GREEN RESIDENTIAL BUILDINGS

Methodology Paper

Arion Banki

COWI

Foreword

Former revision of this report was initially published in early 2021 and is now re-published as some of the presumptions for the calculations of the carbon footprint have changed. Icelandic Housing and Construction Authority (HMS) has now published new numbers on emissions from the building industry in Iceland based on a wider base than previous presumptions. Moreover, there have been changes in emission coefficients published by the Environmental Agency of Iceland (Umhverfisstofnun, 2024).

COWI 2024

1. Introduction

Climate change is one of the main challenges of our time. The international community agreed on climate action with the implementation of the Paris Agreement in 2015 and the United Nations' Sustainable Development Goals, which act as a guide for a more sustainable world by the year 2030. The interest in investing in and financing climate-friendly projects has increased, and projects are increasingly being assessed with regards to environmental and social impacts. Green finance (including green bonds) is designed to support projects that reduce greenhouse gas emissions and thus support the goals of the Paris Agreement and the United Nations' global goals.

The purpose of this report is to analyze the residential building assets in Arion Bank's mortgage portfolio (loan portfolio) and to establish a credible set of criteria for the identification of green residential units in Iceland. This report does not cover analyses of other types of building assets in the loan portfolio, such as offices, shops, and industrial premises.

The National Statistical Institute of Iceland (Statistics Iceland) provides information on the construction of residential units in Iceland from 1970 to 2019, showing a breakdown of the number of residential units built each year.

The loan portfolio contains around 15,600 residential units built between 1900 and 2023. A comparison was made of the total number of residential units in the loan portfolio and the total number of residential units built in the whole country during this period (figures from Statistics Iceland). According to this comparison, Arion Bank has around 16% of all residential units in the country in its loan portfolio (around 15,600 residential units out of around 97,000 residential units built in the period 1900-2023). Based on this information, it can be assumed that the residential units in Arion Bank's loan portfolio also reflect the general distribution of residential units in Iceland.

In Figure 1 a geographic focus of Arion Bank's current mortgage portfolio is presented alongside the composition of residential units in Iceland. The Greater Reykjavik area dominates the mortgage portfolio as most Icelanders live in this area. Using Arion Bank's portfolio as a suitable proxy for the Icelandic residential building stock therefore allows us to establish a threshold to identify the top 15% carbon-efficient residential units in Iceland.

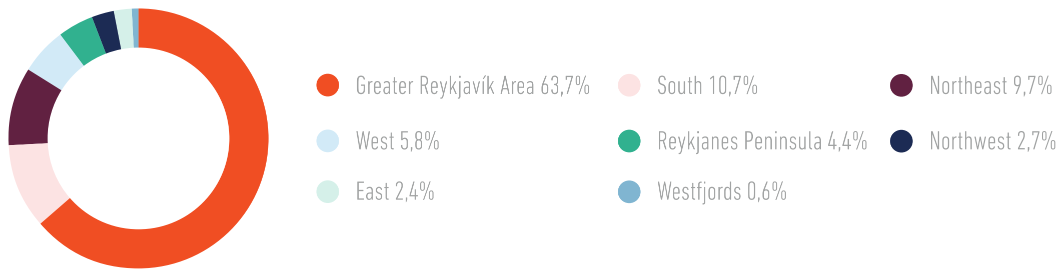


Figure 1: Geographic focus of current mortgage portfolio

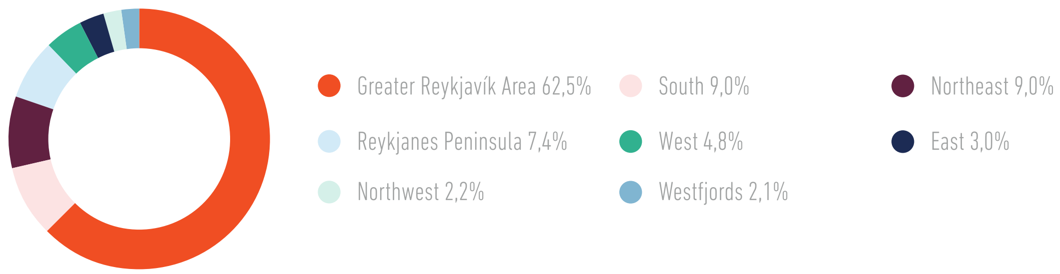


Figure 1: Geographic focus of Iceland

This report describes the methodologies used to establish a carbon intensity threshold from the current building stock, taking operational and embodied carbon emissions into account. It then sets out the minimum criteria for Icelandic residential units to be considered eligible under Arion Bank's Green Financing Framework. The decision on minimum criteria for energy efficiency is, among other things, based on the Icelandic Building Regulations from the years 1984-2020: the standards ÍST 66 2008 and 2016 (heat loss from buildings – calculation) and RB sheet 30 (1992-2008), which cover heat loss of buildings. RB sheets contain technical information on various aspects of maintenance, design, and construction of structures and are issued by the Iceland Innovation Center. Furthermore, criteria for embodied carbon in building materials are now, based on recent publications from the Icelandic Housing and Construction Authority (HMS) about results from 10 LCA calculations from Icelandic buildings and relevant information obtained from the software One Click LCA.

2. Background knowledge

2.1 Iceland's Climate Policy

The Icelandic government has signed the ambitious Paris Agreement which aims to reduce greenhouse gas emissions by 55% by the year 2030 compared to 1990 emissions, and the government has set a goal of carbon neutrality by 2040. Strong measures are needed to achieve these goals and reverse the trend in greenhouse gas emissions.

