Per-diem, International and Domestic)						

Combining the daily expenditure of an average visitor with the level of geoscience activity allows us to estimate an overall expenditure value attributable to geoscience. The results are shown in Table 2.10 and the total revenues equals almost €330 million in 2016.

Table 2.10: Expenditure by Overseas and Domestic Tourists Attributable to Geotourism Activities					
	2012	**2013**	**2014**	**2015**	**2016**
Overseas Visitors					
Hiking and Cross-country Walking	578,000	742,000	1,193,000	1,674,000	2,077,000
Weighted-per diem (€)	69.8	73.5	74.3	79.5	79.5
1-day Expenses (€ million)	40.3	54.5	88.6	133.0	165.1
Domestic Visitors					
Hiking and Cross-country Walking	1,824,000	2,019,000	1,978,000	2,099,000	2,321,000
Per-diem (All visitors) (€)	60	67	69	73	71
1-day Expenses (€ million)	109.4	135.3	136.5	153.2	164.8
Total 1-Day Expenses (€ million)	**149.8**	**189.8**	**225.1**	**286.3**	**329.8**
Source: Indecon analysis					

2.6 Total Economic Impact of the Geoscience Tourism Sector

The table below presents the results of our three methodological approaches for estimating the economic impact of the geotourism and geoheritage sector in Ireland. Where data constraints existed, we have extrapolated figure to 2016 in line with the overall trend in tourism numbers to Ireland. The geotourism sector is a major contributor to the Irish economy, with total revenue attributable amounting to €371 million in 2016.

Table 2.11: Economic Impact of Geotourism, 2012 – 2016 (€ Million)					
Revenue From	**2012**	**2013**	**2014**	**2015**	**2016**
Top Fee-paying Sites	17.0	19.7	22.8	28.2	33.6
Top Non-Fee-Paying Sites	1.2	2.4	5.2	6.8	7.3
Hiking and Cross-Country Walking	149.8	189.8	225.1	286.3	329.8
Total Revenue	***167.9***	***211.9***	***253.1***	***321.3***	**370.7**
Gross Value Added	***108.6***	***137.0***	***163.6***	***207.7***	***239.6***
Source: Indecon analysis					

The total direct economic contribution of the geotourism sector is €371 million in 2016. The gross value added to the Irish economy is estimated using economic multipliers. These are estimated using Indecon's model of the Irish economy, explained in detail in Section 1. This economic activity supported nearly 6,900 FTE employees.

Table 2.12: Direct Economic Impacts of Geotourism Sector - 2016			
	Output (€ million)	**GVA (€ million)**	**Employment (FTEs)**
Fee paying Geo Heritage Sites	33.6	21.7	624
Free Geo Heritage Sites	7.3	4.7	135
Geoscience Activities	329.8	213.2	6,129
Total	**370.7**	**239.6**	**6,888**
Source: Indecon modelling			

This direct economic activity requires supportive industries providing economic inputs. Household consumption is also stimulated through increases in wages and employment

supported. These effects are referred to as indirect and induced effects respectively. These additional impacts are presented below. The indirect and induced impacts amounted to €290 million in output in 2016, €176 million in GVA, and 1,879 FTE employees.

Table 2.13: Indirect and Induced Impacts - 2016

	Output (€ million)	GVA (€ million)	Employment (FTEs)
Fee paying Geo Heritage Sites	26.3	15.9	170
Free Geo Heritage Sites	5.7	3.4	37
Geoscience Activities	258.3	156.5	1,672
Total	**290.3**	**175.9**	**1,879**

Source: Indecon analysis

Combining the direct, indirect, and induced impacts provides an estimate for the economy-wide impacts of this economic activity. Geotourism supported over 8,750 jobs, and €660 million in output.

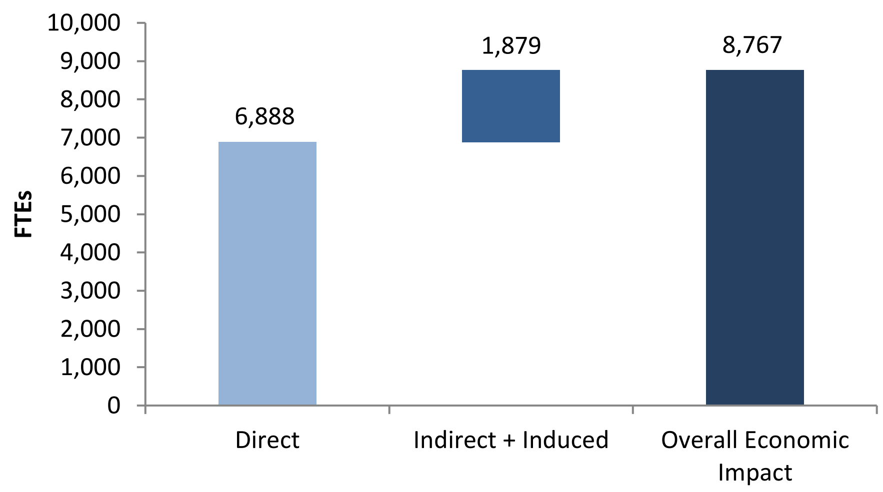
Table 2.14: Economy-Wide Impacts - 2016

	Output (€ million)	GVA (€ million)	Employment (FTEs)
Fee paying Geo Heritage Sites	59.8	37.6	794
Free Geo Heritage Sites	13.0	8.1	172
Geoscience Activities	588.1	369.8	7,801
Total	**660.9**	**415.5**	**8,767**

Source: Indecon analysis

A waterfall chart showing the direct, indirect, and induced effects of geotourism on Irish employment is provided in the next figure.

Figure 2.3: Employment Impact of Geotourism and Geoheritage



Source: Indecon analysis

2.7 Summary of Key Findings

- The number of overseas and domestic tourists has been increasing, with total number of visitors in 2016 reaching almost 19 million, a 6% increase on the previous year. Tax revenue from tourism has also grown in recent years, with the total tax revenue attributed to tourism by Fáilte Ireland almost €2 billion in 2016.
- Indecon estimated that four and a half million tourists visited fee-paying geotourism sites in 2016, including the Cliffs of Moher and the Rock of Cashel. Based on the entry fee to these sites, Indecon attributed a figure of €33.56 million to fee-paying geotourism sites in 2016.
- To evaluate the economic impact of free geotourism sites, Indecon used a method called the contingent valuation method. Using estimates of willingness-to-pay from studies and academic research, Indecon employed a willingness-to-pay of €5.07 for entry into non-fee paying geotourism sites in Ireland. Doneraile Wildlife Park, Connemara National Park and Sliabh Liag Cliffs had the highest attendance of the free geotourism sites included in this study and made up the majority of the €7.26 million value attributed to the non-fee paying geotourism sites in 2016.
- The third element of geotourism included in this report is hiking and cross-country walking. Indecon attributed a day's expenditure to those tourists, both domestic and overseas, who went hiking or cross-country walking during their trip in or to Ireland. Over four million tourists went hiking or cross-country walking in Ireland in 2016, leading to an estimated economic value of almost €330 million.
- The value of fee-paying and non-fee paying geotourism sites was added to the value of hiking and cross-country walking to obtain an estimate for the total direct output of geotourism in Ireland in 2016, which was €370.7 million. Using Indecon's Input-Output Sectoral Model, we estimated GVA of almost €240 million and employment directly supported by geotourism as 6,888 FTEs. When indirect and induced effects are taken into account, Indecon estimates that the economy wide output related to geotourism was €660.9m, with GVA of €415.5m and 8,767 FTEs supported.

3 Groundwater Resources, Protection and Remediation

3.1 Introduction

Groundwater is a critical source of freshwater for drinking and irrigation. Around 75% of the drinking water supply in the European Union is derived from groundwater.[13] In Ireland, groundwater accounts for approximately 25%-33% of drinking water from public and group schemes, and private wells. Further, it contributes to maintaining wetlands and acts as an essential buffer during periods of dry spells. Thus, it is imperative to actively participate in groundwater protection, management and remediation to both protect the environment and support societal access to a key human need.

The need for groundwater protection arises to minimise pollution that affects the quality of groundwater and is eventually reflected in the quality of surface water. This is due to the fact that the groundwater eco-system provides base-flow for surface water. The effect of pollution from human, industrial and agricultural activities on groundwater can persist for many decades as the pollutants stay and continue affecting the slowly moving groundwater through the sub-surface.

The regulatory framework for groundwater protection and management for the EU started back in 1970. Since then, a number of directives and action plans have been launched, including the EU Water Framework Directive (WFD, 2000/60/EC), and the Groundwater Directive (Directive 2006/118/EC). In addition to the above, there are certain other directives which contribute to the groundwater regulatory framework such as the Drinking Water Directive (EU) 2015/1787, Environmental Impact Directive (2014/52/EU), Nitrates Directive (91/676/EEC) and Environmental Quality Standards Directive (2008/105/EC).

3.2 Background

In Ireland, the GSI advises government departments, agencies and local authorities on groundwater issues. Amongst various tasks undertaken by the GSI, preparing county Groundwater Protection Schemes (GWPS) in order to facilitate the protection and preservation of the quality of drinking water is particularly important. Under the scheme, the GSI has developed land surface zoning maps combining aquifer and vulnerability maps to provide groundwater resource protection zone maps. Also, the vulnerability maps are combined with source protection area maps to develop the source protection zone maps. The map, as shown in Figure 3.1, is the combination of the groundwater vulnerability and the source protection area maps.

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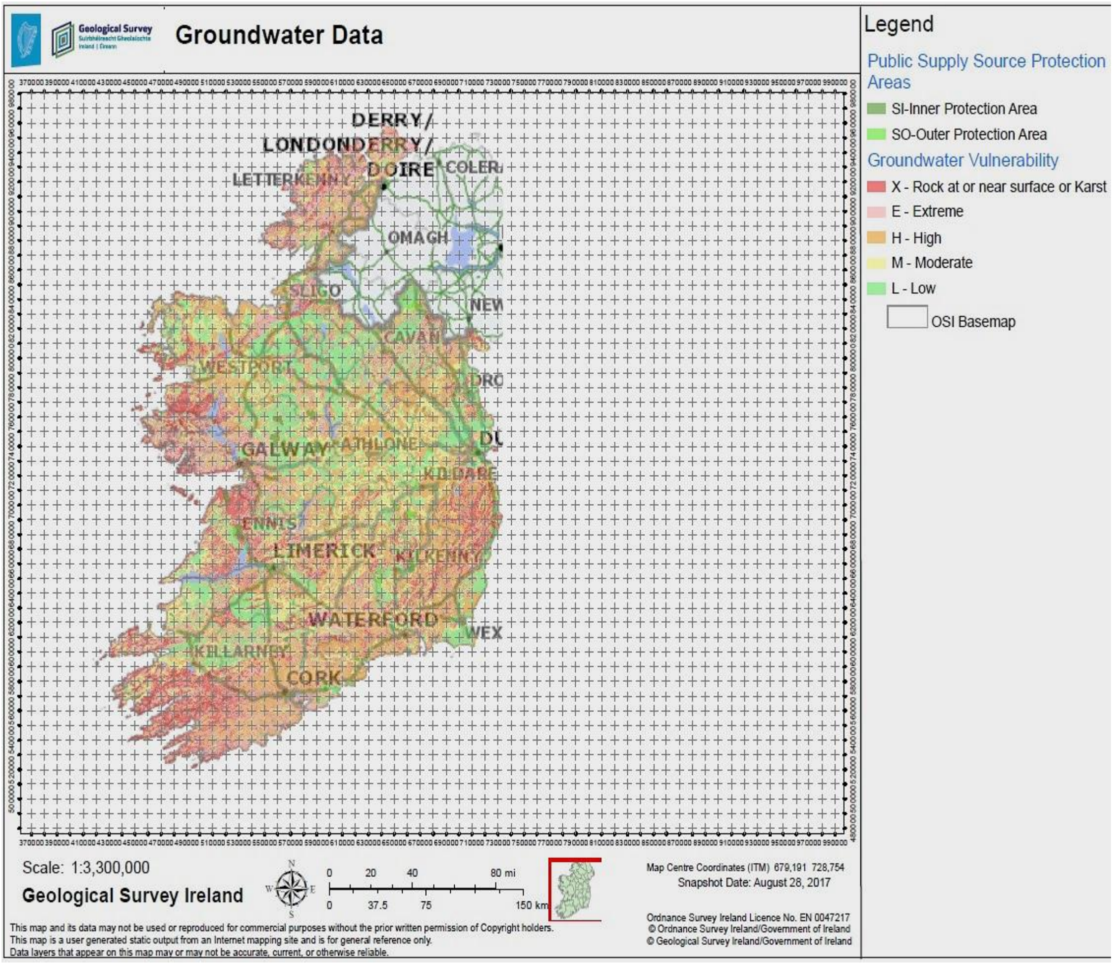
[13] European Commission (2008). Groundwater Protection in Europe. *Office for Official Publications of the European Communities*. Luxembourg.

Figure 3.1: Groundwater Vulnerability and Source Protection



Source: Geological Survey Ireland. Groundwater Data Viewer

The vulnerability mapping is essential as it indicates the likelihood of contamination and therefore what land management practices are appropriate. Secondly, the mapping ensures that the Groundwater Protection Schemes are not unnecessarily restrictive on human activity. Lastly, the map helps in the choice of preventive measures enabling sustainable development.

3.3 Profile of Groundwater Use, Quality and Risks

It is estimated that there are more than 160,000 wells and springs in use nationally. This comprises:

- More than 160,000 private supplies, of which the majority are boreholes or dug wells
- More than 250 Group Water Schemes (GWSs) which supply more than 50 people rely on boreholes, dug wells or springs, some with more than one abstraction point. This represents two thirds of the larger GWSs.
- According to IW there are 865 boreholes supplying 476 Water treatment plants, and 148 springs supplying 148 water treatment plants.

With such a large supply of water from the ground in use, maintaining the quality of groundwater is critical. Under the EU Drinking Water Directive[14] (DWD), which applies to all supplies serving more than 50 people or supplying more than $10m^3$/day, certain drinking water quality standards, which are defined by a range of parameters, must be met.[15] The EU Water Framework Directive (WFD - 2000/60/EC) requires EU member states to achieve good quality and quantity status in all water surface and groundwater bodies. In Ireland, The Environmental Protection Agency (EPA) is responsible for monitoring the quality of drinking water, with the local authorities being responsible for group water schemes and small private supplies serving more than 10 cubic meters or 50 people per day, or being used in food preparation or related activities. The EPA are responsible for the national water quality monitoring network, and reports on drinking water quality and on environmental groundwater and surface water quality.

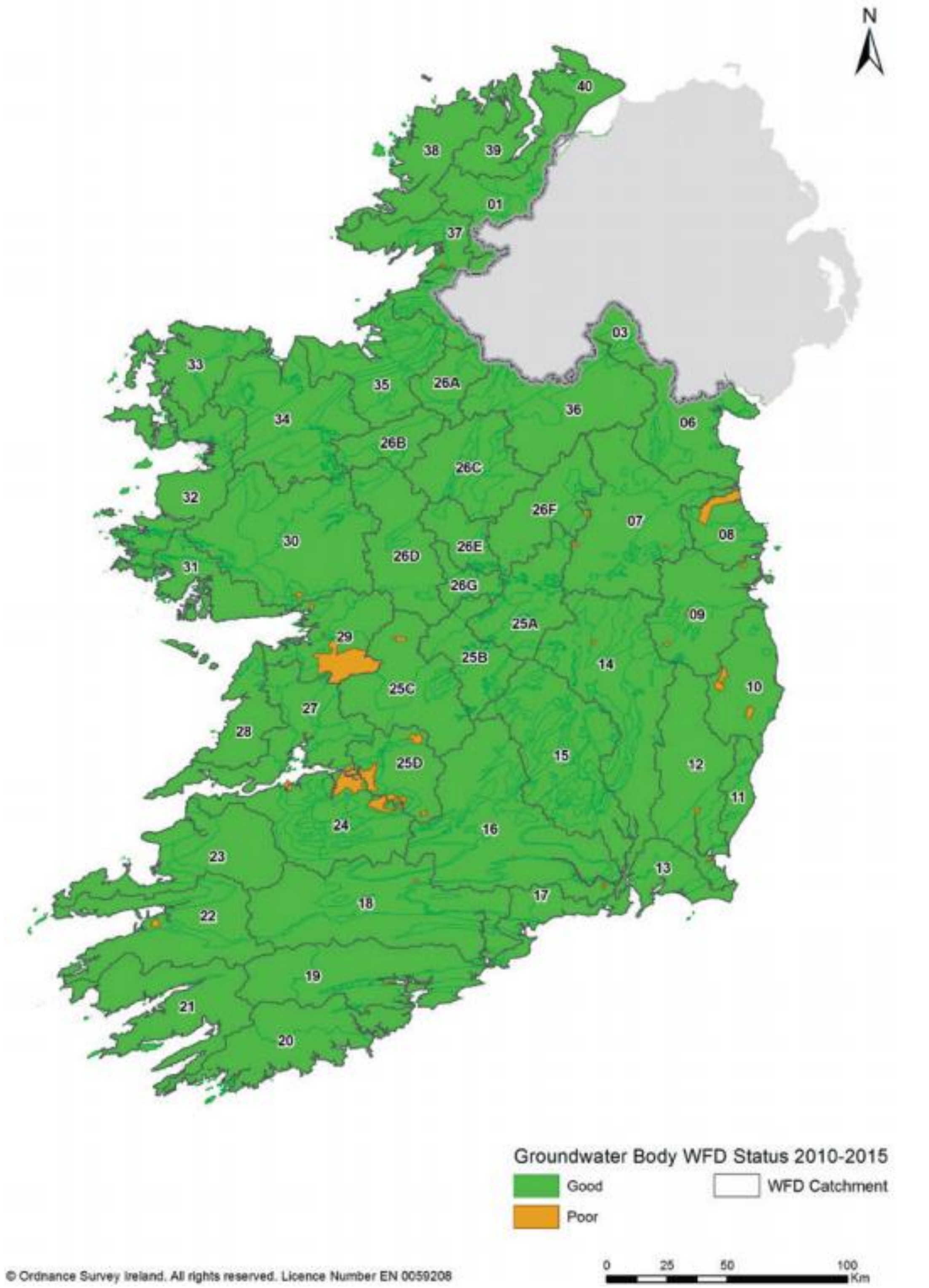
In the report on the Water Quality of Ireland 2010-2015,[16] an in-depth analysis of groundwater quality was conducted, which found that around 1% of the area of groundwater bodies in Ireland are classified as 'poor' based on chemical status. This represented an improvement from the first cycle of the WFD river-basin management planning, when around 14% of groundwater bodies were classified as poor. Whilst the number of bodies at poor chemical status increased, this was due to improved information and technical approach, rather than water quality deterioration. The bodies with poor chemical status also tended to be smaller groundwater bodies, with their poor chemical status relating to historic contamination from sources such as mines, industry and landfill.

[14] Council directive 98/83/EC updated in (EU) 2015/1787.

[15] Moe, H., Ciurana, O., Barret, P. et al. (2014). Baseline Characterisation of Groundwater, Surface Water and Aquatic Ecosystems. *Environmental Protection Agency.*

[16] Fanning, A., Craig, M., et al. (2017). Water Quality in Ireland 2010-2015. *Environmental Protection Agency*. http://www.epa.ie/pubs/reports/water/waterqua/Water%20Quality%20in%20Ireland%202010-2015.pdf

Figure 3.2: Status of Groundwater Bodies



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Source: Water Quality in Ireland 2010-2015

The most prevalent sources of groundwater pollution include: impacts from agricultural activities (diffusely distributed nitrates, pesticides/ herbicides, microbial contamination), septic tanks, and contaminated land associated with industrial activities. The WFD, GWD and EQS Directives established a legal framework[17] for controlling pollutants such as organophosphorus compounds, metals, and materials in suspension. Among these pollutants, there are priority hazardous substances, identified as 13 out of a total of 33 priority substances, which do not break down and remain existent in the environment. They pose long-term risks to human health and the eco-system; therefore, the directive aims to phase out these contaminants completely within the next 10 years.

Another potential source for groundwater contamination arises from Unconventional Gas Exploration and Extraction (UGEE). UGEE involves hydraulic fracturing of low permeability rocks to permit the extraction of natural gas on a commercial scale from unconventional sources such as shale gas deposits, coal seams, and tight sandstones. Hydraulic fracturing involves the drilling and construction of deep wells with an associated environmental risk. It should be noted that onshore fracking was banned in Ireland in July 2017.[18]

Groundwater pollution can impose additional costs upon society, including the costs of treating polluted waters to drinking water standards, and providing alternative water supply to those communities reliant on groundwater resources. This will include *inter alia* the cost of additional drilling activity, infrastructural investment, and/or the economic and time costs of utilising tankered or bottled water in the short term and the costs of clean-up and treatment of polluted groundwaters and any associated surface waters.

3.4 Economic Value of Groundwater

There are three main aspects of the economic value of groundwater in Ireland:

- Economic activity in relation to groundwater services;
- The economic value of groundwater resources used for drinking water or other purposes; and,
- The economic value of groundwater in the ecosystem service it provides.

While economic activity in relation to groundwater services represents the most obvious and tangible measure of economic activity, it is useful to examine the economic value of groundwater in Ireland. We estimate the value of ground water on two bases. The first is the yield value of wells, estimated from GSI data on yields and gross to total population values using GSI, EPA and CSO data. The yield does not represent activity *per se*. However, it could be considered a measure of the potential value of a national asset. The second value is in terms of estimates of actual usage, and for this we use CSO data on usage per household and households by type of water scheme usage. We also report an estimate of groundwater reserves, though given that abstraction for some of this source is not currently possible, we have not put an economic value on it. The value of groundwater in providing ecosystem services, such as the typical 30-70% of baseflow to rivers, is not quantified. There are several important, protected, ecosystem types which are reliant on groundwater.

[17] Directive 2000/60/EC of European Parliament.

[18] Petroleum and Other Minerals Development (Prohibition of Onshore Hydraulic Fracturing) Act 2017, *Number 15 of 2017.*

Indecon has undertaken an econometric investigation into the value of groundwater in Ireland. The GSI provided an online database of all Irish groundwater wells collated on a county-by-county basis. This database includes, *inter alia*:

- Yield per well;
- Production class,
- Well type; and,
- Well and Rock Depth.

Approximately half of the wells have values reported for the variables outlined above. In order to accurately estimate the total yield values of all wells, it was necessary to create a predictive econometric model using ordinary least squares (OLS) regression techniques for the other wells. Indecon has created an econometric model of categorical variables to predict the total yield for all Irish boreholes measured. Almost 37,000 observations have been included in our model. Indecon applied OLS regression techniques to the log value of the yield, on categorical variables (yield class, production class) and continuous variables (Depth_m, Depth_rock_m also in logs) which yielded a predictive model with 79% R-squared, and statistically significant relevant coefficient estimates.

