# Tomorrow's Energy Scenarios 2017
# Locations

## Planning our Energy Future

EIRGRID

The current. The future.

# Disclaimer

EirGrid has followed accepted industry practice in the collection and analysis of data available. While all reasonable care has been taken in the preparation of this data, EirGrid is not responsible for any loss that may be attributed to the use of this information. Prior to taking business decisions, interested parties are advised to seek separate and independent opinion in relation to the matters covered by this document and should not rely solely upon data and information contained herein. Information in this document does not amount to a recommendation in respect of any possible investment. This document does not purport to contain all the information that a prospective investor or participant in the Single Electricity Market may need.

For queries relating to this document please contact: scenarios@eirgrid.com



The Oval, 160 Shelbourne Road, Ballsbridge, Dublin 4, D04 FW28, Ireland.

# Table of contents

# Document structure

This document contains a glossary of terms, an executive summary, seven main chapters and appendices. The structure of the document is as follows:

The **Glossary of terms** explains some technical terms used in the document.

The **Executive summary** gives an overview of the main highlights of the document.

**Chapter 1** summarises the key changes made as a result of the locations consultation.

**Chapter 2** explains the purpose of the locations report, how our scenarios are used in the grid development process and lists other EirGrid planning publications.

**Chapter 3** describes the stories behind the four scenarios and explains the scenario development cycle.

**Chapter 4** introduces some of the focus areas of the locations consultation and discusses where key information is sourced from and how it is presented.

**Chapter 5** focuses on the future locations of the technologies which make up electricity demand and explains how these locations have been determined.

**Chapter 6** focuses on the future locations of the technologies which make up electricity supply and explains how these locations have been determined.

**Chapter 7** focuses on the future locations of the technologies which make up electricity storage and interconnection and explains how these locations have been determined.

# Glossary of terms

**Capacity factor**
The ratio of a generators actual power output over a period of time, to its potential output, if it were possible for it to operate at full capacity continuously over the same period of time.

**Combined Cycle Gas Turbine (CCGT)**
A collection of gas turbine(s) and steam unit(s); waste heat from the gas turbine(s) is passed through a heat recovery boiler to generate steam for the steam turbine(s).

**Demand**
The amount of electrical power that is consumed by a customer, typically measured in megawatts (MW), in a general sense, the amount of power that must be transported from connected generation stations to meet all customers' electricity requirements.

**EirGrid**
EirGrid plc is the state-owned company established to take on the role and responsibilities of Transmission System Operator in Ireland as well as market operator of the wholesale trading system.

**Electric vehicle**
A vehicle driven by an electric motor that is powered by a battery. The battery is typically charged by plugging into the low voltage electricity distribution system.

**Embedded generation**
Refers to generation that is connected to the distribution system or at a customer's site.

**European Union (EU)**
A political and economic union of 28 member states that are located in Europe.

**Greenhouse gas**
A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range.

**Heat pump**
A device that provides heat energy from a source of heat to a destination called a 'heat sink'.

**Interconnector**
The tie line, facilities and equipment that connect the transmission system of one independently supplied transmission system to that of another.

**Maximum export capacity**
The maximum export value, measured in megawatts, provided in accordance with a generator's connection agreement. The maximum export capacity is a contract value which the generator chooses as its maximum output.

**Megavolt Ampere (MVA)**
1,000,000 volt amperes, a unit of apparent power.

**Megawatt (MW)**
1,000,000 watts, a unit of active power.

**Megawatt hour (MWh)**
1,000,000 watts hours, a unit of energy.

**Open Cycle Gas Turbine (OCGT)**
A type of electricity generator that combines gas and compressed air in a combustion chamber to drive a turbine.

**Peak demand**
The maximum electricity demand in any one fiscal year. Peak demand typically occurs at around 5:30pm on a week day between November and February. Different definitions of peak demand are used for different purposes.

**Single electricity market**
The single electricity market is the wholesale electricity market operating in Ireland and Northern Ireland.

**Solar Photovoltaic (PV)**
Solar PV technologies produce electrical energy from solar radiation directly by converting light to electricity.

**Transmission system**
The transmission system is a meshed network of high-voltage lines and cables (400 kV, 275 kV, 220 kV and 110 kV) for the transmission of bulk electricity supply around Ireland and Northern Ireland.

**Transmission system operator**
In the electrical power business, a transmission system operator is the licensed entity that is responsible for transmitting electrical power from generation plants to regional or distribution operators.

# Executive summary

## Scenario planning

At EirGrid, one of our roles is to plan the development of the electricity transmission system to meet the future needs of society. Key to this process is considering a range of possible ways that energy usage may change in the future. We call this scenario planning.

In 2017 we introduced scenario planning into our grid development process as a way of ensuring the electricity grid continues to support Ireland's economic growth and expanding population.

We developed a set of four scenarios outlining four possible futures for the supply and consumption of electricity out to 2040. Our scenarios are:

- **Steady Evolution**
- **Low Carbon Living**
- **Slow Change**
- **Consumer Action**

## Locations

This document, *Tomorrow's Energy Scenarios* (TES) *2017 Locations*, proposes assumptions about where various demand and generation technologies may connect in the future. Modelling future locations enables us to identify potential areas of stress on the network which require further investigation.

We have used Ireland's regions to present our locations in a concise and consistent way. We have taken electricity demand, electricity supply, electricity storage and interconnection figures presented in *TES 2017* and disaggregated these by region.

This locations report reflects feedback received as part of the *TES 2017 Locations Consultation* which took place over a nine week period beginning in April 2018. Changes made as a result of the consultation are summarised in Chapter 1.

## Electricity demand

Understanding the future locations of electricity demand is an important step in testing that the transmission system of tomorrow can support this growth.

There is approximately 250 MVA [EirGrid (2017a)] of data centre capacity installed in Ireland at present. Data centres account for over 75% of new electricity demand growth in our scenarios. Future data centre locations have been assumed primarily based on connection offers and enquiries. However, other information sources have also influenced locations in some scenarios.

Dublin has become a hub for data centre development to date. Other locations in Ireland, such as Cork, Limerick and Galway are expected to experience some growth in data centre development. **Low Carbon Living** assumes the highest level of data centre growth outside of Dublin. This growth is expected to be driven by increased investment in regional infrastructure supported by the *National Planning Framework* (*NPF*) [Government of Ireland (2018)], and facilitated by new policy and regulatory measures.

Electricity demand for electric vehicles is expected to be heavily concentrated in urban areas. This is because urban areas are more densely populated, resulting in higher volumes of electric vehicles charging via the electricity distribution system.

Higher concentrations of heat pump demand are also assumed for urban areas due to higher proportions of new housing stock expected in these regions. A review of plans for strategic development zones has underpinned this approach, as the majority of new housing is planned for urban areas.

## Electricity supply

Grid connection applications received are central to our assumptions for future renewable energy technologies such as onshore wind, offshore wind and solar PV capacities. This information source is a strong indicator of future connection locations. We have also used Government policy publications and regulatory guidelines to assess the likelihood of connections occurring.

The Government's *Renewable Electricity Support Scheme (RESS)*, the *Renewable Electricity Policy and Development Framework (REPDF)* and the *NPF* may influence future locations of renewable electricity developments. Our scenarios align with various energy policy proposals as a means of preparing for changes to current connection patterns.

There is currently 3,200 MW[1] of onshore wind generation capacity in Ireland with the vast majority situated on the south, west and north coasts reflecting the high availability of wind resource in these areas.

Our **Steady Evolution** and **Slow Change** scenarios assume that future onshore wind connections will follow a similar pattern to those observed in recent times. Our **Low Carbon Living** scenario considers a different development pattern reflecting a plan-led approach to future wind energy development. It assumes that energy policy developments and changes to planning guidelines lead to a broader regional spread of onshore wind development.

Our **Consumer Action** scenario aligns with increased community participation in onshore wind projects. This community participation is assumed to be supported by the Government's future *RESS*, and is reflected by the assumed regional distribution of future onshore wind capacity.

EirGrid has received a number of applications from offshore wind farms seeking connection to the transmission system. These applications form the basis for assumed future locations with the majority on the east coast of Ireland.

The assumed future locations of large-scale solar PV generation capacities are also influenced by connection applications. Rates of uptake of rooftop solar PV, or micro generators, affect the future locations of small-scale solar PV capacity. We have assumed that the mix of large and small-scale generators and the associated rates of connection vary depending on the scenario.

**Low Carbon Living** accounts for the highest levels of large-scale solar PV, predominantly based in southern regions of Ireland where sun exposure is highest. **Consumer Action** assumes the highest levels of rooftop solar PV, which is most concentrated in urban areas.

The amount of energy produced by fossil fuel generators in Ireland is expected to reduce in the future [EirGrid (2017b)]. Assumptions relating to the future locations of fossil fuel generators are based on information provided by our stakeholders as part of the *TES 2017* consultative process. A number of existing fossil fuel generators are expected to repower to gas or biomass and other generators will close.

## Electricity storage and interconnection

New energy storage locations are expected in the future, primarily as a result of battery energy storage systems connecting to the transmission and distribution systems. Locations of future battery energy storage connections are scenario dependent and have been primarily based on connection applications received by EirGrid and ESB Networks.

Ireland is currently interconnected with Great Britain through the East West Interconnector and to Northern Ireland via a 275 kV double circuit line. Further interconnection with Northern Ireland is planned with the high voltage alternating current North South Interconnector planned to be completed in 2023. This project will increase the total transfer capacity between Ireland and Northern Ireland to 1,200 MW.

The expected quantity of High Voltage Direct Current (HVDC) interconnections by 2030 varies from one to three depending on the scenario. **Low Carbon Living** assumes the highest level of HVDC interconnection by 2030 including the existing East West Interconnector, the proposed Celtic Interconnector, and the proposed Greenlink Interconnector with Great Britain connecting in the South-East region. However, **Slow Change** assumes that East West Interconnector is the only interconnector location in Ireland by 2030.

[1] As of, January 2018

# 1. Key changes

## 1.1. Locations consultation

In April 2017, we published the *TES 2017 Locations Consultation*, a report detailing the future locations of electricity infrastructure in Ireland. We requested feedback on the assumptions used to determine these future locations.

We experienced a high level of engagement from a wide range of stakeholders and received a lot of useful feedback. This feedback has been reviewed and used to prepare this *TES 2017 Locations* report. We will also use this feedback to help shape future TES publications.

## 1.2. Summary

A summary of changes made to the report, as a result of the locations consultation, is provided below in Table 1.

| Chapter | Key changes |
|---|---|
| **Introduction** | • A new section titled "Why do we use scenarios" explains EirGrid's role as the transmission system operator and why EirGrid uses scenarios.<br>• A new section titled "Report purpose" outlines the document motivation.<br>• A new section titled "TES and the grid development process" explains the role of scenarios in the grid development process.<br>• A new section titled "EirGrid planning publications" lists other EirGrid publications, summarises the information contained within them and how they relate to TES. |
| **Electricity demand** | • We have revised our data centre locations for the **Low Carbon Living** scenario reflecting further alignment with the *NPF* and the Government's recent statement on data centres. |
| **Electricity supply** | • We have revised our onshore wind locations for the **Low Carbon Living** scenario reflecting further alignment with the *NPF*. |
| **Electricity Storage and Interconnection** | • We have revised our interconnector capacity for the **Low Carbon Living** scenario to reflect the project details of the Greenlink Interconnector. |

Table 1 – Summary of changes

# 2. Introduction

## 2.1. Report purpose

The purpose of the *TES 2017 Locations* report is to detail the future locations of electricity infrastructure for each scenario and the assumptions used to determine these locations.

## 2.2. Why we use scenario planning

EirGrid is the licensed transmission system operator on the island of Ireland. As the licence holder we are required to secure the ongoing operation, maintenance and development of the electricity transmission system.

Scenario planning allows us to assess the performance of the electricity system against four credible futures, helping to maintain required levels of system safety, security and reliability over the long-term.

## 2.3. TES and the grid development process

EirGrid's consultative approach to grid development is described in *Have Your Say* [EirGrid, 2017], which details our six-step grid development process as shown in Figure 1.

In Step 1 of the process we identify future needs of the electricity transmission system brought about by changes to:

- Electricity demand,
- Electricity generation,
- Electricity storage and Interconnection, and
- Asset condition.

We use scenarios to identify system needs brought about by changes to electricity demand, generation, storage and interconnection.

