The short term employment impacts of TIM scenarios to meet the Climate Action Bill 2021

- Scoping study, Part B

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1. Introduction

The Climate Action and Low Carbon Development (Amendment) Bill 2021 outlines an ambition for a 51% reduction in total greenhouse gas (GHG) emissions by 2030 in Ireland, relative to 2018, in preparation for net zero emissions by 2050. This paper is Part B of a report which considers the short-term employment implications of the Climate Action Plan 2021 (CAP2021). Part A presented the current available employment data in Ireland, by sector and location, and the outputs from the energy sector model TIMES-Ireland or 'TIM'. The capital investment required in the power, residential and transport sectors between 2018 and 2030 to meet the GHG emissions targets under four different mitigation scenarios was estimated. Comparing changes in investment flows with current sectoral and regional employment numbers from the CSO aimed to provide preliminary insights into where employment effects might occur.

In this section of the report, an input-output model has been developed for Ireland to quantitatively determine the employment impacts of the capital investment to meet targets in the power and residential energy efficiency sectors. Input-output (I-O) models estimate the multiplying output and resulting employment effect that a change in demand in one sector has on itself, and all other sectors in the economy. Section 2 of this part of the report briefly revisits the TIM scenarios that are under consideration. Section 3 introduces the input-output model, and employment multipliers in the Irish economy, with a more in depth discussion of input-output models and different employment methodologies included in the Appendix. Section 4 describes the direct and indirect full time equivalent (FTE) employment impacts from capital investment in each technology. Section 5 discusses the aggregate jobs impact in different sectors referring back to the analysis in Part A. Limitations to interpretation of figures from the model as it stands and potential further developments are included in section 6 and section 7 finishes with concluding remarks.

2. TIM scenarios and investment assumptions

Four mitigation pathways from TIM (formerly the TIMES-Ireland Model) are described below. All meet the overall 51% GHG emissions reduction target by 2030 but have various levels of abatement in the agricultural and energy sectors:

1. A51-E51: Agriculture and the energy sector reduce their emissions equally, by 51%.
2. A33-E61: More effort on the energy side and less on agriculture by 2030, such that agriculture achieves 33% emissions reductions, and energy achieves 61% emissions reductions.
3. A51-E51-LED: Same as (1) with additional policies and infrastructure in place to reduce energy service demands (e.g. a shift to walking and cycling to reduce demand for car travel).
4. A33-E61-highREN: Same as (2), but with higher installed capacity of renewables, most notably, onshore wind and solar PV.

The outputs in TIM are split between primary energy supply, change in installed electricity generating capacity, and energy consumption by the transport, residential, commercial, industrial, and agricultural sectors. This report focuses on the employment arising from the capital investment to meet new electricity generating capacity and energy efficiency targets in Irish homes; the two sectors which are expected to experience a large share of the investment impacts from revised targets up to 2030. The implications of efficiency targets in the commercial, industrial and transport sectors, the long term employment, and the wider macroeconomic, competitive and distributive impacts require further data and/or alternative modelling techniques.

Capital investment to meet 2030 targets in power generation and energy efficiency

In the power sector, between 2020 and 2030, the scenarios imply up to 6.5 GW of additional onshore wind installed capacity, up to 8 GW of offshore wind, up to ~5 GW of solar power, and up to 1.4 GW of new gas plant capacity. This translates to capital investment in wind farms from between €10 billion (A51-E51-LED) and €31 billion (A33-E61-highREN) and up to €4 billion in utility scale solar.[1] The investment costs for at least one additional interconnector to France or Great Britain and upgrades to the transmission grid are taken separately from EirGrid's Grid 25 report and assumed to be constant at €4 billion across all of the scenarios.

In the residential sector, scenarios 1, 2 and 3 assume that 250k shallow retrofits and 175k deep retrofits take place between 2018 and 2030. No retrofit activity occurs in the LED scenario. With higher mitigation targets for the energy sectors (A33-E61) there is an additional 175k deep retrofits in the attached residential building stock and almost double the amount of heat pumps installed (458k compared to 259k). Using retrofit cost estimates from TABULA[2], to reach these targets approximately €13 billion will need to be invested in deep retrofits (shallow retrofit plus cavity, internal, external wall and new renewable heating systems) and €2.6 billion will need to be spent on shallow retrofits (roof and loft insulation, windows and doors, lights). The more ambitious A33-E61 target would require an additional €5.5 billion spent on deep retrofits, €21.1 billion in total.

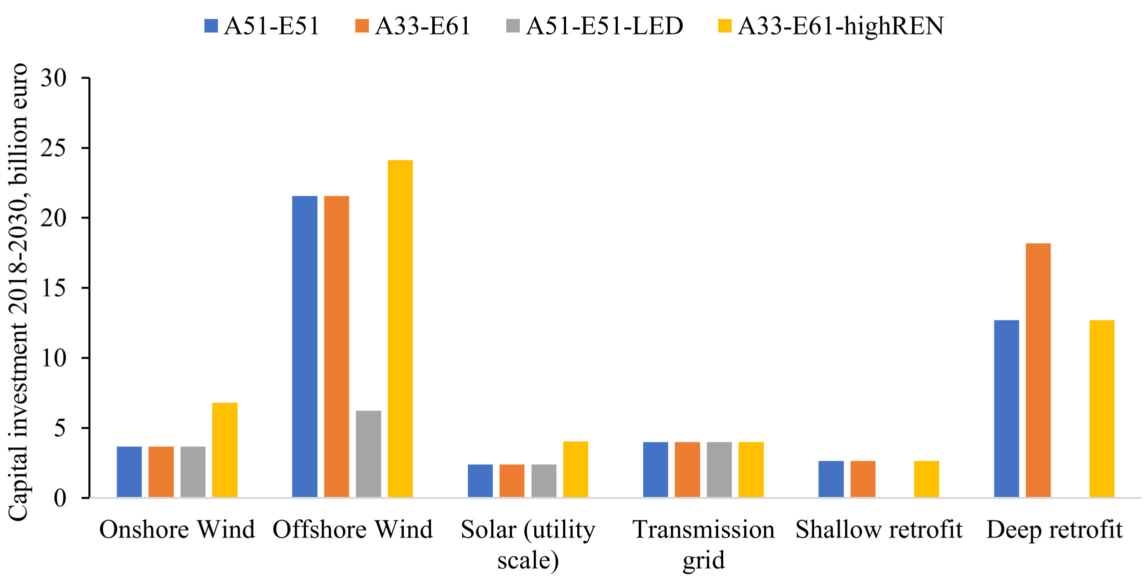

Figure 1. Capital investment to meet 51% GHG emission reduction target for 2030 under four TIM pathways

3. Input-Output model for Ireland

An Input-Output model has been created for Ireland to provide a basic tool for measuring the output, employment and emissions impacts of a change in final demand. Data is sourced from the Irish Supply and Use tables, available from the CSO website, and transformed by the OECD into a single I-O table.[3] Production in the Irish I-O table is classified into 36 different industries, based on the United Nation's

[1] Calculated using investment costs per kW from TIMES 2018, 2015 prices.
[2] Calculated from the number of retrofits in each scenario multiplied by retrofit costs for shallow/deep, attached/detached dwellings taken from TABULA: https://episcope.eu/fileadmin/tabula/public/docs/brochure/IE_TABULA_TypologyBrochure_EnergyAction.pdf
[3] OECD Input-Output Tables, 2018 edition: https://stats.oecd.org/Index.aspx?DataSetCode=IOTSI4_2018

International Standard Industrial Classification (ISIC), Revision 4, and consistent with Eurostat's NACE Revision 2. The latest I-O tables in the OECD database are from 2014 and 2015. More recent tables may be easily uploaded into the model once they become available.

