MANNVIT

GREEN RESIDENTIAL BUILDINGS

Methodology Paper

Arion Banki

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GREEN RESIDENTIAL BUILDINGS - METHODOLOGY PAPER
Arion banki

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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 regard 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 Arion loan portfolio contains around 13,000 residential units built between 1900 and 2020. 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 9.5% of all residential units in the country in its loan portfolio (around 8,500 residential units out of 90,500 residential units built in the period 1970-2019). 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. 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 most carbon-efficient residential units in Iceland.

This report describes the methodologies used to establish a carbon intensity threshold from the current building stock, taking into account operational and embodied carbon emissions. 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 based on results from LCA calculations for an Icelandic standard house and relevant information is obtained from the software 'One Click LCA'.

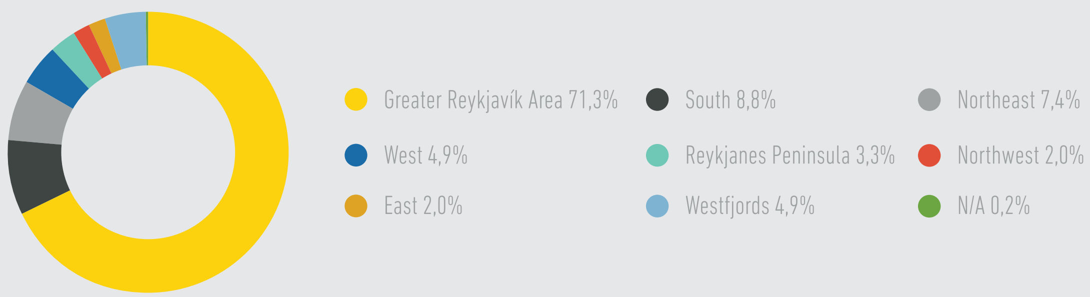


Figure 1: Geographic focus of current mortgage portfolio

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 40% 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, as can be seen in Figure 2.

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. A project is currently being developed within the Housing and Construction Authority in Iceland that focuses on mapping greenhouse gas emissions for the whole life cycle of the construction industry, including energy consumption of buildings.