Our scenarios are not used to identify network refurbishment needs. These are determined based on changes to the condition of existing electricity transmission assets.

Scenario development, as described in Figure 3, is performed in Step 1 of the grid development process. As part of scenario development we test the performance of the transmission system against our scenarios and detail the results in the *TES System Needs Assessment* report.

Needs identified in this report are subsequently assessed in more detail and, if verified, proceed to Step 2 of the grid development process.

We use our scenarios to assess needs throughout each of the remaining steps in the grid development process, ensuring that needs remain valid as the electricity transmission system changes over time and more information becomes available.

## 2.4. EirGrid planning publications

As the licensed transmission system operator in Ireland, EirGrid produces a number of planning documents that share a relationship with TES. These are shown in Figure 2. They, alongside TES, provide a holistic view of the future electricity transmission system.

TES aligns with these reports and is informed by other publications such as the *Ten Year Network Development Plan 2016* [ENTSOE, 2016]. TES provides a wider view of the electricity transmission system beyond a ten-year planning horizon.

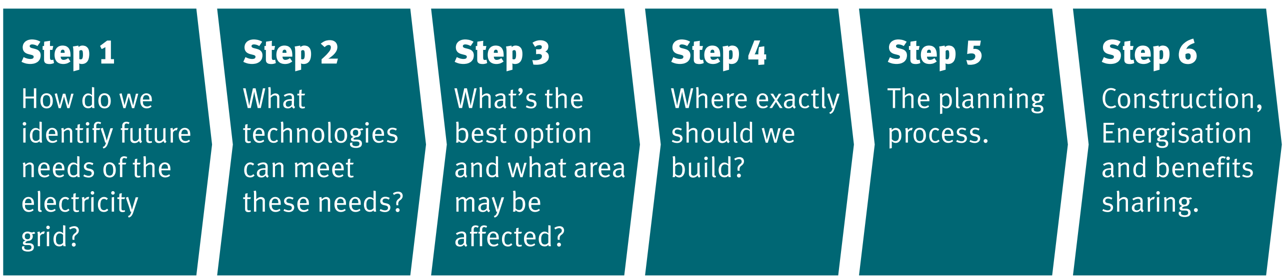



Figure 1 – Grid Development Process

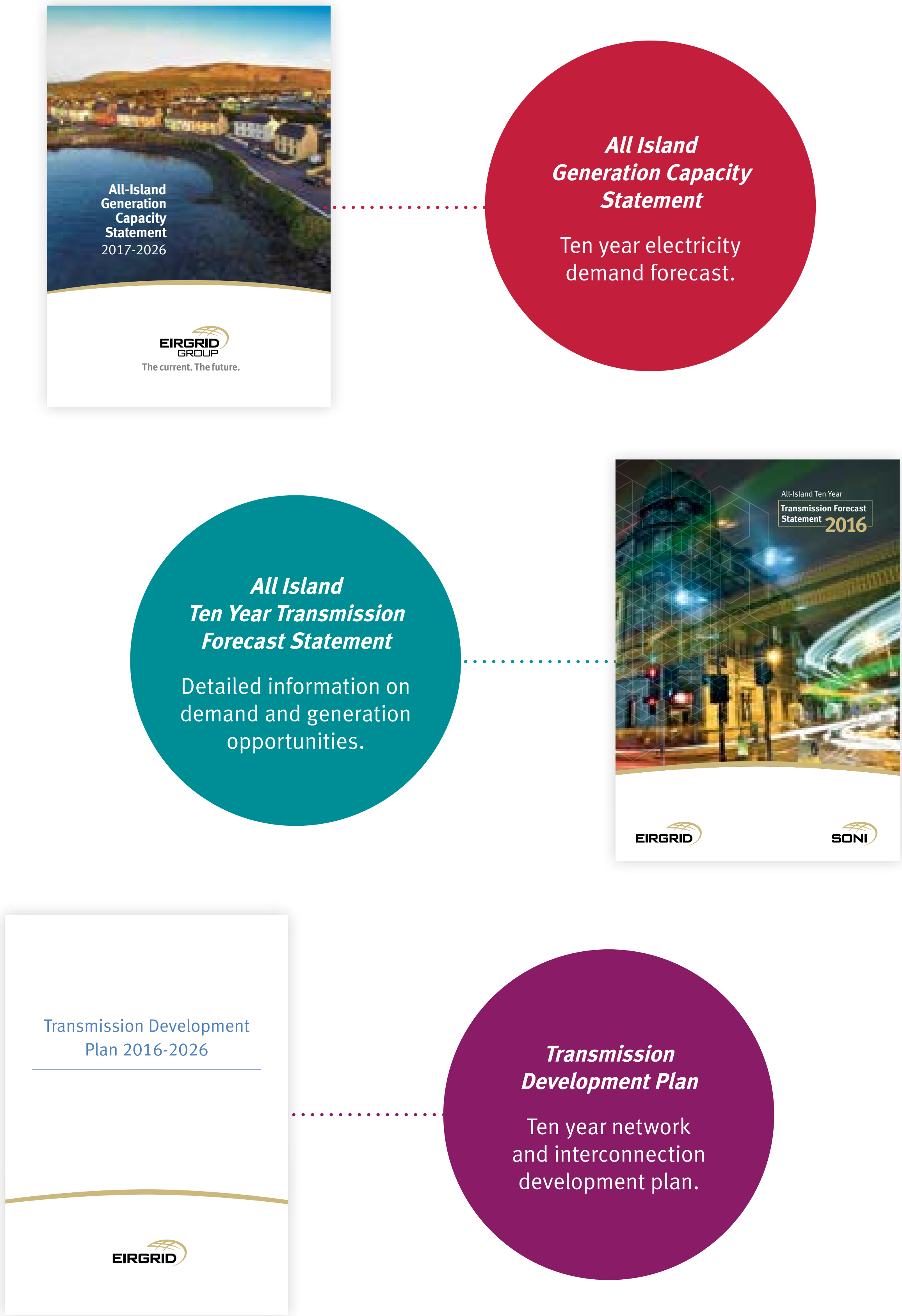



Figure 2 – EirGrid planning publications

# 3. Tomorrow's energy scenarios 2017

## 3.1. Our scenarios

EirGrid is responsible for the ongoing development of the transmission system so that it continues to meet the needs of electricity consumers into the future. The factors that influence the future usage of the transmission system are changing and becoming more varied. The level of uncertainty of each of these factors can be high.

The electricity industry is undergoing change driven by the adoption of new technologies and by new consumer behaviours. In 2017 we introduced scenario planning as a way of developing the transmission system so that it continues to support Ireland's economic growth and expanding population in the face of an uncertain future.

We published *Tomorrow's Energy Scenarios 2017* [EirGrid (2017b)] – a document outlining four possible futures for the supply and consumption of electricity in Ireland out to 2040.

*Tomorrow's Energy Scenarios 2017* brought together a wide range of factors that may shape the future electricity sector into a set of four discrete scenarios.

Our final scenarios are described in Figure 4.

## 3.2. Scenario development

We take a cyclic approach to scenario development. Involving our stakeholders in the development cycle is key to ensuring continuous improvement of our scenarios.

Figure 3 illustrates the consultation milestones and publications as part of the current scenario development cycle.

This locations report is phase four of the current development cycle. It details finalised assumptions and methods relating to our future locations.

With the final assumptions, we will conduct a technical assessment. This will be achieved by performing a number of different power system studies for each scenario out to 2040.

These studies will help us identify any future needs on the transmission system brought about by changes in electricity generation, electricity demand, electricity storage or interconnection.

The results will be presented in *Tomorrow's Energy Scenarios 2017 System Needs Assessment* report which will be published towards the end of 2018. This report will conclude the current scenario development cycle.

## 3.3. TES 2019

Our scenario development cycle will begin again in spring 2019. We will streamline TES development in 2019 by combining consultations on scenarios and locations and producing one consolidated report. We look forwarding to engaging with our stakeholders as part of TES 2019 scenario development.

## 3.4. Continuing the conversation

For more information on TES, or to access other TES publications, please visit our website.

Alternatively, you can email your views on TES to: scenarios@eirgrid.com and one of our team will be in touch.

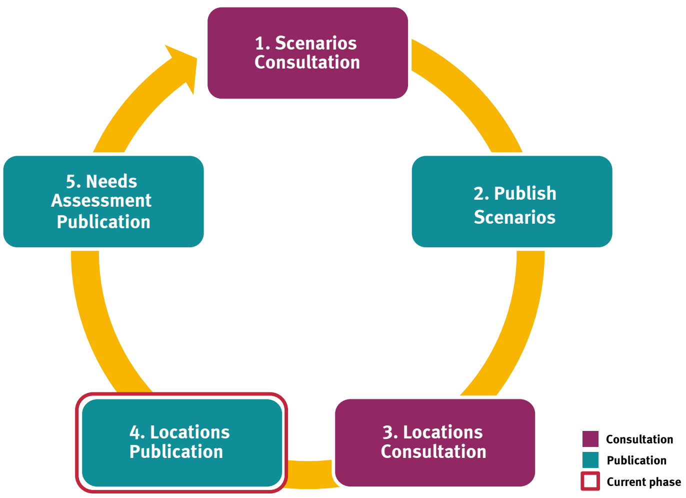



Figure 3 – Scenario development cycle

## Steady Evolution

Renewable electricity generation maintains a steady pace of growth. This is due to steady improvements in the economy, and in the technologies which generate electricity. New household technologies help to make electricity consumers more energy aware. This increases energy efficiency in homes and businesses. Over time, electricity consumers gradually begin to make greater use of electric vehicles and heat pumps. This means that, over time, electricity powers a larger proportion of transportation and heating.

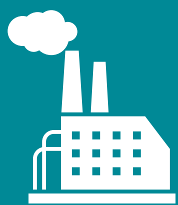
Onshore wind generation increases to approximately 5,200 MW by 2030


Ireland's 2030 emissions targets are met

New 700 MW interconnector to Europe is in place by 2025

## Low Carbon Living

The economy enjoys high economic growth. This encourages the creation and rollout of new technologies for low carbon electricity generation. There is strong public demand to reduce greenhouse gas emissions. In addition to high carbon prices and incentives for renewables, this creates a high level of renewable generation on the grid. This clean energy then combines with improvements to broadband and transport to drive growth in large data centres.



Coal generation is repowered to Gas and Peat generation is repowered to Biomass by 2025

The total demand for electricity increases by 53% by 2030 compared to today

Data Centre connections reach 1950 MVA in 2030 - most of these are based in Dublin

Figure 4 – Tomorrow's Energy Scenarios

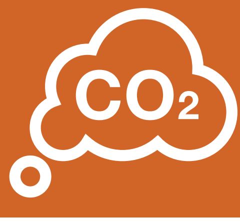
## Slow Change

The economy experiences very slow growth. Investment in new renewable generation is only in established, low risk technologies. Due to poor economic growth, new technologies that could increase the use of renewable generation at household and large-scale levels are not adopted. Overall there is little change in the way electricity is generated when compared to today. Domestic consumers and commercial users are also avoiding risk and uncertainty. The only source of demand growth is the connection of new data centres but the level of investment slows down significantly after 2025.

**Fossil fuel generation capacity remains over 5,000 MW by 2030**

**The total demand for electricity increases by 22% by 2030 compared to today**

**Ireland's 2030 emissions targets are missed**



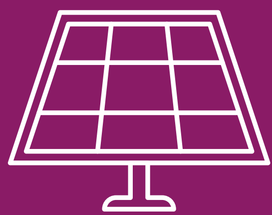

## Consumer Action

A strong economy leads to high levels of consumer spending ability. The public want to reduce greenhouse gas emissions. Electricity consumers enthusiastically limit their energy use and generate their own energy. This results in a large number of community-led energy projects and a rapid adoption of electric vehicles and heat pumps in the home.

**There are almost 560,000 electric vehicles on the road by 2030**

**17% of residential houses are heated through heat pumps by 2030**

**Household batteries and Solar PV help to increase self-consumption of electricity**



# 4. Focus areas

## 4.1. Introduction

To assist with presenting the information in this locations report in a concise way we have focused on certain aspects of Tomorrow's Energy Scenarios 2017. This approach enables a deeper examination of the assumptions and methodologies used to determine our future locations.

## 4.2. Technologies driving future change

In this document we consider generation, demand and interconnection and storage developments whose locations, either individually or in aggregate, can have a significant influence on the future usage of the transmission system.