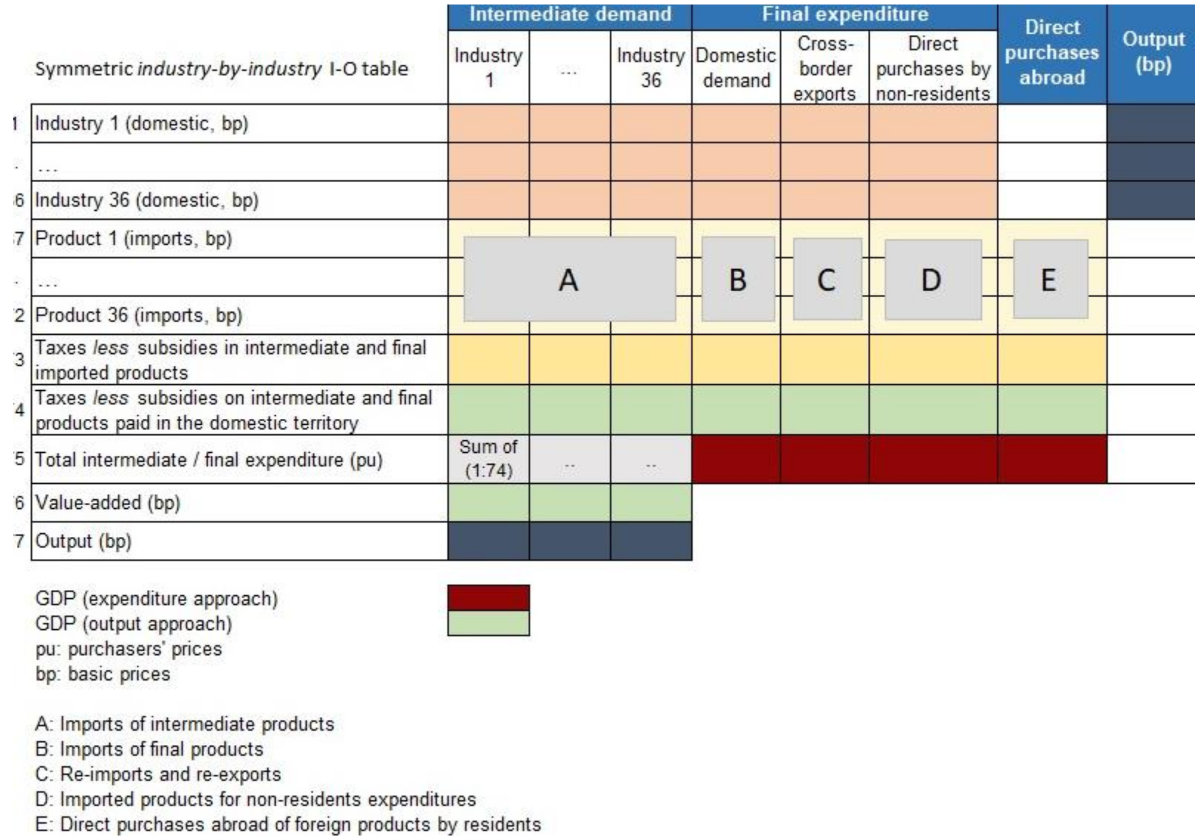

Figure 2. Format of OECD harmonised national Input-Output tables.[4]

The Irish I-O table has been converted into a static I-O model using a Leontif production function (see Appendix 2 for more detailed explanation). Leontief production functions calculate the change in output in different industries as a result of a policy shift or increase in final demand. In addition to the direct impact on output in different sectors, I-O models capture the indirect ripple effect among industries in the wider economy. If the model also includes income and household consumption, 'induced' effects can be reported, where Type I multipliers capture the direct and indirect effects, and Type II multipliers capture direct, indirect and induced effects.

Satellite accounts have been linked to the Irish I-O model with additional information on employment and emissions in Ireland by sector, sourced from Eurostat. Satellite tables with labour intensity per sector facilitates analysis of the direct and indirect employment impacts as a result of capital investment in renewable energy and residential energy efficiency to meet CAP2021 targets. The I-O model developed for Ireland also includes the option of estimating Type II multipliers and environmental impacts, however, for brevity the results in the remainder of the report focus on employment impacts assuming Type I multipliers. The inclusion of Type II multipliers would boost the employment effect in industries stimulated by household consumption.

[4] OECD Input-Output Tables: https://www.oecd.org/industry/input-output-tables.htm

I-O model benefits and limitations

A basic I-O model is able to estimate how much output will need to increase across the economy to meet a rise in final demand in a given sector, based on the domestic production inputs and outputs for a given year. The advantage of this approach is its transparency and ease of use for policy planning and short-to-medium term analysis. A static I-O model has the capacity to provide fundamental information on the structure of the economy, with easily interpreted results. This can be useful for anticipating the sectors that will be stimulated due to a policy shift.

A limitation of I-O models is the assumption of linear and fixed coefficients, with inputs into the production process assumed to stay constant over time. Lack of consideration of changing prices, economies of scale, and production and labour supply constraints, can lead to an overestimation of the economic benefits. More comprehensive analysis, which recognises the effect of policy change on commodity prices, household incomes, consumer spending and economic growth, requires more advanced modelling techniques such as computable general equilibrium (CGE) models (see Appendix 2 for further discussion).

Simulating investment in renewable energy and energy efficiency

To capture the impact of investment in renewable energy and energy efficiency, expenditure is treated as a single demand shock, in an approach outlined by Miller and Blair (2009) and Garrett-Pillar (2017). Separate demand vectors have been created for wind power, utility scale solar power, thermal power plants, the transmission grid, and shallow and deep retrofits, outlined in Table 1 below. The demand vector for different industries in Ireland is taken from analysis undertaken by SEAI,[5] and aligned with the industrial categories in the Irish I-O table. Demand vectors from similar studies in the United States are included for comparative purposes. Simulating a change in demand using this approach is only applicable for analysis of the employment impacts from initial short-term investments. Longer term impacts such as the employment related to operations and maintenance require including additional subsectors into the I-O model, discussed in the section on future developments. The source of the change in final demand is not specified and could come from government expenditure or subsidy schemes, private investment by energy developers, or consumer spending on retrofitting homes.

Ireland (SEAI, 2015)	**Onshore wind**	**Offshore wind**	**Utility scale solar**	**Trans-mission grid and network**	**Shallow retrofit (without heat)**	**Deep retrofit (incl heat)**
Other non-metallic minerals	5%	2%	48%	5%	30%	34%
Fabricated metal products	27%	33%	11%	9%		31%
Electrical equipment	9%	6%	16%	15%		
Machinery and equipment n.e.c.	28%	19%				
Construction	25%	27%	12%	64%	62%	31%
Transportation and storage	1%	6%				
Financial and insurance activities	2%	2%	3%	2%	2%	1%
Other business sector services	3%	5%	10%	4%	6%	3%
United States (Pollin et al, 2015)	**Onshore wind**	**Offshore wind**	**Utility scale solar**	**Smart grid**	**Residential retrofits***	**Commer-cial retrofits***
Other non-metallic minerals	12%	12%				

[5] SEAI 2015. Ireland's Sustainable Energy Supply Chain Opportunity: https://www.seai.ie/publications/Ireland___s-Sustainable-Energy-Supply-Chain-Opportunity.pdf

Fabricated metal products	12%	12%	17.5%			14%
Electrical equipment	6%	6%	17.5%	50%	28.6%	28%
Machinery and equipment n.e.c.	37%	37%	17.5%	25%	41.4%	14%
Construction	26%	26%	30%	25%	30%	30%
Other business sector services	7%	7%	17.5%			30%
*Residential and commercial retrofits from Garrett-Peltier (2017)						

Table 1: Share of demand for input products by energy production sector

Employment multipliers

Employment coefficients and multipliers for the different sectors in Ireland are displayed below. The employment coefficient is the persons in employment per €1 million in output; the employment multiplier is the direct and indirect employment generated due to €1 million increase in final demand. The differences between employment multipliers are attributed to the labour intensity of different sectors, the reliance on imports, and wages. For instance, Figure 3 indicates that in Ireland the accommodation and food sector has the highest labour intensity, that is, it employs the largest number of people (full time equivalent) per unit of output. Industries that have a high share of domestically produced inputs, such as education, health, arts and agricultural sectors, will tend to generate more domestic employment due to a change in demand and therefore have higher employment multipliers.