The government has established a Climate Action Plan, which consists of 48 actions intended to achieve these goals of reducing emissions and reaching the government's aim of achieving carbon neutrality by 2040. The government's action plan on climate change is divided into nine main categories, seven of which fall under the EU Effort Sharing regulation where the aim is to reduce emissions by 35% before 2030 compared to 2005 (European Union, n.d.). The construction industry in Iceland is covered by these actions and one, C.3., is directly focused on the construction industry. The Housing and Construction Authority in Iceland has an ongoing project on how to achieve the goals on emission reduction. They have published a report in three parts called Road Map to Greener Construction Industry 2030 (Vegvísir að vistvænni mannvirkjagerð 2030) (Bjarnadóttir & Marteinsson, 2022). The first part of the report that was published focuses on mapping greenhouse gas emissions for the whole life cycle of the construction industry, including energy consumption of buildings. Arionbanki's emission calculations for embodied carbon are largely based on these results.

2.2 Renewable Energy in Iceland

Renewable energy sources come from natural sources or processes which are constantly being replenished. They can be harnessed in a sustainable way without compromising the natural resources. Examples of renewable energy sources are hydropower, geothermal, solar and wind energy. In Iceland, 71% of energy production comes from hydropower and 29% from geothermal energy (Orkustofnun, 2023).

The Environment Agency of Iceland manages GHG emission factors in Iceland. The emission factor for electricity for the year 2022 was 8.54 gCO_2eq/kWh, and it is the average coefficient for all electricity production in the country, i.e. energy production with fossil fuels, hydropower and geothermal energy. The emission factors for electricity vary from year to year and it is recommended by the Environmental Agency of Iceland to use relevant coefficient representing the emissions that year. For example, an estimate for the emission occurring in 2020 should not use coefficients from 2018. Up until January 2024, emission factors for geothermal energy and hot water were managed in a single figure, i.e. due to the production of both electricity and hot water, the emission factor for hot water in the government's climate calculations used to be 0g CO_2 /kWh (Environment Agency, 2020). Now, however, the agency has published emission coefficients for hot water varying by year like for the electricity. The coefficient for hot water in 2022 is 434g $CO_2íg/m^3$, which can be converted to 7.69 g $CO_2íg/kWh$ (assuming incoming hot water of 80°C and outgoing water of 30°C). Reykjavik Energy (Orkuveita Reykjavíkur) has also assessed emissions from its energy production, and its calculations for 2022 assume 4.1 gCO_2eq/kWh emissions from district heating and 7.6 gCO_2eq/kWh from electricity utilities (Orkuveita Reykjavíkur, 2023). Emissions from district heating in Iceland vary between location of the source and type, hence the difference between coefficients from Reykjavik Energy and Environment Agency of Iceland.

Close to 90% of people in Iceland use district heating. Around 85% of these use district heating, which is subject to special regulations by municipalities. However, some smaller district heating companies do not operate according to patents and regulations. About 1.5% use other geothermal heating utilities and just over 3% use oil or electrical heating. The remaining 10% use electric heating and there is also a small proportion who use heat pumps (Orkustofnun, 2004). Furthermore, the electricity consumption of buildings in Iceland is almost entirely from renewable energy sources. Thus, energy use, i.e. electricity and heating, in Icelandic buildings is mainly powered by renewable energy.

2.3 International Comparison

When it comes to the implementation of renewable energy production, few countries have the same share of low carbon energy production as Iceland, with annual emissions only 8,54 gCO_2eq/kWh. In comparison with energy production in neighboring countries, it is evident that they have notably higher emissions per kWh, e.g. emissions in Denmark were estimated at around 103 gCO_2eq/kWh in 2022, emissions in Germany were around 366 gCO_2eq/kWh that same year and in Finland emissions were 66 gCO_2eq/kWh. However, emissions can be expected to decrease in other countries with increased installation capacity of renewable energy (European Environment Agency, 2024).

In Iceland, the use of renewable energy sources, other than geothermal and hydropower, has been limited. Experimental windturbines have been installed at two locations in Iceland and several wind farms are in the evaluation process with the state and local authorities. According to research by Landsvirkjun, energy production from wind turbines in Iceland is estimated to be very efficient, but due to Iceland's northerly location the efficiency of solar cells is not optimal (Sindri Þrastarson, Björn Marteinsson, & Hrund Ó. Andradóttir, 2019).

2.4 Icelandic Building Regulation

The requirements of the Icelandic Building Regulation that were in force during the year of construction of a building are used to determine its energy consumption. Due to the fact that Iceland runs almost exclusively on renewable energy, the incentive to switch to more energy efficient buildings has been limited in the past.

The Icelandic Building Regulation that was in force from March 9, 1984 until 1998 had almost the same U-values (thermal conductivity) as the one which is used today, i.e. the requirement for a weighted average wall of a single-family houses was 0.80 W/m²K, which is why single-family houses from this period and under a purely operational energy demand lens can be classified as energy-efficient houses. Apartments in apartment buildings did not fall under this requirement at that time.

Minor changes were made to the Icelandic Building Regulations between 1998 and 2011 and from 2013 to 2016 with respect to the thermal conductivity of a building component or so-called U-value. Because calculations in the calculation model are not for individual residential units, these changes are not reflected in the results. What has most impact on the results of calculations in the calculation model is the requirement of the regulation that the weighted average of walls (walls, windows and doors) must not exceed the U-value 0.85 W/m²K.

The only Icelandic Building Regulation in recent times to which significant changes were made with regard to U-values is the Icelandic Building Regulation from January 2012 - December 2012. The requirements for individual U-values increased by 15-33% and the weighted average of walls (walls, windows and doors) was a maximum of 0.80 W/m²K. Due to dissatisfaction at the time, the Building Regulation was amended in December 2012 and requirements for individual U-values were reduced again by 15-45%, moving the weighted median to 0.85 W/m²K.

Changes to the standard ÍST 66, which deals with heat loss in buildings, until 2016 are low in terms of percentage (0-15% for certain thermal conductivity values for individual building components). The main changes are that the insulation thickness and the structure of the insulation in the roof, and in one case in the wall, have been lowered or split up to get an overlap of the insulation to reduce thermal conductivity. The main change in the reduction of the U-value from the 2008 standard is that the thermal conductivity (λ) W/mK insulation decreased from the previous standard. In the 2016 standard, a cold bridge has been removed by a window and it is now included in the U-value of a window. However, these changes are not reflected in calculations in the calculation model as there is no information on the size or number of windows and therefore the weighted average value of walls is used according to the Icelandic Building Regulation.