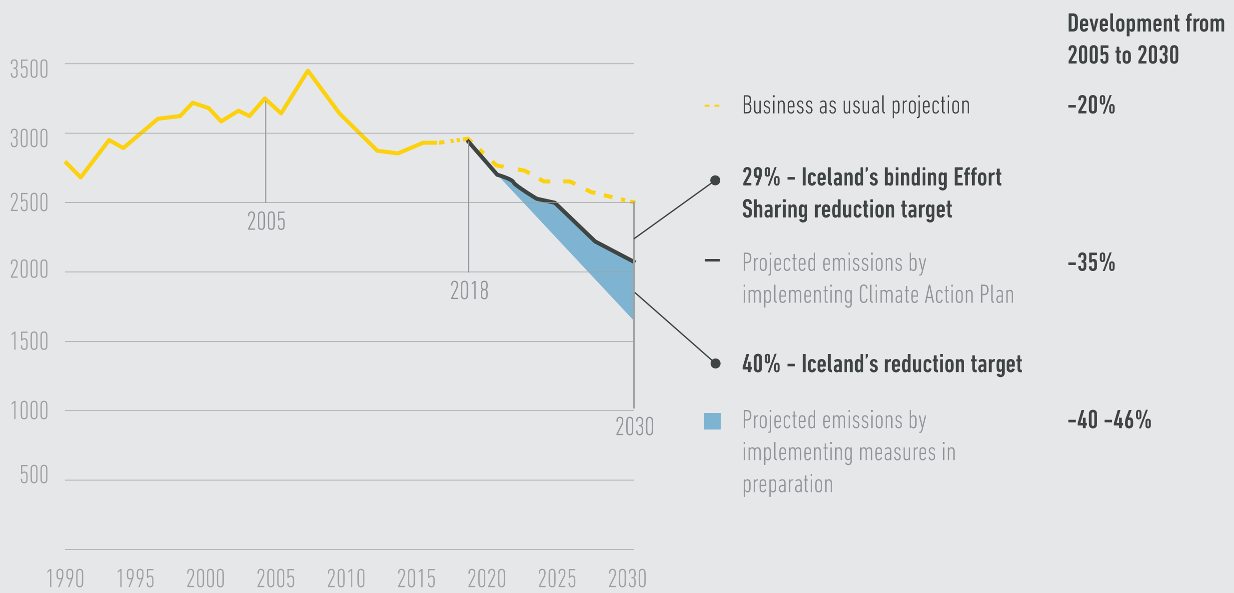


Figure 2: Historical development of greenhouse gas emissions that fall under the Effort Sharing Regulation to 2018, and projected emissions in 2030 without the Icelandic Climate Action Plan, with the Action Plan and measures currently in preparation. (Umhverfis- og auðlindaráðuneytið, 2020)

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 these renewable energy sources are hydropower, geothermal, solar and wind energy. In Iceland, 69% of energy production comes from hydropower and 31% from geothermal energy (Orkustofnun, 2021). The proportion of renewable energy sources out of total energy consumption (which also includes vessels, vehicles, machines etc.) in Iceland is just over 72%, which is the second highest in Europe (Orkustofnun, 2020). A life cycle analysis of the energy production from geothermal sources and hydropower shows that emissions can be estimated at 34 gCO_2eq/kWh from geothermal energy and 1.2 gCO_2eq/kWh from hydropower (Energy Sector Management Assistance Program, 2016), (Landsvirkjun, 2018). Greenhouse gas (GHG) emissions from energy production in Iceland are therefore among the lowest globally.

The Environment Agency of Iceland manages GHG emission factors in Iceland. The emission factor for electricity for the year 2019 was 9.8 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. Where all emissions from geothermal energy are 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 is 0g CO_2 /kWh (Environment Agency, 2020). Reykjavik Energy (Orkuveita Reykjavíkur) has also assessed emissions from its energy production, and its calculations for 2020 assume 3.9 gCO_2eq/kWh emissions from district heating and 8.6 $gCO2eq/kWh$ from electricity utilities (Orkuveita Reykjavíkur, 2020). Emissions from district heating in Iceland vary between location of the source and type. There is limited information available regarding emissions related to district heating, but Reykjavik Energy's information is believed to reflect reasonably accurately overall emissions from district heating and electricity production for most households in 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 around 9.8 gCO_2eq/kWh. In comparison with energy production in neighbouring countries, it is evident that they have notably higher emissions per kWh, e.g. emissions in Denmark were estimated at around 189 gCO_2eq/kWh in 2018, emissions in Germany were around 406 gCO_2eq/kWh that same year and in the UK emissions were 250 gCO_2eq/kWh. However, emissions can be expected to decrease in other countries with increased installation capacity of renewable energy. Many countries are working hard towards increasing their share of renewable energy, and while the UK reached a new low in emissions in 2020, emissions per kWh were still at 181 gCO_2eq/kWh, which is 18 times higher than emissions per kWh in Iceland (European Environment Agency, 2020) (NationalgridESO, 2021).

In Iceland, the use of renewable energy sources, other than geothermal and hydropower, has been limited. Experimental windmills have been installed around the country and several wind farms are in evaluation process with 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).

The IPCC (Intergovernmental Panel on Climate Change) regularly publishes a list of emissions from various energy sources. Table 1 shows estimated emissions from several renewable energy sources. As can be seen from the table values for emissions can vary considerably and values for solar energy and wind energy can in some cases be higher than for geothermal and hydropower, for example.

It is worth noting that emissions from non-renewable energy sources are considerably higher than the average emissions for renewable energy sources shown in table 1. As an example, the average emission factor for energy production with coal is around 888 gCO_2eq/kWh (World Nuclear Association). Therefore, it can be concluded from the table that emissions from Icelandic energy sources are among the lowest in the world.