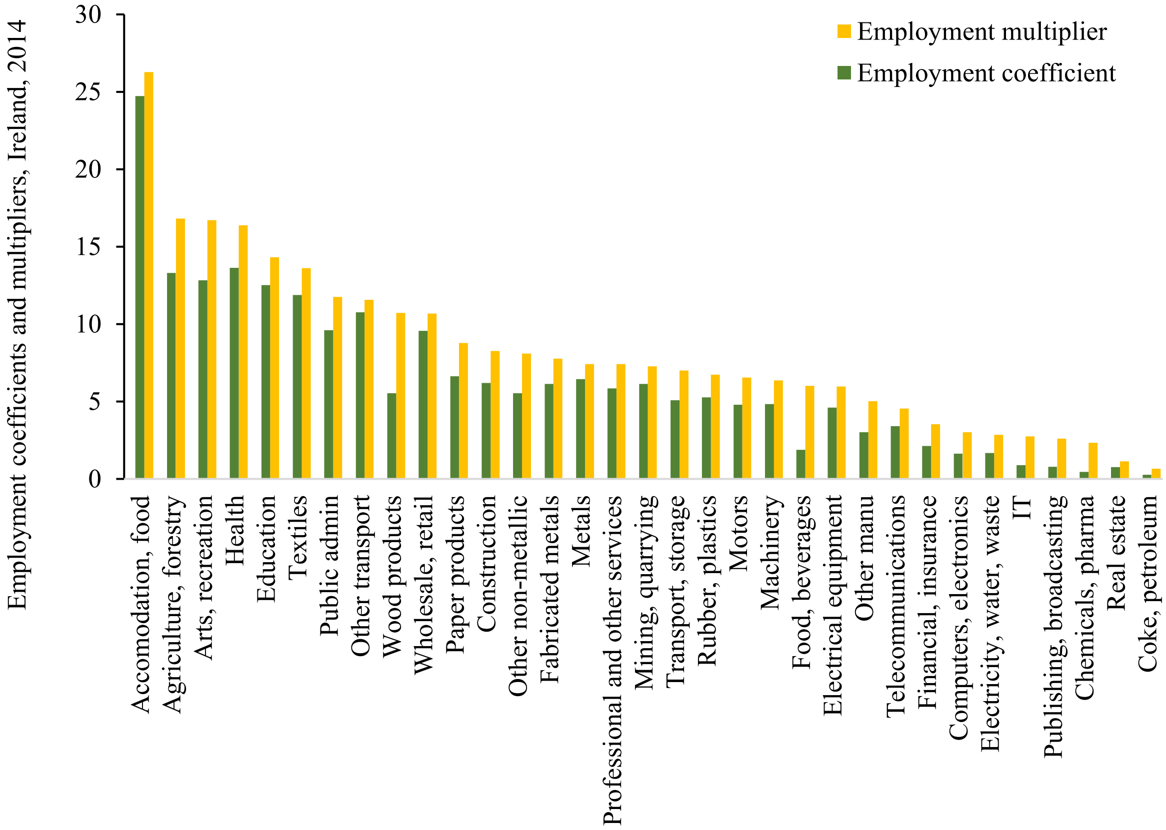

Figure 3. Employment coefficients per €1 million output and multipliers per €1 million change in demand, 36 economic sectors, Ireland 2014

4. Gross full time equivalent (FTE) employment impacts due to capital investment, by technology

The remainder of this report presents gross employment figures as a result of capital investment in different technologies to meet the revised 2030 GHG emission targets. Employment is often defined in terms of “full time equivalent” (FTE) or “job-years”. One job year refers to full time employment for one person for one year. This can be further broken down by how many years the job exists, for instance, construction may take 3 to 5 years while manufacturing may take less. In this section, the total number of job-years are presented for each technology. In section 5, jobs are aggregated by sector and divided by the expected length of employment to derive annual jobs estimates.

The direct and indirect employment impact as a result of capital investment in wind power, utility scale solar power, the transmission grid and retrofit activity (shallow and deep) are presented below. Initially, the domestic employment effects across the 36 industry sectors from a €1 million increase in final demand is simulated for each investment category to compare the relative impacts. Based on recent manufacturing trends in Ireland, it has been assumed that all solar panels, turbines, blades and transmission grid power cables will be imported in the next ten years and therefore the related manufacturing investment has been excluded. Retrofits have the highest domestic employment impact due to less reliance on manufactured imports and higher labour intensities in the dominant direct industries - construction and non-metallic manufacturing - when compared to renewable power development. Construction is also heavily reliant on domestic inputs and therefore stimulates more indirect employment in the wider economy (Figure 5).

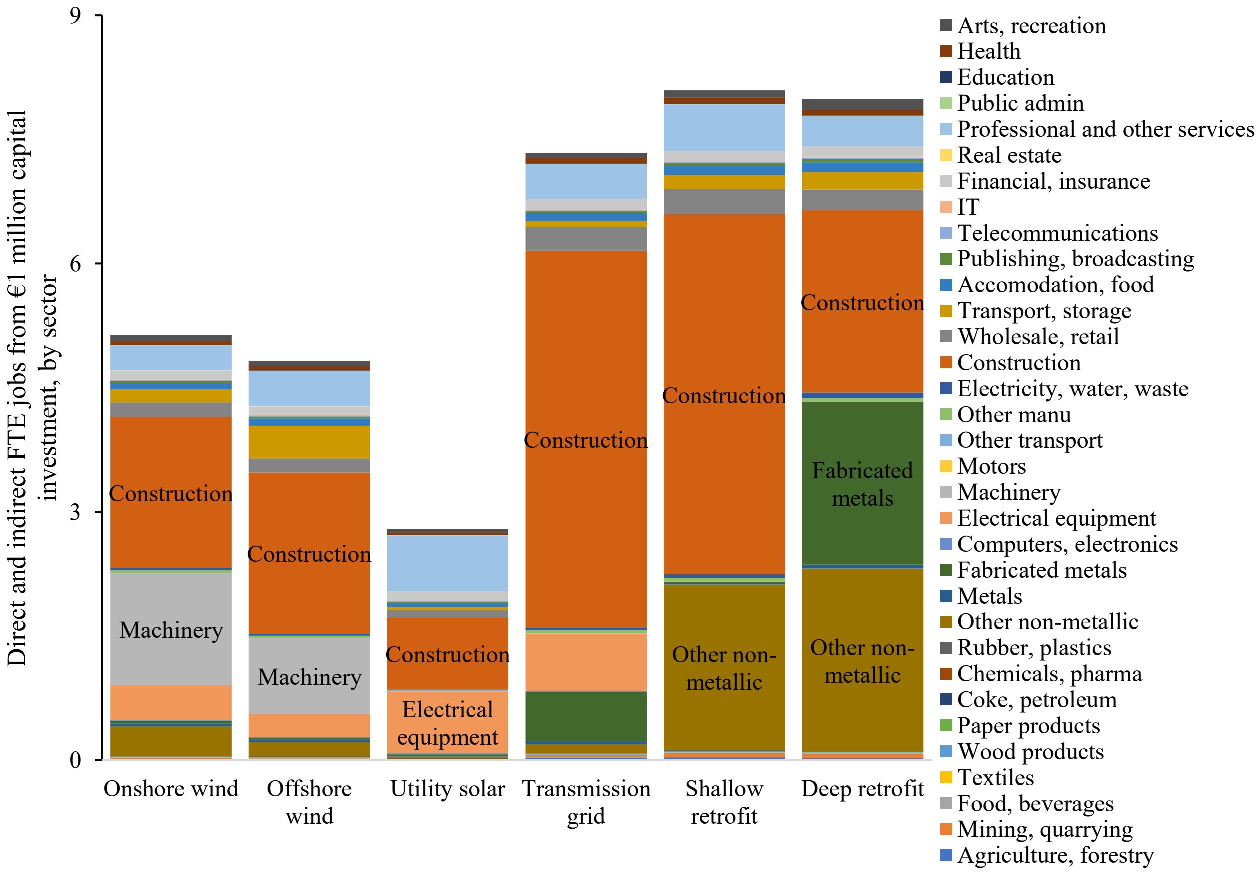

Figure 4. Direct and indirect jobs by NACE sector from €1 million capital investment, excluding manufactured turbines, blades, solar panels, and transmission grid cables, all of which are assumed to be 100% imported.