This predictive model was used to estimate the yield of total groundwater resources in Ireland through predicting the yield of those wells with missing values. The average daily yield prediction for all wells (including those predicted) is $86m^3$ per day across 36,346 observations (wells/resources). A variable in the database allows us to break down the actual data, and also the predictions by source/usage type. The breakdown of the actual yields, and the predicted yields where these are missing, by type is provided in the table below.

Table 3.1: Breakdown of Yield and Predicted Yield for Groundwater by Type

Source Use	Actual Yield	Number	Predicted Yield	Number
Agricultural & domestic use	55.8	5,534	42.9	8,543
Agricultural use only	124.0	146	56.7	430
Domestic use only	55.0	2,748	42.1	4,462
Group Scheme	373.2	363	289.3	504
Industrial use	446.3	451	258.3	841
Other	521.4	312	81.5	2,760
Public supply (County Council)	819.8	1,138	481.3	2,134
Unknown	83.0	8,784	56.4	16,693

Source: Indecon analysis of GSI data

The 36,346 wells represent a sample of the total number of wells in Ireland. CSO Census data tracks household water usage by type of scheme. This is shown in the table overleaf.

Table 3.2: Private Households by Type of Water Supply, 2011			
	State	**Aggregate Town Area**	**Aggregate Rural Area**
Public mains	1,247,185	965,010	282,175
Local authority group scheme	144,428	44,794	99,634
Private group scheme	45,774	1,998	43,776
Other private source	161,532	3,700	157,832
No piped water	2,080	235	1,845
Not stated	48,409	34,336	14,073
All types of water supply	**1,649,408**	**1,050,073**	**599,335**
Source: CSO Census 2011			

GSI has informed Indecon that the vast majority of the other private source water and some of the private group schemes in rural areas would be groundwater resources. GSI has provided an estimate of 170,000 total groundwater-using households in Ireland.

Our next step is to estimate the total yield for the State from the above data. We assume that small and domestic and domestic and agricultural users are once-off wells, e.g., one user per well. We gross these up in proportion to the 161k other private wells nationally (the total in the GSI database yield is increased proportionally). A shadow price of water of €0.14/m^3 was used as the average variable cost of a large public scheme.

For private group scheme users and for local authority group schemes, we estimated the percentage of total private group schemes and local authority group schemes which were groundwater using and the number of HH served per scheme using EPA data. We then grossed up/proportionally adjusted the yield figures in the GSI data to the totals based on the total household figures from CSO. We present two estimates, with and without the unknown and other category. We did not attempt to gross these up to the State total. Further, no attempt was made to gross the sector referred to as agricultural only up to the State total. It is noteworthy that many agriculture users will be agriculture and domestic, and some may be industrial and connected to public mains, but the proportion of the users represented in the GSI sample and predicting the national total would be beyond the scope of our work.

We then applied the value of €0.14/m^3 by 365 days a year to get an estimate of the total value of the annual yield, and summed over the classes.

Table 3.3: Yield and Value of Groundwater by Type			
Type	**Estimated Number of Abstraction Points**	**Yield State m^3/d**	**€m Value per annum**
Domestic & Agriculture	161,532	6,867,551	350.9
Local Authority Public Group	1,013	487,590	24.9
Private Group*	365	105,599	5.4
Industrial & Commercial**	841	217,222	11.1
Unknown/other/agriculture	19,883	2,335,737	119.4
Total without Unknown/Other & Agriculture		**8,257,751**	**392.3**
Total with Unknown/Other/Agriculture		**10,593,488**	**511.7**

Source: Indecon analysis

Notes: * Estimated number base on the number of privately sourced schemes federated to the National Federation of Group Water Schemes, as well as the estimate of 15 privately sourced schemes that were not federated for 2016.[19]

** Dublin City Council, in February 2009, identified 160 industrial wells but noted that this was likely to be a fraction of total industrial or commercial groundwater users.[20]

As an indicative lower bound on potential yields, Indecon estimated the value of the groundwater resource for those wells that excluded the value of yield from wells listed as 'other' 'unknown' and 'Agriculture only' in the GSI database; for the upper bound we include those values. We note that a total count of groundwater sources for the State from the EPA database gives about 38,000 ground water sources.

It should also be noted that the above estimates are sensitive to the price applied to the well yields. As such, our estimates could be higher (or lower)[21] if using consumer or willingness-to-pay value rather than production cost value of water, or could be lower if marginal production cost value for smaller groundwater wells are lower than large water scheme unit costs.

Table 3.4: Annual Value of Irish Groundwater Resource	
Lower Bound, € Million	**Upper Bound, € Million**
392.3	511.7

Source: Indecon analysis

The calculation above is based on the potential yield of Irish groundwater through existing extraction points. An estimate can also be made of the total potential yield in any one year of the groundwater resource in Ireland. Groundwater is volumetrically significant in Ireland,

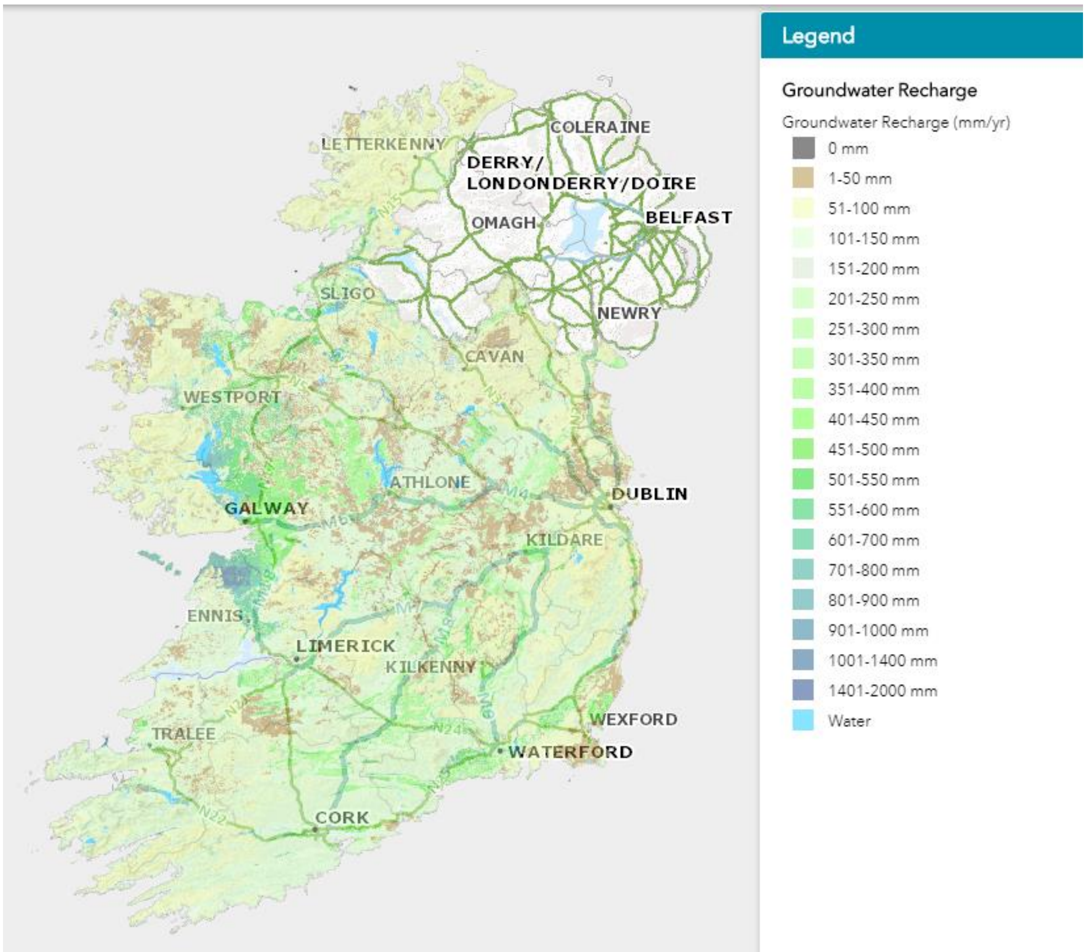
[19] National Federation of Group Water Schemes. *Annual Report, 2016. http://www.nfgws.ie/f/2016%20Annual%20Report.pdf*

[20] Dublin City Council. *Groundwater Abstractions Pressure Assessment, February 2009. http://www.wfdireland.ie/docs/24_Abstractions/Groundwater%20Abstractions%20February%202009%20ISSUE_v2.pdf*

[21] In general, consumer willingness-to-pay estimates must come from contingent valuation surveys which are subject to potential biases in stated preferences. Consumers' 'true' willingness-to-pay will be governed by available alternatives. It cannot be assumed that, for example, the cost of bottled water is a reasonable figure for the average consumer value for all household water, although, this is probably an upper bound for drinking water. However, the vast majority of household water use is not for drinking.

despite the fractured bedrock aquifer having low storage capacity (<5%). An estimate of the groundwater reserves that are replenished annually from rainfall can be made using the Geological Survey Ireland groundwater recharge map (Figure 3.3). This is achieved by multiplying the land surface area receiving different amounts of recharge.

Figure 3.3: Groundwater Recharge Map



Source: GSI

Not all of the replenished groundwater reserves are available for abstraction, because rivers, lakes and other groundwater-dependent ecosystems need groundwater to sustain them. The WFD Groundwater Working Group give a range of 2-10% of as acceptable to abstract without putting the dependent rivers and large lakes at risk (Table 3.5).

Table 3.5: Groundwater Abstraction Thresholds for Reviews and Large Lakes		
	Avg. Specific Yield or Storage of Groundwater Screening Unit	
	Low Storage (<5%)	**High Storage (>=10%)**
>30%*	**High Potential Impact**	**High Potential Impact**
20%-30%	**High Potential Impact**	**Mod. Potential Impact**
10%-20%	**Mod. Potential Impact**	**Low Potential Impact**
2%-10%	**Low Potential Impact**	**Low Potential Impact**
<2%	**No Potential Impact**	**No Potential Impact**

Source: GSI. * i.e. if groundwater abstraction is greater than 30% of long term average recharge.

The theoretical usable groundwater reserves are between approximately 650,000 – 3,250,000 m3/d. This estimate does not take into account the technical limitations on abstracting this volume. Beyond technical limitations, it should also be noted there are regulatory and environmental restrictions on abstracting additional groundwater. With these caveats in mind, it is important to emphasise that the abstractable resource will be considerably less than the 'usable' groundwater resource.

Groundwater is abstracted via wells, springs and dug wells to provide drinking water. The supplies to dwellings and businesses may be public, Group Water Schemes, or private. There are private abstractions for other purposes, such as food and drink manufacture (e.g., food processing, food components, bottled water), the agriculture sector (dairying, piggeries, irrigation), the hospitality industry (hotels, bars, restaurants), and industry and manufacture (e.g. pharmaceuticals, IT, building materials). Estimates of the value of abstracted groundwater used for drinking water are calculated based on the following:

- Public abstraction data: Irish Water (October 2017).
- Group: National Federation of Group Water Schemes (August 2017)
- Private domestic: CSO (2016).

The shadow price of €0.14/m^3.is used to calculate an aggregate value of €41.3m per annum.

Table 3.6: Estimate of Value/Cost of Extracted Groundwater			
Type	**Volume m^3/d**	**Daily Value (€ thousand)**	**Annual Value (€ million)**
Public	700,000	€98	€35.8
Group	46,750	€7	€2.4
Private (domestic)	61,867	€9	€3.2
Total	**808,617**	**€113**	**€41.3**

Source: Indecon analysis

3.5 Economic Impact of Groundwater Supply Services

Groundwater is used to supply drinking water to public and group schemes and private businesses or individuals. Groundwater is also used via private wells/springs in the agriculture sector, the food and drink sector, and industry. The supply chain includes services and products from drillers, hydrogeologists, engineers, pump manufacturers/distributers, water chemistry analytical facilities, water treatment systems, maintenance, and caretaking.

There is other economic activity associated with assessing and protecting groundwater, though which is not directly related to its use to supply drinking water. For example, Environmental Impact Assessments are required for any infrastructural or other large developments to address groundwater and assess impacts, and are undertaken by hydrogeologists.

Within published Central Statistics Office data on actual economic activity, the NACE Rev.2 code 36 identifies water collection, treatment and supply. According to the CSO this NACE Rev.2 code includes activities, both public and private, such as collection of water from rivers, lakes and wells, treatment of water for industrial and other purposes, water desalting, water collection, purification and distribution as well as water conservation.

Groundwater contributes approximately 25% of the total water supplies, and our estimate of the total turnover and GVA of the groundwater collection, treatment and supply was derived by taking 25% of the values that applied to this NACE code. This is shown in the next table. Indecon notes the sudden increase in turnover and GVA post-2013.

Table 3.7: Groundwater Collection, Treatment and Supply (Turnover and GVA)

	2008	2009	2010	2011	2012	2013	2014	2015	2016*
Total Turnover (€million)	4.7	17.3	6.1	5.1	5.1	29.2	14.4	35.0	35.2
Gross Value Added (€million)	1.8	3.7	2.0	2.2	2.3	15.3	5.5	-29.0	18.3
Labour Costs - Wages and salaries (€million)	1.3	3.5	1.4	1.7	1.9	2.0	5.1	11.2	11.3

Source: Indecon analysis of CSO data

*Note: GVA based on Indecon multipliers for 2016. 2016 values estimated based on CSO Industry turnover growth indices. These figures suggest a lower bound based on 25% of public water supply being groundwater and are conservative and prudent estimate.

The direct economic impacts of this turnover are presented next in terms of employment (FTE) and GVA. Groundwater services supported approx. 205 jobs and €18.3 million in GVA in 2016. This is a result of the activities carried out under NACE REV. 2 code 36 as outlined previously and is likely to be a conservative estimate of the size of the direct impacts of groundwater supply services in Ireland.

Accounting for cross-sectoral flows, the indirect and induced impacts account for an additional €29.5 million in output. This is equivalent to €17.8 million in GVA and 539 jobs in full-time equivalent terms. Indirect groundwater activities such as environmental impact assessments conducted by hydrogeologists and groundwater specialists and geotechnical engineers engaged in construction projects. The Institute of Geologists of Ireland had 188 professional members in

2016 for example[22] These indirect and induced impacts would also include activities in the supply chain such as pump manufacturing, water chemistry analytical facilities, maintenance, caretaking and drillers.

The overall economy wide impacts of groundwater collection, treatment and supply services is presented in Table 3.8, and shows that Indecon estimates there to be 745 FTEs supported by groundwater collection, treatment and supply, as well as €36 million in GVA. This excludes any social and other benefits to users associated with having a source of groundwater resources, and is therefore likely to underestimate the overall value of the sector. Water is an essential requirement for householders, as well as for the farming sector and for businesses, and any disruption to water supplies can have significant economic consequences.

Table 3.8: Economic Impacts of Groundwater Collection, Treatment, and Supply - 2016

Groundwater Collection, Treatment and Supply	Output (€million)	GVA (€million)	Employment (FTE)
Direct Economic Impacts	35.2	18.3	205
Indirect and Induced Impacts	29.5	17.8	539
Economy-Wide Impacts	**64.7**	**36.0**	**745**

Source: Indecon analysis

3.6 Summary of Key Findings

This section examined the groundwater resources in Ireland in terms of the economic value of the groundwater and the impact of expenditure on groundwater services. Also provided is a profile of the quality and risks of groundwater in Ireland. The key findings were as follows:

- Groundwater provides approximately 20-25% of the public water supply by volume in Ireland, however there is a strong degree of geographic variation in this number. At least 100,000 wells or springs are currently in use in Ireland.
- Groundwater quality is regulated on an EU level by the EU Drinking Water Directive (WFD) which regulates the acceptable levels of a wide range of parameters. Irish Water and the EPA are involved in the collection and testing of water in Ireland.
- Groundwater research, data and mapping exercises, including at risk and vulnerability mapping is carried out by GSI.
- The risks of groundwater pollution can impose additional costs upon society, including the costs of providing alternative water supply to those communities reliant on groundwater resources. This will include *inter alia* the cost of additional drilling activity, infrastructural investment, and/or the economic and time costs of utilising tankered or bottled water in the short term.
- Indecon has undertaken innovative new econometric modelling of the value of groundwater resources. Using the GSI groundwater well database, a predictive model

[22] Institute of Geologists of Ireland. *Annual Report and Financial Statements 2015-2016.* *http://igi.ie/assets/files/Annual%20Reports/IGI%20Annual%20Report%202015-2016_Appended.pdf*

was used to estimate the potential yield of total groundwater resources from existing extraction points in Ireland. Indecon has estimated an indicative value range of €392 million to €512 million.

- The economic impact of groundwater resources in expenditure terms is estimated via the economy's expenditure on groundwater services, including collection, treatment, and supply. Groundwater services supported approx. 205 jobs in 2016. Accounting for cross-sectoral flows, the overall economic impacts account for €64.7 million in output. This is equivalent to €36 million in GVA and 745 jobs in full-time equivalent terms.

4 Geoscience Education & Research

4.1 Introduction

Geoscience education and research employs highly skilled individuals and contributes to Ireland's knowledge base. In this section, Indecon examines geoscience education through an analysis of the educational institutions and related graduate output. Geoscience research is also examined across several institutions, with a particular focus on the Irish Centre for Research in Applied Geosciences (iCRAG). Major geoscience-related activities and projects, such as Tellus and INFOMAR, are also included.

4.2 Geoscience Education

There are a number of Higher Education Institutions who are involved in geoscience education and research in Ireland. The activities of these bodies are discussed below.

University College Dublin

University College Dublin currently has 23 Postdoc Research Fellows and 32 Postgraduate students in the UCD School of Earth Sciences. They group their research into the following areas: fault analysis, geochronology, petrology and isotope geochemistry, geophysics, marine and petroleum geology, palaeobiology and palaeoclimatology. The School of Earth Sciences at UCD is the host for the Irish Centre for Research in Applied Geosciences (iCRAG) which will be discussed in more detail subsequently. UCD also facilitates research into isotope geochemistry with the National Centre for Isotope Geochemistry (NCIG) located in the UCD School of Earth Sciences. It supports three of the areas of research at UCD – geochronology, petrology and isotope geochemistry, marine and petroleum geology and palaeoclimatology, as well as collaboration with Trinity College Dublin and the University of Cork and international institutions.

Trinity College Dublin

The Geology Department in Trinity College Dublin is part of the School of Natural Sciences and investigates a number of different areas from energy and resource security to climate change. Their research follows three main themes, which are geochemistry, earth resources, and evolution and environment. Geochemistry has 11 researchers investigating areas such as spatial and temporal variability of element cycles and the make-up of rocks, minerals and other compounds, as well as the evolution of magmas and tectonic processes. There are 10 researchers investigating how resources accumulate due to earth system process on what the impacts of their extraction and use are. This involves research into mineral, groundwater and hydrocarbon resources such as petroleum. They work with other institutions, both industrial and governmental, to discover new resource reserves and advise on public policy that is sustainable, as well as promoting awareness of environmental issues. The evolution and environment theme currently involves 13 researchers who are investigating the evolution of the planet and its climate. This involves geological mapping and examining fossils to help determine past environments and potential future environments.

NUI Galway

NUI Galway has a number of different research projects and programmes in its Earth and Ocean Science divisions of the School of Natural Sciences. They are outlined below:

- The Biogeoscience Research Group, which consists of 12 members. These members come from a number of disciplines ranging from geophysics to oceanography and sedimentology, to investigate groundwater and seawater interactions in coastal areas as well as metals in the environment in Ireland. They are currently studying, amongst other projects, the sedimentary processes that initiate and maintain bedforms with the focus of the project in Galway Bay.
- The Coral Fish Research Project, which is an EU-wide study looking into the relationships between coral, fish and fisheries.
- The Geofluids Research Group has two members and attempts to gain a clear understanding of geological processes such as the deposition of ore and petroleum by determining the chemistry of fluid components in crystal cavities.
- The Geoscience Visualisation Research Group which has four members currently and is working on projects such as the communication of geo-knowledge, focussed in the Burren region, to schools, visitor centres and to the population.
- VOCAB – The Ocean Acidification and Biogeochemistry programme which is funded by the Marine Research Programme 2014-2020, looks into assessing marine ecosystems in Irish waters and their vulnerability to ocean acidification.

University College Cork

Research conducted by University College Cork at their School of Biological, Earth and Environmental Sciences (BESS) is divided into four main areas of research; environmental science, geosciences research, plant science and zoology and ecology. Environmental science has seven researchers in areas such as water quality monitoring and management, pharmaceutical emissions, wetland ecosystems and the biological treatment of water and wastewater. They recently established, as a result of collaboration with the United Nations Environment Programme (UNEP) and the Irish Government, a UNEP Centre for global water quality monitoring in BEES. The geosciences research section is involved with iCRAG, conducting research into solid earth, ancient life and environments and applied geosciences. It currently has 14 staff members. The main areas of plant science research in BEES are plant-environment interactions, sustainable crop production and plant biotechnology. Members of the zoology and ecology research team in BEES also serve on boards of institutions such as the Marine Institute, the Heritage Council and UN Water. Their areas of research include fisheries and aquaculture, marine biology, freshwater biology and behavioural ecology, amongst others.

Maynooth University

The Department of Geography at Maynooth University explores the relationships between natural sciences, the social sciences and arts and the humanities. It is home to a number of research centres such as the:

- National Institute of Regional and Spatial Analysis (NIRSA);

- The National Centre for Geocomputation (NCG);
- The Irish Climate Analysis Research Unit (ICARUS);
- Environmental Physics Research Unit; and,
- The Centre for Health Geoinformatics.

ICARUS is the leading centre for climate change research in Ireland and has three main strands or themes – paleoclimate analysis, climate analysis and regional climate modelling. ICARUS also hosts the Irish Sediment Core Research Facilities (ISCORF) which is a national research facility analysing sediment cores.

University of Limerick

UL is involved in geoscience-related academic teaching and research. The University consists of four faculties, with geoscience activity primarily being undertaken by the Faculty of Science and Engineering. The Department of Biological Sciences is active in the geoscience space through its offering of courses such as Environmental Science. Research undertaken by the Department that is related to geoscience includes environmental research into areas such as greenhouse gas emissions and soil carbon stocks. The Department of Chemical Sciences also conducts geoscience-oriented research, in areas such as environmental modelling and peat technology. UL's School of Engineering has a large number of graduate student output and research, whose skills are applicable to areas within geoscience.