A project is ongoing to gather information on estimated GHG emissions and on the climate impact of the construction industry with respect to action C.3 in Iceland's Climate Action Plan. This work, along with increased government emphasis on reducing environmental impact, is already affecting updates of the Building Regulation. Currently, a draft of the latest update is open to public consultation and includes requirements for life cycle assessments. It is also worth noting that the Icelandic Buildings Regulation has the tendency to follow the development of building regulations in other Nordic countries.

2.5 Certification schemes

BREEAM and the Nordic Swan Ecolabel are the most common certification systems in Iceland. The aim of the certification systems is to reduce the environmental impact over the lifecycle of the buildings and increase the sustainability of the construction sector.

Energy calculations using approved energy simulation software are a part of the certification process. However, it is optional within BREEAM, when assessing a planning project under the BREEAM Communities scheme the energy calculations are mandatory. In both cases projects are modelled and calculated based on current design and compared with the minimum requirements of the Icelandic Building Regulation. There are no minimum requirements in BREEAM, but points are given according to the reduction in energy consumption (and greenhouse gas emissions) achieved. Furthermore, efforts to reduce energy use and increase energy efficiency are promoted.

The Building Research Establishment (BRE), which operates the BREEAM certification system has estimated that a certified building which achieves a "Very Good" rating reduces GHG emissions by an average of 15%, while a building which achieves an "Excellent" rating reduces emissions by an average of 32% (BREEAM, 2016).

The Nordic Swan's ecolabel energy requirement for Iceland is to be 20% lower than the minimum requirements of the Icelandic Building Regulation #112/2012 with later additions. The evidence needed to confirm this is demonstrating calculation results from an energy simulation model of the building using approved software (for example IDA ICE, VIP+ and BV2).

3. Green residential buildings methodology

3.1 Residential building units in Iceland

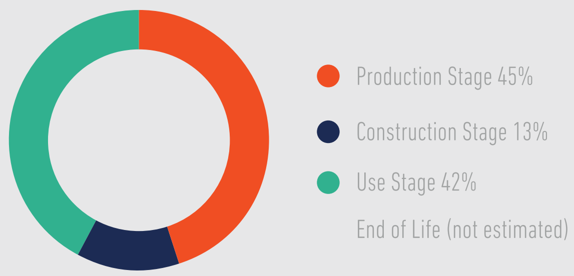
The building sector has a significant environmental impact, e.g. due to the production of building materials, disruption of land, emissions related to construction practices, energy consumption, maintenance, and demolition. Therefore, green buildings should be defined as those buildings that have considerably less environmental impact over their lifetime compared to conventional buildings.

There is a requirement for energy calculation and an approved methodology for energy calculation of buildings in the Icelandic Building regulation, but unlike in other Nordic countries there is no energy labelling (energy performance ratings).

The first steps have been taken to roughly estimate the overall environmental impact of the construction sector in Iceland with respect to action C.3 in Iceland's Climate Action Plan. The estimate is based on ten LCAs, information from energy companies, contractors, Environmental Agency of Iceland and energy calculations. The results of share of emissions between different phases in the lifecycle of the building are shown in Figure 2. This demonstrates that embodied carbon is the biggest factor when reviewing the climate impact over the lifetime of Icelandic buildings.

Figure 2 shows that there are two stages in the building life cycle that produce the most carbon footprint emissions over the lifetime of an Icelandic building: the production stage and the use stage. The main emission contributors in those stages are energy consumption that is heating and electricity used over its lifetime and embodied carbon in steel and concrete used in the construction. Energy consumption falls under the use stage while embodied carbon is under the production stage (Grænni byggð, 2020).

Figure 2. Life Cycle Emissions for the Icelandic Standard Building.



3.2 Description of the methodology

The overall goal is to establish a carbon intensity threshold (kg CO_2/year/m^2) that will be used to identify the top 15% of the most carbon efficient residential building units in Iceland. This is done by calculating the operational carbon emissions from energy use during the use stage and the carbon emissions from embodied carbon in the production and construction stage as these two factors are the biggest contributors to CO_2 emission in the Icelandic real estate sector.

No data is publicly available for the total Icelandic building stock to derive the threshold from, so the total Arion Bank mortgage portfolio is used as a sample. The mortgage portfolio has an almost 16% share of all buildings and as such can be regarded as a representative sample for the overall Icelandic building stock.

The loan portfolio includes following information for each residential building unit: year of construction, building materials, postal code, square meter size, type of heating, number of floors, distance to public transport, type of housing (single-family houses, terraced houses, apartments in apartment buildings, etc.). The location of the property is only specified by postal code. The analysis of the portfolio must therefore be based on the postal code for the location of the property.

When analyzing each residential unit, it is assumed that the property has been designed and built in accordance with the current standards and Icelandic Building Regulation at any given time. No information is available on whether the property has been constructed better in terms of energy savings than the standards and the current Icelandic Building Regulation stipulates, and therefore it cannot be taken into account.

To find the most favorable residential units in the loan portfolio based on the terms of energy consumption and embodied carbon, data from the loan portfolio was used as a basis for the calculation model.

Residential units in the bank's loan portfolio are classified according to the following information:

1. Form of each residential building unit, i.e. single-family house, two-family house, terraced house, semi-detached house, and apartments in apartment building
2. Initial year of construction
3. Icelandic Building Regulation in accordance with the initial year of construction
4. Standard ÍST-66 (Heat loss from buildings – Calculation) based on year of construction
5. Size of the residential units
6. Building materials

COWI has developed a calculation model based on which it is possible to identify the residential units in the loan portfolio that are the most favorable in terms of energy consumption (see 3.3 Calculation of energy efficiency of residential buildings). The Icelandic Building Regulations and the ÍST-66 standard are used, but there are also various assumptions considered for the calculations.