Data centres, electric vehicles and heat pumps account for the majority of future electricity demand growth as described in *Tomorrow's Energy Scenarios 2017* and each technology is given a section in this document. Assessments of generation developments have focussed on the potential locations of offshore wind, onshore wind, solar PV and fossil fuel generation technologies. Ireland's transmission system is expected to have more interconnection with other countries in future along with an increase in levels of electricity storage and both of these are also examined.

These technologies will influence Ireland's future transmission system and therefore it is important that our assumptions are validated. We have outlined the assumptions used to determine future locations for these technologies and welcome your feedback as part of this consultation.

## 4.3. Timeframe

*Tomorrow's Energy Scenarios 2017* presented demand, generation and interconnection information for four different time periods; 2020, 2025, 2030 and 2040. However, this document concentrates on 2030 and uses this year to demonstrate our approach to determining locations for all Tomorrow's Energy Scenarios study years. The 2030 information is sometimes compared against current data as a way of gauging levels of change for different technologies.

We have selected 2030 because it is an important year for a number of reasons. The level of certainty of the future energy system decreases over time. To account for this we consider more scenarios the further into the future we look. This is the first year that all four of our scenarios are used.

Further, 2030 is relevant in terms of energy policy as performance against EU emission targets will be assessed in 2030. The Government's *Energy White Paper* [Department of Communications, Energy & Natural Resources (2015)] set out a framework to help guide energy policy in Ireland out to 2030, highlighting 2030 as a 'milestone' in Ireland's journey towards a low carbon future.

Finally, 2030 is important from a grid development perspective as system needs that require grid reinforcements to be in place by 2030 may need to begin to develop solutions in the short term. Costs and benefits associated with potential grid development projects can be quantified with confidence within this 10 – 15 year planning horizon.

## 4.4. Ireland's regions

EirGrid uses regions to plan the development of the transmission system in Ireland as described in the *Transmission Development Plan 2015-2025* [EirGrid (2015)]. These regions, known as Nomenclature of Territorial Units for Statistics (NUTS) 3 regions [Ordnance Survey Ireland (2017)], have been in use in Ireland since 1994 and comprise the eight regional authorities established under the local Government act, 1991.

NUTS 3 regions are also used by Government agencies in Ireland, including IDA Ireland and the Central Statistics Office. The eight regions are illustrated in Figure 5. These regions will be used within this report to disaggregate information presented at a national level in *Tomorrow's Energy Scenarios 2017*.


Figure 5 – Ireland's regions

## 4.5. Information sources

Our assumptions for future locations of electricity supply, generation and storage and interconnection are underpinned by a number of sources of information. These have been identified through comparison with our peers, consultation with our stakeholders during the scenario development phase and through research of available internal and external information sources. We have explained the role of these information sources in forming our future locations in chapters 5, 6 and 7 of this document. Some of the key sources are listed below.

- Transmission and distribution grid connection applications
- Electrical load data at transmission substations
- *Renewable Electricity Suport Scheme* (*RESS*)
- Ireland's *National Planning Framework* (*NPF*)
- County development plans and energy strategies
- Interconnector project plans
- Population growth projections
- Government energy policy development and energy position papers
- Energy asset owner plans and statements
- Transmission system operator plans in other jurisdictions

We have used this information and our experience as the transmission system operator to develop what we believe to be the most credible locations for future electricity generation, demand and storage and interconnectors in Ireland.

In April 2017, we launched an open consultation to help us improve our locations based assumptions. Our stakeholders have helped us identify additional information sources which have been used to further refine our future locations.

# 5. Electricity demand

## 5.1. Data centres

Ireland supports a growing digital economy and is recognised as a "digital gateway to Europe" for many US-based companies [Host in Ireland (2017)]. Ireland's attractiveness as a destination for digital infrastructure investment can be attributed, in part, to the availability of skilled English speaking workers, fibre connectivity, power availability and reliability of the electricity network.

There is approximately 250 MVA of data centre capacity installed in Ireland at present. These large facilities house computer servers used to store and process data and requires uninterrupted supply of electricity to ensure data is secure. The Irish Government has recently signalled an intention to include data centres in the Strategic Infrastructure Act [eISB (2006)]. This measure is expected to streamline the future development of new data centre facilities. Data centres account for over 75% of new electricity demand growth in our scenarios.

Data centre developers assess the suitability of potential locations in Ireland against a number of key criteria including the availability of the five Ps: People, Policy, Pedigree, Power and Pipes [Host in Ireland (2017)]. EirGrid is currently processing multiple data centre connection enquiries indicating that suitable development sites are available in a number of locations. Current forecasts suggest data centre capacity will marginally exceed 1,400 MVA by 2026 [EirGrid (2017a)].

Connection offers and enquiries form the basis for the assumed future locations of data centres. However, other supplementary information sources have also influenced locations in some scenarios.

Dublin has become a hub for data centre development and is recognised as a destination possessing all the required attributes. Other locations in Ireland, such as Cork, are developing these attributes [Host in Ireland (2017)] and are starting to experience growth in data centre development. The Government's *NPF* [Government of Ireland (2018)] supports ambitious growth and introduces a strategy to increase investment in regional infrastructure. A recent statement on *The Role of Data Centres in Ireland's Enterprise Strategy* [Department of Business, Enterprise and Innovation (2018)] reinforces the Government's commitment to continued development in Ireland and discusses the need for a plan-led approach.

Future data centre locations are primarily based on connection offers and enquiries. Some of our scenarios forecast data centre capacities in 2030 and 2040 in excess of our data centre demand forecast of 1,400 MVA.

**Slow Change** and **Steady Evolution** forecast data centre capacity in 2030 of 850 MVA and 1,100 MVA respectively which are both lower than 1,400 MVA. Regional data centre investment patterns are not expected to deviate from current trends with assumed locations for these scenarios in 2030 solely based on the connection offers and material enquiries.

**Low Carbon Living** and **Consumer Action** forecast data centre capacity in 2030 of 1,950 MVA and 1,675 MVA respectively. The assumed locations for capacities in these scenarios have been determined based on a combination of connection applications, scenario storylines and assumed investment patterns for each scenario.

Current connection offers and material enquiries suggest that the majority of data centre capacity growth, over the next ten years, is expected in the Dublin region.

**Slow Change** forecasts 850 MVA in 2030, all of which is assumed to locate in Dublin. Meanwhile, 1,030 MVA is assumed to be located in Dublin in our **Steady Evolution** scenario with the remaining 15 MVA and 60 MVA situated in the West and South-West regions respectively.

**Low Carbon Living** assumes the highest levels of data centre growth of all four scenarios. This scenario is associated with plan-led development which is influenced by Government initiatives delivered under the *NPF*. The Government's recent statement on *The Role of Data Centres in Ireland's Enterprise Strategy* promotes future regional growth. This paper suggests that long-term planning of the electricity transmission system "should be guided by the objective for more balanced regional development" set out in the *NPF* and discusses the introduction of regulatory measures such as "locational signals" to facilitate this.

Figure 6 illustrates the assumed regional distribution of data centre capacity by 2030 in **Low Carbon Living**.

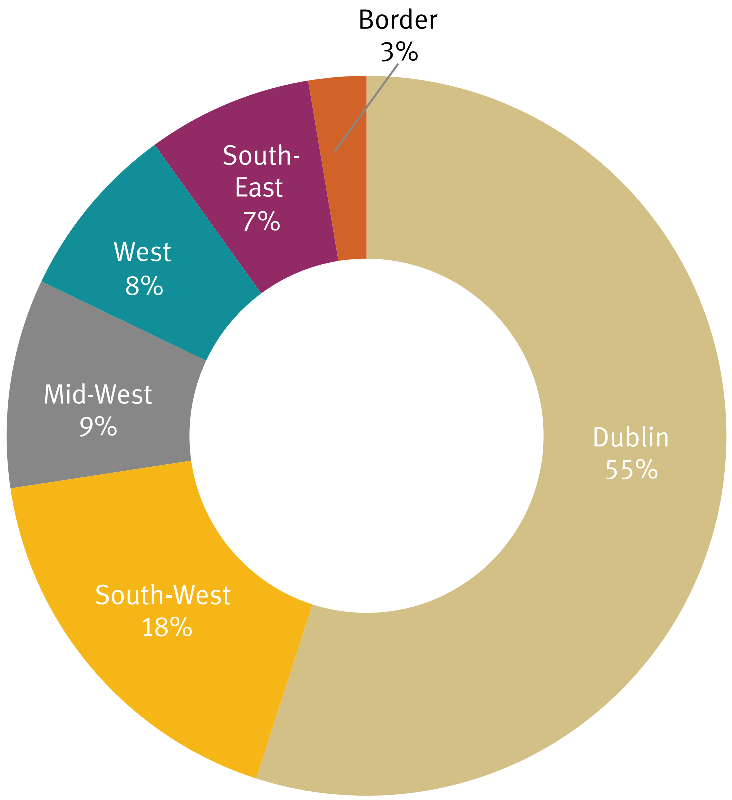



Figure 6 – Data centre capacity in 2030 by region, **Low Carbon Living**

High-speed fibre optic networks support development of new data centre facilities. **Low Carbon Living** assumes that investment in fibre networks in the South-West, South-East, Mid-West, West and Border regions increases the likelihood of data centre development in these regions by 2030.

The majority of these regions are already serviced by the high-speed fibre optic backbone network or will be serviced by a new line which will complete construction in 2019, as shown in Figure 7. These regions also account for Ireland's submarine fibre cable landing points in counties Mayo, Cork, Wexford and Dublin [Telegeography (2018)] which may support expansion to current off-island fibre connectivity in the future.

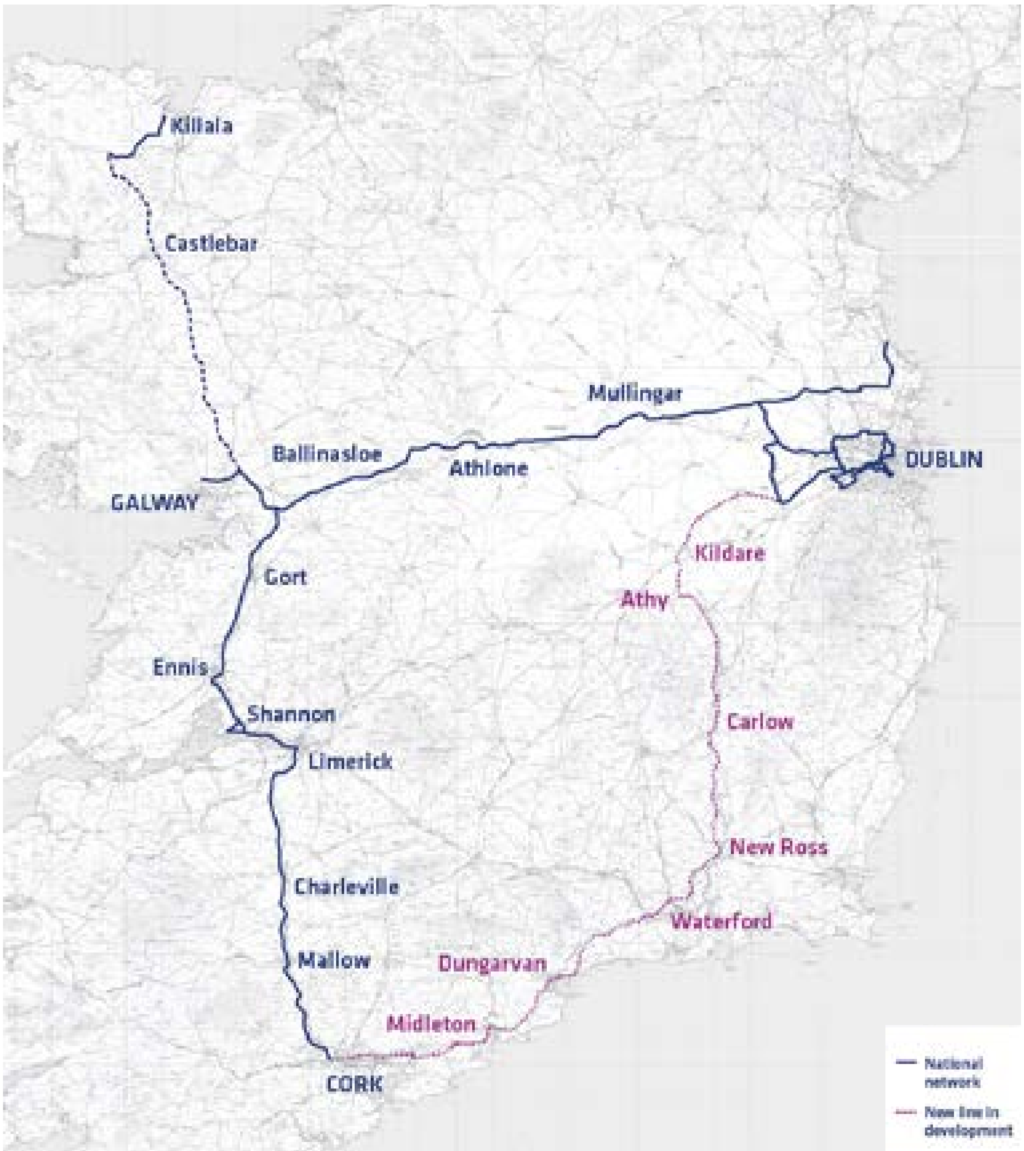



Figure 7 – National high speed fibre optic network [Aurora Telecom (2017)]

**Consumer Action** differs somewhat from our other scenarios in terms of the scale and types of data centres connecting to Ireland's electricity infrastructure in the future. **Consumer Action** assumes that approximately 7% of new data centre capacity in 2030 (105 MVA) will be small-scale distributed data centres connected to the distribution electricity network in our cities.