Mary Immaculate College (MIC), whose university level College of Education and the Liberal Arts is academically linked with the University of Limerick, offers geoscience-related courses through its School of Geography. The Department accepts approximately 450 students per annum, and is also involved in research in areas such as environmental change and palaeoecology. The Department is currently in receipt of research funding from the Environmental Protection Agency.

Dublin City University

Dublin City University (DCU) has an interdisciplinary School of History and Geography which has a number of different research interests including:

- The Historical Geography of Ireland;
- Social Geography;
- Economic Geography;
- Urban Geography; and,
- Past and present climates and climate interactions.

The last of these focuses on Irish historical geology and geomorphology, as well as Irish landscape formation. This research helps to shape understanding and policy in Ireland in this area.

Dublin Institute for Advanced Studies (DIAS)

DIAS is a statutory corporation established in 1940. It is a publicly funded independent centre for research in basic disciples. DIAS has three schools (Celtic studies, Cosmic Physics, Theoretical Physics). The school of Cosmic Physics contains sub-areas of research related to geoscience. The

School is involved in geophysics, and the geophysics section studies the tectonic and dynamic structure of the Earth using the methods of physics combined with the other geosciences – geology, geochemistry, petrology, geochronology and paleoecology. The school also specialises in marine geophysics. DIAS also provides training courses in advanced quantitative analysis that have been promoted in conjunction with GSI.

Institute of Technologies (IoT)

The network of Institutes of Technologies in Ireland is closely involved in educating graduates for work in the geoscience sector. A list of IoTs with geoscience-related degrees is provided below. These courses are generally in the fields of science and engineering, and a high proportion were environmental in nature, reflecting the demand for these degrees.

- Dublin Institute of Technology
- Institute of Technology Tallaght
- Institute of Technology Blanchardstown
- Letterkenny Institute of Technology
- Dundalk Institute of Technology
- Sligo Institute of Technology
- Athlone Institute of Technology
- Carlow Institute of Technology
- Waterford Institute of Technology
- Galway Mayo Institute of Technology
- Limerick Institute of Technology
- Tralee Institute of Technology
- Cork Institute of Technology

University Rankings

The table below presents the rankings of Irish academic institutions across different subject matters, according to the QS World University Rankings. Trinity College Dublin is ranked in the top 100 in both metallurgical sciences and geography. Ireland has four academic institutions in the top 300 for environmental sciences and two in the top 200 of earth and marine sciences.

The QS World Rankings by subject take account of four components: academic reputation; employer reputation; research citations by paper; and a H-Index (measures productivity and impact of published work). These are weighted according to each discipline.

Table 4.1: QS World University Rankings of Irish Universities by Subject, 2016

Academic Institution	Earth and Marine Sciences	Environmental Sciences	Metallurgical Sciences	Geography
Trinity College Dublin	-	201-250	51-100	51-100
University College Dublin	151-200	201-250	151-200	101-150
University College Cork	-	201-250	-	-
NUI Galway	151-200	251-300	-	151-200
Maynooth University	-	-	-	151-200

Source: QS World University Rankings

It should be noted that the above only includes institutions with university status and so excludes DIAS and institutes of technologies.

Geoscience Graduates

In terms of geoscience graduates, Indecon has collated a selection of studies by ISCED classification,[23] presented in the table below. In 2016 there were 1,547 graduates in geoscience-related fields. Indecon considers this an underestimate as many graduates from traditional engineering and scientific fields are likely to find employment in geoscience-related fields.

Table 4.2: Geoscience Graduates Across All HEA-Funded Institutions, 2016

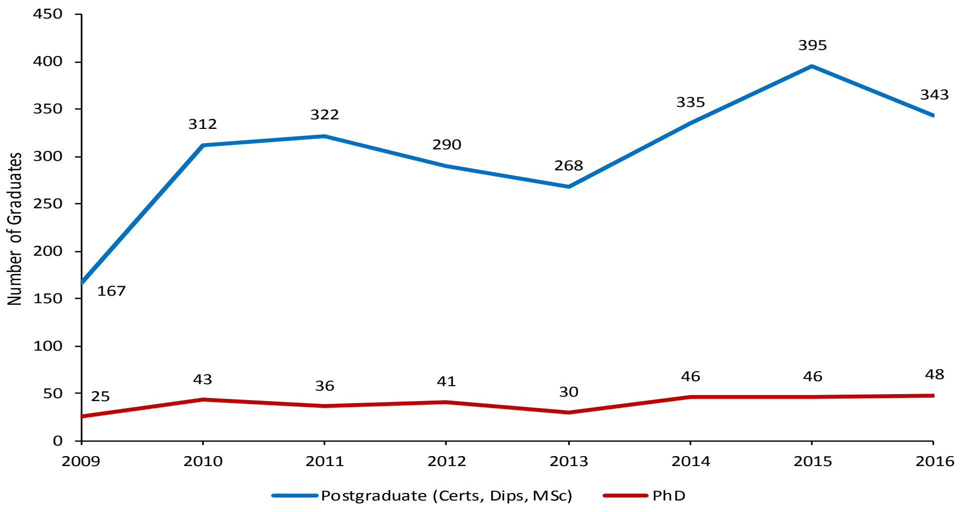
Direct Geoscience Degrees	**Undergrad (Certs, Dips, Degrees)**	**Postgrad (Certs, Dips, MSc)**	**PhD**	**Total**
(0532) Earth sciences	139	77	26	242
(0712) Environmental protection technology	40	8	0	48
(0520) Environment not further defined	26	12	17	55
(0521) Environmental sciences	351	129	2	482
Indirect Geoscience Degrees				
(0522) Natural environments and wildlife	17	48	3	68
(0713) Electricity and energy (engineering)	461	69	0	530
(0812) Horticulture	95	0	0	95
(0821) Forestry	27	0	0	27
Total	**1,156**	**343**	**48**	**1,547**

Source: Indecon analysis of HEA statistics

A historical examination of postgraduate and PhD graduates in geoscience related fields is provided in the figure below. The evidence shows that the number of postgrads (non-PhD) has grown since 2009 and accounted for 343 postgraduates in 2016 and there were an additional 48 PhD graduates.

[23] International Standard Classification of Education

Figure 4.1: Geoscience-Related Graduates (Postgraduates and PhD), 2009-2016



Source: Indecon analysis of HEA statistics.
Note: Field of Study has changed over time. These have included Enivronmetnal Science, Earth Science, Energy engineering, mining & extraction, horticulture, forestry, environmental protection

4.3 Geoscience Activities & Research

Various organisations are directly involved in the geoscience sector. These include:

- The Geological Survey Ireland;
- The Marine Institute;
- Teagasc;
- Met Éireann;
- Environmental Protection Agency;
- The Department of Communications, Climate Action and Environment;
- Science Foundation Ireland (SFI);
- Irish Research Council (IRC);
- Sustainable Energy Ireland; and,
- Socio-Economic Marine Research Unit at NUI Galway.

Geological Survey Ireland

The Geological Survey Ireland (GSI), is the national geoscience agency and acquires and manages geoscience information, partners on geoscience projects and supports research. GSI conducts research into geoscience, but its main focus is on data gathering initiatives and mapping projects such as INFOMAR, Tellus and Groundwater3D. GSI also engages in research with GSI publishing in academic journals, presenting their findings and research at conferences, conducting data gathering for future research and funding research initiatives.

The GSI supports and conducts research into this valuable sector in the Irish economy and allows for the development of natural resources and compilation of key geological and geoscience

databases for the research that they do. The Research Roadmap published by the GSI established the following as the GSI's Principal Goals:[24]

- To support sustainable development of Ireland's natural resources;
- To provide reliable geoscience support for environmental protection and effective spatial planning;
- Complete geological surveys and mapping in priority areas in response to the needs of the specific sectors and customers; and,
- To support the knowledge economy through the provision of access to geoscience databases and supporting business development, priority research and education services.

In order to meet these goals, GSI has a number of different programmes; the Bedrock Mapping Programme, the Groundwater Programme, Heritage and Planning, INFOMAR, the Minerals Programme, the Quaternary and Geotechnical Programme as well as support services such as information management and cartography.

Marine Institute

The Marine Institute was set up under the Marine Institute Act of 1991 and is responsible for marine research, technological development and innovation in Ireland. The Marine Institute currently has over 170 staff working in areas such as aquaculture, oceanography and seabed mapping. The Marine Institute recently published a new National Marine Research and Innovation Strategy.[25] This identifies the key areas of research such as renewable energy, climate change, ocean observation and seabed mapping. They maintain a number of data services in the National Marine Data Centre, including Ireland's Digital Ocean which contains a number of services such as online maps and also marine forecasts made by oceanographers.

Petroleum Affairs Division

The Petroleum Affairs Division (PAD) operates under the Department of Communications, Climate Action and Environment. Their role is to maximise the benefits of exploration and production of oil and gas resources that are indigenous to the state. They are responsible for licencing exploration and production activities, as well as regulating these activities. PAD is involved in supporting research into oil and gas resources in Ireland, which can inform their policy advice in the area.

Teagasc

Teagasc is the Agriculture and Food Development Authority in Ireland. It provides research, advice, support and training services to the food and agriculture industries as well as rural communities. Their four main research areas are: animal and grassland research and innovation; crops, environment and land use; food; and, rural economy and development. Some of their

[24] Geological Survey Ireland – Research Roadmap Presentation, 2016, Aoife Braden (Research Manager).

[25] Marine Institute, National Marine Research & Innovation Strategy 2017–2021.

research departments are involved in geoscience related research such as their Departments of Grassland Science Research and Agri-Environment Research.

Met Éireann

Met Éireann, a division of the Department of Housing, Planning, Community and Local Government, has a mission which is to monitor, analyse and predict weather and climate in Ireland. The information obtained through is the shared with the public, as well as specific institutions in the agriculture industry, amongst other industries. Amongst their key functions are a number related to the geoscience sector such as their commitments to:

- Enhance the quality of our climatological archives and provide easy and effective access to our databases; and,
- Contribute to the effective monitoring and good management of the natural environment.[26]

Environmental Protection Agency (EPA)

The EPA is Ireland's environmental protection and policing agency. The agency was established under the Environmental Protection Act 1992, and have derived additional mandates through other additional legislation and provisions.[27] The EPA's stated primary responsibilities include:

- Environmental licensing;
- Enforcement of environmental law;
- Environmental planning, education, and guidance;
- Monitoring, analysing and reporting on the environment;
- Regulating Ireland's greenhouse gas emissions;
- Environmental research development;
- Strategic environmental assessment;
- Waste management; and,
- Radiological protection.

Several of the above primary responsibilities relate directly to the geoscience sector in Ireland, and therefore it is necessary to consider research conducted by the EPA. For example, the EPA conducted a radon mapping programme to assess the geoscience hazard posed by this natural phenomenon (discussed in detail in Section 6). The EPA's involvement in the protection of the water supply also considered to be within the geoscience sector (in particular for the groundwater resources in Ireland).

Sustainable Energy Authority of Ireland (SEAI)

The SEAI is Ireland's national sustainable energy authority and was established via legislation (Sustainable Energy Act) in 2002. The SEAI has a wide-ranging remit including in the area of supporting energy policy through:

[26] Met Éireann, 2017. *About Us.* https://www.met.ie/about/default.asp.

[27] Waste Management Act 1996, Protection of the Environment Act 2003, Radiological Protection (Miscellaneous Provisions) 2014.

- Energy modelling, policy analysis and advice to inform policy making, programme design and reporting against EU energy efficiency and renewable energy targets;
- Official national and sectoral statistics for energy production, transformation and end use; and,
- Energy related research to inform the next generation of technology development and development of effective energy policies and measures.

The SEAI produce energy-related geoscientific maps of Ireland (e.g., geothermal maps and bioenergy maps), which have been completed in conjunction with GSI datasets. This indicates a high degree of cross-agency collaboration.

Other Institutions

There are other institutions providing research funding for geoscience in Ireland. Science Foundation Ireland (SFI) is a statutory body with responsibility for funding research in Science, Technology, Engineering and Mathematics (STEM) fields. SFI provides research funding for geoscientific research, and since 2015 has formally partnered with the GSI, the Marine Institute, and Teagasc to fund large scale research projects

The Irish Research Council (IRC) has a mission statement to enable and sustain a vibrant research community in Ireland by supporting excellent researcher in all disciples from arts to zoology. IRC support has been granted to research related to the geoscience sector in Ireland and, more recently, in direct collaboration with GSI. For example, the IRC launched a pilot programme entitled Research for Policy and Society and in 2016 this included geoscientific-research supported by GSI and the SEAI.

SEMRU is based at NUI Galway at the Whitaker Institute for Innovation and Societal Change. SEMRU's main focus is on assessing the economic importance of coastal and off-shore marine environments. Measuring the economic importance of these marine environments requires examination of the ecological value and utility, through fisheries and aquaculture, of the marine environment. SEMRU works with a number of different institutes, such as Teagasc and the Marine Institute, to carry out research, build research capacity, attract funding, developing third-level education modules and train PhD students as well as future researchers.

In 2017, SEMRU published *Ireland's Ocean Economy* which estimated the economic impact of marine industries in Ireland, as well as giving a profile of Ireland's ocean economy.[28] SEMRU calculated the value of each sector involved in the marine industry, such as sea fisheries, shipping and maritime transport, tourism, oil and gas exploration and production, and marine retail services amongst others. As can be seen in the next table, SEMRU estimated that turnover in the ocean economy was €5.7 billion in 2016, whilst direct GVA was €1.8 billion as a result. These figures were 23% and 20% higher than their 2014 estimates, reflecting the growth in the ocean economy in Ireland. In 2012, GVA was 0.8% of GDP, compared to 0.94% of GDP in 2016 which further shows the growing importance of the ocean economy. When indirect impacts are taken into account, SEMRU estimated that the ocean economy had a GVA of €3.37 billion in 2016 which was 1.7% of GDP.

[28] Socio-Economic Marine Research Unit, 2017. *Ireland's Ocean Economy.* Available at: http://www.nuigalway.ie/semru/documents/semru__irelands_ocean_economy_2017_online.pdf

Employment directly supported by the ocean economy grew by 18% between 2012 and 2016, with an estimated 30,176 FTEs directly supported by the ocean economy in 2016 compared to 25,523 in 2012.

Table 4.3: Economic Profile of Ireland's Ocean Economy

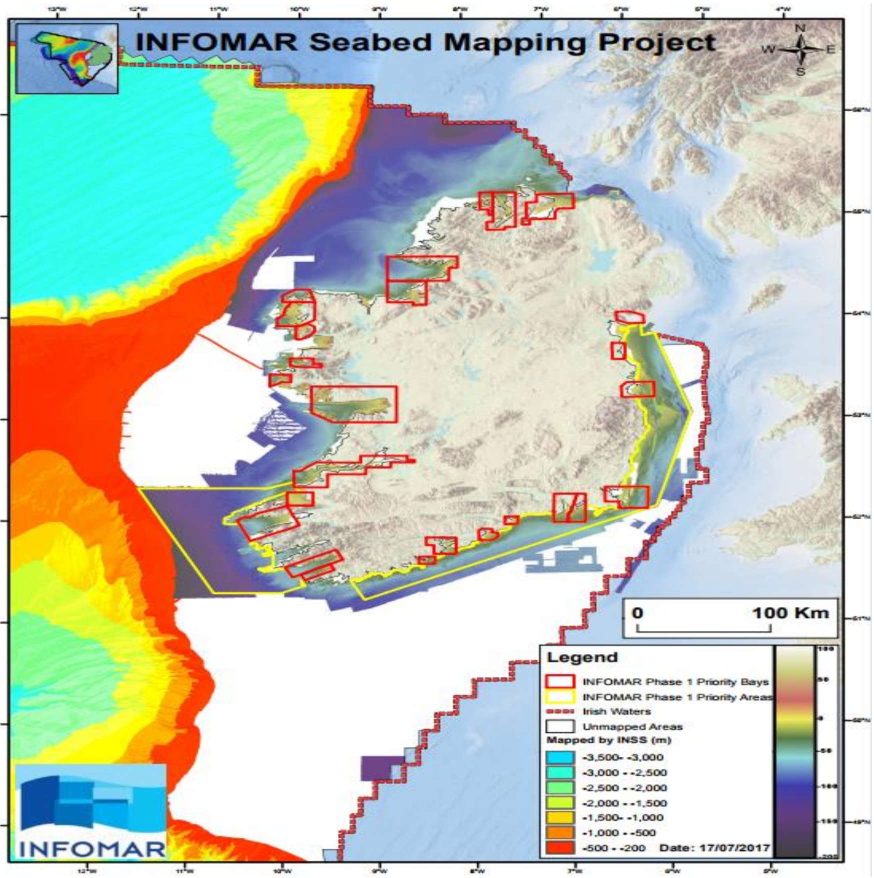
	2012	2014	2016	% Change 2012-2014	% Change 2014-2016
GVA	€1.2b	€1.5b	€1.8b	19%	20%
GVA as a % of GDP	0.8%	0.85%	0.94%	-	-
Turnover	€4.7b	€4.6b	€5.7b	-2%	23%
Employment (FTEs)	25,523	27,391	30,176	7%	10%

Source: SEMRU – Ireland's Ocean Economy

INFOMAR

INFOMAR is the Integrated Mapping for the Sustainable Development of Ireland's Marine Resource programme and is Ireland's national marine mapping programme. It is funded by DCCAE through GSI and delivered as a joint venture between the Geological Survey Ireland and the Marine Institute. INFOMAR is the successor of the GSI's Irish National Seabed Survey (INSS) and is producing world class digital mapping of Ireland's seabed, which underpins modern charting and all offshore development. While INSS and an earlier government shelf delimitation survey mapped all of Ireland's deeper waters (over 200m), INFOMAR is mapping all of Ireland's remaining marine territory. Phase 1 (2006-15) mapped 26 Priority Bays and three Priority offshore areas. Phase 2, to complete 100% mapping coverage, commenced in 2016 and will run to 2026. The value of INFOMAR is included as a contribution to the aggregate research activity conducted in Ireland of relevance to geoscience. The next figure presents the progress of INFOMAR as of July 2017.

Figure 4.2: INFOMAR Progress as of July 2017



Source: INFOMAR[29]

The outputs of INFOMAR are being utilised extensively by those active in offshore industry, including the fishing and aquaculture industry, extractive industries, charting and transport, marine research and marine renewable energy. The next table presents the estimated impact INFOMAR has had on the marine economy in 2016. These results are based in part on the SEMRU 'Ireland's Ocean Economy' study in 2017, and the INFOMAR Marine Mapping Options Appraisal Report completed in 2008.[30,31] This latter report attributed a specific proportion of each industry as part of its medium impact assessment of INFOMAR.

Data collected by, and made available through, the INFOMAR mapping programme has been used by researchers across all areas of the marine sector[32,33]. The maps inform fisheries and habitat researchers, the offshore renewable energy industry and shipping and transport. A range of research projects utilising this data have been directly funded in recent years.

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[29] INFOMAR, 2017. *INFOMAR Seabed Mapping Project.* http://www.infomar.ie/documents/INFOMAR_Progress_July_2017.pdf

[30] Socio-Economic Marine Research Unit, Ireland's Ocean Economy 2017

[31] PWC, INFOMAR Marine Mapping Study – Options Appraisal Report: Final Report, 2008

[32] DCCAE and GSI. *2015 SFI-GSI Investigator's Programme and 2016 SFI-GSI Investigator's Programme.* https://www.gsi.ie/documents/SFI-GSI%20IvP%202015%20and%202016.pdf

[33] http://www.gdgeo.com/projects/research-and-development

Recent work undertaken by UCC is jointly funded by GSI, SFI and the Marine Institute and gives an example of the interdisciplinary and applied nature of marine geoscience research. The project is investigating submarine canyons in the deep ocean which are rich environments supporting fisheries and with potential oil reservoirs. Advanced robotic technology and novel 3D visualisation tools are being used to study deep-water coral reefs in the Irish Porcupine Bank Canyon. The project will also monitor the seabed processes that dictate where corals occur and their sensitivity to climate change and fisheries/oil industry impacts. The results will include recommendations for the development of sustainable, responsible fisheries and hydrocarbon activity, and for effective management in response to climate change.

Other research by industry and academic partners has recently investigated the suitability of a range of offshore areas for renewable energy devices. Essential geological and hydrodynamic studies have used INFOMAR and GSI data and expertise to determine the geotechnical properties at the proposed locations. This work has included close partnerships between SMEs, universities/research centres and large international energy corporations.

The sea fisheries sector had an estimated 2016 turnover of approximately €280 million, however only 2% of this value was attributable to INFOMAR. Alternatively, renewable energy turnover was €59 million in 2016, and 20% of this was attributable to INFOMAR. Across the four sectors examined, INFOMAR has contributed €24.6 million to the economy in 2016.

Table 4.4: Marine Economy and Impact of INFOMAR, 2016

Sector	**2016 € million**	**INFOMAR % Medium Impact**	**INFOMAR 2016, € million**
Sea Fisheries	279.8	2	5.6
Aquaculture	169.2	4	4.0
Biodiversity/Biotech	43.6	10	3.4
Renewable Energy	59.0	20	11.6
Total	**551.6**	**-**	**24.6**

Source: GSI, SEMRU, PWC

Tellus

Tellus is a ground and airborne geoscience mapping programme, collecting chemical and geophysical data. This data is then used to inform the management of Ireland's environment and natural resources.[34] The programme is funded by the Department of Communications, Climate Action and the Environment and undertaken by the Geological Survey Ireland. Two methods of surveying are used in the programme:

- Ground-based geochemical surveying. This involves surveying soil, stream water and stream sediment; and,
- Airborne geophysical surveying conducted using low-flying aircraft.

Tellus plans to have completed surveying 50% of the island of Ireland by the end of 2017, 75% by 2020 and 100% by 2023. They aim to do this on a phased basis, having already completed the following regions:

- Northern Ireland;

[34] http://www.tellus.ie/

- The border region of Ireland;
- The north midlands region; and,
- The eastern midlands region.

Tellus conducts and supports research in six main areas: mineral exploration, agriculture, the environment, water, geological mapping and radon. Tellus provides high quality data for research into mineral exploration, with Ireland's geological databases ranked sixth in the world by the Fraser Institute.[35] Tellus worked in conjunction with the British Geological Survey and Geological Survey Ireland to attempt to predict cobalt deficiency in sheep using soil geochemical data. Tellus has also funded research into the mining contamination impacts on stream sediment in Northern Ireland, with the work being conducted by the British Geological survey. In relation to radon, Tellus is trying to improve its mapping of radon by working with the Office of Radiological Protection as part of the National Radon Control Strategy.