Also included in the calculation model is an estimation of embodied carbon used in residential units based on building materials used and specified in the portfolio. The first part of the Road map to greener construction industry 2030 report shows that the climate impact of embodied carbon in the production stage of building materials is similar to the energy use of the building over its whole life cycle. Therefore, it is important to include calculations of embodied carbon when estimating the climate impact of buildings in Iceland (see 3.4 Calculation of embodied carbon emissions of residential buildings and 3.5 Threshold for the top 15% most carbon-efficient buildings in Iceland).

3.3 Calculation of energy efficiency of residential buildings

When calculating the most energy efficient residential building units from a lifetime perspective, total energy loss is divided by its square meters. Certain criteria need to be assumed in the calculation model due to the lack of information from the bank's portfolio. The assumptions for the energy calculations of residential units are based on COWI's expertise, known standards, the energy requirements of the certification systems as well as BREEAM and the Nordic Swan Ecolabel.

It can be assumed that the real energy consumption of residential units is lower than stated in COWI's calculations, as most buildings have a lower weighted average of the walls than what is stated in the Building Regulations.

When calculating the energy consumption of residential units in the bank's portfolio the following criteria are used which are based on information from standards, reference projects and other information and data. The given criteria are:

- It is assumed that all residential units have a wooden roof with a slope of about 20° in the calculations. It is not stated in the data whether the residential units have a flat or a sloping roof (this affects the heat loss through the roof).
- The assumption is made that the weighted average of walls, windows and doors are based on the maximum requirement of the Building Regulation which is in force during the year of construction of the building in question. The premise of external walls has the greatest effect on the heat loss of buildings and means that in proportion all buildings have the same heat loss of external walls based on the Building Regulation of the year of construction.
- Terraced and semi-detached residential building units are fully connected (the full width of the building), and it is therefore assumed that semi-detached residential units have three outer walls and terraced residential units with an average of 2.5 outer walls. When calculating the perimeter of single-family residential unit, it is assumed that the ratio of the length of the walls is 1:2, i.e. that their long wall has twice the length of short walls. When calculating terraced and semi-detached residential units, the ratio is 1:1, all walls are equal in length.
- When calculating residential units in apartment buildings, it is assumed that units that are smaller than 80m2 have one outer wall, units 80m² and up to 160m² have two outer walls, while units that are 160m² and larger have 3 outer walls.
- To simplify calculations of the energy consumption of residential units and to obtain a fairer comparison, the average temperature in Reykjavík is based on a period of 30 years, regardless of the location of the property.
- The total energy consumption of residential units in the calculation model shows the energy loss of residential units regardless of location. 15% is added on top of the thermal energy consumption for electricity.
- When calculating heat loss in residential units in apartment buildings, it is assumed that heat loss through the roof and floor is divided equally between all residential units regardless of location in the building, and this is in line with what is customary in apartment buildings when dividing heating costs within the building.
- Calculations of the U-value of walls, windows and doors are based on the weighted average of walls according to the Icelandic Building Regulations.
- Single-family houses built after March 1984 and up until 1998 had a strict requirement for a weighted average wall or a maximum of 0.80 W / m²K. This does not apply to apartments with 2 floors or more.
- To simplify calculations of the energy consumption of residential units and to obtain a fairer comparison, the average temperature in Reykjavík is based on a period of 30 years, regardless of the location of the property.
- It is assumed that garages are located next to residential units, their area is deducted, and not included in the calculations. When calculating the residential units it is assumed that they are specially built and not part of the residential unit.
- The total energy loss of residential units is calculated from the loss of conductivity through the walls, roof and floor together with the air exchange loss of the unit.
- The final calculations are based on the following assumptions regarding size (+/- 5) of each type of residential unit:
  - 160 m² single family house.
  - 260 m² single family house on two floors.
  - 165 m² terraced house.
  - 80 m² residential unit in apartment building.

Carbon emission from energy use of residential building units in Iceland is low compared to other countries as energy is produced by sustainable resources and prices are low. Therefore, the urge to design more energy efficient residential units has been limited. Calculations show that buildings constructed in 1964 can be as energy efficient as buildings built in 2014. The results of the calculations show that the building type is the biggest determining factor.

Residential units in apartment buildings (apartments) are more energy efficient and emit less carbon from energy use over their life cycle than other types of residential buildings.

It should be noted that energy use is not the only contributing factor in the use stage of a building as emission from maintenance, repairs and replacements are also a big contributing factor during that stage. Therefore, these values cannot be compared to the percentage value representing the emission in the use stage of the Icelandic standard building in Figure 2 in chapter 3.1.

3.4 Calculation of embodied carbon emissions of residential building units

To estimate embodied carbon the results from the report Road Map to Greener Construction Industry 2030 (Vegvísir að vistvænni mannvirkjagerð 2030) are used. For concrete buildings the emissions are assumed to be 355 $kgCO_2/m^2$ and 115 kgCO2/m² for timber buildings. For steel buildings calculations were obtained using the software One Click LCA. This software is an online LCA tool that calculates the life cycle impacts of a building or infrastructure using a material's Environmental Product Declaration (EPD), and is approved for use in many certification schemes, for example BREEAM. According to the results from One Click LCA, the embodied carbon of an Icelandic building with a steel structure is 205 $kgCO2/m^2$.

The following assumptions are made for embodied carbon calculations of residential units in Iceland;

- To estimate embodied carbon in buildings with mixed materials, such as concrete and wood or concrete and steel, it is assumed that the mixture is 50/50, resulting in 235 $kgCO_2/m^2$ and 280 $kgCO_2/m^2$, respectively.
- Brick and hallow stone are not commonly used building materials in Iceland and their embodied carbon is unknown. For simplification, it is estimated that brick and hallow stone have the same embodied carbon as concrete.
- In order to calculate embodied carbon emissions per m^2 and year, a building is assumed to have a lifetime of 60 years.

Given the methodology described here above, residential building units in Arion Bank's portfolio are ranked based on their embodied carbon as shown in table 1.