EMISSIONS	GEOTHERMAL	HYDRO	LAND BASED WIND	ROOF MOUNTED SOLAR PANELS
Min	6	1	7	26
Max	79	2200	56	60
Median	38	24	11	41

Table 1: Emission rates [g/CO2] according to IPCC (Intergovernmental Panel on Climate Change, 2014)

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, will probably affect future updates of the Building Regulation. Also, 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 has not yet been defined but the work is in progress. The initial idea was to define a threshold for energy demand (heat and electricity) at 160 kWh/m² but currently it is likely it will be defined as 20-30% lower than the minimum requirements of the Icelandic Building Regulation. The evidence needed to confirm this will be in line with those needed for a BREEAM certification, i.e. results from an energy simulation model of the building using approved software.

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.

The overall environmental impact of the construction sector in Iceland is unclear, but 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. 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). However, based on the results of life cycle assessments, embodied carbon is the biggest factor when reviewing the climate impact over the lifetime of Icelandic buildings.

Life cycle assessments:
Life cycle assessments (LCA) have been carried out for several buildings in Iceland, including one which has been identified as the standard Icelandic building. According to the preliminary results of an LCA for the standard Icelandic building it is estimated that related emissions are around 666 kgCO2/m². Figure 3 shows the share of emissions over different life stages.

Figure 3 shows that there are two stages in the building life cycle that produce the most carbon footprint emissions over the lifetime of a standard, concrete building in Iceland: 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).

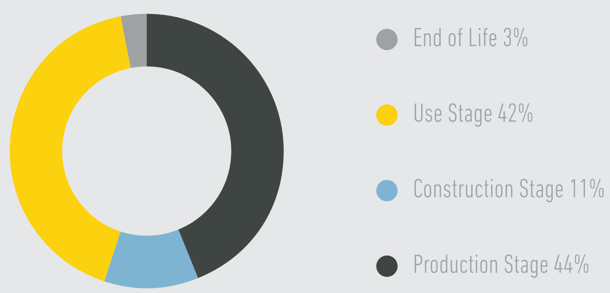


Figure 3. Life Cycle Emissions for the Icelandic Standard Building (Grænni byggð, 2020).

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 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 10% share of all residential 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

Mannvit 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. Results of a life cycle analyses of a standard Icelandic building (í. viðmiðunarhús) show 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).

Furthermore, additional sustainability factors are discussed, and methodologies suggested to measure their impact; (i) proximity of the respective building to public transportation, (ii) climate resilience and (iii) waste recycling. Suggestions are made on how these sustainability factors can be included in the screening process (see 3.6 Other sustainability considerations).

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 Mannvit'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 Mannvit'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 $80m^2$ and up to $160m^2$ have two outer walls, while units that are $160m^2$ 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 / m^{2}K. 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 of each type of residential unit:
  - 160 m^2 single family house.
  - 260 m^2 single family house on two floors.
  - 165 m^2 terraced house.
  - 80 m^2 residential unit in apartment building.

Carbons 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 shows 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. Table 2 shows the average carbon emissions from energy use of residential units per year.

It is a clear result that 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 3 in chapter 3.1.

	HEATING	ELECTRICAL	TOTAL	CARBON emission
BUILDING TYPE	kWh/m^2	kWh/m^2	kWh/m^2	kgCO2/m^2
Single family house timber	235	42	277	1.28
Single family house concrete	235	42	277	1.28
Single family two story house concrete	226	40	266	1.04
Terraced house	196	35	231	0.90
Apartment	148	26	174	0.68

Table 2: Average carbon emissions from energy use during the use stage (excluding emission from maintenance and renovation during the use stage) of residential units per year.

3.4 Calculation of embodied carbon emissions of residential building units

To estimate embodied carbon in concrete buildings, results from an LCA conducted for a standard Icelandic building were used (Wallevik, 2020). The standard building is a 4-storey apartment building, with a concrete structure and frame which represents the typical Icelandic external wall. The typical Icelandic wall is not designed specially to be eco-friendly and the standard building is not designed with any specific environmental measures. Results show an estimated carbon footprint of 666 $kgCO_2/m^2$, of which 55% is embodied carbon or 366 $kgCO_2/m^2$. Included in embodied carbon are all emissions included in the production and construction stage that is related to the construction of the building, including extracting, transporting, manufacturing and installing of building materials. For wood and steel buildings calculations obtained using the software One Click LCA are used. 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 timber structure is 70 $kgCO_2/m^2$ and 205 $kgCO_2/m^2$ for a steel structure.