The Department of Public Expenditure and Reform conducted a Value for Money Policy Review of the GSI Tellus Border Project in July of 2016[36]. The review found that in relation to expenditure on the Tellus Border activities GSI successfully met budgeted targets. However, there was some minor overspend with GSI spending €160K more than they received. Under the effectiveness and rationale metrics, the project was on time, its goals were achieved successfully and it remedied a market failure (the previous lack of high quality geophysical and geochemical data). The CBA used to evaluate the project found a positive benefit-to-cost ratio and a net present value of €660K over a twenty-year appraisal period. This suggests that such a project is likely to deliver a net positive outcome to the economy. The main benefits outlined in the report are a reduction in lung cancer deaths from 2020, valued around 300K based on DTTAS's value of life guidelines and an increase of 0.07% of gross value added in the mining sector. The estimated figure of €180k came from Indecon's own study into the mining sector in Ireland.[37]

One example of how Tellus data us used for research purposes in 2017, was by researchers at Trinity College, GSI, and the EPA to detect radon prone areas of Ireland at a greater level of detail than the previous indoor radon measurements.[38] This was achieved through the application of logistic regression techniques to predict the indoor radon measurements with geogenic factors. A comparison of the predicted radon-prone areas of Ireland vis-à-vis the EPA indoor radon map is provided below.

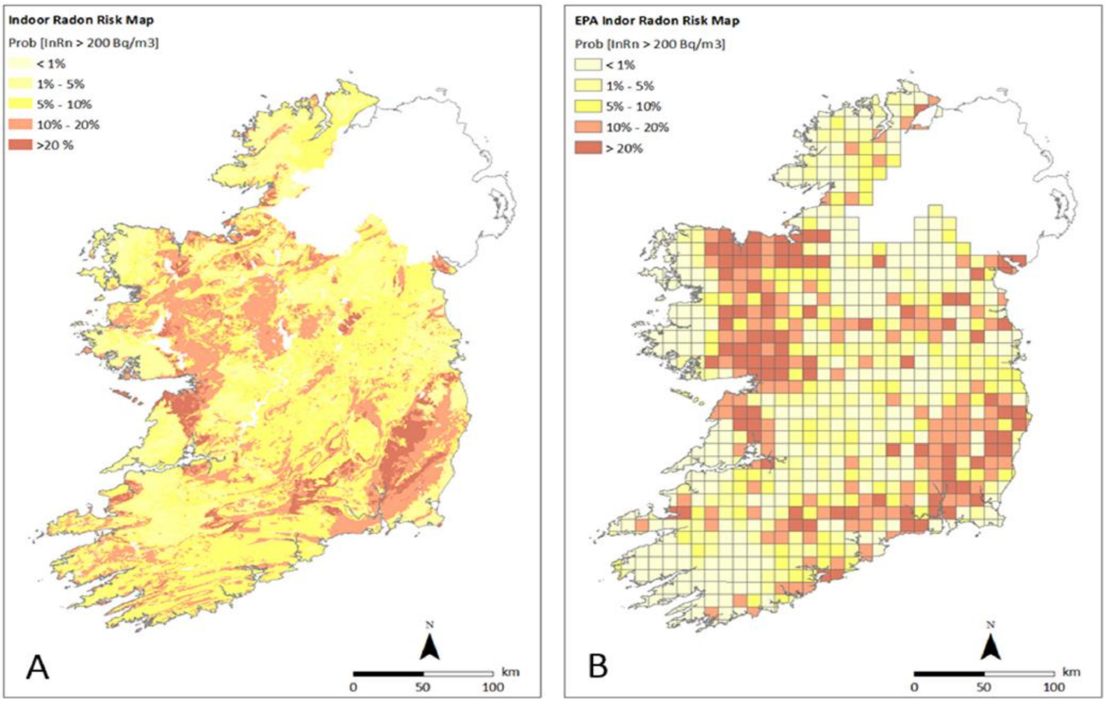
[35] Taylor Jackson, Fraser Institute Annual Survey of Mining Companies, 2014.

[36] The review was carried out by an Steering Committee comprising members of DPER, DCENR and an independent chair, in keeping with the evaluation framework set out in Central Expenditure Evaluation Unit (CEEU) (2007).

[37] Indecon, Assessment of Economic Contribution of Mineral Exploration and Mining in Ireland. 2013. Report for Department of Communications, Energy and Natural Resources.

[38] J. Elío et al. (2017) Logistic regression model for detecting radon prone areas in Ireland, Science of the Total Environment

Figure 4.3: Predicted Radon Prone Areas of Ireland vis-à-vis EPA Indoor Risk Map, 2017



Source: J. Elío et al. (2017) Logistic regression model for detecting radon prone areas in Ireland, Science of the Total Environment

Members of the geoscience community, including iCRAG, are engaged in a number of programs and initiatives in schools around Ireland in order to foster an early interest in geosciences and STEM subjects in general. This includes workshops in groundwater, geology and minerals and resources.

At third- and fourth-level, iCRAG is involved with running a number of research competitions such as FameLab Ireland, Thesis in 3 and ResearchFest. These competitions allow research students to showcase their research and findings, with Thesis in 3 being dubbed the 'Elevator Pitch for a PhD'. It gives research students the opportunity to give a presentation on their thesis in three minutes using just three slides. The goal of the competition is to spread the latest research to as wide an audience as possible.

There are a number of national events at which geoscience researchers actively take part in including:

- The National Ploughing Championships;
- Regional festivals such as the Cavan/Monaghan science festival;
- Movie screenings;
- Culture Night;
- University/Institutes of Technology open days;
- The BT Young Scientists Exhibition;
- European Researchers Night; and
- Science Week.

4.4 Irish Centre for Research in Applied Geosciences (iCRAG)

iCRAG is a multi-site geoscience research centre, funded by SFI, the European Regional Development Fund, and industry and government partners including GSI and Geoscience Ireland. The research centre has 136 researchers (employed by various institutions), seven research institution partners and works with over sixty industry partners to research into the fields of raw materials supply, groundwater protection, energy security, the geomarine environment, geotechnical engineering and natural hazards. A selection of current iCRAG industry partners is provided below.

Table 4.5: Selection of Current iCRAG Industry Partners

Apex Geoservices	Hannan Metals	PW Nigeria
AWN Consulting	HomeBond	QME
Azeire Petroleum	IE Consulting	Repsol
Boliden	IGSL	Rubicon Heritage
bp	International Lithium Corporation	San Leon Energy
BRG	Intersocial Consulting	Serica Energy
BuckleyQuarries	Irish Drilling	Shell
Byrne Looby	JB Barry & Partners	SLR
Cairn Energy	Kosmos Energy	Sorhill Advocates
Chevron	LTMS	Sosina Exploration
Chrysaor	Lundin Mining	srk consulting
David Ball & Associates	Maersk	Statoil
Designer Group	Meehan Drilling	Teck
ENI	Murphy Surveys	Tobin Consulting Engineers
Europa Oil & Gas	Nexen	TII
ExxonMobil	Nicholas O'Dwyer	Trench Control
FLI Group	Pavement Management Services	Trevali Mining Corporation
Geological Survey Ireland	Petroleum Infrastructure Programme	TullowOil
Geoscience Ireland	Priority Drilling	Verde Environmental Group
Geoserv	Providence	Woodside Energy
Group Eleven Resources	PW Mining	

Source: iCRAG and SFI

Currently iCRAG is partnered with the following institutions:

- University College Dublin;
- Trinity College Dublin;
- Dublin Institute for Advanced Studies;
- NUI Galway;
- University College Cork;
- NUI Maynooth; and
- Teagasc.

Research

As mentioned previously iCRAG conducts research into a number of different fields, including groundwater protection and raw materials supply. This section looks at the latest research conducted by iCRAG researchers into the various fields that iCRAG researches.

By way of example, researchers at Trinity College Dublin's Department of Civil, Structural and Environmental Engineering published in the journal, *Science of the Total Environment*, this year on the topic of the accumulation of heavy metals in a constructed wetland's sediment and plants which have been used to treat highway runoff in Ireland.[39] The authors found that sediment accumulated a greater mass of metals in the constructed wetland compared to vegetation, but that vegetation played an important part in the treatment process.

In relation to raw material supply, iCRAG has four main research areas; zinc-lead mining, mineral exploration, energy critical elements and building materials. iCRAG's research into the mining of zinc and lead attempts to extended the productive life of those two elements, whilst also attempting to identify prospective mineral deposits that are currently not being utilised or exploited. Research into energy-related technologies geochemistry is conducted in iCRAG's Energy Critical Element centre of excellence.

4.5 Economic Impact of Geoscience Research

Indecon's measurement of the economic impact of geoscience research is based on the expected return on investment in the geoscience sector as well as the economic impact of geoscience research expenditure on the Irish economy.

In order to estimate the rate of return on research in the geoscience sector Indecon analysed studies into the rate of return on research and development investment. According to the Department of Business, Enterprise, and Innovation (citing an OECD study in 2015) the private rate of return to R&D investment is approximately 0.2-0.3.[40] Indecon has also researched historical studies which suggest a wide range of estimated return, which are presented in the Annex. Indecon therefore decided to use a conservative estimate of 15% for the rate of return on investment in research in the geoscience sector.

The table below shows the 2016 budget for various research and development programs related to geoscience, sourced from the Department of Business, Enterprise, and Innovation and GSI. For the purpose of this study the data acquisition programmes and activities of GSI are being treated as "research". Using the ROI of 15% Indecon estimates that there will be a return of €1.6 million on the amount spent in 2016 on these geoscience research and development programmes.

[39] Laurence W. Gill et al. (2017). Long term heavy metal removal by a constructed wetland treating rainfall runoff from a motorway. *Science of the Total Environment*

[40] Department of Business, Enterprise, and Innovation: Economic and Enterprise Impacts from Public Investment in R&D in Ireland

Table 4.6: Research and Development Programmes - 2016			
Programme	**2016 Outturn (€'000)**	**ROI (2016 - €'000s)**	
		ROI 15%	**ROI 20%**
GSI Geoscience Initiatives	2,099	315	420
GSI Geoscience Research Awards	824	124	165
Tellus Programme	3,237	486	647
INFOMAR	3,162	474	632
DIAS School of Cosmic Physics (including initiatives with iCRAG)	1,584	238	317
Total	**10,906**	**1,636**	**2,181**

Source: GSI and DJEI Research and Development Budget 2015-16
Note: Indecon applied an estimate of ROI of between 15%

Using the above budget, and the level of iCRAG funding as well as the number of employees or researchers in public and academic institutions Indecon is able to estimate a value for the direct impacts of research in the geoscience sector. Indecon estimates that geoscience research contributes €24.3 million in GVA and 465 FTEs.

Table 4.7: Direct Impacts of Geoscience Research, 2016			
	Output* (€ million)	**GVA (€ million)**	**Employment (FTEs)**
DCCAE	10.9	8.5	97
iCRAG	5.5	4.3	136
Other Academic Institutions (incl. University Departments)	10.8	8.4	167
Public Institutions	3.8	3.1	65
Total	**30.9**	**24.3**	**465**

Source: Indecon analysis
Note: * For the purposes of measuring the economy-wide expenditure impact, output is taken as being equivalent to expenditure.

It is also important to identify the indirect and induced impacts of geoscience research, with Indecon estimating GVA of €16.7 million and 259 FTEs.

Table 4.8: Indirect and Induced Impacts of Geoscience Research, 2016			
	Output (€ million)	**GVA (€ million)**	**Employment (FTEs)**
DCCAE	7.6	5.9	54
iCRAG	3.8	3.0	76
Other Academic Institutions (incl. University Departments)	7.5	5.9	93
Public Institutions	2.7	1.9	36
Total	**21.5**	**16.7**	**259**

Source: Indecon analysis

Estimates of the direct, indirect and induced impacts of geoscience research indicate that this activity led to output of €52.5 million, GVA of €41.0 million and FTEs supported by geoscience research of 724.

Table 4.9: Wider Economic Impacts of Geoscience Research, 2016			
	Output (€ million)	**GVA (€ million)**	**Employment (FTEs)**
DCCAE	18.5	14.4	150
iCRAG	9.2	7.2	212
Other Academic Institutions (incl. University Departments)	18.3	14.3	261
Public Institutions	6.5	5.1	101
Total	**52.5**	**41.0**	**724**
Source: Indecon analysis			

4.6 Summary of Key Findings

- There are a number of Higher Education Institutions who are involved in geoscience education and research in Ireland including TCD, UCD, UCC, DCU, DIAS, Maynooth University and University of Limerick, as well as government bodies such as GSI, EPA, MI and Teagasc.
- iCRAG is a multi-site geoscience research centre, funded by SFI, the European Regional Development Fund, and industry and government partners. As of 2016, the research centre has 136 researchers (employed by various institutions), seven research institution partners and works with over sixty industry partners to research into the fields of raw materials supply, groundwater protection, energy security, the geomarine environment, geotechnical engineering and natural hazards.
- Indecon's measurement of the economic impact of geoscience research is based on the expected return on investment in the geoscience sector as well as the economic impact of geoscience research expenditure on the Irish economy.

5 Extractive Industries

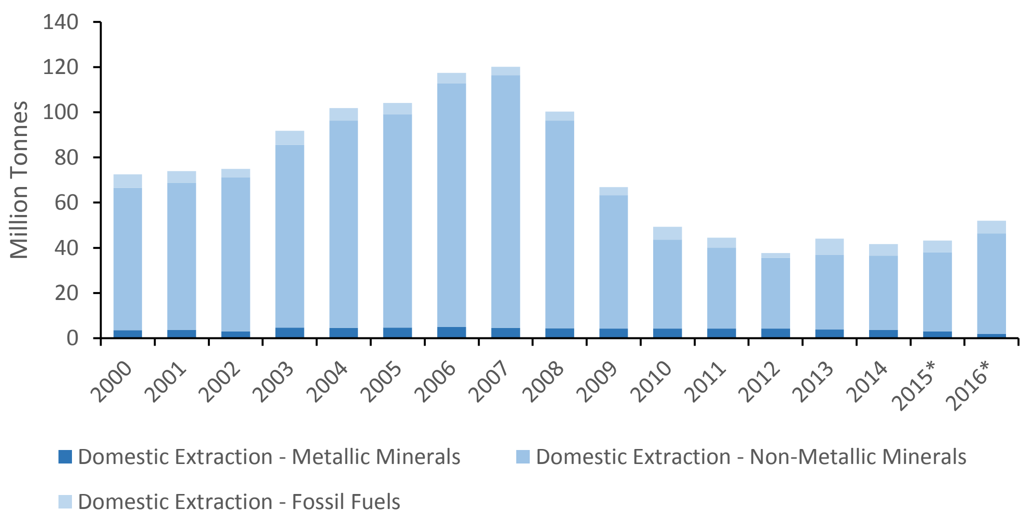
5.1 Introduction

The European industrial activity classification (NACE Rev.2) identifies mining and quarrying under the category Codes B05 to 09. This includes mining of coal and lignite, extraction of crude petroleum and natural gas, mining of metal and non-ferrous ores, and mining support service activities. In the Irish context, Codes B05-09 simply comprise the extractive industries including metallic minerals, non-metallic minerals and fossil fuels. The economic impacts of these sectors are explored in this section.

5.2 Background

The domestic extraction of mineral resources in Ireland since 2000 is shown in Figure 5.1. The graph clearly shows how non-metallic minerals have had major share in the sector; enjoying higher levels of extraction for the period starting from 2003 and continuing until 2007.

Figure 5.1: Domestic Extraction (Million Tonnes) – 2000-2016



Source: CSO and Indecon analysis
Note: * denotes that figures for 2015 and 2016 are estimates.
Note: Figures do not include Corrib's arrival due to its measurement in million tonnes of oil equivalent.

As per the Irish Mining and Quarrying Society (IMQS) Annual Report 2016,[41] the two zinc-lead underground mines in Ireland (Lisheen and Boliden Tara Mines) accounted for 24% of European zinc mine output and 7% European lead mine output.

Globally, Ireland ranked 11th and 16th in relation to zinc and lead mine output. It was only due to the closure of Galmoy zinc-lead mine in 2012 and the winding down of operation in Lisheen that

[41] Irish Mining and Quarrying Society (2016). Minister's Foreword. *Annual Review*. Pg. 7

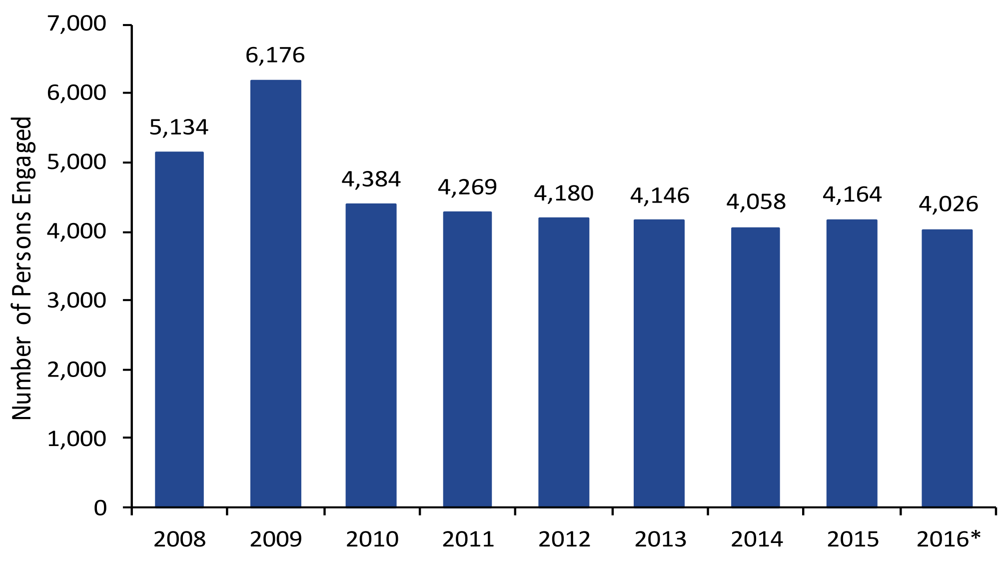
Ireland slipped at the second place for European zinc mine output for the first time in many years. However, it still maintains significant status for zinc production in Europe, due to operations at the Boliden Tara Mines, the largest underground zinc mine in Europe. The IMQS also reports that Ireland ranked 4th globally by the Fraser Institute of Canada's survey of mining companies (2015) in investment attractiveness index.

In terms of other mineral resources, Irish Gypsum Ltd. is reported to have mined approximately 250kt of gypsum which fed the company's production operations in Kingscourt, Co. Cavan. Further, there are a number of programs being rolled out by the government and its agencies in order to support exploration and mining of natural resources. One good example is the Tellus programme of the Geological Survey Ireland to map and collect the geophysical data.

Ireland's oil and gas industry has developed substantially in recent years, most notably through the launch of production of the Corrib gas field in January 2016. According to the petroleum affairs division of the Department of Communications, Climate Action and the Environment, offshore Ireland however remains under-explored. As of November 2016, there were 66 licences and leases, ranging from petroleum leases to petroleum prospecting licences, granted in Ireland. Nationally, the number of authorisations are at an all-time high, however it should be noted that relative to other European countries Ireland has fewer global firms in operation. Since 1979 there have been 159 wells drilled offshore, primarily for exploration. The Department supports on-going research in the areas of oil and gas, through institutions such as iCRAG and the Petroleum Infrastructure Programme (PIP) with the aim of complementing industry-led investment in exploration activity.

With regard to the labour market conditions in the mining and quarrying sector, there was a sharp decline in the number of people employed in 2009. However, the labour force has remained more or less constant ever since, increasing marginally in 2015, as shown below.

Figure 5.2: Mining and Quarrying (Number of Persons Engaged), 2009 – 2016



Source: CSO
Note: * 2016 estimated based on index growth of turnover in this sector

5.3 Economic Impact of Extractive Industries

This section will examine the economic impact of extractive industries across three broad groups: the fossil fuel sector, metallic extraction, and non-metallic extraction.

Fossil Fuels

Oil and gas in Ireland are primarily driven by the natural gas fields at Corrib and Kinsale. Kinsale Head gas field was discovered in 1973 and began operation in 1978. Since this time Kinsale has been in continued operation, with satellite gas fields such as Ballycotton, Seven Heads and Southwest Kinsale Gas Fields also operated by Petronas since 2009. Peak production was reached in 1995 and at this stage is considered to be nearing the end of its commercial viability. Corrib Gas Field was discovered in 1996 and began production in January 2016, after significant delays. Corrib Gas Field is considered to be at the beginning of its useful economic life and has an estimated production life of 15 years. A summary of these fields is presented below.

Table 5.1: Value of Gas Fields in Ireland

Field	Kilotonnes of Oil Equivalent	Value of Gas (€ million)
Kinsale	131	25
Corrib	7,662	533.5

Source: Indecon analysis
Note: Corrib KTOE based on expected peak rate. Value of gas in Kinsale based on front month futures contracts averaged over the previous five years and published turnovers in national press. Value of gas in Corrib based on Vermillion Annual Report 2016.

The direct economic impacts of the Kinsale and Corrib gas production were estimated using economic multipliers for the mining, quarrying, and extraction sectors (NACE Code B05-09) which includes extraction of natural gas. This level of output equates to €181.5 million in GVA, while the number of FTEs, 265, is based on the estimate contained in *Ireland's Ocean Economy.*[42] The economy-wide impacts, including direct, indirect, and induced impacts, of natural gas in Ireland is estimated to be approximately €984 million in output, €411 million in GVA, and 571 in FTE terms.

Table 5.2: Economic Impacts of Natural Gas - 2016

Gas	Output (€ million)	GVA (€ million)	Employment (FTE)
Direct Impacts	558.5	181.5	265
Indirect and Induced Impacts	425.6	230.4	306
Economy-Wide Impacts	984.1	411.9	571

Source: Indecon analysis

Peat is an important and unique fossil fuel for Ireland. This is primarily extracted by Bord na Móna. Turnover in relation to peat is presented below, alongside other direct economic impacts for 2016. Indecon has estimated the Gross Value Added impact of this turnover through the application of economic multipliers derived from an Input-Output model of the Irish economy.