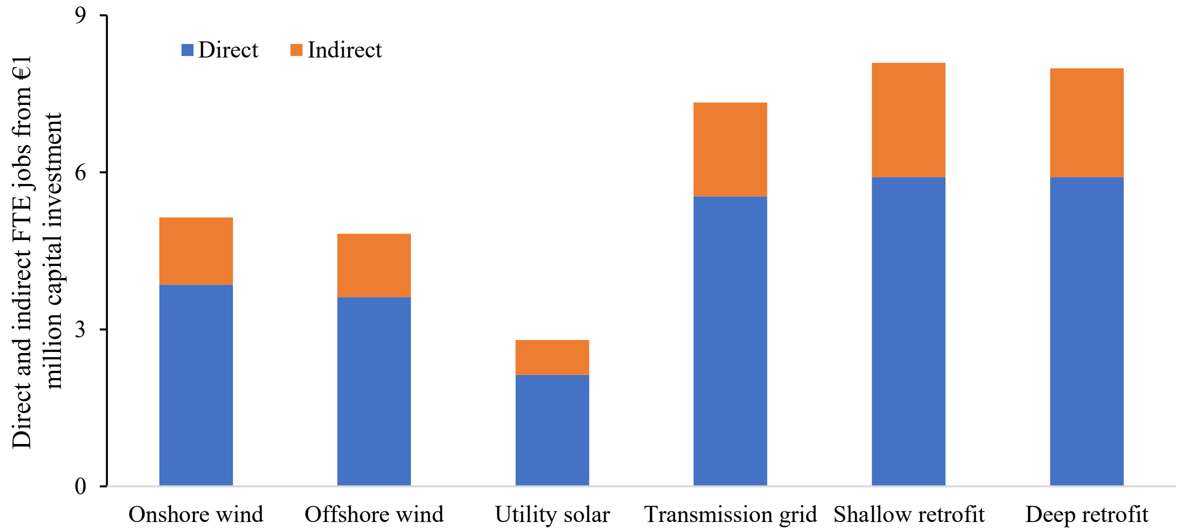

Figure 5. Direct and indirect jobs from €1 million capital investment, excluding manufactured turbines, blades, solar panels, and transmission grid cables, all of which are assumed to be 100% imported.

Approximately 8 full time equivalent (FTE) positions per €1 million investment are created for retrofits, with approximately 4.3 FTE jobs in construction and 2 FTE jobs in manufacturing. For deep retrofits, a higher share of investment goes toward heating, where around 2 FTE jobs per €1 million investment are generated in the manufacturing of renewable heat technologies. Solar power has the lowest domestic FTE employment impact due to solar panels accounting for almost half of the total investment cost, all of which are imported.

In contrast, a similar study in the United States found employment impacts of between 6.5 and 8.2 FTE direct and indirect jobs per $1 million investment in wind capacity, solar capacity and retrofit activity (Garrett-Peltier, 2017). Higher employment impacts in the United States can be attributed to more domestic production of goods and services in the supply chain, and different labour intensities and compensation rates in various sectors, in comparison to Ireland.

When interpreting multipliers, it is beneficial to have knowledge of the economy under consideration and the limitations of the modelling approach. Large investments such as those required to meet targets outlined in the Climate Action Plan are likely to alter costs, prices and inter-industry relationships, which are not reflected in these results. In addition, the results may overstate the multiplier effects if an industry is already operating at capacity, such as the construction industry, or has an unusually high import intensity, as may be the case with certain mechanical components in the power sector.

Investment in wind power

Figure 7 displays that a €1 million increase in demand for wind capacity in Ireland leads to 3.8 direct jobs and 1.29 indirect jobs. Since I-O models are linear, increasing investment in onshore wind from €1 million to €3.67 billion leads to direct employment of almost 6 thousand FTE jobs in the construction sector, over 7 thousand FTE jobs in the manufacturing of foundations and electrical and mechanical components (if a share of production is captured in Ireland), and approximately 1 thousand FTE jobs in transportation, finance and professional services. In addition, almost 5 thousand FTE jobs would be generated in the wider economy to indirectly supplement direct employment.

Compared to onshore wind, offshore wind requires a higher share of investment in fabricated metals (towers, blades, etc) and construction, transport and planning. Excluding employment in manufacturing of metal products, the installation of 7.3 GW of offshore wind capacity would directly require over 33 thousand FTE construction workers. Another 1 thousand plus FTE jobs would be required in transport, and approximately 5 thousand direct jobs in professional services such as environmental planning, research and consultancy. Again, the majority of employment in the installation phase is related to manufacturing, which is likely to stimulate job creation in countries that already manufacturing offshore wind turbines and components. If Ireland were able to capture a share of production in the foundations, platforms, electrical and mechanical equipment, up to 44 thousand jobs (in FTE job-years) could be created. The activity as a result of capital investment in wind generates additional indirect employment, however, again this should be interpretated in light of the domestically produced manufactured products in the wind sector.

The A51-E51-LED scenario and the A33-E61-HighRES scenarios offer the employment impact of the two extremes, with less investment in renewable electricity in the LED scenario versus high investment in the HighRES scenario. As a result, the impacts on domestic jobs, most pertinently in construction, transport and professional services, decrease or increase in the model accordingly (see Figure 8).

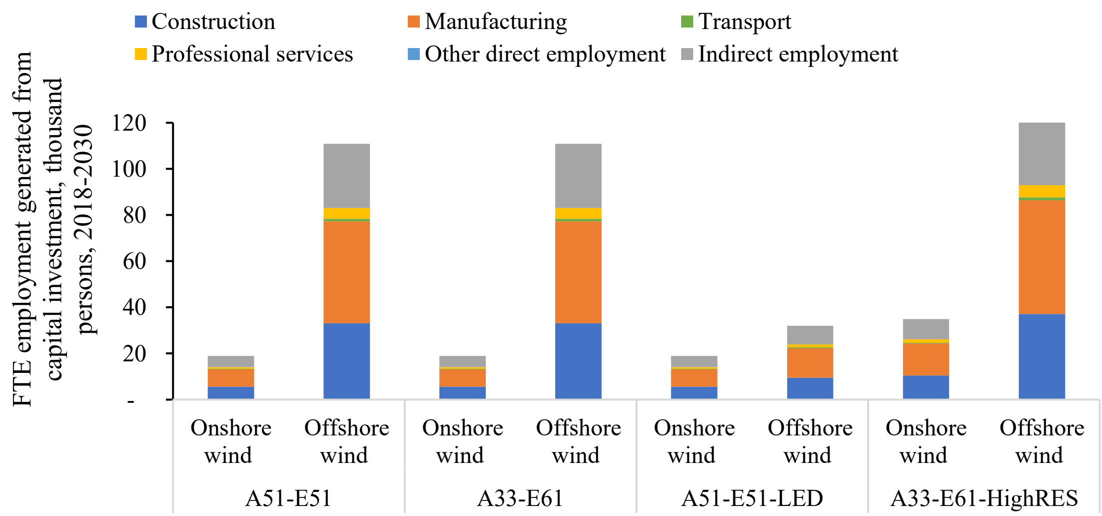

Figure 6. Employment generated from capital investment in wind, by TIM scenario, thousand persons, 2018-2030

Direct Jobs per MW

Direct FTE jobs per average MW installed capacity in the construction phase have been calculated in Table 2 using a similar methodology to that outlined in Wei et al. (2010) and compared with employment studies which used alternative approaches.