Expansion of these small-scale facilities, known as edge data centres, is reliant on the maturity of 5G communications networks in our cities and more widespread use of controllable smart devices in homes and businesses. Adoption of these technologies aligns with **Consumer Action** as electricity users proactively leverage smart devices to limit their energy use and reduce their carbon footprint. We have assumed that edge data centres will exist in the cities of Dublin, Cork, Galway and Limerick by 2030.

**Consumer Action** assumes the highest levels of data centre capacity in Dublin (1,358 MVA) by 2030 based primarily on connection offers and material enquiries. Growth is also forecast in the South-West, South-East and West regions due to a combination of large and small-scale data centre developments in the three largest cities outside of Dublin.

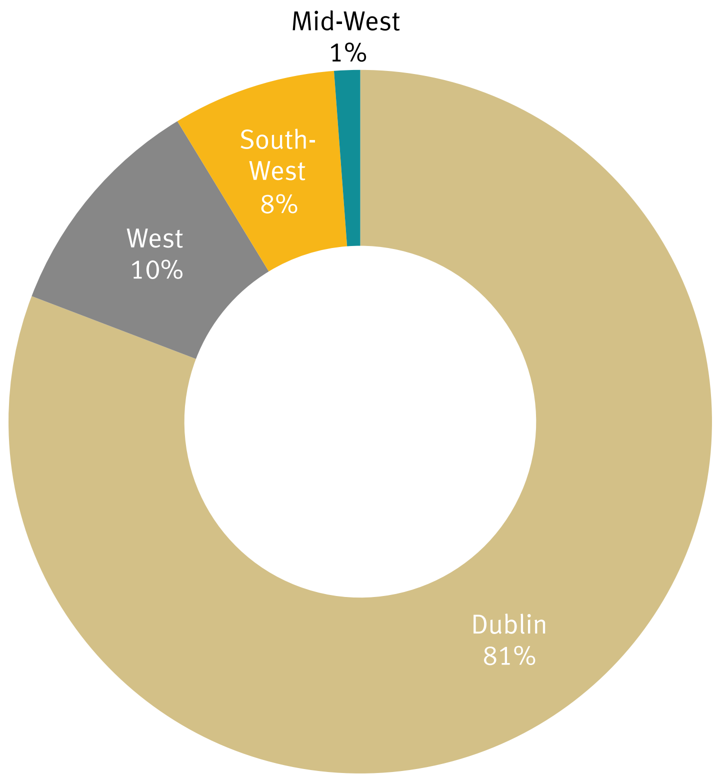



Figure 8 – Data centre capacity in 2030 by region, **Consumer Action**

## 5.2. Electric vehicles

Future electricity demand for electric vehicles will vary across the transmission system. This variation will depend on the points of the distribution network that the fleet of electric vehicles connect to for charging. It is expected the charging locations will be reflective of population densities with most charging occurring over night at the homes of electric vehicle owners.

We have distributed future electricity demand for electric vehicle to transmission stations on a pro-rata basis based on distribution demand readings. These readings are taken as an approximation of the number of domestic consumers fed by each transmission station. We have discussed this approach with the distribution asset owner, ESB Networks. ESB Networks has endorsed the method and provided feedback on ways to refine future calculations of electric vehicle demand.

Figure 9 provides a spatial view of electric vehicle capacity in 2030. The regions with the highest population densities, such as Dublin, the South-West, the Mid-West and the Mid-East, are expected to account for the largest proportion of electric vehicle demand. These four regions make up just less than three quarters of the average demand across the four scenarios.

Figure 9 illustrates a clustering of future capacity around the major cities in these regions. This is most pronounced in **Consumer Action** which assumes there will be 560,000 electric vehicles on our roads in 2030 – the highest levels of all four scenarios. The largest electric vehicle electricity demand in 2030 is assumed to occur in Dublin. This region accounts for an average of 38% of electric vehicle demand.

**Slow Change** assumes the lowest levels of electric vehicle uptakes in all regions by 2030 resulting in an overall quantity of 309,000. **Low Carbon Living** and **Steady Evolution** assume the second and third highest numbers of electric vehicles in all regions by 2030 respectively.

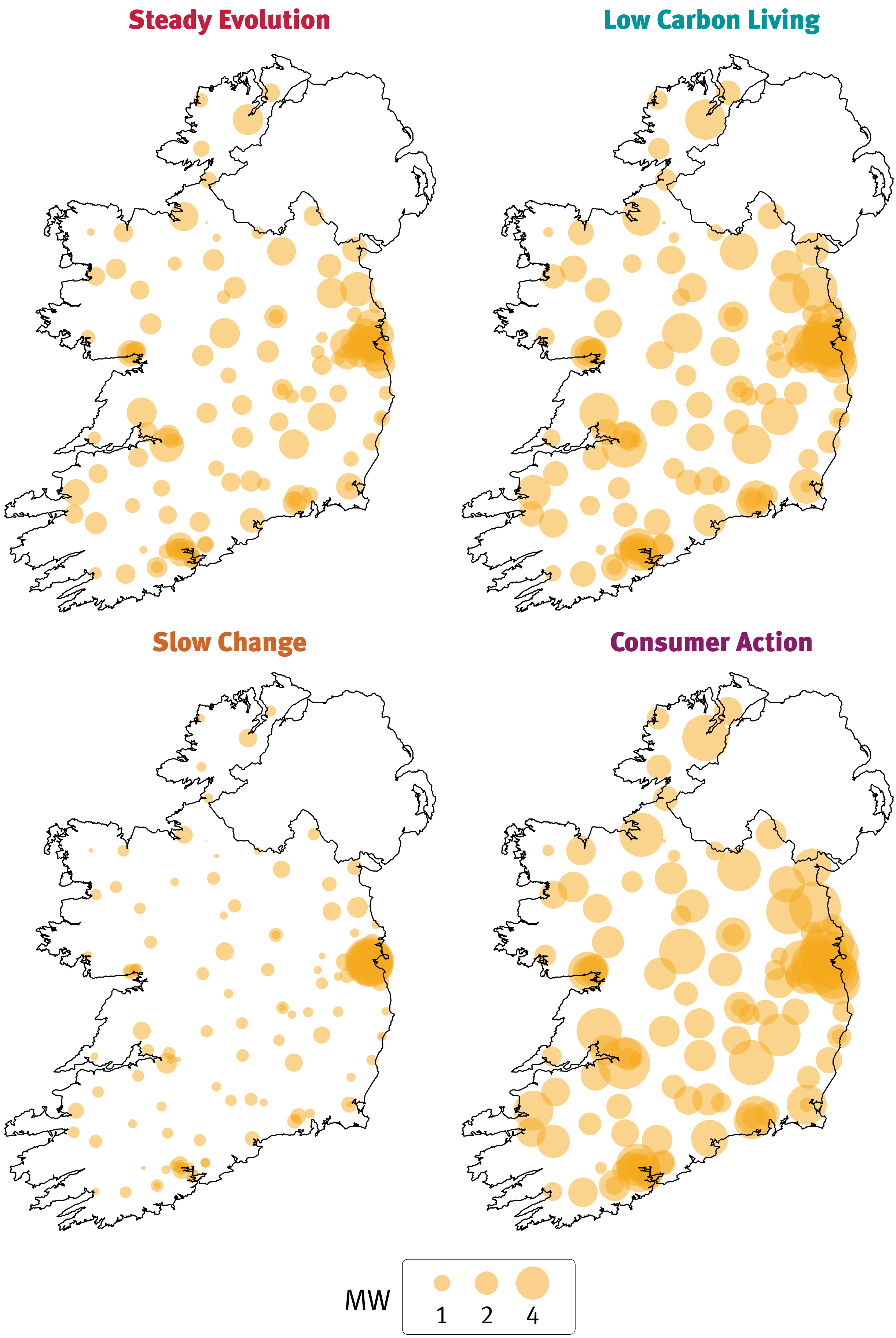



Figure 9 – Electric vehicle capacity in 2030 by transmission station

## 5.3. Heat pumps

Expectations for heat pump capacity growth are supported by the volume of new houses required to be built to meet Ireland's growing population demands. Ireland's population is expected to increase by 15% in 2030 [Central Statistics Office (2013a)]. Approximately 33% [PWC (2017)] of the housing stock in 2050 has not yet been built yet and it is expected that most new homes will be building energy rated 'A' homes with high quality insulation that will be heated using heat pumps.

Future growth of heat pump capacity is assumed to correlate with locations of new housing stock in areas zoned for future residential development. Land zoning [Department of Housing, Planning, and Local Government (2017)] conducted by the Government indicates that new housing development will be concentrated in urban centres.

We expect that 60% of all future heat pump demand will be fed from transmission stations situated in the urban centres and commuter areas of Dublin, Cork, Galway and Limerick. The commuter areas were assumed to be within a 50 kilometre radius of each city centre. The remaining 40% of heat pump capacity was assumed to be situated outside of these four major urban centres and commuter areas.

The heat pump capacity was then distributed across individual transmission stations on a pro-rata basis using distribution demand recorded at each station. The method used to allocate heat pump capacity to transmission stations is illustrated in Figure 10.

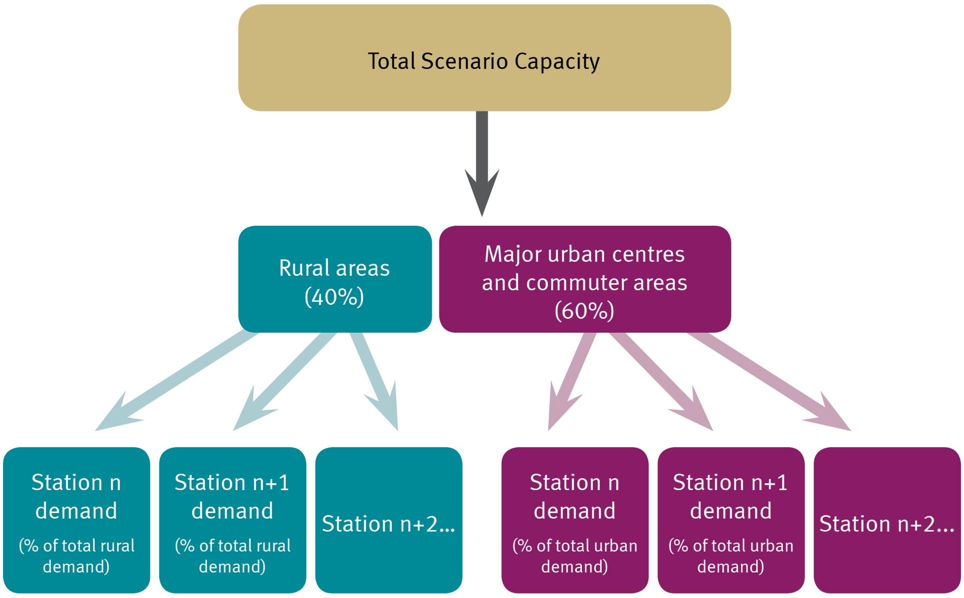



Figure 10 – Allocation of heat pump capacity to transmission stations

Figure 11 illustrates the assumed heat pump capacity in 2030. Dublin's population is set to grow faster than any other region [Central Statistics Office (2013b)] which will drive the construction of new buildings that are heated using heat pumps. This explains the high concentration of heat pump capacity shown in Dublin.