[42] Socio-Economic Marine Research Unit. *Ireland's Ocean Economy.* Available at: http://www.nuigalway.ie/semru/documents/semru__irelands_ocean_economy_2017_online.pdf

Table 5.3: Fossil Fuels - Peat (Turnover and Gross Value Added)							
		2011	2012	2013	2014	2015	2016
Peat	Turnover (€ million)	69.5	62.9	75.3	78.2	80.7	85.8
	GVA (€ million)	22.6	20.4	24.5	25.4	26.2	27.9
Source: Indecon analysis of Bord na Móna data							

The indirect and induced economic knock-on impacts of the direct expenditure outlined above equates to additional output of €65.4 million and GVA of €35.4 million. An issue arises in terms of what to include as part of the employment in the peat sector because there are links between the extraction of peat and its use. Bord na Móna have 2,300 employees in Ireland, though their figures also indicate that 1,200 people worked in their peat business unit in 2015. As such this 1,200 is the figure used as a basis to calculate the economy wide impacts on employment in the peat sector. Independent peat cutters have been excluded from these figures, however will be captured by the CSO's overall extractive industry NACE Code. On a combined economy-wide basis the economic impact of the peat industry amounted to €151 million, €63 million in GVA and 2,584 FTEs. This indicates that the peat industry is a major contributor to the Irish economy. The long-term trends in this sector should however be noted. Bord na Móna has a target to cease activities in their energy peat business units by 2030.

Table 5.4: Economic Impacts of Peat - 2016			
Peat	Output (€ million)	GVA (€ million)	Employment (FTE)
Indirect and Induced Impacts	65.4	35.4	1,384
Economy-Wide Impacts	151.2	63.3	2,584
Source: Indecon analysis			

Metallic Extractive Industries

Zinc and lead are the most important metal extractions in Ireland. The total turnover and GVA for these two components is shown in the table overleaf. These values have been estimated independently by Indecon and are based on a multitude of sources, including the CSO, the Department of Communications, Climate Action, and the Environment, Indecon's previous mining report,[43] and price indices for these metals. The level of metal concentrates was recorded as 7.70% for lead and 9.31% for zinc in 2012.[44] These values are then used to derive the amount of metal obtained from the extracted ores in other periods. Once these are obtained, the total turnover is estimated by multiplying the extracted volumes with the prices. The prices are obtained from the index mundi database[45] using the monthly values to obtain annual average prices.

[43] Indecon (2013). Assessment of Economic Contribution of Mineral Exploration and Mining in Ireland. *Department of Communications, Energy and Natural Resources.*

[44] The figures are based on the data used in the DCENR report prepared by Indecon in 2013 (see footnote above).

[45] Sourced from the GEM commodities, World Bank Group.

Table 5.5: Zinc and Lead Extractions (Metal Obtained, Turnover, and Gross Value Added)							
Metallic Extraction		**2011**	**2012**	**2013**	**2014**	**2015[a]**	**2016[a]**
Lead	Total Metal Obtained (million tonnes)	0.046	0.046	0.039	0.039	0.031	0.020
	Price (€/tonne)	1,724	1,604	1,611	1,578	1,612	1,739
	Total Turnover (€ million)	**79.6**	**74.1**	**62.0**	**60.8**	**50.5**	**34.1**
	Gross Value Added (€ million)	**25.9**	**24.1**	**20.2**	**19.7**	**16.4**	**11.1**
Zinc	Total Metal Obtained (million tonnes)	0.34	0.34	0.31	0.29	0.24	0.15
	Price (€/tonne)	1,578	1,516	1,438	1,631	1,741	1,892
	Total Turnover (€ million)	**528.8**	**508.3**	**442.0**	**470.8**	**411.3**	**278.2**
	Gross Value Added (€ million)	**171.8**	**165.2**	**143.6**	**153.0**	**133.7**	**90.4**

Source: Indecon analysis of CSO, DCCAE and international metallic price data
Note: a) Source for Metal Obtained: International Lead and Zinc Study Group given in the DCCAE report on prospecting licenses (2017/2016) DCCAE (2017). Prospecting license areas open for application under competition. Minerals Ireland.

The direct economic impacts of metallic extraction activity in 2016 is presented in the table below.

Table 5.6: Direct Impact of Metallic Extraction - 2016			
Area	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Lead Extraction	34.1	11.1	586
Zinc Extraction	278.2	90.4	

Source: Indecon analysis
Note: Employment figures are from Boliden's 2016 Annual Report[46]

Using Indecon's Input-Output model of the Irish economy, we have estimated the indirect and induced economic impacts of this activity. This is presented in the next table.

Table 5.7: Indirect and Induced Impacts of Metallic Extraction - 2016			
Area	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Lead Extraction	26	14	676
Zinc Extraction	212	115	

Source: Indecon analysis

The economy-wide impacts of these extractive industries are presented overleaf, accounting for the direct, indirect, and induced impacts.

[46] Boliden Annual Report 2016. *Metals and Innovation for the Future.* https://vp217.alertir.com/afw/files/press/boliden/201703089998-1.pdf

Table 5.8: Economy Wide Impacts of Metallic Extraction - 2016			
Area	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Lead Extraction	60.1	25.1	1,262
Zinc Extraction	490.1	205.2	
Source: Indecon analysis			

Non-metallic Extractive Industries

For the non-metallic extraction, the analysis uses PRODCOM statistics available for key mineral resources. This data reports the volumes extracted, as shown in the table below. The extraction of non-metallic minerals also supports the construction projects of buildings and roads.

The most important of these extractions is granite, sandstone, porphyry, basalt quartzites, limestone flux, construction sand, and crushed stones. The tables below do not report all non-metallic extractions; for example, gypsum remains unreported due to data suppression in the PRODCOM database. This is due to confidentiality concerns regarding the publicity of data. However, these are included in the overall figures provided at the end of this section. The products contained in the table below are used in the manufacturing of concrete and cement. Including these industries would potentially result in double counting as they manufacture materials counted in extractive industries, and thus we include the base materials from which concrete is made. The Irish Concrete Federation estimates that there are approximately 4,000 people directly employed in the aggregates and concrete products industry in Ireland, with approximately four million cubic metres of ready mixed concrete consumed in Ireland in 2016.[47]

Table 5.9: Non-Metallic Extractions in Ireland (Volume - 000'tonnes), 2011 - 2016						
Non-Metallic Extraction	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Ecaussine and other calcareous monumental or building stone	NA	NA	NA	NA	NA	NA
Granite, crude or roughly trimmed	NA	26	9	18	17	20
Granite merely cut into blocks and other shapes	NA	42	38	38	35	49
Sandstone	293	261	176	75	79	80
Porphyry, basalt quartzites and other monumental or building stone	472	464	464	360	407	1,078
Limestone flux, limestone and other calcareous stone used for the	5,145	3,093	2,470	2,634	2,697	3,478
Silica sands (quartz sands or industrial sands)	134	NA	NA	245	238	252
Construction sands such as clayey sands, kaolinic sands, feldspathic	3,378	1,489	2,380	1,803	1,584	2,238
Gravel and pebbles for concrete aggreg.	3,393	3,288	5,005	3,897	4,813	6,046
Crushed stone used for concrete aggregates	17,926	13,649	13,781	13,182	13,753	16,797
Granules chippings and powder of travertine, Ecaussine, granite	864	NA	NA	NA	101	170
Mixtures of slag and waste product	NA	NA	NA	NA	NA	NA
Source: CSO PRODCOM statistics						

Turnover from these extractions is presented in the next table. This data is also from the CSO PRODCOM dataset. In terms of the sales value, the largest contribution is made by the crushed

[47] Irish Concrete Foundation. *The Industry at a Glance. http://www.irishconcrete.ie/industry-at-a-glance/*

stone used for road metalling, constituting almost one-third of the total revenue generated from the sale of the non-metallic extraction. The second most important contributor is limestone, followed by gravel, porphyry, building sand. The total sales from this sub-sector was recorded as €316.3 million in 2016, slightly higher than the previous year.

Table 5.10: Non-Metallic Extractions in Ireland (Turnover - € million), 2011 - 2016

Non-Metallic Extraction	2011	2012	2013	2014	2015	2016
Ecaussine and other calcareous monumental or building stone	5.2	4.1	2.1	NA	NA	NA
Granite, crude or roughly trimmed	1.6	1.0	0.9	1.5	2.6	2.9
Granite merely cut into blocks and other shapes	10.8	8.5	7.2	7.2	7.0	9.6
Sandstone	NA	6.1	4.8	3.8	3.9	4.4
Porphyry, basalt quartzites and other monumental or building stone	NA	13.7	12.0	12.3	18.7	25.8
Limestone flux, limestone & other calcareous stone	79.5	37.5	31.3	35.3	38.1	52.2
Silica sands (quartz sands or industrial sands)	2.3	NA	10.5	3.7	3.7	4.6
Construction sands such as clayey sands, kaolinic sands, feldspathic	35.7	16.3	26.1	19.3	16.2	23.1
Gravel and pebbles for concrete aggreg.	33.0	32.4	49.2	38.4	38.0	44.9
Crushed stone of a kind used for concrete aggregates for road metalling	132.4	104.3	109.5	158.1	107.9	131.9
Granules chippings and powder of travertine, Ecaussine, granite	11.3	NA	NA	NA	14.6	16.1
Mixtures of slag and waste product	NA	0.5	0.5	0.7	0.8	1.0
Total	**311.6**	**224.5**	**254.1**	**280.2**	**251.4**	**316.3**

Source: CSO PRODCOM

The direct impacts of this turnover are presented in the next table for each non-metallic subcomponent. The total output supported is equivalent to €102.8 million in GVA and 1,223 FTE jobs.

Table 5.11: Direct Impacts of Non-Metallic Extraction in Ireland - 2016

Area	Output (€ million)	GVA (€ million)	Employment (FTE)
Ecaussine and other calcareous monumental or building stone	NA	NA	NA
Granite, crude or roughly trimmed	2.9	1.0	11
Granite merely cut into blocks and other shapes	9.6	3.1	37
Sandstone	4.4	1.4	17
Porphyry, basalt quartzites and other monumental or building stone	25.8	8.4	100
Limestone flux, limestone and other calcareous stone	52.2	16.9	202
Silica sands (quartz sands or industrial sands)	4.6	1.5	18
Construction sands such as clayey sands, kaolinic sands, feldspathic	23.1	7.5	89
Gravel and pebbles for concrete aggregates.	44.9	14.6	173
Crushed stone of a kind used for concrete aggregates for road metalling	131.9	42.9	510
Granules chippings and powder of travertine, Ecaussine, granite	16.1	5.2	62
Mixtures of slag and waste product	1.0	0.3	4
Total	**316.3**	**102.8**	**1,223**

Source: Indecon analysis

The indirect and induced impacts of non-metallic extraction are presented below. The indirect and induced output amounts to 241 million, while equivalent GVA amounts to 130 million. In employment terms this equals 1,410 jobs in FTE terms.

Table 5.12: Indirect and Induced of Non-Metallic Extraction in Ireland - 2016

Area	Output (€ million)	GVA (€ million)	Employment (FTE)
Ecaussine and other calcareous monumental or building stone	NA	NA	NA
Granite, crude or roughly trimmed	2.2	1.2	13
Granite merely cut into blocks and other shapes	7.3	4.0	43
Sandstone	3.3	1.8	20
Porphyry, basalt quartzites and other monumental or building stone	19.6	10.6	115
Limestone flux, limestone and other calcareous stone	39.7	21.5	232
Silica sands (quartz sands or industrial sands)	3.5	1.9	20
Construction sands such as clayey sands, kaolinic sands, feldspathic	17.6	9.5	103
Gravel and pebbles for concrete aggregates.	34.2	18.5	200
Crushed stone of a kind used for concrete aggregates for road metalling	100.5	54.4	588
Granules chippings and powder of travertine, Ecaussine, granite	12.2	6.6	72
Mixtures of slag and waste product	0.8	0.4	5
Total	**241.1**	**130.5**	**1,410**

Source: Indecon analysis

The overall economy-wide impacts of these areas are presented below and these include the direct, indirect, and induced impacts. Given the extent of housing and other construction requirements in Ireland, employment in this sector which currently amounts to over 2,600 is likely to expand.

Table 5.13: Economy-Wide Impacts of Non-Metallic Extraction in Ireland - 2016

Area	Output (€ million)	GVA (€ million)	Employment (FTE)
Ecaussine and other calcareous monumental or building stone	NA	NA	NA
Granite, crude or roughly trimmed	5.2	2.2	24
Granite merely cut into blocks and other shapes	16.9	7.1	80
Sandstone	7.7	3.2	36
Porphyry, basalt quartzites and other monumental or building stone	45.4	19.0	214
Limestone flux, limestone and other calcareous stone	91.9	38.5	434
Silica sands (quartz sands or industrial sands)	8.1	3.4	38
Construction sands such as clayey sands, kaolinic sands, feldspathic	40.7	17.0	192
Gravel and pebbles for concrete aggreg.	79.0	33.1	373
Crushed stone of a kind used for concrete aggregates for road metalling	232.4	97.3	1,098
Granules chippings and powder of travertine, Ecaussine, granite	28.3	11.8	134
Mixtures of slag and waste product	1.8	0.8	9
Total	**557.4**	**233.3**	**2,632**

Source: Indecon analysis

Mining Exploration

The economic activity generated through mining exploration (rather than extraction) will have nontrivial economic impacts on the Irish economy. The Department grants prospecting licences and activity in this area has been strong in recent years. Expenditure on mining exploration is presented in the table below. In 2016, just over €13 million was spent on mining exploration activities in Ireland. As of 2016 there were 43 corporate entities with a total of 591 prospecting licences.

Table 5.14: Expenditure on Mining Exploration (2015-2016)		
Area	**2015**	**2016**
Total Exploration Expenditure, € million	14.9	13.1
Source: Department of Communications, Climate Action, And Environment - Prospecting Licence Areas Open for Application Under Competition and Industry News		

Indecon has applied economic multipliers as derived from our Input-Output model of the Irish economy to the above expenditure to estimate the associated GVA and employment figures in direct terms. These are presented below. The economy-wide impacts, including the direct, indirect, and induced impacts, of mining exploration activities in Ireland, account for approximately €36.2 million in output, €13.9 million in GVA, and 160 FTE jobs.

Table 5.15: Economic Impacts of Mining Exploration - 2016			
Mining Exploration	**Output (€ million)**	**GVA (€ million)**	**Employment (FTE)**
Direct Impacts	13.1	4.3	51
Indirect and Induced Impacts	23.1	9.7	109
Economy Wide Impacts	36.2	13.9	160
Source: Department of Communications, Climate Action, And Environment - Prospecting Licence Areas Open for Application Under Competition and Industry News			

Total Extractive Industry Impacts

The economic impact of all mining and quarrying or extractive industries (NACE Codes 05-09) in terms of total turnover is shown below, with turnover estimated to be €939.9 million in 2016. This data is sourced from the CSO and is presented on an aggregated basis so as to ensure items excluded from the detailed assessments above, such as gypsum or alumina, are accounted for. The data suggests that there has been decline in total turnover and GVA for the industry in past few years. The decline was more significant in 2013, and this can be attributed to the closure of Galmoy mine in 2012. The closure of Lisheen mine in 2015 also contributed to the fall in turnover in extractive industries. There was also a reduction in GVA, which fell from €613 million in 2008 to an estimated €283 million. The IQMS annual report adds that even against the backdrop of mine closures, the exploration of minerals in Ireland is quite active with significant increase in mining licence applications. Therefore, it can be deduced that the sector has expanded the business turnover, adding more value to the Gross National Income and continue to serve as one of the core segments of the geoscience sector in Ireland.

The economic impact of all extractive industries in terms of Gross Value Added (GVA) and persons engaged is also shown below. Indecon estimates that GVA of extractive industries was slightly lower in 2016 than it was in 2015.

Table 5.16: Turnover in Extractive Industries, GVA, and Persons Engaged, 2008 - 2016

	2008	2009	2010	2011	2012	2013	2014	2015	2016*
Turnover (€ million)	1,637.4	1,660.8	1,456.8	1,485.1	1,421.7	1,092.6	1,054.3	972.2	939.9
GVA (€ million)	612.6	473.4	557.9	593.8	543.8	529.4	504.5	292.6	282.9
Persons Engaged	5,134	6,176	4,384	4,269	4,180	4,146	4,058	4,164	4,026

Source: CSO
*Note: 2016 forecasted using CSO Index

The economic impacts of all extractive industries in terms of total turnover and Gross Value Added (GVA) and employment (FTE) is shown below. The total economy-wide output of all extractive industry activities in Ireland accounts for €1.65 billion to the Irish economy.

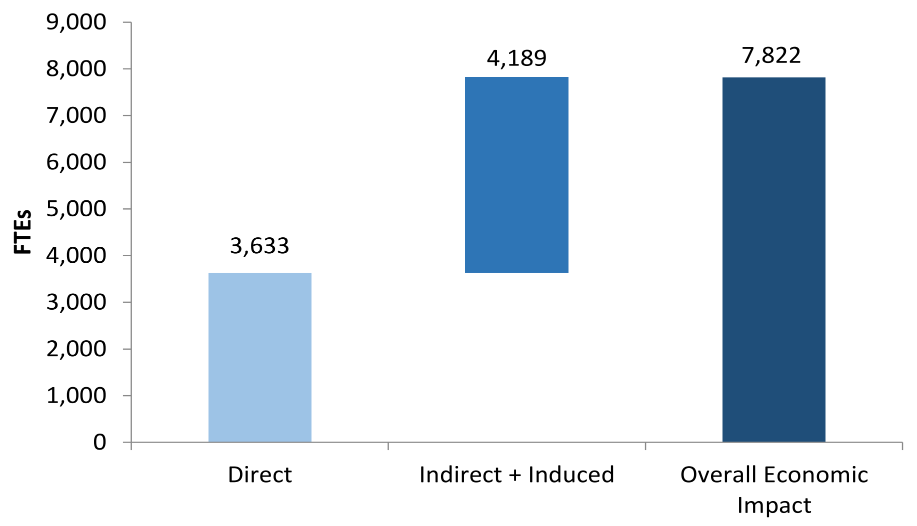
Table 5.17: Economic Impacts of the Extractive Industry - 2016

All Mining and Quarrying	Output (€ million)	GVA (€ million)	Employment (FTE)
Direct Impacts	939.9	282.9	3,633
Indirect and Induced Impacts	716.3	359.2	4,189
Economy-Wide Impacts	1,656.2	642.1	7,822

Source: Indecon analysis

A graphical representation of the levels of employment in FTE terms supported through all extractive industry activities is presented below.

Table 5.18: Employment Impact of the Extractive Industry 2016



Source: Indecon analysis

5.4 Summary of Key Findings

- Using CSO data on all mining and quarrying activities (NACE Codes 05-09) Indecon estimates that turnover in the sector in 2016 was €939.9 million, with GVA of €282.9 and 3,633 FTEs supported directly.
- When looking at the economy-wide impact, which includes direct, indirect and induced impacts, Indecon estimates output of €1.656 billion in 2016 and 7,822 FTEs supported by the sector.
- Indecon also examined individual sub-sectors and estimated the impact of these sub sectors. In the case of the peat industry, on a combined economy-wide basis, the economic impact of the peat industry amounted to €151 million of output and 2,584 FTEs supported.
- The economy-wide impacts, including direct, indirect, and induced impacts, of natural gas in Ireland are estimated to be approximately €752 million in output and €314 million in GVA. A large portion of this is due to Corrib gas field, in which production began in late 2015.
- The economy-wide impacts of the lead and zinc sectors were €230.3 million in terms of GVA and 1,262 FTEs supported.
- Indecon also estimated the economic impact of the non-metallic extractive industries. It is important to note that certain materials, such as gypsum and alumina, are not included in this analysis due to the nature of information provided by the CSO. The overall economy-wide impacts the non-metallic extractive industry were estimated to be €557.4 million in terms of output, with 2,632 FTEs supported.
- The economic activity generated through mining exploration (rather than extraction) was estimated to have a nontrivial economic impact on the Irish economy in 2016. Using information on prospecting licences Indecon estimated that mining exploration activities in Ireland accounts for approximately €36.2 million in output and €13.9 million in GVA.

6 Economic Impact of Natural Hazards

6.1 Introduction

Natural hazards can have major negative impacts on economies and on human life. Moreover, certain natural hazards, such as flooding and landslides, are an increasingly significant risk in the context of climate change. The economic costs of certain natural hazards can be reduced or mitigated through research and information provided by geoscience. This can also reduce the human costs, in terms of lives saved and reduced injuries or illness due to flooding, landslides, coastal erosion, subsidence, groundwater pollution, radon or other hazards. This section examines the evidence on the economic impact of the major natural hazards affecting Ireland, namely landslides, radon exposure, and flooding.

6.2 Background

The recent episodes of extreme cold in 2010, destructive windstorms in 2013 and 2014 and some events of flooding in 2011 and late 2015, and 2017, are all examples of the changing climatic patterns. Rising sea levels, reduction in water quality, increased risk of pests and diseases, and changes in the distribution of the life-cycles of animals and plants pose longer-term risks (National Risk Assessment Draft Report, 2017).[48] In the case of Ireland, where the economic component of food-based industry is quite high, any change in the natural environment would have serious consequences for the economy. As a result, Ireland, as a member of UN Framework Convention on Climatic Change (UNFCCC), has undertaken certain objectives such as reduction of greenhouse emission gas, participation in funding actions on climatic change in developing countries, support and utilisation of emerging institutions on the topic, and meeting of the target framed under the EU Climate and Energy package (CEP).[49] In addition to these, it is further suggested that the country strives to achieve the national goals of sustainable development, economic advancement, and international engagements for a resource-efficient and climate-friendly Ireland by 2050.