51% emission reduction scenario with equal mitigation efforts between energy and agriculture (E51-A51)			
Jobs per MW	**Onshore wind**	**Offshore wind**	**Utility scale solar**
Total direct employment (job-years)	14,141	83,061	5,071
Project lifetime (years)	20	20	30
Additional installed capacity (MW)	3,530	7,310	2,770
Capacity factor (%)	0.35	0.45	0.11
Domestic jobs (construction phase) per average MW	**0.57**	**1.26**	**0.55**
Jobs per MW (Deloitte/IWEA 2009)	1.37		
Jobs per MW (Siemens/IWEA 2014)	2.35		
Jobs per MW (BWEA)	1.33		

Table 2: Estimate of breakdown of jobs per MW by electricity production type

Investment in the transmission grid and utility scale solar power

Figure 9 displays the employment impacts from investment in utility solar and the transmission grid across the four scenarios. Investment in the transmission grid is kept fixed at €4 billion, in line with Grid 25, which assumes only one interconnector is built. However, it is likely an additional interconnector will be built between now and 2030 and therefore the jobs could be scaled upward. Assuming only one new interconnector and network reinforcements, 16 thousand FTE jobs would be needed in construction (or 4000 full time employees over 4 years), approximately 5 thousand jobs in the manufacturing of towers and electrical equipment, and over 1 thousand technical consultants, financial, legal and other professional roles. The development of the transmission system could also indirectly stimulate up to an additional 7000 jobs.

The majority of investment in utility scale solar power goes towards the materials (~50% on panels, 11% on mounting equipment, and 16% on electrical equipment). Excluding the capital investment in panels, 2.8 GW of additional utility scale solar capacity would require around 1.7 thousand jobs in construction and 1.5 thousand jobs in finance and other professional services. If installed solar capacity increases from 2.8 to 4.7 GW in the high renewables scenario (4), employment in construction increases to 3 thousand and 2.6 thousand in professional services.

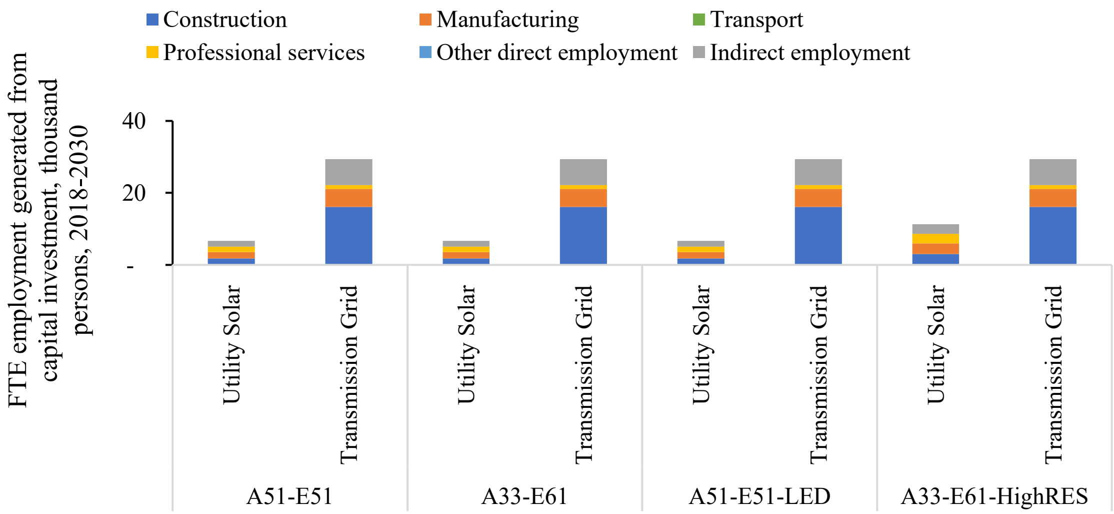

Figure 7. Employment generated from capital investment in utility scale solar and the transmission grid, by TIM scenario, thousand persons, 2018-2030

Investment in retrofits

Investment in retrofits to meet energy efficiency ambitions in the residential sector has the potential to generate the most employment in Ireland since there is already an existing indigenous efficiency products and skills base. However, employment estimates assume the availability of workers with the necessary skill profiles at prevailing wage rates. Attempts to hire more workers in a tight labour market may inflate wages rather than create employment. Including indirect employment which supplies the industries directly affected by investment, over 120,000 skilled FTE positions would be required to meet the change in demand for shallow and deep retrofits in the A51-E51 and A33-E61 High Renewables scenarios.

If the materials were domestically sourced, it would imply over 33,000 FTE positions in the manufacturing of non-metallic materials. For deep retrofits, almost 25,000 manufacturing positions would be needed to supply upgraded heating systems, and almost 40,000 jobs would be created in the construction sector. Another 6,000 jobs would be created in professional services. The A33-E61 scenario increases the employment figures for deep retrofits by 43% leading to a total of 40,000 direct and indirect jobs in deep retrofit construction, 35,000 jobs in manufacturing of heating technologies, 40,000 jobs in the manufacturing of insulating material, and an additional 30,000 jobs split between the other sectors in the economy (Figure 10).

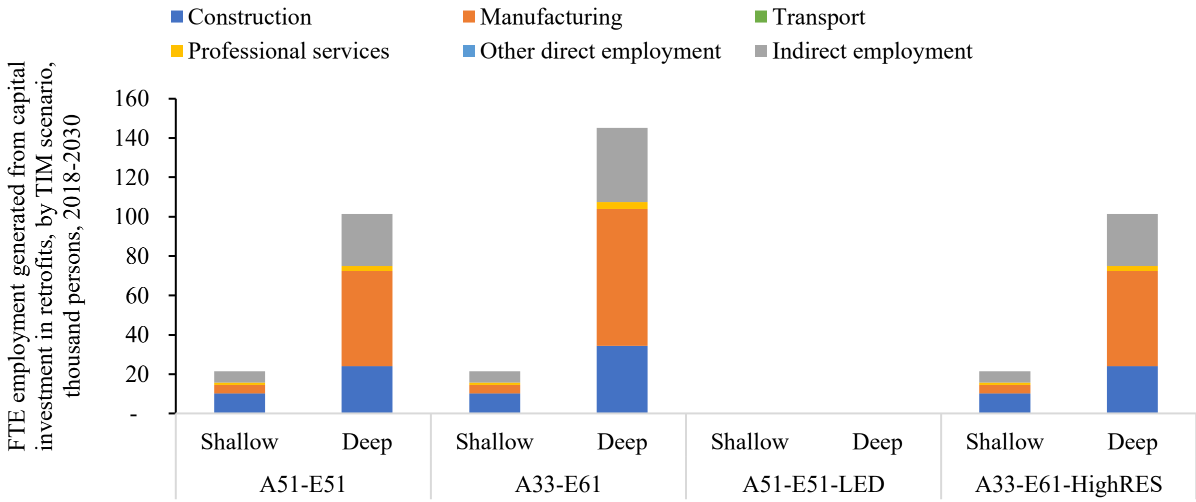

Figure 8. Employment generated from capital investment in retrofits, by TIM scenario, thousand persons, 2018-2030

5. Gross impact on the number of jobs, by sector

Table 3 presents estimates of the number of jobs created (rather than job-years) using the FTE employment estimates above and assumptions regarding the length of time a job takes. These numbers can be spread across the years up to 2030 depending on when investment takes place. For annual figures, it is assumed that investment is evenly split across the seven years leading up to 2030.