Building Material	Embodied carbon [$kgCO_2/ m^2 /year$]
Wood	1.9
Steel	3.4
Concrete - wood	3.9
Concrete - metal	4.7
Concrete*	5.9

Table 1: Building Material based on embodied carbon
* including concrete – brick, hallow stone and pre-concrete

3.5 Threshold for the most carbon-efficient buildings in Iceland

Based on the above methodologies, a final criteria set has been developed to calculate and identify the most carbon efficient residential building units in Iceland. The criteria account for the carbon emission over the building life cycle from embodied carbon in the production and construction stage and the energy consumption during the use stage. These two factors are the main contributors to carbon emission in an Icelandic building life cycle according to the results of a life cycle analysis of the standard Icelandic building.

These criteria are used to identify the threshold representing the top 15% of the most carbon efficient residential units in Iceland shown in table 2. The carbon emission produced by each residential unit was calculated and compared in a calculation model. The results are that all buildings that have carbon emission equal to or below 6.99 $kgCO_2/m^2$/year are part of the top 15% of the most carbon efficient buildings in the Icelandic building stock. It should be noted that this threshold will develop as the composition of loan portfolio changes, but this result is based on a snapshot of the loan portfolio in May 2024.

It should be noted that residential units with high energy efficiency, e.g. low carbon emissions are not automatically included in the top 15% bucket when using this combined approach. For example, residential units with low emission intensity from energy use can have very high embodied carbon emissions which excludes them from the top 15% when using the combined carbon emission intensity threshold.

Emissions from embodied carbon in Iceland are in most cases much higher than emissions from energy use except for wood buildings which have estimated embodied carbon emissions intensity at 1.9 $kgCO_2/m^2$/year. All wood buildings that use traditional local energy sources are included in the top 15% even though they can use much more energy in comparison to concrete buildings where the embodied carbon emissions are estimated to be 5.9 $kgCO_2/m^2$/year. However, only 12% of residential units in Arion Bank's portfolio have wood as the main building material that use traditional Icelandic energy sources. Therefore, to determine the top 15% most carbon efficient residential units in Iceland, buildings made of other construction materials, such as concrete, need to be included and this is where energy efficiency becomes the determining factor.

Threshold for the most carbon efficient residential units	**6.99 kg CO_2 / m^2 /year**

Table 2: Threshold for the top 15% most carbon efficient residential units in Iceland, May 2024.

3.6 Other sustainability considerations

Embodied carbon and energy consumption are the main contributors to carbon emissions in the life cycle of Icelandic buildings. However, there are additional sustainability considerations that should be considered in order to establish a more holistic methodology in a sustainability estimate of buildings. An attempt was made to establish simple methodologies in estimating other environmental factors that contribute to climate resilience and environmental impact.

3.6.1 Climate resilience

For climate resilience, a methodology was established based on whether municipalities or regions had established a minimum building elevation in their masterplans, which can be considered as an action to protect buildings against rising sea level or severe flooding events due to climate change. Grades from A to F were defined for areas that had a coastal boundary based on level of definition for minimum building elevation in masterplans as described in Table 3. This could be considered as an indicator for consideration of climate resilience for the building.

After reviewing the outcome when following the above methodology, it became evident that there are still too many F's to create a clear result from this methodology. Therefore, further work should be considered.

Criteria	Grade
Clear definition for minimum building elevation	A
Unclear definition for minimum building elevation	B
No definition	F
No coastal boundary	N/A

Table 3. Grading scale for resilience of buildings

3.6.2 Environmental impact - Waste

An important action in mitigating climate change is reducing waste and promoting a circular economy. Therefore, it is important to increase recycling and re-using as this reduces the amount of waste that goes to landfills. The Icelandic Environmental Agency and many municipalities have an online dashboard publishing recycling and re-using rates in Icelandic waste. As an attempt to estimate a building's impact with regards to waste, an indicator was developed based on the number of waste categories offered in its municipality/region. Recycling categories in each municipality give an idea about the amount of waste which is diverted from landfill. It is assumed that the more recycling categories have been introduced, the higher the recycling ratio will be. A grading scale described in Table 4 was developed.

This methodology was discarded as it is very limited. Also, Icelandic legal requirements to handling of waste became stricter in 2023 due to changes in the EU legal requirements on waste management (no. 103/2021, EU Directive 2008/98/EC) to create better conditions a circular economy. After this legal implementation, all municipalities and areas and changing and improving. Arion will monitor these changes and consider implementing an improved methodology in estimating the environmental impact of a building because of waste.

Household waste recycling	Grade
Metals, paper, plastics, batteries and small electrics, organic waste	A
Metals, paper, plastics, organic waste	B
Metals, paper, plastics	C
No recycling	D

Table 4.Grading scale for waste recycling.

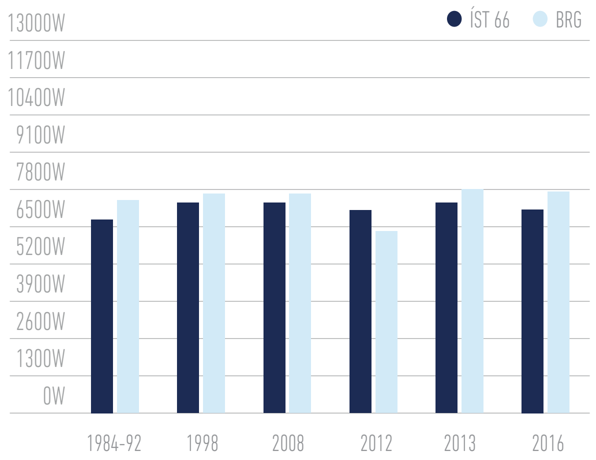
4. Identifying green residential buildings in Iceland

Based on the above methodologies, a final criteria set has been developed to identify green residential building units in Iceland. The criteria considers the amount of embodied carbon in the production and construction stage of a building life cycle and the energy consumption or energy efficiency in the usage stage. These two factors are the main contributors to carbon emissions in an Icelandic building life cycle and outline the criteria for eligible green residential building units in Iceland for the purpose of Arion Bank. Residential units should belong to the top 15% of most carbon efficient buildings in Iceland if they have a total carbon emission intensity factor equal to or below 6.99kgCO_2/year/m^2.