Other regions such as the South-West, Border and South-East are also expected to see increases in new housing stock by 2030. High concentrations of heat pump capacity are expected in towns and cities within these regions.

The highest levels of heat pump capacity growth are consistent with **Consumer Action** as individual electricity consumers seek to reduce their carbon emissions by electrifying the heating of their homes. **Consumer Action** includes the highest volumes of heat pumps across all eight regions followed by **Low Carbon Living**, **Steady Evolution** and **Slow Change**.

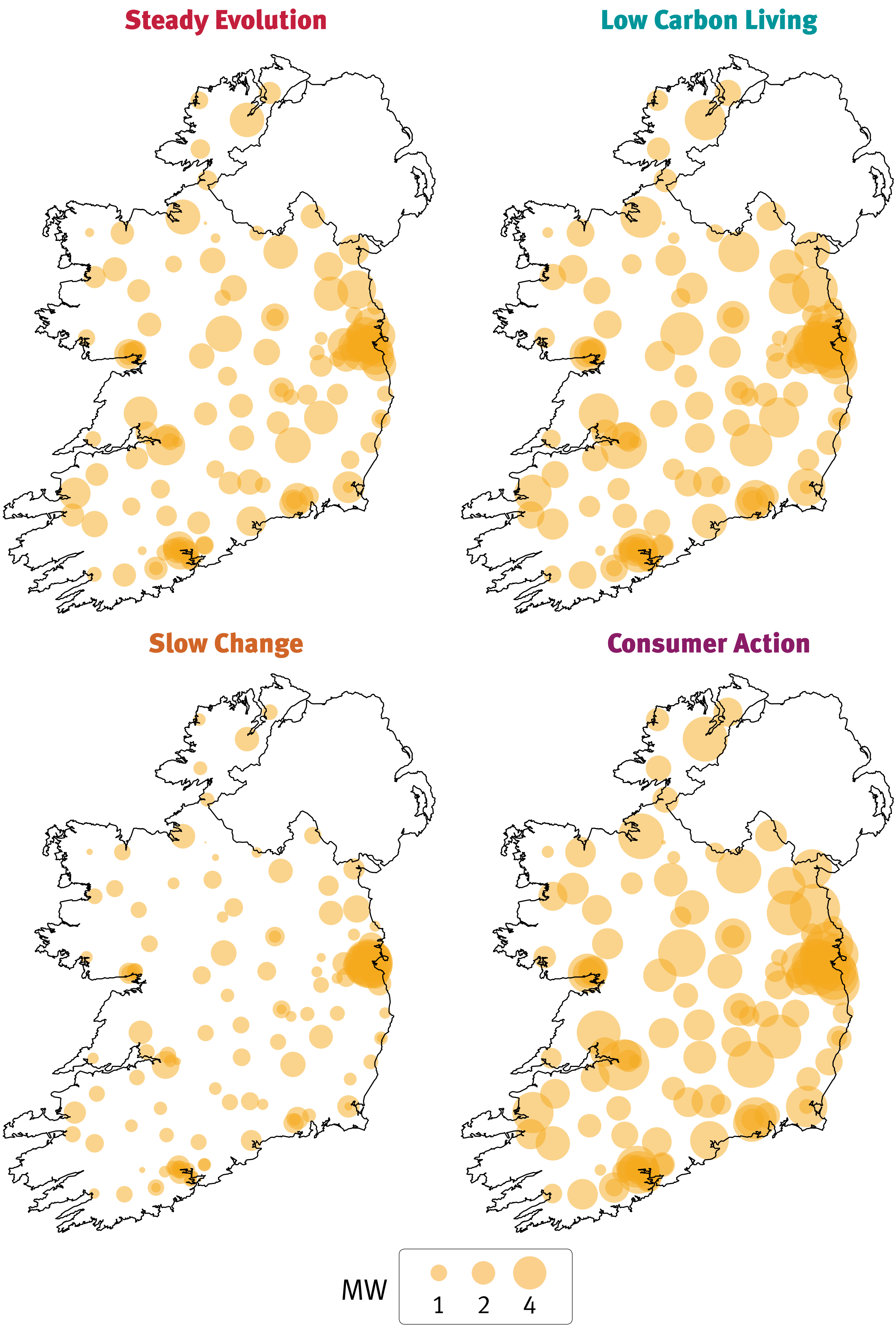



Figure 11 – Heat pump capacity in 2030 by transmission station

# 6. Electricity supply

## 6.1. Onshore wind

There is currently 3,200 MW[2] of onshore wind generation capacity connected in Ireland. Figure 12 displays existing onshore wind capacities by region. Ireland's wind resource availability is highest on the north, west and south coasts of Ireland. This is reflected in the location of existing capacity with the majority of wind farms situated in the regions on these coasts.

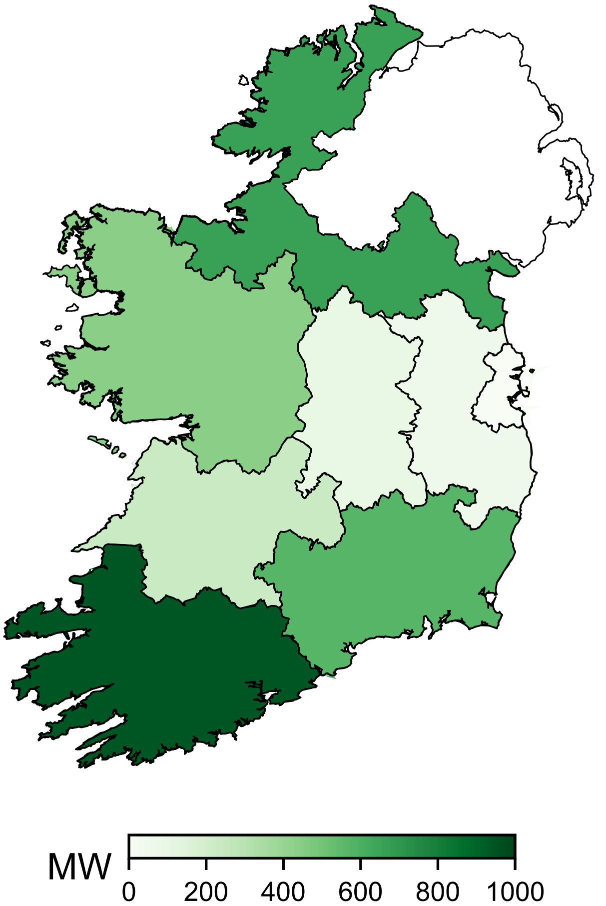



Figure 12 – Current onshore wind capacity by region

The pipeline of connection projects suggests that 1,100 MW of onshore wind generation capacity will connect to the electricity distribution and transmission networks in the coming years. This 1,100 MW of new capacity is made up of applications in advanced stages of the connections process with signed contracts and approved planning permission. Combining these new connections with existing connections provides locations for 4,300 MW [EirGrid (2017d)] [ESB Networks (2018)] of onshore wind generation[2].

Our scenarios forecast onshore wind capacities in excess of the 4,300 MW from 2025 onwards and so we must assume future generator locations based on best available information sources.

[2] As of, January 2018

Future locations of onshore wind generators are assumed predominantly based on generation connection applications [EirGrid (2017c)]. Connection applications include information about the proposed location, maximum export capacity and date of connection.

We have also used additional information sources, such as the Government's *NPF*, proposed changes to wind energy guidelines [Department of Environment, Community and Local Government (2013)] and the *RESS* to determine the most likely onshore wind connection patterns for each of our scenarios. These information sources have been used to allocate capacities up to the capacity limit for each scenario.

**Slow Change** and **Steady Evolution** scenarios are closely aligned with an industry-led approach to wind energy development. These scenarios both suggest a continuation of current connection patterns. **Slow Change** and **Steady Evolution** forecast capacities of 4,640 MW and 5,140 MW in 2030. Capacities above 4,300 MW are made up of contracted connection applications only, with application connection dates used to determine the connection timing.

**Low Carbon Living** is associated with a shift towards a plan-led approach to future wind energy development. As part of this scenario we assume that the Government's *NPF* and the Governments planned REPDF influence future patterns of wind energy development. Under this scenario investments are directed to sites deemed suitable for wind energy development under the new wind energy development guidelines.

Modelling performed by the Sustainable Energy Authority of Ireland (SEAI) indicates that there will be a limited number of sites suitable for development under the new guidelines. This will mean that regions, such as the South-West, may experience a deceleration in development due to the unavailability of suitable sites. However, other regions with a higher proportion of suitable sites may see an increase in wind energy development.

The Government's *NPF* discusses an intention to explore the viability of state-owned peatlands for renewable energy development. **Low Carbon Living** assumes that the relatively high availability of suitable sites in the West, Midland and Mid-East regions will result in connections in these areas. Improvements in wind turbine technologies may support this shift by increasing generator output in areas with relatively lower wind resources. We also assume some repowering of existing wind farms that have reached end of life in the South-West, West, South-East and Border regions.

In 2018, the Government released a high level design of the *RESS*. The *RESS* is intended to assist Ireland in meeting its 2020 renewable energy targets and 2030 energy ambitions by providing support for the development of renewable energy. Increased community participation in, and ownership of, renewable electricity projects is a key feature of the high level *RESS* design. Proactive involvement in renewable energy projects is consistent with **Consumer Action** as individuals and groups, seek to reduce their carbon footprint.

Although the size and scale of future onshore wind generators are expected to remain mostly consistent with recent experience, **Consumer Action** assumes a small increase in the number of community-led projects. This shift towards smaller scale distributed wind generation is expected in response to the new *RESS*. Community-led projects are expected to be relatively small capacities, less than 30 MW, and will connect to the distribution electricity network.

We have assumed that locations with existing applications, consistent with community-led projects, are likely to connect as part of our **Consumer Action** scenario. This results in a more balanced regional spread of community-led projects consistent with the SEAI's experience to date with projects of this nature.

Figure 13 provides a spatial view of assumed onshore wind capacity growth, from current levels, by 2030 for each of our scenarios. The magnitude and regional distribution of capacity growth varies across our regions depending on the scenario. **Steady Evolution** and **Slow Change** assume continued growth on the west coast, whilst **Consumer Action** and **Low Carbon Living** assume a more 'balanced' regional spread.