51% emission reduction scenario with equal mitigation efforts between energy and agriculture (E51-A51)							
Thousand jobs (total direct domestic employment)	Assumed length of job (years)	**Onshore wind**	**Offshore wind**	**Utility scale solar**	**Trans-mission grid and network**	**Shallow retrofit (without heat)**	**Deep retrofit (incl. heating)**
Manufacturing (if share of components captured domestically)	1	7.5	44	1.7	5	4.4	48
Power construction	3	1.8	11	0.6	5.3		
Transport	2	0.1	0.5				
Power-related services	2	0.4	2.3	0.8	0.5		
Retrofit construction	1					10	24
Retrofit-related services	1					1	2.4
Thousand direct jobs per year assuming investment evenly spread from 2023 to 2030							
Manufacturing		1.1	6.3	0.3	0.7	0.6	6.9
Construction		0.3	1.6	0.1	0.8	1.4	3.4
Professional roles and other services		0.1	0.4	0.1	0.1	0.1	0.3

Table 3:Estimated number of jobs created in the TIMS E51-A51 scenario

Manufacturing

Mass retrofitting of homes in Ireland is likely to stimulate job creation in the domestic manufacturing of materials such as insulation, cladding, double/triple glazing, heating technologies and controls, lights, piping, and wiring. Up to ~€7 billion will need to be spent on retrofitting materials to meet 2030 targets which, if a share of materials are manufactured domestically, would support 4.4 thousand direct jobs in the production of manufactured materials for shallow retrofits and, depending on the scenario, between 48 thousand and 70 thousand direct jobs in the manufacturing of materials for deep retrofits and heating (or between ~7 and 10 thousand jobs over 7 years depending on the scenario).

In the case of power generation, the majority of capital investment goes towards the purchasing of imported end products such as turbines, solar panels and other electrical and mechanical components. In Part A of this report it was estimated that ~€23 billion would need to be directed toward manufactured goods to meet installed generation capacity targets across the different generation types by 2030. It is assumed that at least €10 billion of this will be fully spent on imports. The remaining €13 billion is on products that have the potential to be partially manufactured locally, such as foundations, controls, instruments and mechanical handling, if the capacity in domestic supply chains is available. If Ireland is able to capture some of this investment, a similar number of manufacturing jobs for retrofits could be created to supplement the redesign of the power sector (~8 to 10 thousand jobs over 7 years depending on the scenario).

Construction

In the construction sector, at least €6 billion is expected to be directed toward demand for specialised labour to retrofit residential households and install new heating technologies, and another €2 billion will be required for the construction of new wind farms, solar power plants, and thermal generation facilities. Further investment will also be needed to upgrade the electricity transmission grid and distribution network, as well as to install new EV charging and smart metering capabilities. Construction activity in Ireland traditionally has a relatively low import intensity so the majority of this investment could be captured domestically if the required skills and workforce are locally available.

Under the assumption that it takes an average of three years to build a renewable power facility or upgrade the grid, this translates to nearly 13 thousand direct jobs in the construction of wind farms, 600 direct construction jobs in the development of utility scale solar plants, and 5 thousand direct construction jobs in a new interconnector and upgrades to the transmission grid. Retrofitting activity would add demand for another 34 thousand direct jobs to upgrade the efficiency of people's homes. If investment is spaced out evenly over 7 years, this translates to 2.8 thousand direct jobs created in the construction sector per year to build new renewable forms of electricity generation, plus nearly 5 thousand jobs a year in retrofitting the housing sector.

In the scenario where a higher share of the emission reductions are undertaken by the energy sector (A33-E61), 1.4 thousand additional skilled construction workers would be required every year for 7 years due to more deep retrofit activity. The LED scenario removes the need for construction labour for retrofits, but may have employment impacts in other areas such expanding public transport, mobility options and related infrastructure projects in urban areas. The high renewables scenario (A33-E61 HighRES) implies an additional 3 thousand workers would be required up to 2030, or just over 400 skilled construction and installation workers in the power sector each year for seven years.

Professional roles and other supporting services

Professional roles and services span activities such as research and development, project management, engineering consultancy, energy utilities and agencies, environmental and safety expertise, financial, insurance, and legal services, transportation, and public administration. These roles can last a few months, or can begin before construction and continue beyond the completion of a single project. For simplicity, however, to calculate job numbers it has been assumed that professional roles are for 2 years.

Approximately 15% of total capital investment goes towards professional and other supporting services, which amounts to a capital investment of ~€4.6 billion from the power sector up to 2030 and €2 billion related to residential retrofits. This would directly create 4 thousand professional jobs to support the development of renewable power capacity, with an additional 600 jobs required in the transport sector. Another 3.4 thousand professional services would be required to supplement retrofit activity. Over seven years, this implies demand for over 1 thousand positions in professional roles and other services each year.

Indirect employment

In addition to direct employment from capital investment in different sectors, the I-O model captures indirect employment effects in the domestic supply chain to support an increase in economic activity. This ranges from an additional 73 thousand FTE positions across different sectors in the A51-E51 pathway to ~85 thousand indirect jobs in different domestic industries in the A31-E61 pathways. It is less straightforward to assume a job length across the different sectors, but assuming they last for one year, this would imply 10-12 thousand additional indirect jobs across the domestic economy per year if investment is spread evenly from 2023 to 2030.

6. Limitations and future developments to the model

The I-O model created for this analysis is an initial template and would benefit from future developments. A drawback of using I-O models for climate policy analysis is that renewable energy and energy efficiency industries are not explicitly represented in national accounts. To properly model the demand and supply impact of investment in renewable energy and efficiency, subsectors related to a change in climate policy, such as the construction of wind farms or retrofitting homes, should be added to the I-O table by altering the share of production inputs, or 'technical coefficients', in an aggregated parent sector such as construction or manufacturing.

Retrofit activity, for instance, is already implicitly included in the I-O table within the construction industry, but needs to be explicitly separated out. Including subsectors with their own unique inputs would resolve some of the limitations of this analysis, such as the impact of average import intensities in the manufacturing sector on the employment results. Distinguishing between the different subsectors is particularly important for longer term analysis of operations and maintenance employment in the electricity sector. At present, the 'Electricity, water, waste' sector in the Irish I-O table aggregates the inputs and externalities of all power, waste and water systems. In reality, depending on the technology, electricity generation has very different inputs, labour requirements, value added and emissions.

The static I-O analysis applied in this paper is most useful for comparing the impact of investments across different technologies under the assumption that the economy is fixed in its current state and that the labour market is able to meet increased demand. However, multipliers, prices and productivity in different sectors respond to changes in demand. For broader analysis of the macroeconomic impact of the injection of capital investment into the energy sector requires more complex dynamic CGE models where time is explicitly modelled and quantity and price interactions are endogenized. Income effects in CGE models and the substitution between capital and labour would enable an estimate of the displacement of jobs. The I-O model presented here is a first step in that process and could be developed further but would require programming in a development environment due to the added complexity and data requirements.

Further topics of relevance to the macroeconomy and the wider implications for net employment include the consumer, government and commercial savings due to investment in efficiency, the cost and affordability of investments, how investment is financed, and the implications for the balance of payments. More complete analysis would consider the opportunity costs, or the jobs displaced, by a cut in government expenditure elsewhere, crowding out of private investment, raising taxes, or government borrowing. In terms of households, expenditure on energy efficiency projects reduces a household's budget in the short term, but may result in saving money in the long term leading to additional wider expenditure and induced employment. Conversely, renewable energy may increase the cost of the household or commercial energy bills and therefore reduce expenditure and employment elsewhere. As a general rule, when omitting wider macroeconomic effects such as these, employment estimates due to investment in new projects should be viewed as being in the upper bounds.

Input output models can also provide information on the induced employment impacts as a result of changes in household expenditure. This captures the spending patterns of indirect and direct workers on goods and services and is influenced by sectoral wages, income taxes and savings. Accounting for induced employment would increase levels of employment and include a wider range of sectors such as education, health and recreational services.

7. Conclusions

Input output tables offer a detailed picture of a national economy, useful for studying the impact of climate policies. Detailed sectoral breakdowns provide snapshots of the economy-wide implications of investment in renewable energy and energy efficiency technologies. They can offer a guide to the benefits in terms of gross jobs created and the potential to identify skill shortages that may emerge from a large energy programme.

This report has found that, in terms of FTE, between now and 2030, up to ~400 thousand direct and indirect FTE jobs would be created through capital investment in renewable power and residential retrofits to reach greenhouse gas emissions targets for 2030. The A33-E61 and A33-E61 HighRES scenarios are on the higher end of the employment estimates due to the additional number of deep retrofits in the A33-E61 pathway and the higher level of installed onshore wind and solar capacity in the A33-E61 HighRES pathway, relative to A51-E51.