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 218 $kgCO_2/m^2$ and 286 $kgCO_2/m^2$, 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.
- The mixture of concrete in each building in Arion Bank's portfolio is not known, thus it is estimated that they all have the same embodied carbon as the Icelandic standard building (í. viðmiðunarhús).
- 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 3.

Building Material	Embodied carbon [$kgCO_2$/ m^2 /year]
Wood	1.2
Steel	3.4
Concrete - wood	3.6
Concrete - metal	4.8
Concrete*	6.1

Table 3: 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 of the most carbon efficient residential units in Iceland shown in table 4. 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 6.84 $kgCO_2/m^2$/year are part of the most carbon efficient buildings in the Icelandic building stock.

It should be noted that residential units with high energy efficiency, e.g. low carbon emissions are not automatically included most carbon efficient 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 being among the most carbon efficient buildings using the combined carbon emission intensity threshold. Furthermore, high energy intensive buildings which use more than 300kWh/m^2 per year are excluded.

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 1.17 $kgCO_2/m^2$/year. All wood buildings that use traditional local energy sources are included even though they can use much more energy in comparison to concrete buildings where the embodied carbon emissions are estimated to be 6.1 $kgCO_2/m^2$/year. However, only 11.6% 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 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	**6.84 kg CO2 / m2 /year**

Table 4: Threshold for the top 15% most carbon efficient residential units in Iceland

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. In the following chapters more factors are specified and the methodology of estimating them explained. These factors are considered where information is available.

3.6.1 Proximity to sustainable transportation

Emissions from the road transport sector are the largest contributor to greenhouse gas (GHG) emissions in Iceland according to the National Inventory Report (NIR). Therefore, sustainable transport modes can have a strong impact on reducing emissions in Iceland.

To estimate emissions from an average family car in Iceland, information and data was gathered from the Icelandic Transport Authority's (Samgöngustofa) vehicle registry. According to the registry, most cars are categorized as passenger vehicles (Fólksbifreið, M1), where 58% of the cars are fuelled by petrol and 33% diesel (Samgöngustofa). According to emission factors defined by the Environmental Agency of Iceland (Umhverfisstofnun), road transportation linked emissions are 211.0 gCO_2eq/km and 187.9 gCO_2eq/km, respectively. The average distance driven annually by a passenger car in 2020 was 12,665 km (Samgöngustofa, n.d.). Based on these criteria it is estimated that an average family car in Iceland emits around 2,300 $kgCO_2$ eq/year.

In Iceland, there are no formal guidelines or indicators about the preferable walking distance between the home and public transport. However, these guidelines have been defined in neighboring countries, e.g. in Sweden where the distance has been defined as between 250 – 500m. Therefore, an infrastructure in Sweden is deemed to be of good quality if the walking distance to the nearest public transport is less than 250m and poor if it is more than 1000m (Trafikverket, 2020). Information provided by Arion Bank regarding the distance to the nearest public transport is used to grade properties.

It is not known how many cars are linked to each residential unit nor the likelihood of people choosing public transport over a private car. Thus, a reduction in emissions is not estimated and properties are only graded based on their distance to public transport. Municipalities which do not have a public transport system automatically get grade F.

Based on the Swedish guidelines, a grading scale is defined according to the distance between homes and the nearest public transport, see table 5. Buildings which are within 250m of public transport get the grade A while those furthest away or with no access to public transport get the grade F.

Distance	Grade
X < 250 m	A
250 m < X < 500 m	B
500 m < X < 750 m	C
750 m < X < 1000 m	D
X > 1000 m	F

Table 5: Grading scale for distance between houses and nearest public transport.

3.6.2 Climate resilience

The impending impact of climate change on today's society means that it is important to develop adaptation strategies, integrate measures and increase urban resilience. The most impending impact of climate change in Iceland is the melting of glaciers, rising sea levels and increased precipitation. In accordance with natural hazard risk assessments one of the most important actions in order to increase the resilience of Icelandic building stock and communities is to prepare for more severe flooding events.