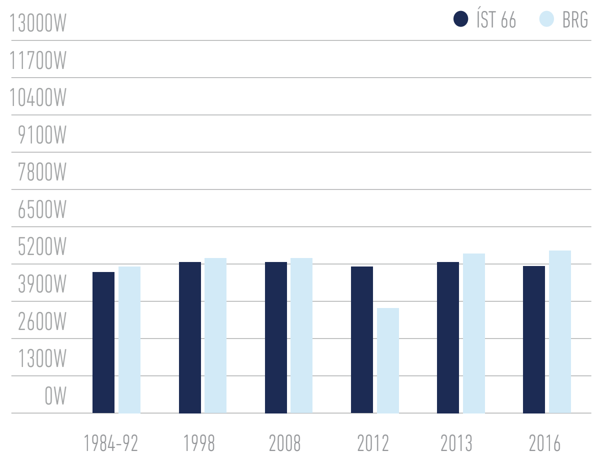
However, there are additional sustainability considerations that should be considered to establish a more holistic approach than only looking at carbon emissions. Climate resilience and waste and recycling opportunities are environmental aspects that were considered to be incorporated into the criteria for eligible green residential buildings. However, further analysis needs to be done in order to incorporate indicators for those aspects, therefore they are not part of the criteria as of yet.

5. Appendix

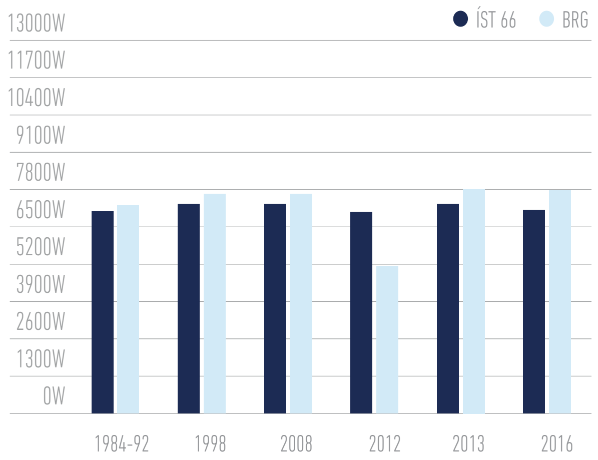
Single family house-timber



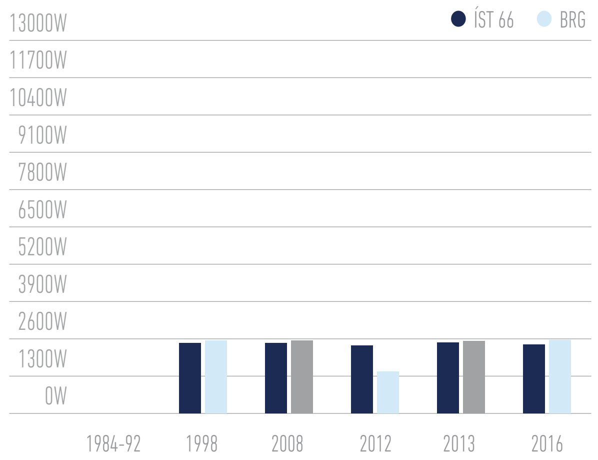
Terraced house



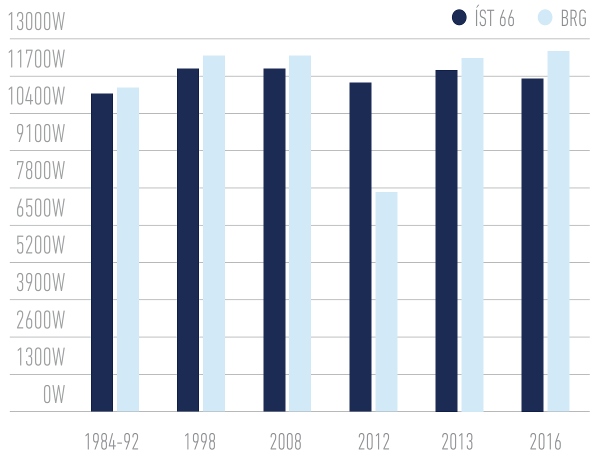
Single family house- concrete



Apartment



Single family two story house-concrete



Comparative Table 5: HEAT LOSS CALCULATION ACCORDING TO ICELANDIC BUILDING REGULATION (BRG) AND ÍST 66 (Staðlaráð Íslands, 2008) (Staðlaráð Íslands, 2016) (Húsnæðis- og mannvirkjastofnun, 2020) (Halldórsson & Sigurjónsson, 1992) (Mannvirkjastofnun, 1984) (Mannvirkjastofnun, 1992) (Mannvirkjastofnun, 1998) (Mannvirkjastofnun, 2012) (Mannvirkjastofnun, 2012) (Mannvirkjastofnun, 2013) (Mannvirkjastofnun, 2016)