The channels through which natural hazards (arising from climate change and other factors) affect the economy are related to the impacts on critical infrastructure. These include water, energy, communications, transport, and emergency services that are impacted in an emergency situation. According to the European Environment Agency (EEA), the total estimation of weather and climate related losses is nearly €433 billion, averaging around €12 billion per year, €75,800 per square kilometre, and €780 per capita in the EEA countries.[50] Ireland ranks 7th in terms of losses per capita; however, this is primarily driven through our relatively low population. The Munich Re data suggests 65 fatalities occurring in Ireland due to natural hazards from 1980-2015. The figure overleaf shows the occurrence of different kinds of natural hazards in the EEA

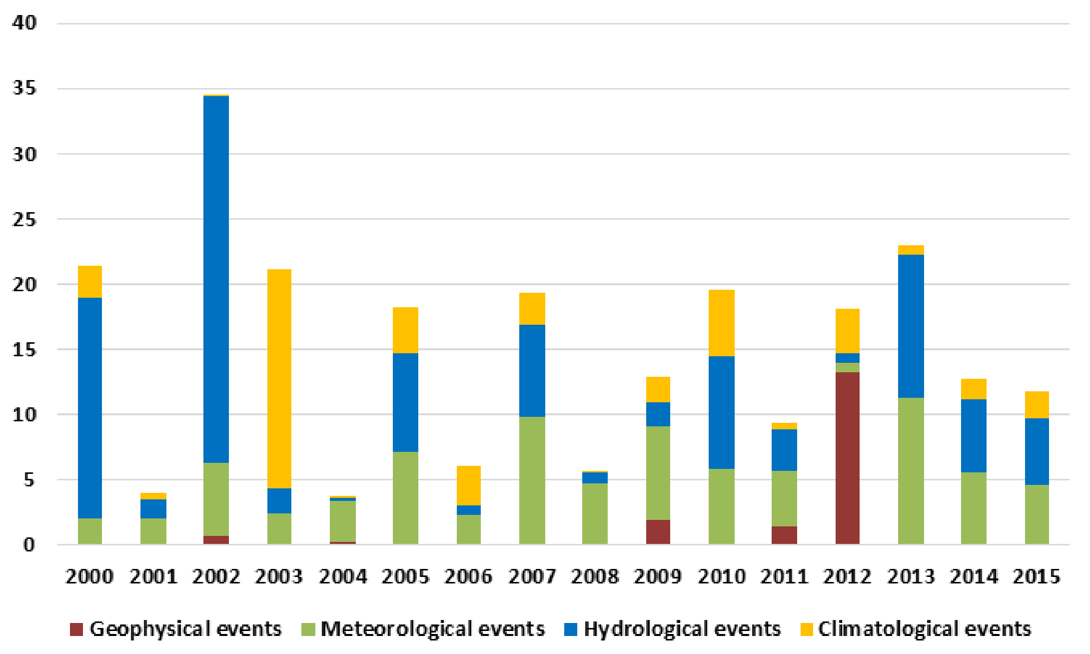
[48] Department of Taoiseach (2017). National Risk Assessment, Overview of Strategic Risks. Retrieved from: http://www.taoiseach.gov.ie/eng/Publications/Publications_2017/Draft_National_Risk_Assessment_2017.html.

[49] O'Reilly G., O'Brian, P., McGovern, F. (2007). Addressing climate change challenge in Ireland. *Report prepared for Environment Protection Agency.* Retrieved from: http://www.epa.ie/pubs/reports/research/climate/ccrp25-addressingclimatechangechallengesinireland.html.

[50] Economic Losses from Climate Related Extremes, 19 Jan, 2017. Retrieved from: https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment.

countries from 2000 to 2015. Barring some geophysical events, most of the hazards were either hydrological or meteorological.

Figure 6.1: Economic Losses Caused by Natural Hazards by Hazard Category, Europe (€ billion, 2015)



Source: NatCatService, Munich Re

This chapter identifies various sources of natural hazards that have either affected or have potential to affect Ireland in the future. Mostly, these risks are associated with the extreme weather events in the backdrop of climate change, as mentioned previously. However, there are certain other issues such as landsides, and radon emissions within the households; which are addressed as well. Landslide has numerous qualitative impacts such as loss of utility of parts of road, the need to make extensive detours, and severance of access to and from remote communities (Winter et al., 2016)[51]. Further, as summarised by Winter and Bromhead (2012),[52] the direct economic impacts of landslides include the cost of clean-up and repair/replacement of infrastructure. The natural hazard arising from indoor radon exposure is also quite serious. This occurs when houses are constructed on top of radon-emitting rocks.[53] The link between exposure to radon emission and increased risk of developing lung cancer has long been

[51] Winter, M.G., Shearer, B., Palmer, D., Peeling, D., Harmer, C. and Sharpe, J., (2016). The Economic Impact of Landslides and Floods on the Road Network. *Procedia Engineering*, *143*, pp.1425-1434.
[52] Winter, M.G. & Bromhead, E.N. (2012). Landslide risk: some issues that determine societal acceptance. *Natural Hazards*, 62, 169-187.
[53] Radon, ASTDR Public Health Statement, December 1990. URL: http://faraday.ee.latrobe.edu.au/~khorsell/radiation/statements/radon.html

demonstrated (UNSCEAR, 1977).[54] Also, non-cancerous diseases such as thickening of certain tissues of lungs may also occur, which can be potentially carcinogenic.

6.3 Natural Hazards Profile

The Environmental Protection Agency (EPA) report regarding extreme weather events in Ireland by Kiely et al. (2010)[55] is an elaborate compilation of historical episodes concerning extremes of cold, wind, precipitation and temperature. The source for such historical records involve references to old Irish Annals, other indigenous Irish records, and newspaper evidences. Based on these, the media and newspaper records, and the information provided in the Annual National Risk Assessment Reports, the sub-sections below discuss the profile of some emergency events occurring in Ireland due to extreme weather conditions in the past.

Flooding

The primary cause for floods in the country is periods of unsettled weather conditions resulting into extended periods of rainfall causing floods. The unsettled weather can be attributed to the Atlantic depressions passing over the island of Ireland and recent climate change which has caused warmer and wetter winter seasons. Floods in Ireland generally occur due to overflowing of river banks, coastal storms or blocked or overloaded drainage ditches,[56] thus relating closely with the geoscience sector. The immediate effects of floods include damage to the property, disruption of travel, and in some cases human and animal fatalities. Therefore, flooding is one of the most critical issues amongst other natural hazards in Ireland.

There have been some measures taken to mitigate as well as prevent the effects of flooding in recent years. The efforts of the Office of Public Works (OPW) have led to an on-going engagement with the Principal Response Agencies to share information on flood risk data. Also, the OPW has made efforts for national flood forecasting and warning systems (National Risk Assessment for Ireland, 2012).[57] The OPW has 88 excavators and it spends €14 million every year for dredging works.[58] Despite all these efforts made in the past, there have been some extreme episodes of heavy rainfall and storms that caused floods, thus calling for more attention towards this issue. As per the meteorological survey and newspaper records, there have been four major episodes of floods in Ireland between 2008 and 2017.

In 2016, in response to a specific action in the Programme for Government, GSI initiated a Turlough/Groundwater Flood Study Programme, GWFlood. This programme, which is costed at €0.5m p.a. and has instrumented more than 60 turloughs (temporary lakes), is carrying out joint research into flood modelling with TCD and is working with both OPW and Local Authorities to provide data and mapping to inform flood prevention and remediation measures. Outputs from

[54] UNSCEAR (1977). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly. Sources and Effects of Ionising Radiation. *United Nations*, New York.

[55] Kiely, G., Leahy, P., Ludlow, F., Stefanini, B., Reilly, E., Monk, M. and Harris, J. (2010). Extreme weather, climate and natural disasters in Ireland. *Extreme weather, climate and natural disasters in Ireland*.

[56] Flooding in Ireland. The Office of Public Works. Retrieved from: http://www.flooding.ie/

[57] Department of Defence (2012). A National Risk Assessment for Ireland.

[58] Spain, J. (2016, January 7). The truth about the flooding in Ireland - reality, prioritizing and planning. Irish Central. Retrieved from: https://www.irishcentral.com/news/irishvoice/truth-flooding-ireland-reality-prioritizing-and-planning

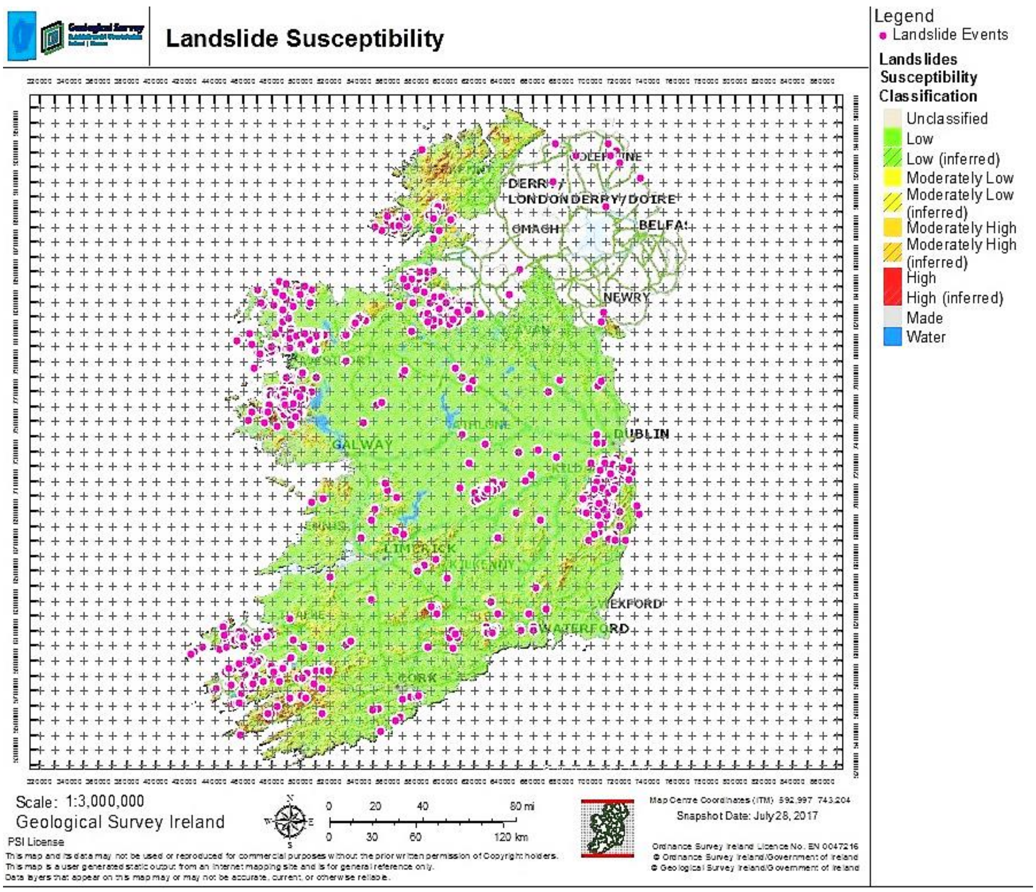
the programme will be incorporated into the next phase of the national Catchment Flood Risk assessment and Management Programme (CFRAM) of OPW.

Landslides

Ireland is not at high risk for extreme landslides events; however, landslides are considered within the category of major geohazards, causing substantial damage to land and loss of lives globally and historically in Ireland. In Ireland, the topic of landslide gained strength after two major events in Pollatomish and Derrybrien in 2003. As a result, a National Landslide Working Group was incorporated by Geological Survey Ireland (GSI) in 2004. This led to the development of a national database on landslide events in Ireland. The group has been involved in intensive research on landslide susceptibility in Ireland, and has produced some essential mapping information, such as the National Landslide Susceptibility Map, shown in Figure 6.2.

This map helps in the assessment of landslide susceptibility on the island of Ireland by mapping landslide events, as well as representing areas which are at risk of a landslide event and areas which can be comfortably concluded as safe in terms of occurrence of a landslide event. The map is measured from high (red) to low (green) susceptibility, and is modelled on the density of landslides which have occurred per 100 km^2 within a particular combination of topographic factors (slope and soil type).

Figure 6.2: Landslide Susceptibility Map of Ireland



Source: Geological Survey Ireland Internet Mapping Tool

A relatively recent landslide occurred in Galway in June 2016, when more than 4,000 tonnes of bog land collapsed on the N59 that connects Galway city to Clifden, a popular tourist route in Ireland.[59] This event was preceded by heavy rain and a cloudburst, thus re-enforcing the link between climate change and geological hazard such as landslides. Similarly, a series of landslides occurred in August 2017 on the Inishowen Peninsula following very heavy rain, which together with flooding resulted in extensive structural damage to roads and bridges including complete loss of one house due to a landslide.

GSI are also Irelands listed advisory body for the Office of Emergency planning in relation to tsunami threat and are members of the North East Atlantic and Mediterranean Tsunami Warning system (NEAMTWS). Work in relation to tsunami preparedness, including simulation exercises, is ongoing in Ireland. Recently, a combination of Science Foundation Ireland, Geological Survey Ireland and the Marine Institute, funded two research projects on climate change and its impact on cold water corals and on the threat of tsunamis in Ireland. Ocean-bottom seismometers will be used by the Dublin Institute for Advanced Studies to understand Ireland's offshore geology and attempt to monitor ocean process, which may help identify potential tsunamis. One of the threats of tsunamis, in addition to flooding, would be the generation of landslides as a result of the tsunami hitting land. Modelling of tsunami impact on Ireland has taken place and will be investigated further for inclusion in the next phase of CFRAM.

Indoor Radon Exposure

Radon is another factor which has economic and social costs which can be reduced by geoscience information and research. Radon is produced by the radioactive decay of radium, found in uranium ores, phosphate rock and several other minerals (Godish, 1989).[60] It is a noble gas which has the capability to seep through the ground and diffuse into the air. Radiation from the short-lived progeny can go all the way in the body causing serious illnesses such as cancer. Due to the extent of harm that radon exposure can cause, it is recognised as one of the greatest radiation health risk in Ireland. As per the EPA, up to 250 cases of lung cancer in Ireland can be linked to radon gas exposure. In Ireland, certain areas are likely to have homes with higher amounts of indoor radon gas. These areas are called High Radon Areas and can be identified on the Radon Map of Ireland, as shown in the figure overleaf.

The Radon Map, is based on the results of the National Radon Survey, carried out by the Radiological Protection Institute of Ireland (RPII) between 1992 and 1999. The results of the survey were published in the report in 2002.[61] The survey was carried out on the radon measurement in certain number of houses, chosen randomly in each 10km grid square of the national grid. In all, 11,000 houses were surveyed, where the results were used to identify the percentage of households having radon concentrations in excess of the reference level in each grid.[62] The mapping comprised five categories depicted by different shades, and it suggests that

[59] Crawford, C. (2016, June 24th). Major landslide sees 4,000 tonnes of bog close popular Galway tourist route. *Independent.ie.* Retrieved from: http://www.independent.ie/irish-news/major-landslide-sees-4000-tonnes-of-bog-close-popular-galway-tourist-route-34830435.html

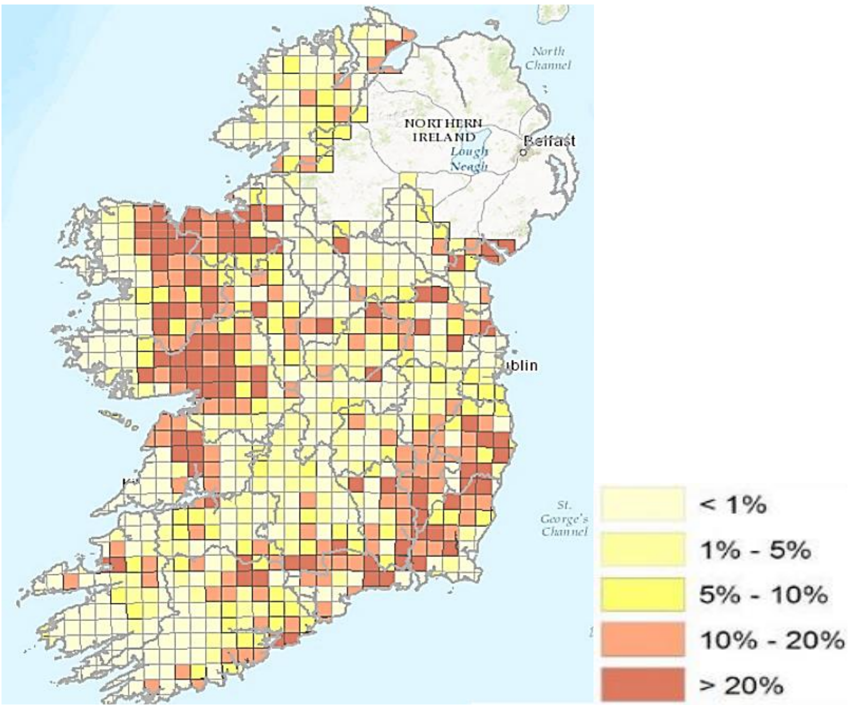
[60] Godish, T. (1989). Indoor Air Pollution Control. Lewis Publishers. *Chelsea, MI*.

[61] Fennell, S. G., Mackin, G. M., et al. (2002). Radon in Dwellings: The Irish National Radon Survey. *Radiological Protection Institute of Ireland.*

[62] The national reference level of radon concentration is 200 Becquerel per cubic metre (Bq/m^3).

if a house is located in the area designated as greater than 20%, then one out of every five houses there would have a radon concentration higher than the national reference level.

Figure 6.3: Radon Exposure in Ireland, Percentage Above Reference Levels



Source: Environmental Protection Agency [63]

Other Hazards

There are a number of other natural hazards including pyrite heave in concrete, subsidence, sinkholes and karst. Pyrite is a mineral comprised of iron and sulphur and is commonly found in sedimentary rocks. Pyrite oxidises to form sulfuric acid, as well as some other products, when exposed to moisture and oxygen. This sulfuric acid can then react with other minerals found in rock, such as calcium carbonate. These reactions can form gypsum and cause issues for buildings and dwellings. According to the Report of the Pyrite Panel in June 2012,[64] this can lead to:

- *The cracking of floors, internal partitions and external walls;*
- *Outward movement of external walls; and,*
- *The heaving of ground floors and bulging of internal partition finishes.*

Pyrite was found to have been used in the construction of a number of dwellings in certain administrative areas such as Dún Laoghaire-Rathdown, Meath, Offaly and Kildare, amongst others. Thus, in 2013 the Pyrite Resolution Board was formed by the Department of the Environment, Community and Local Government under the Pyrite Resolution Act 2013. This

[63] Environmental Protection Agency. *Radon Map.* http://www.epa.ie/radiation/radonmap/

[64] Pyrite Panel, 2012. *Report of the Pyrite Panel.* http://www.pyriteboard.ie/Pyrite/media/Pyrite/Updated/Report-of-Pyrite-Panel-June-2012.pdf.

board was set up to provide remediation for damages to dwellings that were affected by pyrite heave.

Sinkholes, also known as dolines, are formed through one of two main methods:

- The collapse of overlying rock or material into an underground cave or chamber; and,
- The slow solutional removal of rock from the surface downward.

GSI estimates there to be over 6,000 sinkholes, or dolines, in Ireland with these reportedly causing minor collapse of roads and fields in Ireland.

Subsidence is related to changes underground that affect the earth's surface. Similar to sinkholes this is an issue when the subsidence occurs where a dwelling or structure is built in an area that has been affected. Subsidence can be so severe that it leads to foundation failure in buildings which can have knock-on effects, in the form of water damage from drains, etc. Common signs of a building affected by subsidence include cracks in external blockwork, doors sticking in their frames and the rippling of wallpaper.

6.4 Economic Cost of Hazards

This section provides the estimates of the economic costs associated with an event of natural disaster in the Irish context. The data used here is derived from various sources; concerning primarily to the costs associated with the physical damage caused by an event, the remediation undertaken after the damage, and the cost incurred in organising the relief programmes.

As it can be seen in the table overleaf, Ireland ranks seventh for losses per capita amongst the EEA countries, at €1,009. This is higher than UK's €976 per capita. The ranking for Ireland is much lower if the events are ranked on the basis of fatalities. With 65 fatalities in 25 years, Ireland ranks 27th of the 34 countries presented in the list. The sub-sections here present the estimates of the economic costs associated with natural disasters in Ireland.

Table 6.1: Economic Losses from Extreme Weather/Climate Events (1980-2015 in 2015€)						
Country	**Total (€ million)**	**Insured (€ million)**	**Insured (%)**	**Loss Per person (€)**	**Loss Per sq.km (€)**	**Fatalities (number)**
Switzerland	18,740	9,581	51	2,625	453,854	1,155
Denmark	9,644	5,780	60	1,815	224,724	42
Austria	12,257	3,736	30	1,535	146,130	587
Luxembourg	659	407	62	1,519	254,682	130
Germany	87,602	40,458	46	1,159	245,126	9,814
Italy	64,983	2,243	6	1,129	215,122	20,619
Ireland	**3,932**	**2,026**	**52**	**1,009**	**56,336**	**65**
UK	57,823	40,268	70	976	232,656	3,520
France	56,984	28,349	50	948	89,995	23,397
Czech Rep.	9,720	3,252	33	940	123,253	207
Spain	33,602	4,005	13	812	66,414	14,583
Norway	3,380	1,836	54	753	10,439	40
Slovenia	1,471	188	13	738	72,576	241
Greece	7,175	82	4	677	54,336	2,397
Croatia	2,832	4	-	630	50,034	721
Portugal	5,912	324	5	579	64,098	2,993
Hungary	5,717	126	4	556	61,454	703
Cyprus	347	8	2	514	37,493	73
Romania	10,639	58	2	486	44,628	1,294
Sweden	4,134	1,124	27	466	9,425	44
Netherlands	6,435	2,998	47	412	154,912	1,728
Poland	14,258	925	6	376	45,600	1,154
Belgium	3,759	2,196	58	364	123,148	2,163
Finland	1,806	217	12	352	5,335	4
Slovakia	1,641	105	6	309	33,460	104
Bulgaria	2,361	125	5	288	21,393	192
Lithuania	922	6	1	270	14,128	69
Iceland	58	19	208	209	562	52
Liechtenstein	6	4	58	191	37,592	-
Malta	59	25	42	156	186,234	7
Latvia	354	47	13	149	5,478	92
Estonia	101	31	31	71	2,244	9
Turkey	3,782	328	33	60	4,826	1,674
Total	**433,094**	**150,880**	**35**	**779**	**75,778**	**89,873**
Source: NatCatService provided by Munich Re						

The major flood events discussed in previous section had numerous direct and indirect economic costs primarily associated with physical destruction, remediation, relief work, and disturbances to normal business. During the floods of 2009, the Irish government announced an emergency relief fund of €10 million with additional €2 million for the farmers.[65] The 2010 budget of Ireland added a further minimum amount of at least €70 million for those who were affected by the

[65] The Irish Times (2009, 24th November). €12m flood relief fund unveiled. Retrieved from: https://www.irishtimes.com/news/12m-flood-relief-fund-unveiled-1.849586

floods and to provide support for prevention efforts.[66] The capital investment programme of the government for 2012-2016 allocated €225 million on flood (around €45 million per year). In 2015, the government decided to revise these estimates and invest €430 million for next six years (2016-2021) in providing flood relief efforts. This was a huge increase, as compared to €410 million which had been invested overall in last 20 years.[67] In addition to all these investments, there was an announcement of €150 million Cork Flood Scheme in December, 2016.[68]

The cost of floods can be inferred from the estimates of the claims data by Irish insurers, as summarised below. These claims are made in the event of any damages to commercial property or cars during the occurrence of extreme weather situation. The Irish Insurance Federation states that a policyholder is also entitled to receive the claims for alternative accommodation and temporary repairs undertaken. Therefore, the claims data could be taken as a good proxy for estimating the direct tangible costs incurred due to the flooding events.