To estimate the resilience of buildings, masterplans for regions and municipalities are reviewed with regard to their location and resilience measures against climate change and natural hazards. More specifically, actions to prevent buildings against rising sea level or severe flooding events are reviewed.

A risk assessment of the capital area conducted in 2016 has defined low areas which are at greater risk than others from higher sea levels and increased land erosion, i.e. areas which are less than 5m above current sea levels. Thus, it is important that the minimum building elevation for new buildings is defined above the hazard level (VSÓ Ráðgjöf, 2016). Updates of regional and municipality masterplans are reviewed and ranked based on actions taken to increase resilience.

This work is based on data available in municipal masterplans. Since only masterplans are being reviewed, it is possible that more information has been defined in local plans which are not reviewed in this work. Furthermore, some buildings might be located closer to the coast than others and are thus in greater danger when it comes to extreme flooding events. However, there is no segregation in terms of location, and buildings are only graded depending on which municipality they are located in.

Given the criteria, municipalities with defined minimum building elevation in their local plans will be given the grade A, while ones that do not have a clear definition are given the grade B. Those municipalities which don't have any definition or specification at all are given the grade F. Furthermore, those municipalities which do not have any coastal boundaries are given the grade N/A. The grading scale is shown in table 6.

After reviewing the outcome when following the above methodology, it has become evident that there are still too many F's to create a clear result from this methodology. Therefore, further work should be considered like mapping heights of building in the portfolio, which, however, would require significantly more work and as such it is suggested that this will be done in the coming years, depending on data availability and thus, reflecting the outcomes at a later stage.

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 6. Grading scale for resilience of buildings

3.6.3 Waste and recycling

An important action in mitigating climate change is reducing waste and promoting a circular economy. Therefore, it is important to increase recycling as this reduces the amount of waste that goes to landfills. Limited information is available about recycling rates in Iceland. However, many municipalities offer recycling options and the average recycling rate in Iceland is around 30% (Stjórnarráð Íslands, 2019).

Recycling categories in each municipality give an idea about the amount of waste which is diverted from landfill. Areas that recycle organic waste are likely to have less climate impact than those which do not. Information about the waste and recycling categories can be found on the websites of municipalities and/or relevant waste companies. In 2019, each person in Iceland produced around 664 kg of household waste and only 39% of that was recycled or reused (Umhverfisstofnun, n.d.).

It is estimated that the emissions from recycled waste, such as plastics and paper, is 0 tCO_2eq/t. Furthermore, emissions from waste that goes to landfill and organic waste for composting are estimated to be 1.30 tCO_2eq/t and 0.172 tCO_2eq/t, respectively (Umhverfisstofnun, 2020). If all Icelandic household waste in 2019 went to landfill the emissions would be 863,200 tCO_2eq.

The recycling ratio of each municipality is unknown and only the recycling categories are publicly available. Thus, it is assumed that the more recycling categories have been introduced, the higher the recycling ratio will be. Furthermore, it is neither known how much waste per building is produced nor the recycling ratio of each household. Due to these limitations, emissions related to waste are not estimated per household.

Based on the assumptions and limitations mentioned above a grading scale is defined for recycling, based on recycling possibilities in different municipalities, see table 7.

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 7.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 take into account 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. However, there are additional sustainability considerations that should be considered in order to establish a more holistic approach than only looking at carbon emissions.

The following points outline the final criteria that lead to a designation as eligible green residential building unit in Iceland for the purpose of Arion Bank:

1. Carbon emission: Residential units should belong to the most carbon efficient buildings in Iceland if they have a total carbon emission intensity factor equal to or below 6.84kgCO_2/year/m^2.