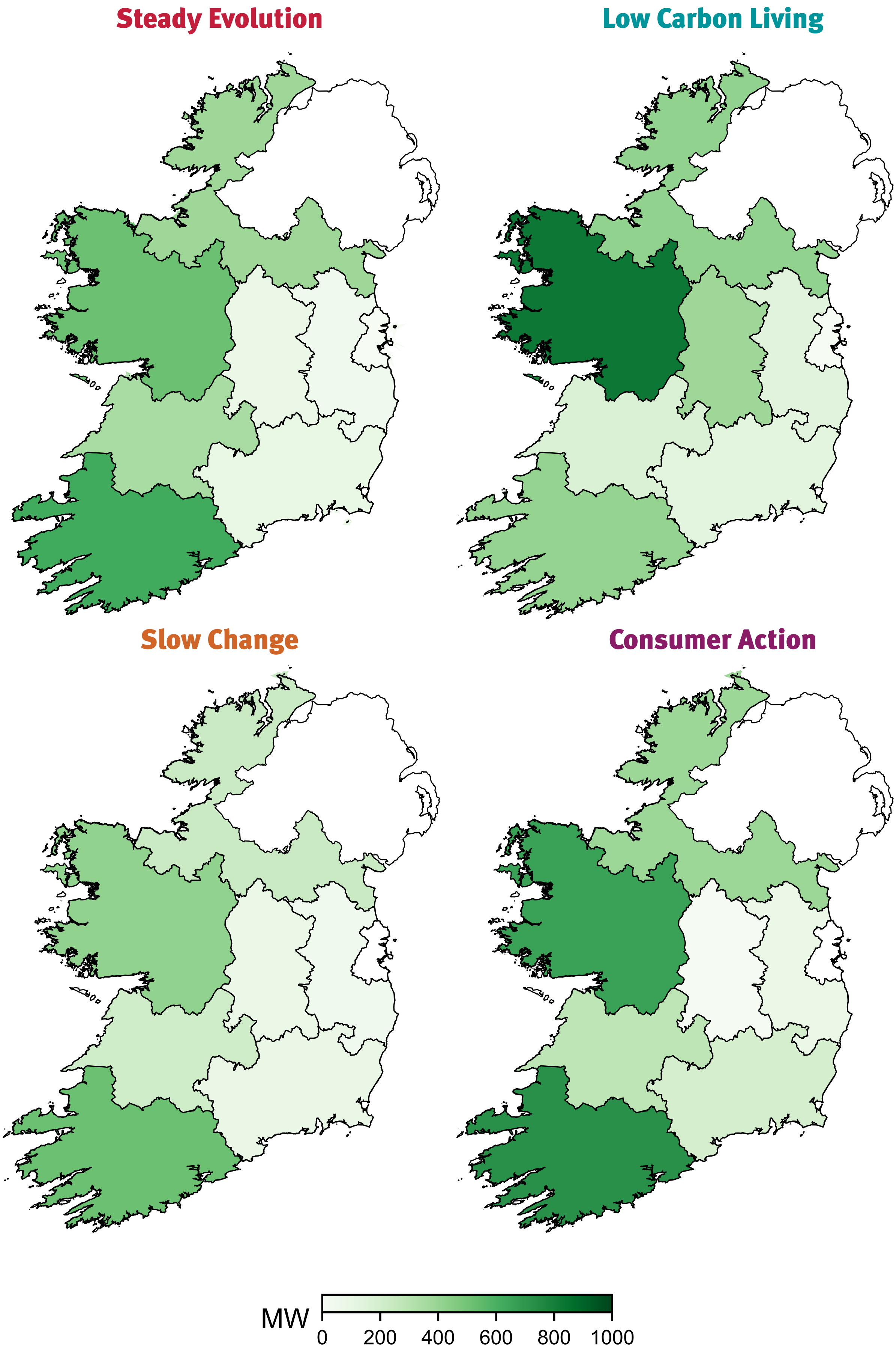


Figure 13 – Onshore wind capacity growth, from current levels, by 2030 by region

## 6.2. Offshore wind

We have received applications for offshore wind farms to connect to the transmission system. These applications provide the basis for assumed locations. Figure 14 displays offshore wind generation capacities in 2030 by region.

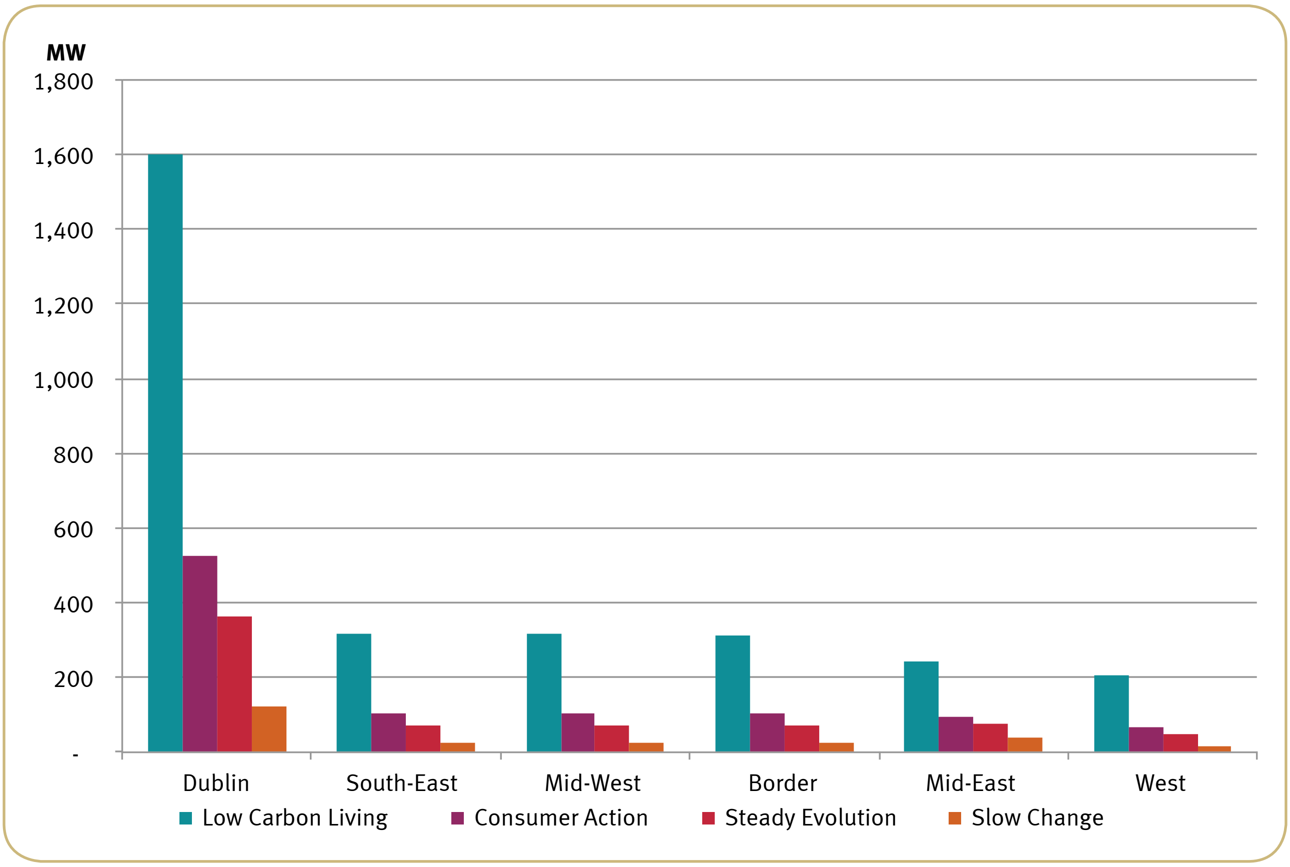



Figure 14 – Offshore wind capacity in 2030 by region

Shallow water depths and sheltered conditions in the Irish Sea make the east coast more favourable for wind farm development. This is reflected in connection applications with an average of 73% of offshore wind capacity seeking to connect on the east coast in 2030. There are a number of proposed wind farm developments at discrete locations off the coasts of Louth, Wicklow, Dublin and Wexford.

The highest levels of offshore wind generation are associated with **Low Carbon Living**. This scenario assumes that offshore wind technology may assist Ireland to meet its EU carbon emission targets and links offshore wind farm development in the Irish Sea with further interconnections to Great Britain. This scenario assumes an overall offshore wind capacity of 1,600 MW will connect in the Dublin area by 2030.

The remaining three scenarios also assume the majority of capacity growth to occur on the east coast, although, the magnitude of capacity growth is much lower.

## 6.3. Solar PV

Connection applications for solar PV generators are most frequent in southern regions of Ireland where sun exposure is highest resulting in greater solar PV generation capacity factors. Figure 15 demonstrates this with the highest assumed growth in capacities shown in the South-East, South-West, Mid-East and Midland regions. This is most pronounced in our **Low Carbon Living** scenario which assumes the largest levels of large-scale connections to the transmission network.

Solar PV capacities were distributed across the transmission system in two ways depending on the scale of the generation. Large-scale solar PV generators connected directly to the distribution or transmission systems were allocated to different regions in Ireland based on connection applications. Small-scale solar PV generators located on domestic or commercial rooftops, also known as micro or embedded generators were distributed across the network based on distribution demand profiles.

The profile of regional capacities is different in our **Consumer Action** scenario, as shown in Figure 15 and 16. **Consumer Action** assumes the highest amount of rooftop solar PV or embedded generation. Although the expected capacities in the South-East, Mid-East and South-West are higher than other regions, the overall spread is flatter across the regions when compared to the three other scenarios. This is due to greater levels of roof-top solar PV up-take in our **Consumer Action** scenario leading to higher capacities in regions with dense populations such as Dublin, the South-East and the Mid-East.