Table 6.2: Historical Insurance Claims During Flood Events (2008-2014)

Flood Event	Total Cost (€ million)
August, 2008	€96
November, 2009	€244
October, 2011	€127
January, 2014	€46
February, 2014	€156

Source: Annual Reports, Irish Insurance Federation (IIF)

Since these estimates are obtained from the insurance claims data, it is expected that the number of households affected by floods must have been recorded most accurately. Also, since the claims are approved post-inspection by insurance surveyors, the possibility of over-reporting or over-estimation of the figures is also minimised. In light of these facts, the insurance claims data is a good estimate of the direct physical losses in the event of floods.

Further, the Report on Flooding (2016)[69] provides detailed estimates of the impact of flooding on the households, as shown in Table 6.3 during the December 2015 - January 2016 flooding.

[66] RTE News. (2009, 9th December). Budget 2010 cuts €4bn in public spending. Source: https://web.archive.org/web/20091214132216/http://www.rte.ie/news/2009/1209/budget2010_main.html.

[67] Spain, J. (2016, January 7). The truth about the flooding in Ireland - reality, prioritizing and planning. Irish Central. Retrieved from: https://www.irishcentral.com/news/irishvoice/truth-flooding-ireland-reality-prioritizing-and-planning

[68] Kelleher, O. (2016, December 12th). Government announces €150 million Cork flood relief scheme. *The Irish Times.* Retrieved from: https://www.irishtimes.com/news/environment/government-announces-150m-cork-flood-relief-scheme-1.2902885

[69] National Directorate of Fire and Emergency Management (2016). Report on Flooding. Department of Housing, Planning, Community and Local Government.

Table 6.3: Impact on Households and Properties Affected (Dec 15-Jan 16 Flood)					
All Local Authorities	**Evacuated**	**Damaged but Habitable**	**Inaccessible (Not Flooded)**	**Threat of flooding**	**Business Flooded**
Total Houses	601	543	2393	1714	606
Source: National Directorate of Fire and Emergency Management (2016). Report on Flooding					

As per the records presented in the report, until September 2016, around 312 households received payments totalling between €100 and €1,000; 174 households received payments between €1,001 and €5,000; and, 76 households received more €5,000 in claims. These payments were made through the Humanitarian Assistance Scheme in response to the severe flooding. The total expenditure for all the humanitarian assistances are shown in Table 6.4.

Table 6.4: Humanitarian Assistance Expense by County (Dec 15-Jan 16 Flood)		
Flood Event	**Number of Houses**	**Total Paid**
Clare	20	€25,000
Cork	78	€281,000
Galway	162	€258,000
Kerry	12	€33,000
Kilkenny	24	€58,000
Limerick	18	€123,000
Mayo	43	€246,000
Offaly	13	€70,000
Roscommon	19	€123,000
Sligo	17	€34,000
Tipperary	45	€107,000
Westmeath	50	€150,000
Wicklow	12	€38,000
Counties with fewer than 10 households: Carlow, Cavan, Donegal, Kildare, Laois, Leitrim, Longford, Louth, Meath, Monaghan, Waterford, Wexford	48	€231,000
Total	**561**	**€1,777,000**
Source: National Directorate of Fire and Emergency Management (2016). Report on Flooding		

The government also decided to allocate €5 million to the small businesses that were affected due to Storm Desmond and were not insured against the damages of floods. The scheme was implemented in two stages, in which the first stage involved immediate contribution of up to €5,000 per business, depending on the scale of the damage; and, the second stage was for those businesses that suffered damages of more than €5,000 with a contribution of up to €20,000 from the government.

The local authorities were asked by the Department of the Housing, Planning, Community and Local Government to compile an initial estimate of the damages caused by the flooding in Dec 2015 - Jan 2016. The initial estimates were compiled which brought into effect the clean-up responses undertaken by the authorities. The table overleaf shows the contributions made by the government for local authorities and different sectors after the flood of December 2015.

A total of €18 million of funding was made available to the local authorities, of which re-imbursements of around €17.7 million had been made. For the transport sector, out of the total fund, around €8 million was allocated to Irish Rail for repairs of the damaged infrastructure. The total amount spent by the government for remediation was around €205 million. Adding the humanitarian expenses to this amount brings the total economic cost of around €207 million for the 2015 flood.

Table 6.5: Government Expenses (Dec 2015-Jan 2016 Flood)

Clean-up Areas	Clean-up costs (€ Million)
Local Authority (emergency related overtime expenses, emergency material and equipment)	18.0
Transport Infrastructure	110.0
OPW Annual Budget for flood relief (€430 million for 2016-2021)	72.0
Small Businesses	5.0
Total	**205.0**

Source: National Directorate of Fire and Emergency Management (2016). Report on Flooding

Total direct estimated expenses of the above two economic costs of floods are presented in the table below. This amounted to €206.8 million for the period examined.

Table 6.6: Estimated Expenses (Dec 2015-Jan 2016 Flood)

Expenses	Costs (€ Million)
Government Expenses	205.0
Humanitarian Relief Expense	1.8
Total	**206.8**

Source: National Directorate of Fire and Emergency Management (2016). Report on Flooding

This is likely to represent only a small element of economic costs and in our analysis, we assume that these amount to 50% of costs so the overall costs are estimated to be €414 million.

As discussed in previous section, landslide events in Ireland are not very frequent; but there have been some episodes in the past decade which entailed certain amount of economic cost. The costs of landslides, much like floods, relate to physical destruction, remediation and *ex-post* disruptions.

Following a landslide in Mayo in 2003, the restoration work took nearly 40 months and cost around €4 million.[70] It involved the installation of kinetic barriers, at the cost of around €900,000 in order to provide shield if there was a similar incident in the future. Over 40 families had been affected directly by the landslide. According to a different source, the evacuation and damage

[70] Dyy, M. (2006, December 5th). Landslide area restored. *The Mayo News.* Retrieved from: http://www.mayonews.ie/news/699-landslide-area-restored.

costed around €10 million in Pollatomish.[71] Also, a landslide in Kerry in 2008 was reported to have killed around 8,000 fish from the debris that flowed.[72]

Iarnród Éireann, in 2016, placed 2,500 tonnes of rocks on the beach to protect the Greystones Dublin railway line, costing €150,000. This contribution was essential as the railway line is on one of the largest coastal wetland complex on the east coast, and is also an EU designated Natura 2000 site supporting wide range plant and animal species.[73]

A more recent landslide occurred on the N59, which connects Galway City and Clifden, was considered as a major event, displacing an estimated 4,000 tonnes of bog. This incident was described as a significant event and required substantial remediation. The amount that was sanctioned for the restoration and clean-up after the incident was close to €250,000.[74] The diversions placed on the road resulted in 45 minutes of delay for passengers.

The National Radon Survey (NRS), which was carried out from 1992 to 1999 produced detailed radon profile of all counties in Ireland. The measurement and monitoring of indoor radon concentration requires installation of detectors which remain in the household for period of the survey. The process is quite detailed and incurs some costs. As per the RPII radon action plan (2006)[75], the uptake of measurement services could be increased if the service is made available for free. The total number of houses located in high radon areas were then estimated around 300,000 and with the current average cost of €40,[76] the total cost of radon measurement in the houses totals around €12 million.

The remediation is the next step and the average cost for the treatment of a house, found to be above the reference level of radon concentration, is €1,000.[77] In light of the limited data, RPII estimates that on an average 4,000 homes per annum would be measured to have higher radon concentration; which if are supported by the government in the form of tax benefits or grants would cost the government €4 million on an annual basis. As per the NRS 2002 survey statistics, 91,000 homes in the country have higher radon concentration, which might increase further with time, implying estimated cost of €91 million for the remediation and installation of preventive measures in the houses.

The public health implication of radon exposure should also be noted. The Joint Position Statement of RPII and Health Service Executive (HSE) [78] of 2010 quotes the findings from Gray et

[71] Hickey, D. (2008, August 26th). Moving mountains- the dangers of our changing rainfall. *Irish Examiner.* Retrieved from: http://www.irishexaminer.com/ireland/moving-mountains-the-dangers-of-our-changing-rainfall-70683.html.

[72] 2008, August 28th. Further Kerry landslides feared as salmon and sea trout toll put at 8,000. *Irish Examiner.* Retrieved from: http://www.irishexaminer.com/story/ireland/qlausnidid/rss2/?utm_source=link&utm_medium=click&utm_campaign=section link.

[73] O'Brien, T. (2016). Wicklow landslide left railway within two metres of sea. *The Irish Times.* Retrieved from: https://www.irishtimes.com/news/ireland/irish-news/wicklow-landslide-left-railway-within-two-metres-of-sea-1.2489740.

[74] (2016, August 24). €250k allocated for repairs following N59 landslide. *Connacht Tribune.* Retrieved from: http://connachttribune.ie/e250k-allocated-repairs-following-n59-landslide/.

[75] Radiological Protection Institute of Ireland (2006). Action plan to Identify and Remedy Irish Houses with Radon Concentrations above the National Reference Level. Retrieved from: https://www.epa.ie/pubs/reports/radiation/radonactionplan.html.

[76] Source: https://www.alpharadon.ie/.

[77] Source: http://theradonshop.com/.

[78] RPII and HSE (2010). Radon Gas in Ireland Joint Position Statement by the Radiological Protection Institute of Ireland and the Health Service Executive. Retrieved from: https://www.hse.ie/eng/services/publications/Environmentalhealth/Radon%20Gas%20in%20Ireland.pdf.

al. (2009)[79] from the study conducted in the UK, suggesting that around 83% of lung cancer cases are due to smoking, of which less than 1% are due to radon only. The effect of smoking and radon combined together is around 3%. In the case of Ireland, around 150 to 200 deaths per year due to lung cancer can be linked to radon. Ireland's mean indoor radon concentration of 89 Bq/m^3 is higher in relation to the international mean of indoor radon concentration being 39 Bq/m^3. This means that Irish population on average is at a higher risk of radon-related fatalities. This also implies that the benefit for radon gas remediation from Irish houses is also higher as compared to other places with low concentrations. Aversion of lung cancer risk due to radon would result into benefit of additional years to the residents.

The Environmental Protection Agency (EPA) states that there are up to 250 cases of lung cancer per year which can be linked to radon.[80] In order to estimate the economic cost of radon-induced lung cancer Indecon used the one-year survival rate of lung cancer found by Cancer Research UK of 32.1%.[81] This means that 32.1% of people diagnosed with lung cancer survived for a year or longer following their diagnosis. Using this we can obtain an estimate of 170 for the number of radon-linked lung cancer deaths in Ireland in 2016. Research into the economic cost of smoking used the statistical value of a life year when estimating the economic cost of cancer due to smoking. Indecon uses the same estimate of €2,000,000.[82] It is also important to include an estimate of the loss of earnings for those who are survivors. The Irish Cancer Society estimates that the average income of cancer patients falls by €16,750 per annum following their diagnosis.[83] Thus, when the estimates for the economic cost of deaths from lung cancer linked to radon and loss of earnings from survivors, Indecon estimates the economic cost of radon-linked lung cancer was approximately €341 million.

Table 6.7: Monetary Impact of Radon Cancer Cases, 2016	
Variable	**Value**
Number of Lung Cancer Cases Due to Radon	250
1 Year Survival Rate Lung Cancer	32.1%
Lung Cancer Deaths Due to Radon	170
Lung Cancer Survivors	80
Value of Statistical Life Year	€2 Million
Average Loss of Earnings for Cancer Diagnosis	€16,750
Cost of Lung Cancer Death Due to Radon 2016	€339.5 Million
Loss of Earnings Due to Radon-Linked Lung Cancer	€1.3 Million
Economic Impact of Radon-Linked Lung Cancer	**€340.8 Million**
Source: Indecon analysis of Department of Health, Cancer Research UK, Irish Cancer Society	

[79] Gray, A., Read, S., McGale, P. and Darby, S. (2009). Lung cancer deaths from indoor radon and the cost effectiveness and potential of policies to reduce them. *British Medical Journal*, BMJ 2009;338:a3110 doi:10.1136/bmj.a3110.

[80] EPA. http://www.epa.ie/radiation/radon/

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[82] http://health.gov.ie/wp-content/uploads/2016/08/Technical-Annex_An-assessment-of-the-economic-cost-of-smoking-in-Ireland.pdf

[83] Irish Cancer Society. https://www.cancer.ie/sites/default/files/content-attachments/the_real_cost_of_cancer_report_final.pdf

6.5 Summary of Key Findings

- This section examined the main natural hazards that affect Ireland, namely flooding, landslides and radon exposure.
- There have been a number of major floods over the last ten years in Ireland with insurance claims from floods equalling €244 million and €156 million due to floods in September 2009 and February 2014, respectively. The most recent, major flooding event occurred in December 2015-January 2016. Government expenditure on remediation since the flood has totalled €205 million, with a further €2 million from humanitarian aid. This is likely to represent only a small element of economic costs and in our analysis, we assume that these amount to 50% of costs so the overall costs are estimated to be €414 million.
- Landslide events in Ireland are not very frequent, but there have been some episodes in the past decade which entailed certain amount of economic cost. The costs of landslides, much like floods, relate to physical destruction, remediation and *ex-post* disruptions.
- Radon exposure is an important issue in Ireland because Ireland's mean indoor radon concentration of 89 Bq/m^3 is higher in relation to the international mean of indoor radon concentration being 39 Bq/m^3. As a result, Ireland has approximately 250 cases of lung cancer linked to radon each year. The estimated economic cost of these cases is just under €350 million.

7 Geoscience Ireland Business Cluster

7.1 Introduction

In addition to considering some of the main economic impacts of geoscience, it is interesting to note that geoscience supports business clusters of economic activity. This can be illustrative by considering the work of Geoscience Ireland business cluster.

Geoscience Ireland (GI) is a network of geoscience-related organisations in Ireland (of which the Geological Survey Ireland is a member) and is supported by Enterprise Ireland. The economic impact of this organisation is explored in this section. However, it should be noted that members of GI will operate in the sectors previously examined. This implies that such economic activity is non-additive.

7.2 Geoscience Ireland Member Organisations

Geoscience Ireland (GI) is a network of geoscience-related organisations in Ireland which was set up and is funded by GSI and is also supported by Enterprise Ireland with participation in steering committee by the Department of Foreign Affairs. The network was established as an initiative for creation and retention of Geoscience jobs by increasing collaboration of Irish companies in the sector in order to win more work in overseas markets and provides common branding, promotion, access to tender opportunities and support.

Geoscience Ireland Network is composed of 33 companies as of mid-2017, which are presented in the table below. GI network companies provide design, consultancy and contracting services to multilateral agencies, governments and the private sector. GI network companies have consultative capacity in areas such as geology, engineering, environment, institutional capacity building, geophysical/ geochemical surveying, and project management. GI network companies can also contract in drilling, lining, infrastructure, mining/quarrying, and building materials. There has been a growth in the number of businesses participating in Geoscience Ireland and in 2017 reached 33.

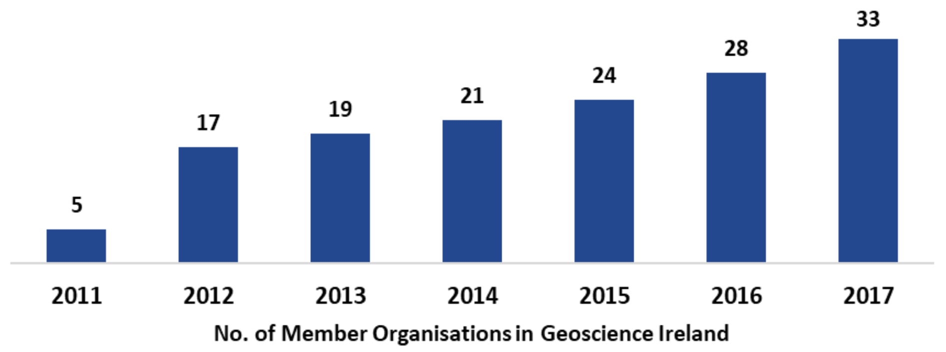
Table 7.1: Geoscience Ireland Member Organisations as of mid-2017

Apex Geoservices	IE Consulting	Pavement Management Services
Arup (Ireland)	IGSL	Priority Group
AWN Consulting	Irish Drilling	PW Mining
BRG	Intersocial Consulting	PW Nigeria
ByrneLooby	J.B.Barry & Partners	QME
Compass Informatics	Lagan Asphalt Group	Roadstone
Designer Group	Lisheen Technical & Mining Services (LTMS)	Rubicon Heritage Services
ERM (Ireland)	Meehan Drilling	SLR Consulting (Ireland)
FLI Group	Mincon Group	Tobin Consulting
Gavin and Doherty Geosolutions (GDG)	Murphy Surveys	Trench Control
Geological Survey Ireland (GSI)	Nicholas O'Dwyer	Verde Environmental Group

Source: Geoscience Ireland

GI was established with five member companies in 2011. As shown above this has grown to include 33 firms. The figure overleaf presents this growth year-on-year. The current 33-member organisation represents 29 SME firms (1-250 employees), three large firms (250+ employees) and the Geological Survey Ireland (GSI).

Figure 7.1: Growth in Geoscience Ireland Member Companies, 2011 – mid-2017

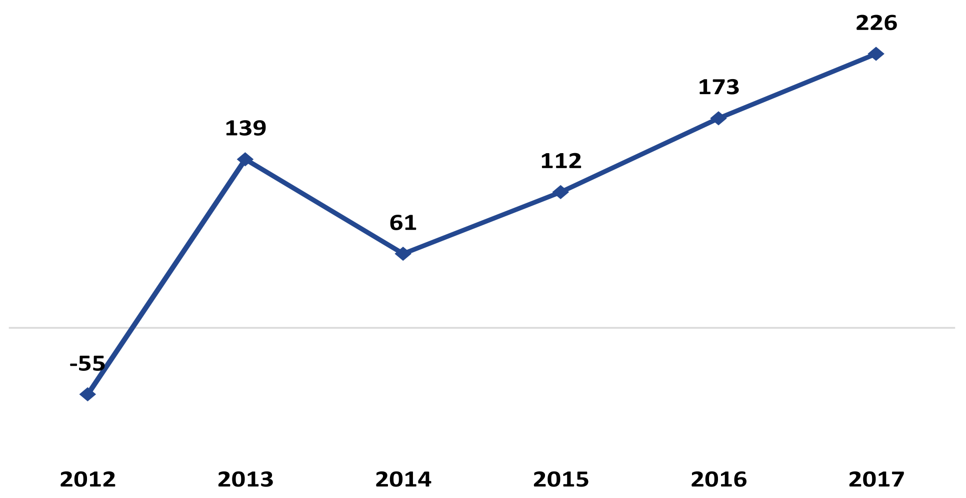


Source: Geoscience Ireland

7.3 Geoscience Ireland Employment

GI network companies have seen several years of sustained net employment increases since its inception, with the exception of 2012. This, however, is unsurprising given the sustained increase in the number of member organisations in GI. Net job creation at GI member organisations is presented on an annual basis in the below figure.

Figure 7.2: Net Job Creation in Geoscience Ireland Member Companies, 2012 - 2017



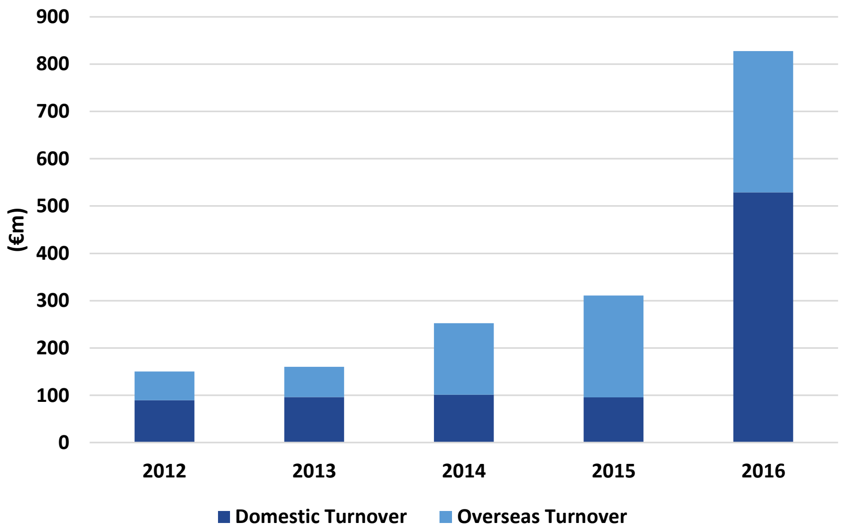
Source: Geoscience Ireland

On an aggregated basis Geoscience Ireland has supported 656 jobs over the period 2012 to mid-2017.

7.4 Geoscience Ireland Economic Impact

Indecon has considered the economic impact of the Geoscience network through an analysis of turnover of GI member organisations. In terms of turnover, the Geoscience Ireland Network's domestic earnings saw strong growth in 2016. Domestic turnover as a share of total turnover fell from 2012 to 2015, however this increased substantially in 2016.

Figure 7.3: Geoscience Ireland Member Companies – Turnover, 2012 - 2016



Source: Geoscience Ireland

7.5 Summary of Key Findings

- Geoscience Ireland (GI) is a network of geoscience-related organisations in Ireland set up, funded and managed by the GSI and supported by Enterprise Ireland. Geoscience Ireland Network is composed of 33 companies, having grown from five companies in 2011.
- The GI network has seen several years of sustained net employment increases since its inception, with the exception of 2012. On an aggregated basis Geoscience Ireland has supported 656 jobs over the period 2012 to mid-2017.
- The domestic turnover of €529.1 million from the GI network made up the majority of the total turnover of GI network companies of €827.2 million. Thus, €298.1 million of GI network turnover was overseas turnover.

8 Summary of Geoscience Economic Profile

8.1 Introduction

The section of the report synthesises the previous sections to estimate an overall economic impact of geoscience to the Irish economy. Indecon recommends interrogation of the previous sections for details as to the methodological approach to the estimation of these results.

8.2 Economic Profile of Geoscience – Output

Indecon's analysis indicates that the geoscience sector in Ireland had an overall economic impact of €3.28 billion in 2016.

Table 8.1: Overall Economic Impacts – Output 2016, (€ million)

Area	Direct	Indirect and Induced	Overall Economic Impact
Geotourism and Geoheritage	370.7	290.3	660.9
Groundwater Collection, Treatment, Supply	35.2	29.5	64.7
Extractive Industries	939.9	716.3	1,656.2
Geoscience Research	30.9	21.5	52.5
Natural Hazards	414.0	429.6	843.6
Total	**1,790.7**	**1,487.2**	**3,277.9**
Non-additive Areas			
Geoscience Ireland	*827.2*	-	-
Groundwater Yield Value	*392-512*	-	-
INFOMAR contribution to Marine	*24.6*		

Source: Indecon analysis

8.3 Economic Profile of Geoscience – Gross Value Added

In terms of Gross Value Added (GVA) the geoscience sector in Ireland contributes approximately €676 million in direct economic activity. Taking account of both indirect and induced activity, the overall GVA terms increases to €1.47 billion.