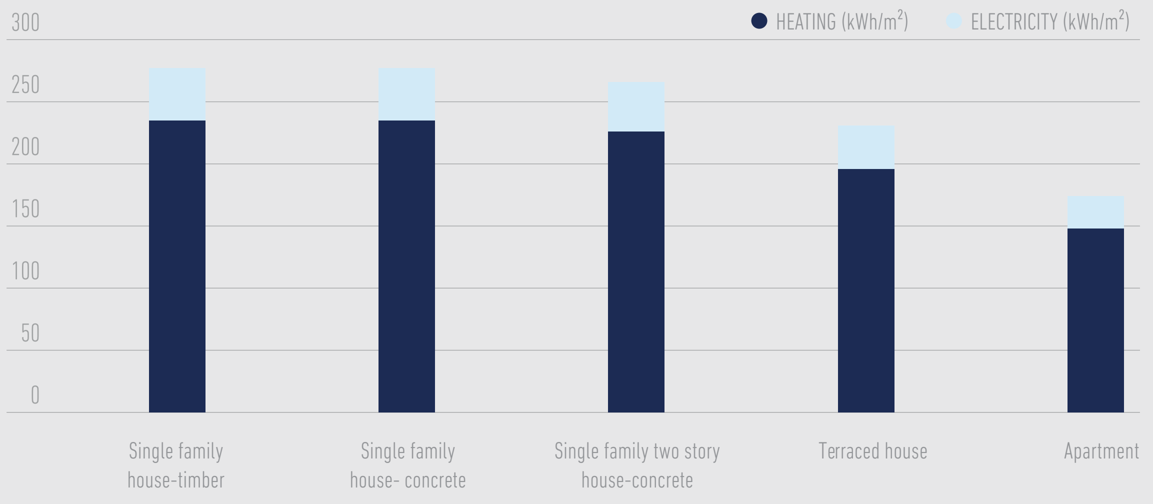
The comparative Table 5 summarizes the energy consumption of different apartment units from the loan portfolio. These apartment units should reflect general properties in the real estate market as nothing has been done to make the apartment unit more energy efficient. Electricity consumption varies little between buildings, as electricity consumption is calculated as a load on the thermal energy consumption of buildings. The table shows the use of hot water and electricity in kWh/m^2 per apartment unit. In Table 6, comparable apartment units have been included as in Table 5, but the difference in the energy consumption of the buildings is that the buildings in Table 7 are built according to stricter Building Regulations that were in force in 2012.

BUILDING TYPE	HEATING (kWh/m^2)	ELECTRICITY (kWh/m^2)	TOTAL (kWh/m^2)
Single family house-timber	235	42	277
Single family house- concrete	235	42	277
Single family two story house-concrete	226	40	266
Terraced house	196	35	231
Apartment	148	26	174

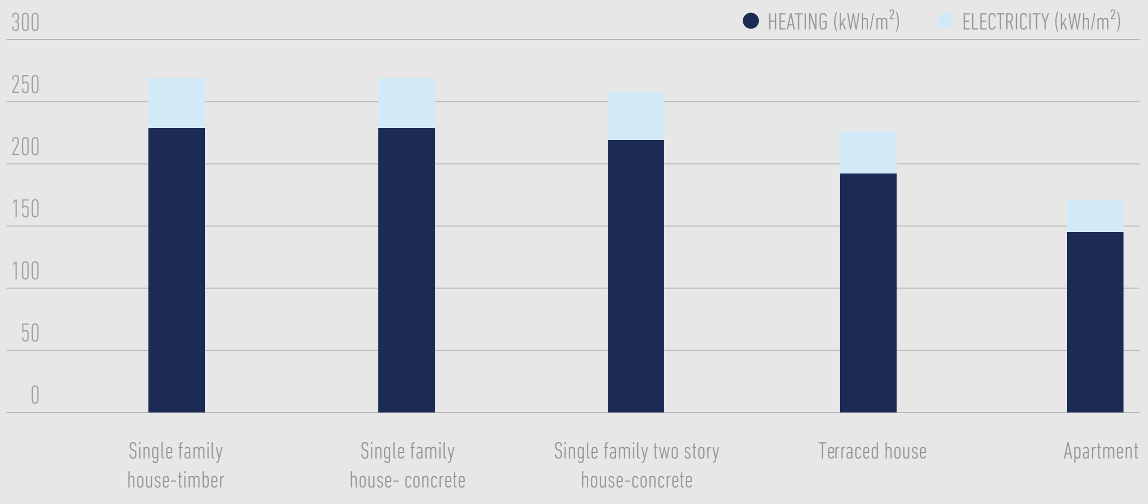
Table 6: Energy use of apartment units according to the calculation model, these properties do not count of economic apartment units

BUILDING TYPE	HEATING (kWh/m^2)	ELECTRICITY (kWh/m^2)	TOTAL (kWh/m^2)
Single family house-timber	229	40	269
Single family house- concrete	229	40	269
Single family two story house-concrete	219	39	258
Terraced house	192	34	226
Apartment	145	26	171

Table 7: Energy consumption of apartment units according to the calculation model, built in 2012



Energy consumptions of building types



Energy consumptions of building types

8. References

Bjarnadóttir, S. Ó., & Marteinsson, B. (2022). Vegvísir að vistvænni mannvirkjagerð 2030 - I. hluti Mat á kolefnislosun frá íslenskum byggingariðnaði. Reykjavík: Húsnæðis- og mannvirkjastofnun, fyrir Byggjum grænni framtíð.

BREEAM. (2016). The value of BREEAM. A review of latest thinking in the commercial building sector. Retrieved from breeam.com: https://tools.breeam.com/filelibrary/Briefing%20Papers/BREEAM-Briefing-Paper----The-Value-of-BREEAM--November-2016----123864.pdf

Energy Sector Management Assistance Program. (2016). Greenhouse Gases from Geothermal Power Production. Technical Report 009/16. Retrieved from www.worldbank.org: http://documents1.worldbank.org/curated/en/550871468184785413/pdf/106570-ESM-P130625-PUBLIC.pdf

European Environment Agency. (2024, February 29). Retrieved from www.eea.europa.eu: https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1

European Union. (n.d.). ec.europa.eu. Retrieved from Effort sharing: Member state's emission targets: https://ec.europa.eu/clima/policies/effort_en

Grænni byggð. (2020). Dagur grænni byggðar. Retrieved from https://www.youtube.com/watch?v=Eqt3pefoaWU&feature=youtu.be

Halldórsson, G., & Sigurjónsson, J. (1992). Varmaeinangrun húsa. Rannsóknarstofnun byggingariðnaðarins.