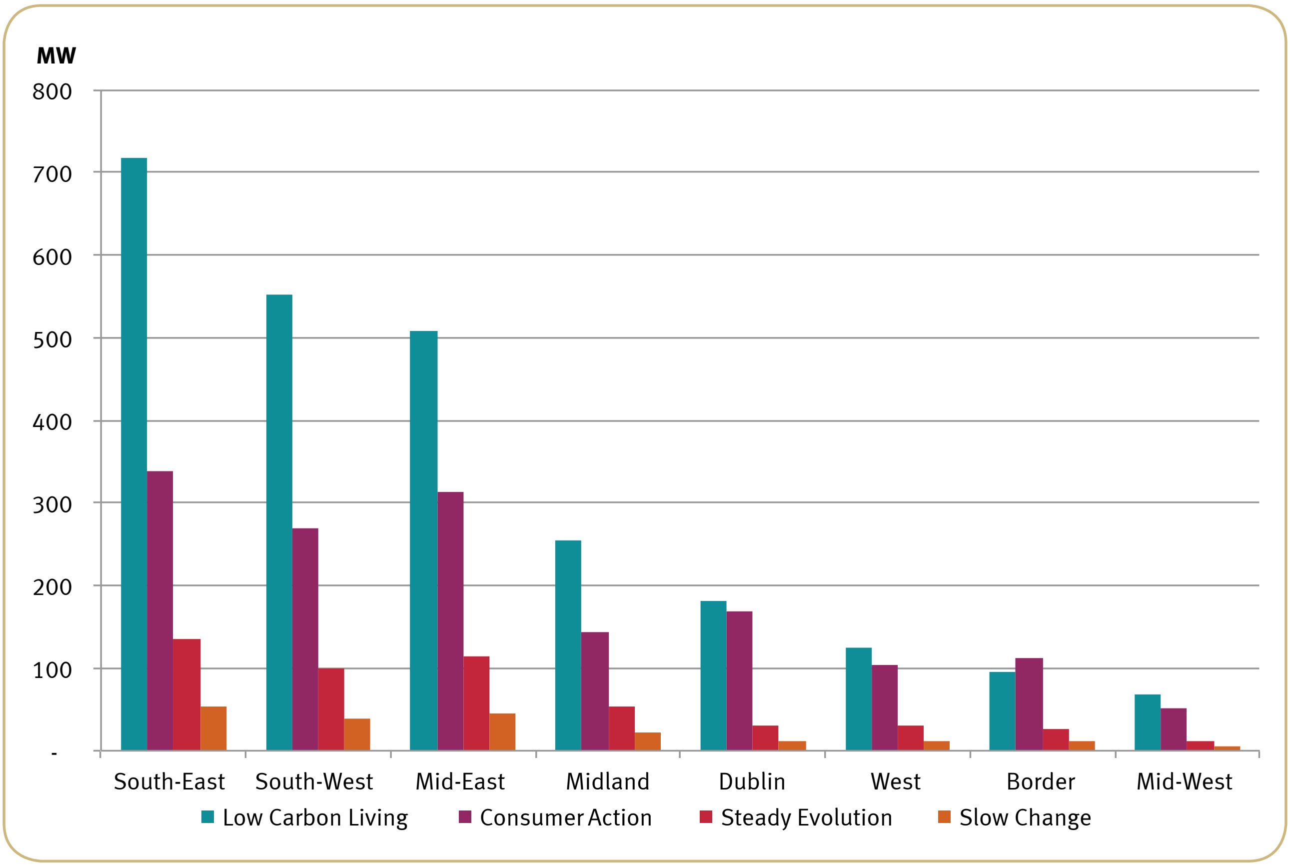



Figure 15 – Solar PV capacity in 2030 by region

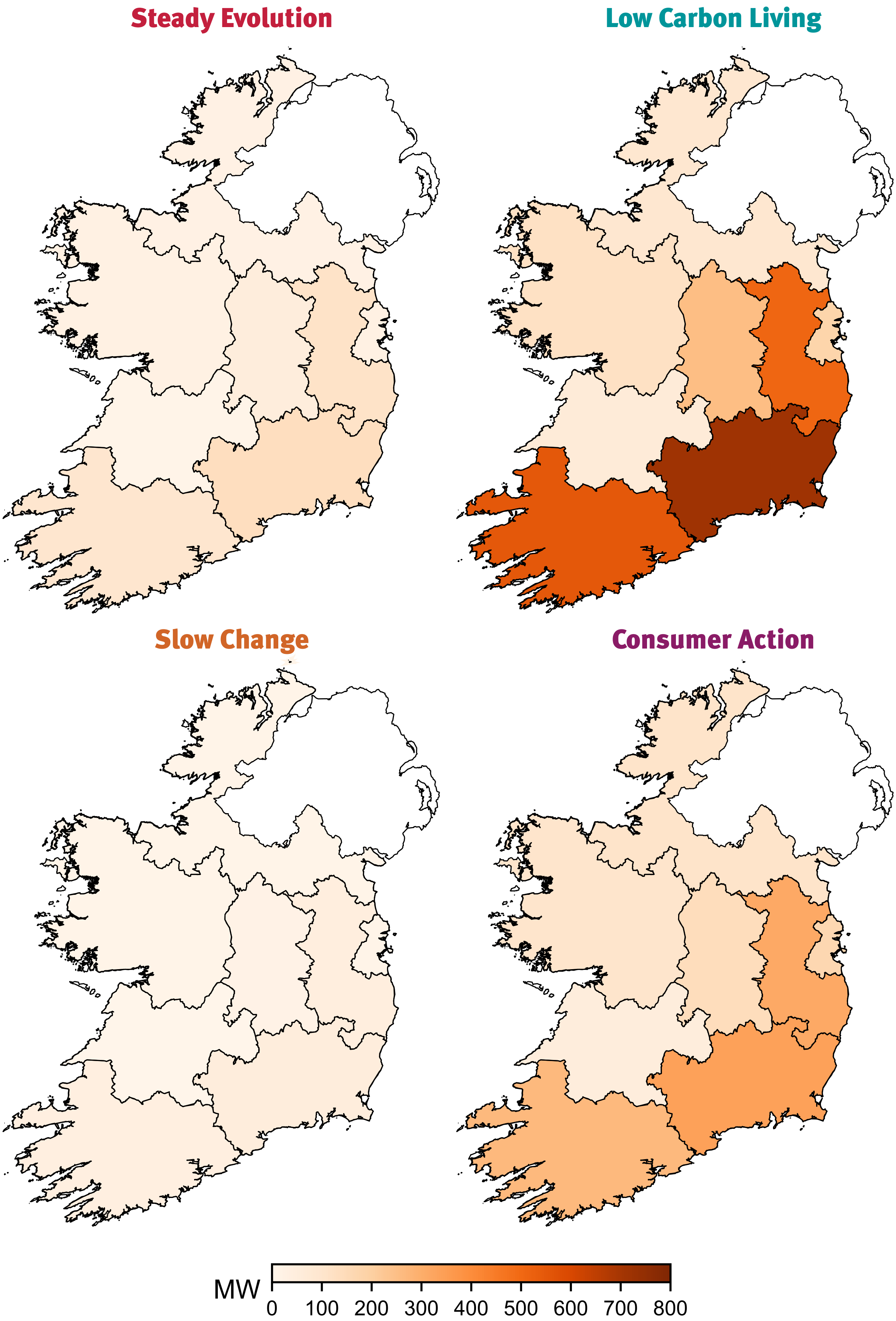



Figure 16 – Solar PV capacity growth, from current levels, by 2030 by region

## 6.4. Fossil fuel generation

Assumptions relating to the future locations of fossil fuel generators were formed based on information provided by stakeholders as part of the *Tomorrow's Energy Scenarios 2017* consultative process. Our stakeholders have suggested that peat and coal fired generation will cease completely by 2030 under all scenarios. **Low Carbon Living**, however, assumes removal of coal and peat generation will occur earlier by 2025. Removal of peat generation by 2025 is also assumed to occur in **Steady Evolution**.

There are currently three peat fired stations in Ireland situated at Edenderry, Lough Ree and West Offaly with a combined capacity of 311 MW. It is assumed that, by 2030, these stations will either repower with biomass or close depending on the scenario. Biomass is already in use at Edenderry which currently generates 35 MW of biomass energy by co-firing with peat.

Ireland's only coal-fired generation station, Moneypoint, in the Mid-West, is assumed to convert to gas between 2020 and 2030. This assumption aligns with Gas Networks Ireland's 2016 Network Development Plan [Gas Networks Ireland (2017)]. Distillate oil generation units at Edenderry, Tawnaghmore and Rhode may convert to gas in some scenarios by 2040 while heavy oil generators at Tarbert is assumed to be removed from service by 2025.

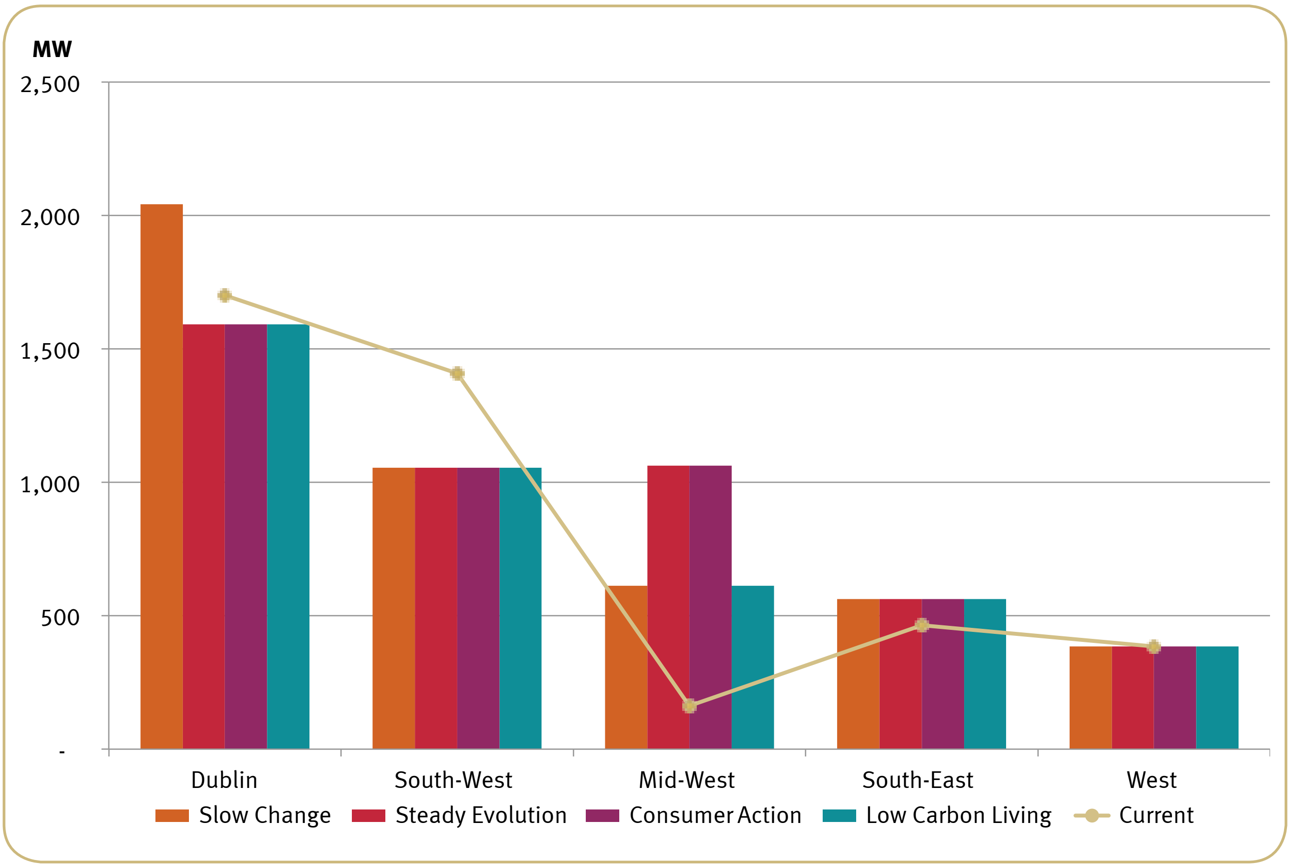



Figure 17 – Gas capacity in 2030 by region

The effect of gas repowering is demonstrated in Figure 17 , which displays gas capacities today and in 2030 by region. We can see an increase in the Mid-West region due to gas repowering of Moneypoint. The South-West sees a reduction in gas capacity in 2030 compared to today as aged gas fired generators are removed from service.

Closure of a Open Cycle Gas Turbine (OCGT) unit is assumed [EirGrid, (2017a)] in the Dublin region for all scenarios by 2030. However, gas capacities are assumed to increase in the Dublin region, by 2030, in **Slow Change** due to comparatively lower levels of renewable generation on the transmission system.

Although some regions may experience decreases in gas capacity an overall net increase in gas capacity is assumed in Ireland by 2030.

# 7. Electricity storage and interconnection

## 7.1. Electricity storage

Ireland has traditionally used pumped hydro energy storage; however, battery energy storage and compressed air energy storage technologies are becoming more widely used in transmission systems around the world.

Ireland's Turlough Hill station in Wicklow uses pumped hydro energy storage technology and has a maximum export capacity of 292 MW. A second pumped hydro energy storage facility is assumed to connect to the transmission system by 2030 as part of our **Low Carbon Living** scenario. This facility is expected to have a maximum export capacity of 360 MW and connect to the grid in the Midland region.

Large-scale battery energy storage systems are assumed to have capacities of 10 MW or greater and are connected directly to transmission or distribution systems or installed within wind or solar PV farms. EirGrid has received applications for a number of large-scale battery energy storage facilities to connect the transmission system. We have used these applications to determine our future battery energy storage locations. The upcoming DS3 volume capped procurement process may affect the future locations of battery energy storage, however, this is not reflected in our Tomorrow's Energy Scenarios locations.

Figure 18 displays large-scale battery energy storage capacities in 2030 by region. **Low Carbon Living** assumes significantly more capacity than the other three scenarios in all regions. For instance, capacities for **Low Carbon Living** are 24 times that of the **Slow Change** which assumes an overall capacity of 50 MW in 2030. This reflects the scale of renewable generation expected in the **Low Carbon Living** scenario compared to the other scenarios.

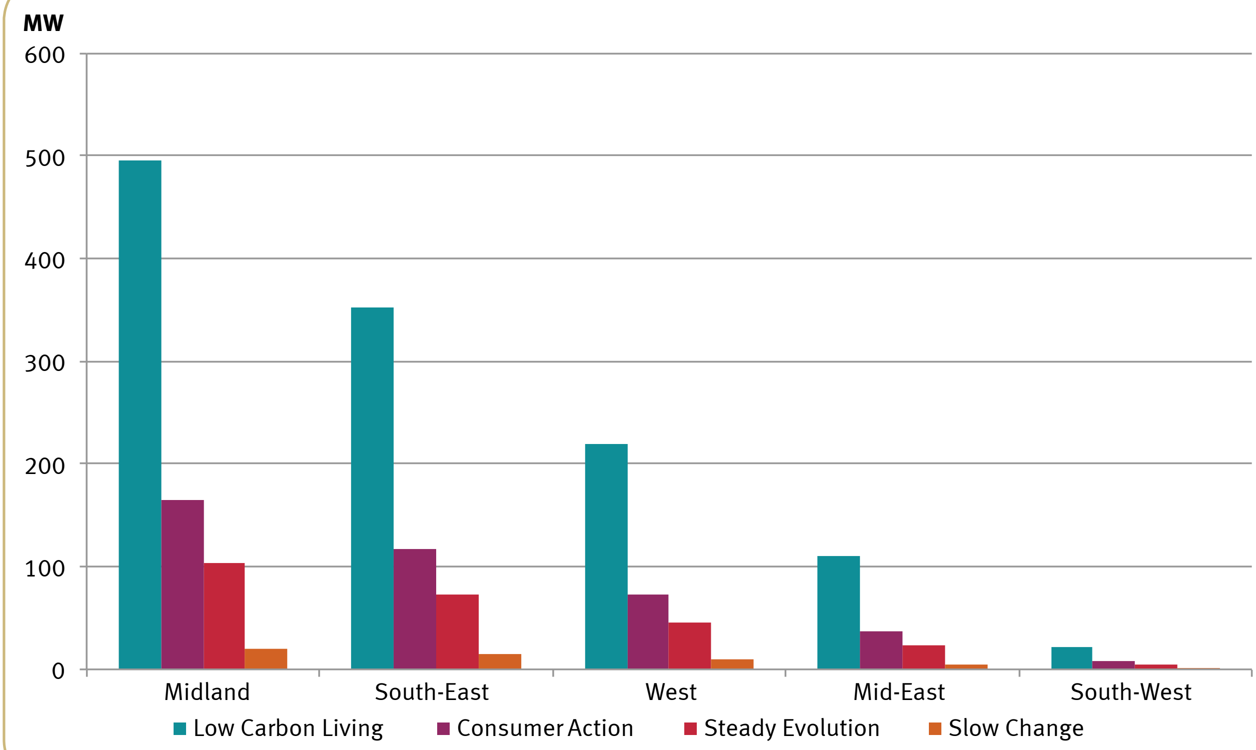



Figure 18 – Large-scale battery storage capacity in 2030 by region

Our scenarios assume that less small-scale battery storage capacity is expected to connect to the transmission system compared to large-scale systems. Small-scale batteries are considered to be domestic household batteries or battery banks with capacities less than 10 MW. We expect that these storage solutions will augment rooftop solar PV generators or small wind and solar PV farms connected to the distribution system.