Table 8.2: Overall Economic Impacts – Gross Value Added 2016 (€ million)

Area	Direct	Indirect and Induced	Overall Economic Impact
Geotourism and Geoheritage	239.6	175.9	415.5
Groundwater Collection, Treatment, Supply	18.3	17.8	36.0
Extractive Industries	282.9	359.2	642.1
Geoscience Research	24.3	16.7	41.0
Natural Hazards	111.1	227.4	338.5
Total	**676.2**	**796.9**	**1,473.2**

Source: Indecon analysis

8.4 Economic Profile of Geoscience – Employment

The geoscience sector is estimated to provide approximately 15,100 jobs in full-time equivalent terms directly. When the indirect and induced impacts are taken into account, almost 25,000 jobs in full-time equivalent terms are supported. This is presented in the table below.

Table 8.3: Overall Economic Impacts – Employment (FTEs) 2016			
Area	**Direct**	**Indirect and Induced**	**Overall Economic Impact**
Geotourism and Geoheritage	6,888	1,879	8,767
Groundwater Collection, Treatment, Supply	205	539	745
Extractive Industries	3,633	4,189	7,822
Geoscience Research	465	259	724
Natural Hazards	3,919	2,763	6,681
Total	**15,110**	**9,628**	**24,739**
Source: Indecon analysis			

8.5 Conclusion

Indecon's independent analysis indicates that the scale of the existing and future economic impacts of geoscience may be much more significant than initially perceived. While all sectors of the economy have an impact, it is evident that geoscience includes a number of areas of activity which contribute significant employment and output in the Irish economy. The sector is also likely to have wider societal impacts and offers potential for future expansion.

9 Future Trends in Geoscience Sector and Concluding Recommendations

9.1 Introduction

In this section of the report we examine the future trends in the geoscience sector. The future trends in geoscience will be driven by both the demand for the work of geoscientists, and the emergence of new technological drivers. Future trends in geoscience globally will be driven by the demands of society, in particular: [84]

- Economic, resource provision, health, quality of life, environmental protection.
- Climate change (including ice sheet dynamics)
- Mining
- Urbanisation
- Energy
- Radioactive waste
- Food production
- Natural Hazards

Geoscience will also be impacted by technological changes and opportunities. In this section we discuss some of the key future trends that are likely to impact on the geoscience sector over the next decade. There are a number of emerging future trends that are likely to impact on the geoscience sector. While there is inevitable uncertainty regarding these developments, changes in societal demands, in policies to handle climate change and natural hazards, as well as the application of technology in mapping and data analytics, will impact on the geoscience sector.

9.2 Technological Change

One of the most significant future trends impacting on the geoscience sector will be changes in the use of technology to help the sector address economic and societal challenges. This will include more extensive use of sensors, UAVs, AUVs and satellites. The impact of geoscience will also be enhanced for users through utilisation of enhanced imaging and telemetering, and sophisticated data analytics.

Technological change is also having a large impact on the way in which geoscience is conducted. The potential role for digitisation in geoscience has been known for some time. For example, digital methods make it easier to re-use pre-existing data (e.g. previous field data, geophysical survey, satellite images) during renewed phases of fieldwork. Increased spatial accuracy from satellite and laser positioning systems provides access to geostatistical and geospatial analyses that can inform hypothesis testing during fieldwork[85].

Examples of more specific technological advances include:

- Earth Observation/satellite-based observations, geodesy, topography
- UAVs/drones to access spatial and temporal data

[84] "What are the societal demands and challenges our research needs to address?" University Geoscience UK - Future Science: a vision for the next 25 years. (2017)

[85] "Unlocking the spatial dimension: digital technologies and the future of geoscience fieldwork," K.J.W. McCaffrey et al (2005)

- Sensors – ocean bottom geodetic, seismic, environmental, networks and associated technology
- Modelling advances – computational, and training.

9.3 Energy Resources

There is likely to be considerable change in the sources of Ireland's energy in the coming decades, which will have significant impacts on the geoscience sector. One example of future changes which will impact on the geoscience sector is the predicted expansion in renewables and biomass.

In terms of renewals, increased focus is being placed on geothermal energy. By definition, geothermal energy is the energy stored as heat underneath the surface of the earth. Its net potential is limitless with regard to humans, and is already utilised for heating, systems that provide hot water or steam to a wide range of units, along with heating and cooling of private and commercial buildings such as residential homes, offices, and shops by utilising geothermal heat pumps. Also, geothermal energy has industrial potential to grow plants in greenhouses, heating water at fish farms, drying crops and many other industrial processes. This energy is also being harnessed to generate electricity through geothermal power plants. The Government have recently launched a consultation on the design options and implementation of a Renewable Heat Incentive.

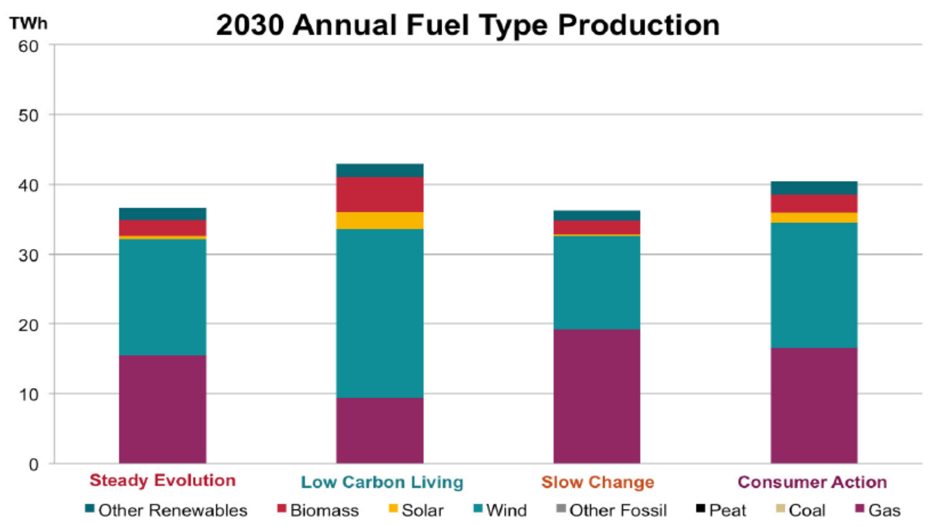
Another source of potentially limitless renewable energy is through offshore energy sources. The Offshore Renewable Energy Development Plan (OREDP), published in 2014, identifies the opportunity for the sustainable development of Ireland's offshore renewable energy resources. Under the OREDP Ireland is developing a suite of world class test infrastructure to encourage the development of our Offshore Renewable Energy potential. The aim of the OREDP is to increase indigenous production of renewable electricity, contribute to reductions in our greenhouse gas emissions, improve the security of our energy supply and create jobs in the green economy. The future use of biomass is relevant to the geoscience sector as it may have an impact on the important peat extraction industry. According to EirGrid, the energy production capacity of biomass in 2030 will range from 270 – 750 MW. While significant, this level of energy production is considerably below levels required by the Irish economy. EirGrid also considered the possibility of the coal-powered Moneypoint power station (the largest in Ireland) switching to biomass alternatives. This option, however, would require significant government investment, as outlined below:

> *"We have considered that Moneypoint repowers to gas in our scenarios. Biomass is being considered as a potential fuel source for Moneypoint in the future. This would require a biomass fuel source far in excess of Ireland's biomass resource potential. Based on projected levelised costs, it would also require a substantial government subsidy to be viable at such a scale."*[86]

The high-end range of 750 MW production of biomass would be able to facilitate the full energy production capacity (370 MW) of the three currently operating peat-fuelled power stations.

[86] Bord na Móna's *Sustainability 2030*

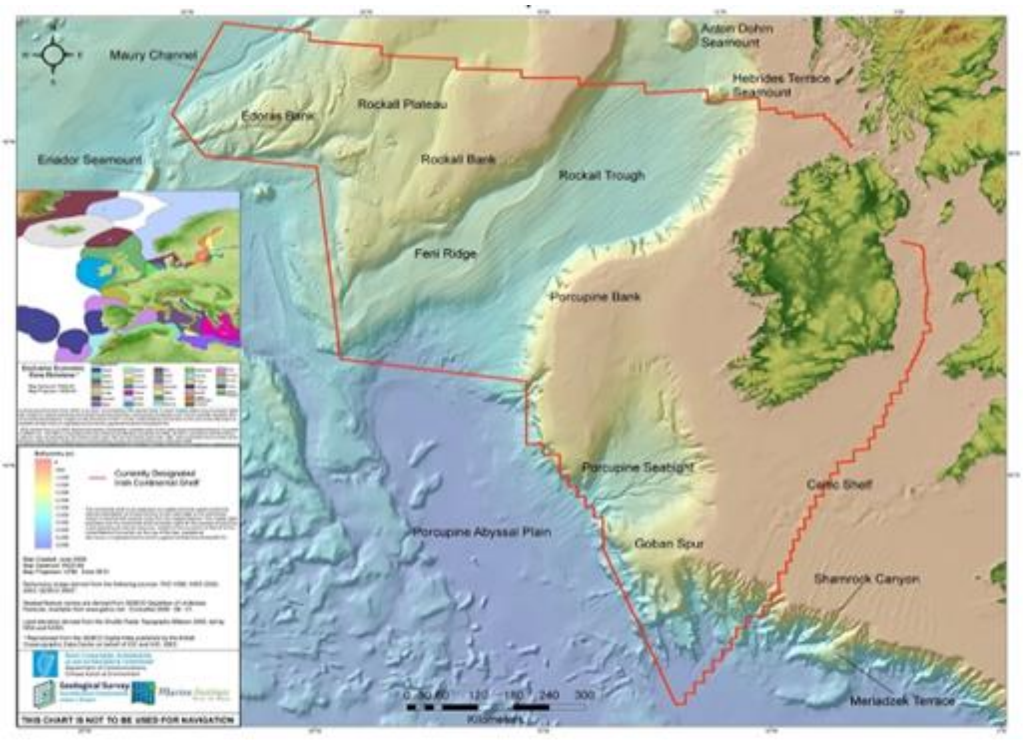
Figure 9.1: Annual Fuel Production Across Four EirGrid Scenarios, 2030



Source: EirGrid Tomorrow's Energy Scenarios 2017 – Planning our Energy Future

Oil and Gas Exploration within Irish terrirtorial waters requires a license regulated by the Petroleum Affairs Division of the Department of Communications, Climate Action, and the Environment. There have been two phases of recent licencing rounds, which have concerned the licencing of acreage primarily within the Porcupine Sea bight and Rockall Trough.

Figure 9.2: Ireland's Marine Territory



Source: The Marine Institute

In addition, a major development is likely to relate to new opportunities provided by Ireland's marine territory. In terms of exploration, only a small proportion of Ireland's territorial waters has been explored to date. Ireland's claimed marine territory covers an area of over 880,000 km^2. As well as any potential for oil and gas finds, our marine territory also offers very significant potential for the marine sector and for marine related research and development.

9.4 Tourism Sector

There is also expected to be potential for expansion of the geotourism and geoheritage sector, as tourists become increasingly aware of the importance and uniqueness of Ireland's natural landscape and other geotourism/geoheritage assets.

For example, the designation of three Irish geoscience sites as UNESCO Geoparks is a positive marketing development that should be commended. The Geological Survey already provides strong support for the Geotourism sector through its Geoheritage programme and outreach initiatives. GSI has provided grant funding, steering group representation and technical advice to the Irish Geoparks and aspiring Geopark projects for over 10 years. Now that the three Irish Geoparks are UNESCO designations (since 2015), it is important that measures are taken to ensure that the Geoparks maintain their UNESCO designation and that other geopark and geotourism initiatives are supported within this growing sector.

9.5 Hazards

As has been outlined in Section 6 of this report, the economic impact of natural hazards will be affected by climate change. This issue is expected to continue to grow in importance and more frequent extreme weather events are expected. This will carry greater economic costs for Ireland. For example, the Department of Defence produce a National Risk Assessment for Ireland, previously mentioned, which includes natural hazards such as extreme weather conditions. The Department indicate that some climate change studies suggest that drought may become more common in the future.

The EPA are also heavily involved in assessing the potential impact of Climate Change for Ireland, and have provided the following predicted adverse impacts:[87]

- ❑ Sea level rise;
- ❑ More intense storms and rainfall events;
- ❑ Increase likelihood and magnitude of river and coastal flooding;
- ❑ Water shortages in summer in the East;
- ❑ Adverse impacts on water quality; and,
- ❑ Effect on fisheries sensitive to changes in temperature.

The above threats and hazards should be considered carefully and Ireland's relatively benign natural hazard risk profile should not be assumed when taking a long-term perspective. Such hazards carry economic costs in terms of protection, remediation, and repair. The potential for geoscience to reduce the economic and social costs of natural hazards is likely to be of growing importance, both to the sector and to wider society. There is likely to be an increasing

[87] Environmental Protection Agency – Climate Change Research Programme – "What Impact will climate change have for Ireland?"

requirement to develop high resolution assessments for natural hazards arising from the need to respond to climate change, and geoscience databases will be an essential component of such responses.

9.6 Extracted Materials

The future trends in extracted materials will be dependent on both the expected future supply and demand of the materials. Zinc is a primary input into a wide range of products, and is the fourth most mined resource on Earth. According to Connemara Mines, future growth in the zinc extraction market will be driven primarily by developing economies such as China and India. Connemara Mines outline that global demand for zinc in 2016 was approximately 15 million tonnes, whereas forecasted demand in 2030 is approximately 22.5 million tonnes.[88]

As of 2016 Ireland produced 1.26% of global zinc production[89] and therefore our position in the zinc market is important and should continue to grow as the demand for zinc increases. Ireland is currently a major European producer of zinc and will be able to benefit from growth in the global zinc market.

According to the International Lead and Zinc Study Group, global lead mine production has fallen over the 2012 to 2016 period; however, it should be noted that 2017 saw higher production levels in January to July relative to the same period in 2016. Metal usage (demand) also grew, however. Irish lead markets will benefit from increased prices if demand continues to exceed supply, due to standard market forces. Demand has fluctuated from 10.5 million tonnes to 11.1 million tonnes across the 2012 to 2016 period. This is presented in the table below.

Table 9.1: Global Lead Usage, 2012 - 2017

	Global Annual Lead Usage					Half Year (Jan-Jul) Usage	
000 tonnes	**2012**	**2013**	**2014**	**2015**	**2016**	**2016**	**2017**
Mine Production	4,905	5,247	4,933	4,772	4,717	2,726	3,000
Metal Production	10,649	11,161	10,963	10,862	11,183	6,435	6,922
Metal Usage	10,583	11,149	10,945	10,881	11,150	6,393	7,031

Source: International Lead and Zinc Study Group

There is also likely to be a significant increase in construction activity in the coming years, which will require an expansion of the activity of extractive industries to meet the need for construction inputs. In an ESRI report, it was suggested that housing supply could reach up to 30,000 units per annum by 2024.[90] A more recent study of the housing market and the Help to Buy incentive undertaken by Indecon for the Minister of Finance suggested that there is likely

[88] Actual and Forecasted demand is presented on Connemara Mines Website (http://www.connemaramc.com/zinc) and sourced via Wood Mackenzie.

[89] United States Geological Survey - Minerals Information – Zinc 2017

[90] Economic and Social Research Institute, 2016. *Ireland's Economic Outlook: Perspectives and Policy Challenges.* December 2016. https://www.esri.ie/pubs/EO1.pdf

to be a significant increase in housing supply over the next three years, and this will provide opportunities for the geoscience sector.[91]

9.7 Geoscience in the National Investment Plan

This report has estimated that the geoscience sector in Ireland has been valued at over €3.2bn p.a. and is associated with almost 25,000 jobs. To support this growing sector a number of strategic initiatives will be further developed over the period of the National Investment Plan, through an investment of €47m in Geological Survey Ireland (GSI). INFOMAR, the national marine mapping programme will progress towards completion of mapping of Irish territorial waters, supporting Harnessing our Ocean Wealth, the Marine Development Plan with funding of €16m. Tellus, the airborne geophysical and ground geochemical mapping programme, will continue towards national completion, mapping another quarter of the country, focussed on midland and eastern counties and developing products for agriculture, environmental protection and investment support, also with funding of €16m.

The new programme of monitoring of groundwater and turlough flooding, initiated under the Programme for a Partnership Government, will deliver new data to inform the next round of the Catchment Flood Risk Assessment and Management programme (CFRAM), to help alleviate long term flooding issues in the midlands and west at a cost of €2m. A series of projects under Geoscience Initiatives, funded to c.€8m, will tackle issues such as Drinking Water and Groundwater Protection, mapping Landslide Hazard, supporting Geotourism and Geoheritage and development of applied products and updated mapping.

GSI, working with Enterprise Ireland and Department of Foreign Affairs, will also continue to support the Geoscience Ireland business cluster of Irish companies, facilitating them in collaborating to support jobs in the geoscience sector throughout Ireland, by winning work in overseas markets. RTDI in the geoscience sector will be expanded through further collaborative research and GSI participation as partner, data provider or funder as appropriate, with continued support of the SFI, industry and government backed Irish Centre for Research in Applied Geoscience. GSI will also further develop the National Geoscience Data Centre, providing continued online free access to digital data as well as supporting physical sample repositories such as the National Core Store. This range of initiatives taken as a whole support balanced regional development and investment, making best use of Ireland’s natural resources and geoscience sector expertise.

9.8 Recommendations

The previous sections have set out the background and economics scale of the geoscience sector in Ireland, as well as reviewing future trends which may affect the future direction of the industry. Indecon have identified a number of recommendations for consideration by the various stakeholders in the industry. Reflecting the diffuse nature of the industry, these recommendations are not directed at one particular organisation per se, such as the GSI, but

[91] Indecon International Research Economists, 2017. *Indecon Impact Assessment of the Help to Buy Tax Incentive.* Published by the Department of Finance. http://www.budget.gov.ie/Budgets/2018/Documents/HTB_Independent_Impact_Assessment_Sept2017.pdf

rather cover the range of activities which are captured under the geoscience label. These recommendations are summarised in the next table, and are further explained below.

Table 9.2: Summary of Recommendations
1. **Recognise of Importance of the Geoscience Sector**   2. **Continue to Invest in Geoscience Research**   3. **Improve Data Availability**

Recommendation 1: Recognise of Importance of the Geoscience Sector

The key conclusion of this report is to emphasise the size and importance of the geoscience sector in Ireland. Given its diffuse nature, the importance of the sector is often not fully appreciated, though in aggregate it is very substantial. When the direct, indirect and induced economic impacts are accounted for, the aggregate Value Added across the sector amounts to €1.5bn per annum. This economic activity ranges over a number of critical areas to Ireland's economy and society, including ensuring access to reliable and clean energy sources; access to high-quality groundwater resources; the identification and management of natural hazards; the sourcing of critical inputs to the construction and other industries; and the supporting of a number of jobs in export-related fields, including but not limited to areas such as geotourism/geoheritage and consultancy services.

Recommendation 2: Continue to Invest in Geoscience Research

Ireland contains a number of public and private organisations involved in research into various aspects related to geoscience. Among Higher Education Institutions, UCD, TCD, University of Limerick, Maynooth University, DIAS, University College Cork, DCU and Institutes of Technology all have significant programmes of Geoscience research. This is both supported and reinforced by a number of public institutions, in particular GSI, but also the Marine Institute, Teagasc, Met Éireann, the Environmental Protection Agency, Enterprise Ireland and Sustainable Energy Authority of Ireland. The scale and cohesiveness of this research activity has been enhanced through the launch of iCRAG in December 2015 as a multi-site geoscience research centre, funded by SFI, the European Regional Development Fund, and industry and government partners.

The continued support of geoscience research remains critical to both the economic and environmental life of Ireland. It also has the potential to encourage international firms in the geoscience space to establish additional research and other facilities in the country. A small number of important research areas are listed below by way of example, though a full research prioritisation exercise is beyond the scope of this report:

- Research is necessary both in terms of potential sources of renewable energy, but also to promote greater energy self-sufficiency in fossil-based fuels given the continued need for such sources for the foreseeable future.

- Research is also needed in terms of achieving a better understanding of soil properties and their relation to valuable ecosystem services, and to ensure continued sustainable food production.
- Ensuring that Ireland has a secure and efficient supply of raw materials remains critical, particularly given the current rise in construction activity on the back of rapid economic growth, strong demographics, continued immigration and the current lack of housing supply.
- The identification and management of Natural Hazards remains a critical area for research, given the very large economic impact of these hazards. Given their nature, no single sector, organisation or discipline can address all aspects of natural hazard identification and mitigation alone, and this effort needs to be a coordinated one.
- The access to, and quality of, groundwater remains a key requirement for the survival of many Irish communities. Continued research is necessary to identify existing and future threats to groundwater availability and quality, particularly as the Irish population continues to increase and the demand for, and pressure on, existing resources rises.

Recommendation 3: Improve Data Availability

Improving data available on the economic impact of geoscience sector would enable the significance of the sector to be monitored on an ongoing basis. In addition, continuing the work of the GSI in the acquisition and dissemination of geoscience data, through initiatives such as the National Geoscience Data Centre, will enhance its impact for users with significant potential societal and other benefits.

Annexes

Annex 1 Historical Studies of R&D Returns

The majority of studies found a private rate of return of somewhere between 5% and 20%, with one study finding a return of 44% in the US and 47% in Japan and another finding a maximum return of 275%.

Sample of Recent Papers Estimating Rate of Return on R&D Investment		
Private Rate of Return Estimate on R&D		
Study	**Sample**	**Estimated Return**
Bernstein and Nadiri (1990)	US, 35 firms	9% to 20%
Mohnen-Lepine (1991)	Canada, 12 mfg industries 1975, 77, 79, 81-83	5% to 275%
Mohnen-Nadiri-Prucha (1986)	1965-77	11% (US) 15% (Japan) 13% (Germany)
Bernstein-Mohnen (1998)	11 industries	44% (US) 47% (Japan)
Mohnen (1992)	OECD 5 countries	6% to 9%
Nadiri-Kim (1996)	7 countries	14% to 16%
Social Rate of Return Estimate on R&D		
Mansfield et al. (1977)	17 industrial innovations	Median social ROR: 56% Median private ROR: 25%
Tewksbury et al. (1980)	20 innovations	Median social ROR: 99% Median private ROR: 27%
Mohnen (1990)	Canadian Manufacturing	29%
Mohnen (1992)	OECD 5 countries	4% to 18%
Coe-Helpman (1995)	22 countries	32%
Source: Hill, Mairesse, and Mohnen (2009)		

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