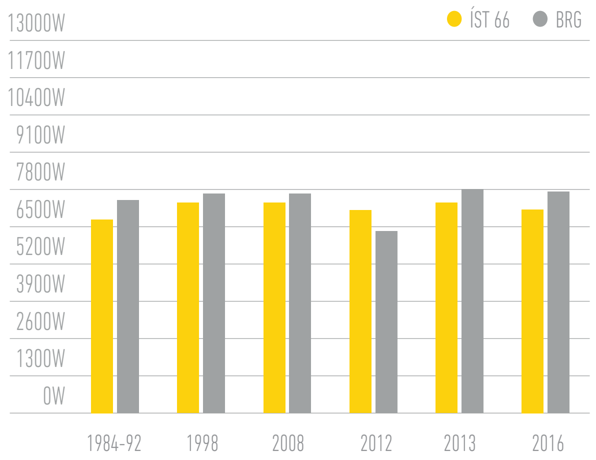
2. Public transportation: Due to importance of public transportation proximity, only buildings that are within 750m reach of a public transportation system should be included.

3. Climate resilience: Only buildings that are located 5 meters above sea level should be included. However, since data on a per building basis is currently not widely available, this criterion is not included in the selection process at the moment. More work such as the mapping of buildings according to their respective height needs to be undertaken before this criterion can be activated.

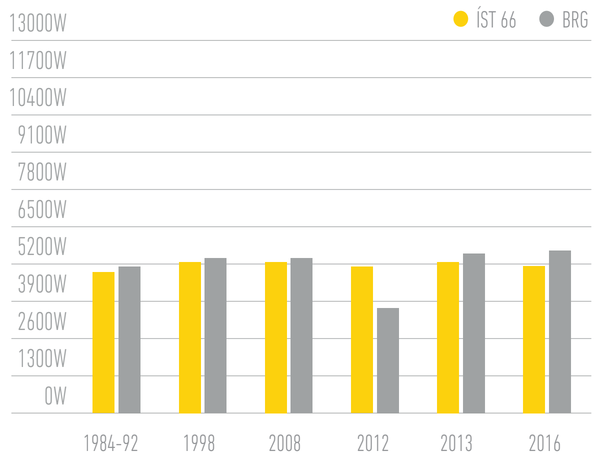
4. Waste and recycling: All buildings located in an area where no recycling is required are excluded as those are considered to have the highest environmental impact. In case recycling rates per building or post codes should become widely available, a methodology update would take this into account.