If employment is presented in terms of jobs numbers per year, and assuming investment is split evenly across seven years leading up to 2030, reaching the A51-E51 scenario would imply demand for 25 thousand direct jobs to support the development of power generation and residential energy efficiency in 2030. Nearly 9 thousand of these are in construction, professional roles and supporting services and last two to three years, and 16 thousand are in manufacturing for one-year. This level of direct employment could stimulate up to 10-12 thousand additional indirect jobs per year in the domestic supply chain.

The gross direct and indirect employment impacts due to capital investment in renewable power, the transmission grid, and residential energy efficiency presented here should be interpretated with knowledge of the limitations of the model. Capital investment of the scale required by the Climate Action Bill 2021 will have far reaching effects on the wider macroeconomy, which will also have an impact on employment. Most pertinently, where investment comes from and the impact that a greener and more efficient energy system will have on the budgets of households, the government, and businesses deserves further analysis and would influence the employment benefits outlined above.

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9. Appendix 1: Synthetic industries

SYNTHETIC INDUSTRIES						
ISIC Description	**ONSHORE WIND**	**OFFSHORE WIND**	**UTILITY SOLAR**	**TRANSM GRID AND NETWORK**	**SHALLOW RETROFIT (WITHOUT HEAT)**	**DEEP RETROFIT (INCL HEAT TECH)**
INTERMEDIATE DEMAND						
Agriculture, forestry and fishing						
Mining and quarrying						
Food products, beverages and tobacco						
Textiles, wearing apparel, leather and related products						
Wood and of products of wood and cork (except furniture)						
Paper products and printing						
Coke and refined petroleum products						
Chemicals and pharmaceutical products						
Rubber and plastics products						
Other non-metallic mineral products	5%	2%	48%	5%	30%	34%
Manufacture of basic metals						
Fabricated metal products, except machinery and equipment	27%	33%	11%	9%		31%
Computer, electronic and optical products						
Electrical equipment	9%	6%	16%	15%		
Machinery and equipment n.e.c.	28%	19%				
Motor vehicles, trailers and semi-trailers						
Other transport equipment						
Other manufacturing; repair and installation of machinery and equipment						
Electricity, gas, water supply, sewerage, waste and remediation services						
Construction	25%	27%	12%	64%	62%	31%
Wholesale and retail trade; repair of motor vehicles						
Transportation and storage	1%	6%				
Accomodation and food services						
Publishing, audiovisual and broadcasting activities						
Telecommunications						
IT and other information services						
Financial and insurance activities	2%	2%	3%	2%	2%	1%
Real estate activities						
Other business sector services	3%	5%	10%	4%	6%	3%
Public administration and defence; compulsory social security						
Education						
Human health and social work						
Arts, entertainment, recreation and other service activities						
Private households with employed persons						

10. Appendix 2: Methodologies to measure employment

Different methodologies exist for estimating the employment impact of climate policies, depending on the question under consideration, the data, and the resources that are available.

Surveys and employment factors

Albeit time and cost intensive, the most straightforward approach is a survey. The Central Statistics Office conducts surveys of over 3 thousand households every week in Ireland to collect detailed data on a range of topics including employment, income and expenditure.[6] Data on existing employment allows a simple extrapolation of the short term effects of increased activity in a sector. This approach has been used in Part A of this report to give a brief overview of the employment trends in Ireland at present and the potential impacts of investment to meet climate action targets. A second approach, commonly used in the energy industry, is to use employment factors. This measures the number of jobs created per unit of energy content (petajoule) or installed generating capacity (megawatt). Employment factors can be derived from industry surveys, data on specific enterprises, or technical literature. However, they tend to be sensitive to the year and the location that they were undertaken in, with limited further applicability.

Input-Output models and multiplier analysis

A slightly more advanced method is to use an input-output (I-O) or Leontief model. This estimates the multiplying output or employment effect that a change in demand in one sector has on itself, and all other sectors in the economy. Input-output tables use data from national accounts to detail the monetary interactions between producers and purchasers of goods and services. Figure 1 below illustrates the monetary flows between agents - households, government, businesses, and the rest of the world - that are depicted in national accounts.

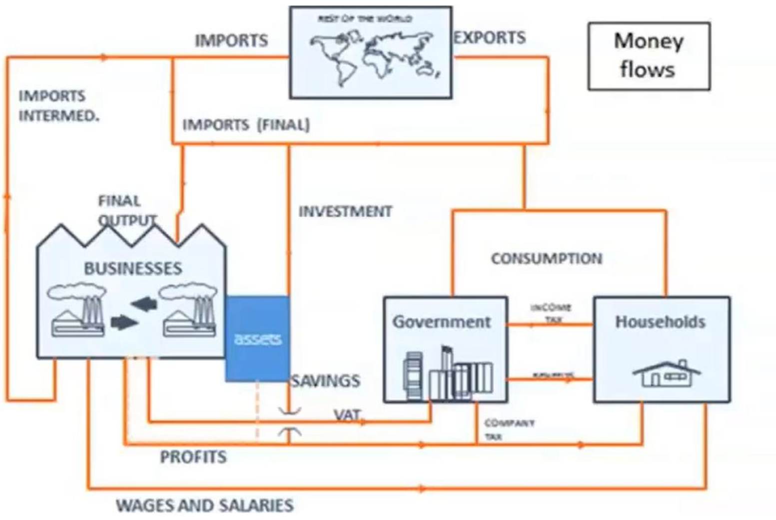

Figure 9. National Accounts Schematic. Source: Eurostat

The I-O table integrates components of value added, output and final expenditure or demand (see Figure 2). The matrices in an I-O table contains all the different production sectors or 'industries' along its row and column headers, where the number of sectors is generally determined by the available data in national Supply and Use tables demand. The rows display the consumption of output by other sectors, final demand by households and the government, private investment, and exports. The columns show the domestic inputs used by a sector, imports, and the value added generated. Under the assumption that

[6] CSO Household Surveys: https://www.cso.ie/en/surveys/householdsurveys/

industry inputs plus final demand equals gross production in each sector, a basic I-O model can measure how much output will need to increase across the economy to meet a rise in final demand.

Wassily Leontif transformed I-O tables into an applied economic tool in the late 1930s, and was later awarded the Nobel Prize in Economics for his work on the topic.[7] To create an I-O model, a matrix of technical coefficients has been generated by dividing the values in each column of the I-O table by their total output. The intermediate demand (or industry) section of the matrix is known as the 'A matrix'. This is a square matrix of inputs per unit of production, useful for studying the underlying structure of an economy. Leontief production functions calculate the endogenous change in output in different industries to meet an exogenous change in final demand. In addition to direct impact on industries using the A matrix, Leontif was able to capture the indirect relationships between sectors in the economy via the Leontif Inverse matrix:

$$I+Ay+A^2y+A^3y+\ldots+A^ny = x \qquad [1]$$

Also written as

$$(I-A)^{-1}y = x \qquad [2]$$

Where I is an identity matrix, x is the output vector, A is the technology coefficient matrix, and y is final demand. This formula estimates the direct increase in inputs required to meet an exogenous shock in a given sector (A), as well as the sectors that will feed into those providing inputs (A^2), and the sectors that feed those (A^3), and so on (A^n). By summing the multipliers in the columns of the Leontif matrix, it is possible to estimate the total domestic output multiplier for each sector.

The I-O model is converted from an 'open' model to a 'closed' model by including income multipliers and their impact on household consumption. Open I-O analysis, described in equations [1] and [2], focuses on the structure of the production system and the inter-sectoral requirements to meet a certain final demand. In closed I-O models, a 'labour feeding' coefficient matrix CL is added to A:

$$x \sim I+(A+CL)y+(A+CL)^2y+(A+CL)^3y+\ldots+(A+CL)^ny \qquad [3]$$

Where C is the consumption of the labour force and L is the factor demand for labour (wages). This facilitates an analysis of the direct, indirect and 'induced' effects in the wider economy due to a change in income and consumption among households. Type I multipliers capture the direct and indirect effects, while Type II multipliers capture direct, indirect and induced effects. A simplifying assumption is that workers do not adjust their consumption bundle, as they would normally in response to changes in incomes or prices.