Húsnæðis- og mannvirkjastofnun. (2020, October 23). Retrieved from www.hms.is: https://www.hms.is/media/8043/byggingarreglugerd_med_breytingum.pdf

Intergovernmental Panel on Climate Change. (2014). Climate Change 2014. Mitigation of Climate Change. Working group III Contribution to the fith Assessment report of the Intergovernmental Panel on Climate Change. Retrieved from www.ipcc.ch: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

Landsvirkjun. (2018). Vistgreining raforkuvinnslu með vatnsafli. Fljótdalsstöð.

Mannvirkjastofnun. (1984, March 9). Retrieved from www.mvs.is: http://mvs.is/library/Skrar/Mannvirkjastofnun/Log-og-reglugerdir/Brottfallnar-reglur/Regluger%C3%B0%20um%20breyting%20%C3%A1%20byggingarregluger%C3%B0%20nr.%20292%2016.%20ma%C3%AD%201979,%201984.pdf

Mannvirkjastofnun. (1992). Retrieved from www.reglugerd.is: https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfisraduneyti/nr/1074

Mannvirkjastofnun. (1998). Retrieved from www.reglugerd.is: https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfisraduneyti/nr/10577

Mannvirkjastofnun. (2012). Retrieved from www.reglugerd.is: https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfisraduneyti/nr/18113

Mannvirkjastofnun. (2012). Retrieved from www.reglugerd.is: https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfis--og-audlindaraduneyti/nr/18509

Mannvirkjastofnun. (2013). Retrieved from www.reglugerd.is: https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfis--og-audlindaraduneyti/nr/18509

Mannvirkjastofnun. (2016). Retrieved from www.mannvirkjastofnun.is: http://www.mannvirkjastofnun.is/library/Skrar/Mannvirkjastofnun/Log-og-reglugerdir/Byggingarreglugerd_iheild.pdf

NationalgridESO. (2021, January 11). Retrieved from nationalgrideso.com: https://www.nationalgrideso.com/news/record-breaking-2020-becomes-greenest-year-britains-electricity

Orkustofnun. (2004). Orkumál. Jarðhiti. Retrieved from orkustofnun.is: https://orkustofnun.is/gogn/Orkumal-arsrit/Orkumal-Jardhiti-2005-1-3.pdf

Orkustofnun. (2004). Orkumál. Jarðhiti. Retrieved 2021, from orkustofnun.is: https://orkustofnun.is/gogn/Orkumal-arsrit/Orkumal-Jardhiti-2005-1-3.pdf

Orkustofnun. (2020). Ársskýrsla 2019. Retrieved from www.orkustofnun.is: https://orkustofnun.is/gogn/OS-arsskyrslur/OS-arsskyrsla-2019.pdf

Orkustofnun. (2021, February 09). OS-2020-T012-01. Retrieved from orkustofnun.is: https://orkustofnun.is/gogn/Talnaefni/OS-2020-T012-01.pdf

Orkuveita Reykjavíkur. (2019). Ársskýrsla OR 2019. Retrieved from www.or.is: https://arsskyrsla2019.or.is/

Orkuveita Reykjavíkur. (2020). Ársskýrsla 2020. Retrieved from www.or.is: https://arsskyrsla2020.or.is/

Orkuveita Reykjavíkur. (2023). Ársskýrsla OR 2022. Reykjavík: Orkuveita Reykjavíkur.

Samgöngustofa. (n.d.). samgongustofa.is. Retrieved from https://bifreidatolur.samgongustofa.is/stada-lok-ars.html

Samgöngustofa. (n.d.). samgongustofa.is. Retrieved from https://www.samgongustofa.is/umferd/tolfraedi/onnur-tolfraedi/

Sindri Þrastarson, Björn Marteinsson, & Hrund Ó. Andradóttir. (2019, 12 July). Fýsileiki virkjunar sólarorku á norðurslóðum: Reynsla af sólarpanelum IKEA á Íslandi. Retrieved from www.vfi.is: https://www.vfi.is/media/utgafa/2019-10-04-Fysileiki-virkjunar-solarorku-a-Nordurslodum2019_loka.pdf

Staðlaráð Íslands. (2008). ÍST 66. Varmatap húsa. Útreikningar.

Staðlaráð Íslands. (2016). ÍST 66 Varmatap húsa. Útreikningar.

Stjórnarráð Íslands. (2019, September). Retrieved from stjornarradid.is: https://www.stjornarradid.is/lisalib/getfile.aspx?itemid=b31679a7-d638-11e9-944d-005056bc530c

Trafikverket. (2020). trafikverket.se. Retrieved from https://www.trafikverket.se/

Umhverfis- og auðlindaráðuneytið. (2020). Aðgerðaáætlun í loftslagsmálum. Aðgerðir íslenskra stjórnvalda til að stuðla að samdrætti í losun gróðurhúsalofttegunda til 2030. Retrieved from www.stjornarradid.is: https://www.stjornarradid.is/library/02-Rit--skyrslur-og-skrar/Adgerdaaetlun%20i%20loftslagsmalum%20onnur%20utgafa.pdf

Umhverfisstofnun. (2020). Losunarstuðlar. Retrieved from www.ust.is: https://ust.is/library/Skrar/Einstaklingar/Loftgaedi/Losunarstudlar_UST.pdf

Umhverfisstofnun. (2024). ust.is. Retrieved from https://ust.is/loft/losun-grodurhusalofttegunda/losunarstudlar/

Umhverfisstofnun. (n.d.). ust.is. Retrieved from https://ust.is/graent-samfelag/urgangsmal/umhverfisvisar-og-tolfraedi/heildarmagn-og-medhondlun/

VSÓ Ráðgjöf. (2016, maí 9). skipulag.is. Retrieved from https://www.skipulag.is/media/pdf-skjol/Haekkud-sjavarstada-a-hofudborgarsvaedinu-ahrif-og-adgerdir.pdf

Wallevik, Ó. H. (2020). graennibyggd.is. Retrieved from https://cfb5f439-74b6-493e-a7fd-f59376383508.filesusr.com/ugd/54e708_63de60892b894528a5f4ad850cacc8c1.pdf

World nuclear association. (n.d.). Retrieved from www.world-nuclear.org: http://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/comparison_of_lifecycle.pdf