It is assumed that small-scale batteries will somewhat offset, at times, existing distribution load and so capacities have been allocated to transmission stations on a pro rata basis based on the recorded distribution load readings. This is illustrated in Figure 19 as the concentrations of small-scale battery capacities in 2030 are highest in regions with high population densities and the largest proportions of distribution load.


Figure 19 – Small-scale battery storage capacity in 2030 by region

Small-scale batteries are most prominent in **Consumer Action** as households seek to better utilise rooftop solar PV generators. Capacities are highest in all regions for this scenario, although, more sparsely populated regions are assumed to experience marginal growth in all scenarios. The Midlands region, for example, is expected to contain maximum capacities ranging between 49 MW and 3 MW under our **Consumer Action** and **Slow Change** scenarios respectively. This is because distribution load levels are relatively low in these regions suggesting that low growth of small-scale battery capacities can be expected.

## 7.2. Interconnection

Ireland is currently interconnected with Great Britain through the East West Interconnector and to Northern Ireland via a 275 kV double circuit line. There are also two 110 kV tie lines between Northern Ireland and Ireland. However, these tie lines are not interconnectors as they do not, on their own, have sufficient power carrying capacity to securely hold the two transmission systems together.

The East West Interconnector uses HVDC technology and connects Deeside in Wales to the Woodland substation in Meath. The maximum transfer capacity of this interconnector is 500 MW. Further interconnection with Northern Ireland is planned with the high voltage alternating current North South Interconnector planned to be completed in 2023. This project will increase the total transfer capacity between Ireland and Northern Ireland to 1,200 MW. This transfer capacity is lower than the combined design capacities of both interconnectors. This is because power flows on these interconnectors must be limited so that the transmission systems, both sides of the border, remain stable if one of the interconnectors were to go down unexpectedly.

Table 2 displays HVDC interconnector capacities in 2030 by region. The expected quantity of HVDC interconnections varies from one to three depending on the Scenario. **Slow Change** assumes that the East West Interconnector provides Ireland's only HVDC transfer capacity in 2030 and that no further interconnectors have been commissioned. This is due to a lack of capital funding caused by unfavourable economic conditions. Under this scenario Ireland does not meet its EU interconnection targets.

**Consumer Action** and **Steady Evolution** assume that an additional interconnector is built in addition to the East West Interconnector. This second interconnector has a capacity of 700 MW and is assumed to connect the electricity transmission systems of Ireland and France. **Low Carbon Living** assumes that an additional interconnector will connect Ireland with Great Britain by 2030. This interconnector is assumed to have a total transfer capacity of 500 MW and connects to the Irish transmission system in the South-East region. This would take Ireland's total HVDC interconnector transfer capacity to 1,700 MW in Low Carbon Living by 2030.

| Region | Low Carbon Living | Consumer Action | Steady Evolution | Slow Change |
|---|---|---|---|---|
| Mid-East | 500 | 500 | 500 | 500 |
| South-West | 700 | 700 | 700 | |
| South-East | 500 | | | |

Table 2 – HVDC Interconnection capacity (MW) in 2030 by region

# Appendix 1 – Demand data

| Demand technology | Region | Steady Evolution | Low Carbon Living | Slow Change | Consumer Action |
|---|---|---|---|---|---|
| **Data Centre (MVA)** | Border | - | 49 | - | - |
| | Dublin | 1,026 | 1,073 | 850 | 1,358 |
| | Mid-West | - | 184 | - | 19 |
| | South-East | - | 147 | - | - |
| | South-West | 60 | 342 | - | 124 |
| | West | 14 | 155 | - | 174 |
| **Data Centre Total (MVA)** | | **1,100** | **1,950** | **850** | **1,675** |
| **Electric Vehicle (MW)** | Border | 27 | 46 | 10 | 61 |
| | Dublin | 66 | 114 | 24 | 150 |
| | Mid-East | 21 | 36 | 8 | 47 |
| | Midland | 14 | 24 | 5 | 31 |
| | Mid-West | 19 | 33 | 7 | 44 |
| | South-East | 26 | 45 | 9 | 59 |
| | South-West | 34 | 58 | 12 | 77 |
| | West | 18 | 31 | 6 | 41 |
| **Electric Vehicle Total (MW)** | | **225** | **388** | **81** | **510** |
| **Heat Pump (MW)** | Border | 37 | 52 | 18 | 63 |
| | Dublin | 85 | 118 | 42 | 144 |
| | Mid-East | 27 | 37 | 13 | 45 |
| | Midland | 19 | 27 | 10 | 33 |
| | Mid-West | 25 | 35 | 13 | 43 |
| | South-East | 37 | 52 | 18 | 63 |
| | South-West | 45 | 63 | 22 | 76 |
| | West | 25 | 35 | 12 | 42 |
| **Heat Pump Total (MW)** | | **299** | **420** | **150** | **509** |

Table 3 – Electricity demand in 2030 by region and technology

# Appendix 2 – Generation data

| Generation Technology | Region | Steady Evolution | Low Carbon Living | Slow Change | Consumer Action |
|---|---|---|---|---|---|
| **Onshore Wind** | Border | 1,049 | 1,081 | 905 | 1,053 |
| | Dublin | 10 | 8 | 10 | 7 |
| | Mid-East | 109 | 204 | 109 | 150 |
| | Midland | 186 | 486 | 186 | 118 |
| | Mid-West | 589 | 404 | 451 | 521 |
| | South-East | 671 | 703 | 665 | 770 |
| | South-West | 1,564 | 1,349 | 1,458 | 1,666 |
| | West | 962 | 1,265 | 856 | 1,095 |
| **Onshore Wind Total** | | **5,140** | **5,500** | **4,640** | **5,380** |
| **Offshore Wind** | Border | 70 | 311 | 23 | 102 |
| | Dublin | 363 | 1,601 | 121 | 525 |
| | Mid-East | 74 | 243 | 41 | 96 |
| | Mid-West | 72 | 319 | 24 | 104 |
| | South-East | 72 | 319 | 24 | 104 |
| | West | 49 | 207 | 17 | 69 |
| **Offshore Wind Total** | | **700** | **3,000** | **250** | **1,000** |
| **Solar PV** | Border | 27 | 95 | 11 | 112 |
| | Dublin | 30 | 181 | 12 | 168 |
| | Mid-East | 114 | 509 | 46 | 313 |
| | Midland | 53 | 255 | 21 | 143 |
| | Mid-West | 11 | 68 | 4 | 52 |
| | South-East | 135 | 717 | 54 | 339 |
| | South-West | 99 | 551 | 40 | 269 |
| | West | 31 | 124 | 12 | 104 |
| **Solar PV Total** | | **500** | **2,500** | **200** | **1,500** |
| **Gas** | Dublin | 1,593 | 1,593 | 2,043 | 1,593 |
| | Mid-West | 1,062 | 612 | 612 | 1,062 |
| | South-East | 562 | 562 | 562 | 562 |
| | South-West | 1,055 | 1,055 | 1,055 | 1,055 |
| | West | 388 | 388 | 388 | 388 |
| **Gas Total** | | **4,660** | **4,210** | **4,660** | **4,660** |
| **Large-Scale Battery** | Mid-East | 23 | 110 | 5 | 37 |
| | Midland | 103 | 495 | 21 | 165 |
| | South-East | 73 | 352 | 15 | 117 |
| | South-West | 5 | 22 | 1 | 7 |
| | West | 46 | 221 | 8 | 74 |
| **Large-Scale Battery Total** | | **250** | **1200** | **50** | **400** |
| **Small-Scale Battery** | Border | 24 | 60 | 6 | 96 |
| | Dublin | 59 | 147 | 15 | 235 |
| | Mid-East | 18 | 46 | 5 | 74 |
| | Midland | 12 | 30 | 3 | 49 |
| | Mid-West | 17 | 43 | 4 | 69 |
| | South-East | 23 | 58 | 6 | 93 |
| | South-West | 30 | 75 | 8 | 121 |
| | West | 17 | 41 | 3 | 63 |
| **Small-Scale Battery Total** | | **200** | **500** | **50** | **800** |

Table 4 – 2030 Electricity generation capacity (MW) in 2030 by region and technology

# References

Aurora TELECOM. National Network. Aurora TELECOM. 2017. https://www.auroratelecom.ie/network-maps/national-network/.

Department of Business, Enterprise and Innovation. The Role of Data Centres in Ireland's Enterprise Strategy. Department of Business, Enterprise and Innovation, 2018.

Department of Communications, Climate Action and Environment. National Energy Efficiency Plan for Ireland #4 2017-2020. Department of Communications, Climate Action and Environment, 2017. https://www.dccae.gov.ie/documents/NEEAP%204.pdf

Department of Communications, Energy & Natural Resources, Ireland's Transition to a Low Carbon Energy Future. Department of Communications, Energy & Natural Resources, 2015.

Department of Communications, Energy and Natural Resources. Offshore Renewable Energy Development Plan. Department of Communications, Energy and Natural Resources, 2014.

Department of Housing, Planning & Local Government. myplan.ie. Ordnance Survey Ireland. 2017. http://www.myplan.ie/webapp/.

Department of the Environment, Community and Local Government, Proposed revisions to Wind Energy Development Guidelines 2006. Department of the Environment, Community and Local Government, 2013.

EirGrid. All Island Generation Capacity Statement 2017-2026. Dublin: Eirgrid, 2017a.

EirGrid. Connected and Contracted Generators - Ireland. EirGrid, 2017d. http://www.eirgridgroup.com/customer-and-industry/general-customer-information/connected-and-contracted-generators/.

EirGrid. Have Your Say. EirGrid, 2016.

EirGrid. Offer Process Transmission Connection Applicant List. EirGrid, 2017c.

EirGrid. Tomorrow's Energy Scenarios 2017. EirGrid, 2017b.

EirGrid. Transmission Development Plan 2015-2025. EirGrid, 2015.

electronic Irish Statute Book (eISB). "Planning and Development (Strategic Infrastructure) Act 2006." electronic Irish Statute Book (eISB), 2006. http://www.irishstatutebook.ie/eli/2006/act/27/enacted/en/print.html.

ENSTOE. TYNDP 2018, Scenario Report, Main Report. ENTSOE, 2016. https://docstore.entsoe.eu/Documents/TYNDP%20documents/TYNDP2018/Scenario_Report_2018_Final.pdf

ESB Networks. Connected and Contracted Generators - Statistics. ESB Networks, 2018. https://www.esbnetworks.ie/new-connections/generator-connections/generator-connection-statistics.

Gas Networks Ireland. Network Development Plan 2017. Gas Networks Ireland, 2017.

Government of Ireland. Project Ireland 2040, National Planning Framework. Government of Ireland, 2018.

Host In Ireland. Ireland's Data Hosting Industry. Host In Ireland, 2017.

International Energy Agency. Renewables 2017. International Energy Agency, 2017. https://www.iea.org/publications/renewables2017/#section-1-3.

Ordnance Survey Ireland. NUTS3 Boundaries Ungeneralised - OSi National Statistical Boundaries. Ordnance Survey Ireland, 2017.

https://data.gov.ie/dataset/nuts3-boundaries-ungeneralised-osi-national-statistical-boundaries.

Central Statistics Office. Population and Labour Force Projections. Central Statistics Office, 2013a.

Central Statistics Office. Regional Population Projections. Central Statistics Office, 2013b.

PWC. Transitioning to a low carbon energy system. PWC, 2017.

TeleGeography. Submarine Cable Map. TeleGeography. 2018. https://www.submarinecablemap.com/#/.

# Notes:

# Notes:

The Oval, 160 Shelbourne Road, Ballsbridge, Dublin D04 FW28 • Telephone: 01 677 1700 • www.eirgrid.com

Printed on recycled paper