Ireland is a small, open economy that relies heavily on external trade, and therefore will tend to have lower type I domestic multipliers due to a high share of imports in some industries, such as coke and petroleum. A change in household income due to a change in output, and the resulting effect on consumption patterns determine the magnitude of induced effects captured by the type II domestic multiplier.

[7] Leontief, W., 1986. Input-Output Economics. 2nd ed., New York, Oxford University Press

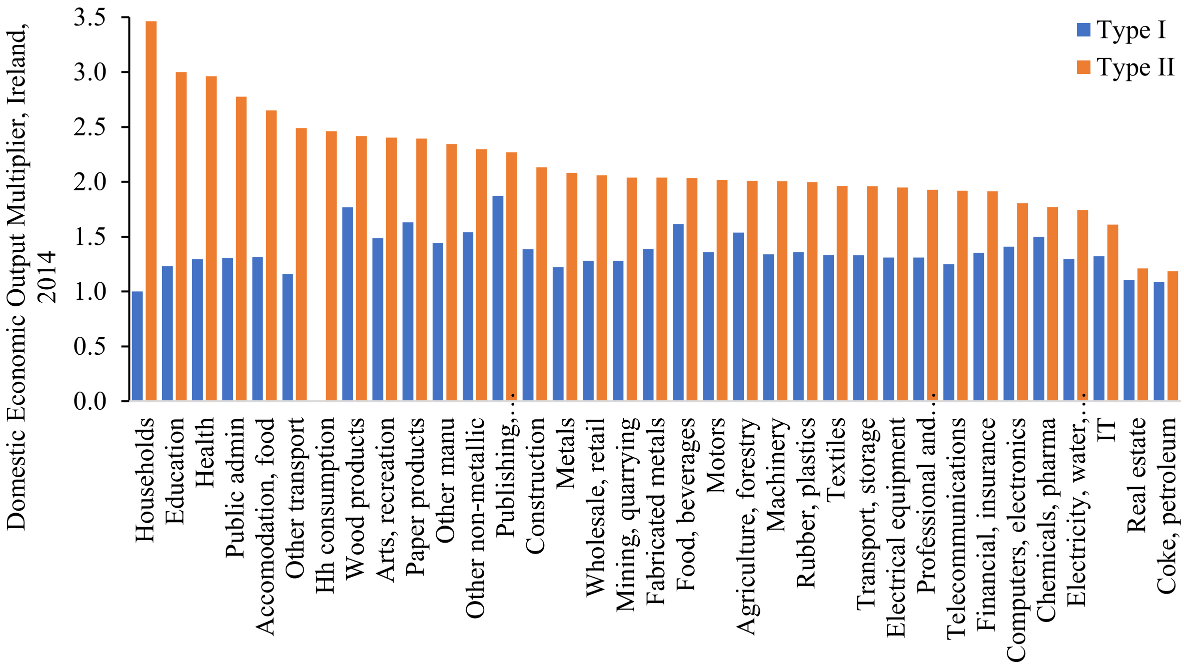

Figure 10. Domestic Type I and Type II Economic Output Multipliers, 36 economic sectors, Ireland 2014.[8]

A Leontief price model has also been created which simulates the impact of an exogenous price change on primary inputs, such as wages or a tax, on product prices (cost-driven inflation). Prices are determined under the assumption that the price per unit of output must equal the total expenditures on inputs, imports, and gross value added (capital, labour, profits) in each sector. Price changes are passed on completely and directly, where higher prices for primarily inputs cause higher product prices in a perfectly competitive market, with no substitution or quantity adjustments as a result of a change in price.

The advantage of this approach is its transparency and ease of use for policy planning and analysis. A static I-O model has the capacity to provide fundamental information on the structure of the economy, with easily interpreted results due to a change in policy. This can be useful for anticipating the sectors that will be stimulated due to a policy shift. However, the assumption of linear and fixed coefficients, where production processes stay the same, is not realistic beyond short term analysis. Similarly, the lack of consideration of prices, economies of scale, and production and labour supply constraints, can lead to an overestimation of the economic benefits.

Social Accounting Matrix

Social accounting matrices (SAMs) expand upon I-O tables by incorporating additional data which links the circular flow of income between businesses, disaggregated classes of labour, households, and the government. For instance, in the ESRI's Energy Social Accounting Matrix (ESAM)[9], upon which the I3E[10] is built, labour supply is split into three different skill types, determined by level of education, with sectoral wages defined for each. Household groups are separated into ten different categories based on disposable income, and urban or rural location, with income determined by wages, net of income tax, which goes toward government income tax revenue. In the SAM accounting structure, the total income (sales) and expenditure (purchases) of each of the agents correspond to the rows and columns

[8] OECD Input-Output Tables: https://www.oecd.org/industry/input-output-tables.htm
[9] De Bruin, K., and Mert Kayut, A. Construction of the Energy Social Accounting Matrix for Ireland, ESRI 2019: https://www.esri.ie/publications/construction-of-the-energy-social-accounting-matrix-for-ireland
[10] Ireland Environment, Energy and Economy Model, ESRI: https://www.esri.ie/current-research/the-i3e-model

of the square matrix. These types of data structures usually provide the base for more advanced macroeconomic modelling.

Computable General Equilibrium Models

More complex computable general equilibrium (CGE) models include additional parameters, behavioural equations, and income and price feedback loops, to provide comprehensive, dynamic, long-term analysis. Rather than a forecasting tool, CGE models run simulations which consider the long term economic impacts of an exogenous shock or policy change when compared to a baseline forecast. For instance, the ESRI's I3E CGE model runs up to 2055 with inbuilt baseline assumptions regarding population and GDP growth. 'General equilibrium' refers to the assumption that all markets (commodities, labour and capital) will return to equilibrium, where supply equals demand, following a shock. This is achieved through the role of equilibrium prices and factor costs in the model. Prices and quantities in CGE models should be considered as indices, in that it is the relative prices between goods that is important. A variation in prices can lead to a shift in industry's consumption (or production) of goods, at a rate determined by its elasticity of substitution (or transformation). This is in contrast to static I-O models, which have no prices, so the quantity of inputs simply increases or declines proportionally with output. Producers and consumers in CGE models are assumed to behave in such a way as to optimize their profit or utility. In the I3E model, the incorporation of budget constraints and income and price elasticities for the ten different household groups allows for analysis of the welfare and distributional impacts of a policy change over time.

CGE models generally also have a more realistic representation of the labour market and its impact on production, with a recognition of unemployment, and job creation and destruction in different sectors. In many CGE models, the total supply of labour and capital in the economy is fixed, with perfect mobility of labour between sectors. This implies that all adjustments occur quickly, and only through wage changes, ruling out frictional unemployment. It is important to be aware of assumptions such as these and their influence on a model's explanatory capacity. In the I3E model, unemployment is calculated as the difference between labour demand, determined by the factor cost minimization problem faced by firms, and labour supply. Total labour supply is calculated as a fixed share of the domestic population (using a fixed labour force participation rate), plus net migration. To reflect the Irish labour market, there is an assumption of migration of labour which fluctuates in response to the real, net-of-tax, wage differentials between Ireland and the rest of the world. In periods where the wage rate increases and unemployment falls, the net migration into Ireland increases. In turn, changes in the labour market, and the distributional effects on income, have feedback loops to demand and production.

Impact assessments using a CGE model such as I3E can estimate the effect of a policy change on investment, economic growth, consumer spending, government revenue and debt, commodity prices, wages, and profits. Net employment is distinguished from Gross employment by considering the displacement of jobs, for instance, due to changes in the consumption or production of goods. However, one of the drawbacks with these models is in the interpretation of results. With many moving parts, particularly so with a large number of industries who are faced with changing commodity prices and wages, feeding into incomes, and quantities demand by different agents, among other things, it can be difficult to identify exactly which assumptions are driving the final results. In addition, depending on the availability of data, elasticities may be borrowed from other regions.