5. Appendix

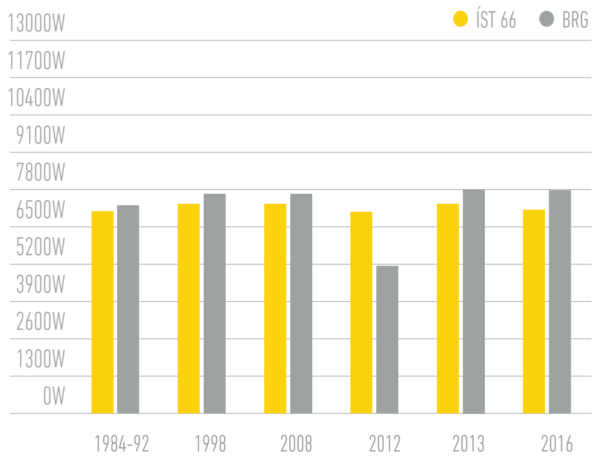
Single family house-timber



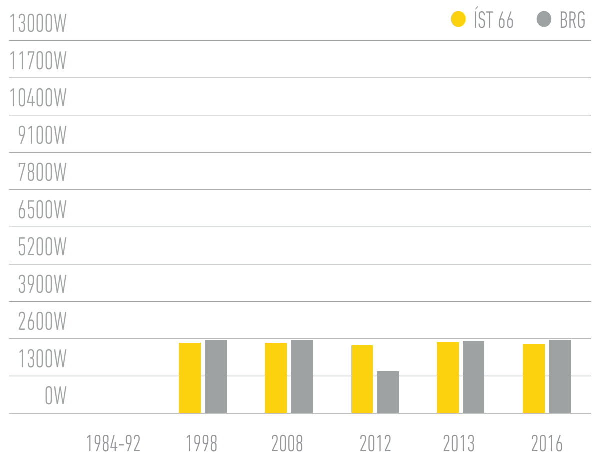
Terraced house



Single family house- concrete



Apartment



Single family two story house-concrete

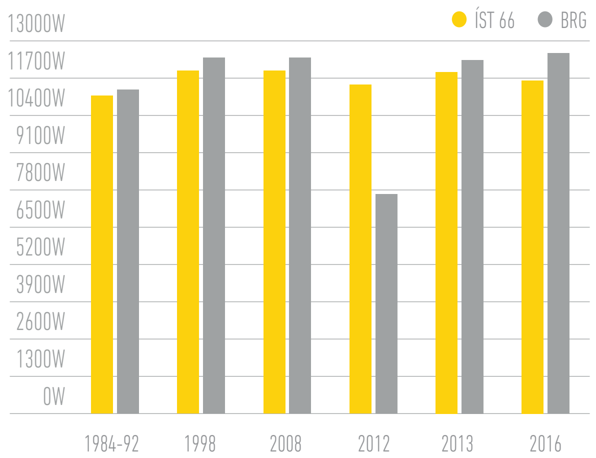


Table 8: HEAT LOSS CALCULATION ACCORDING TO ICELANDIC BUILDING REGULATION (BRG) AND ÍST 66 (Staðlaráð Íslands, 2008) (Staðlaráð Íslands, 2016) (Húsnæðis- og mannvirkjastofnun, 2020) (Halldórsson & Sigurjónsson, 1992) (Mannvirkjastofnun, 1984) (Mannvirkjastofnun, 1992) (Mannvirkjastofnun, 1998) (Mannvirkjastofnun, 2012) (Mannvirkjastofnun, 2012) (Mannvirkjastofnun, 2013) (Mannvirkjastofnun, 2016)

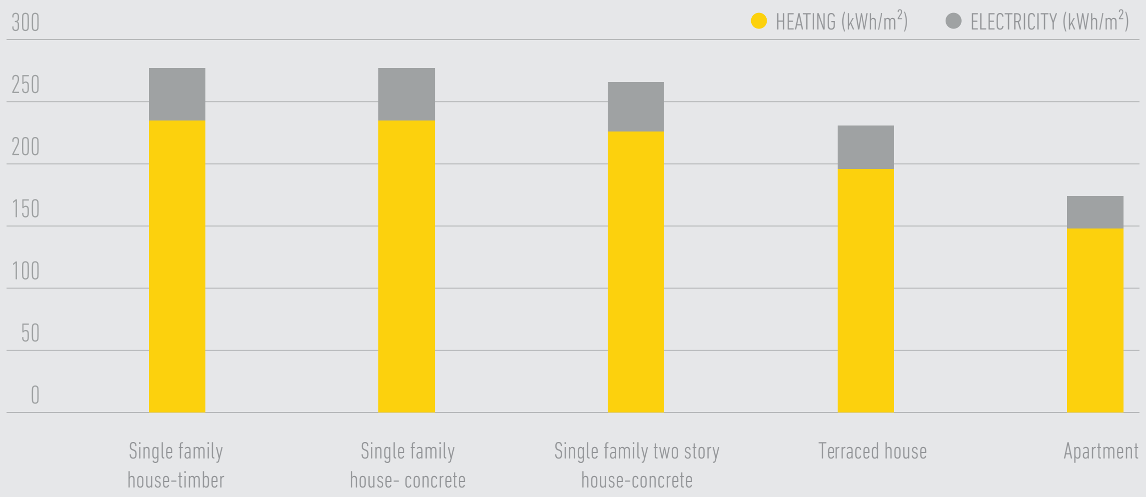
The comparative Table 9 summarizes the energy consumption of different apartment units from the loan portfolio. These apartment units should reflect general properties in the real estate market as nothing has been done to make the apartment unit more energy efficient. Electricity consumption varies little 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/m² per apartment unit. In Comparative Table 10, comparable apartment units have been included as in Table 9, but the difference in the energy consumption of the buildings is that the buildings in Table 10 are built according to stricter Building Regulations that were in force in 2012.

BUILDING TYPE	HEATING (kWh/m²)	ELECTRICITY (kWh/m²)	TOTAL (kWh/m²)
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

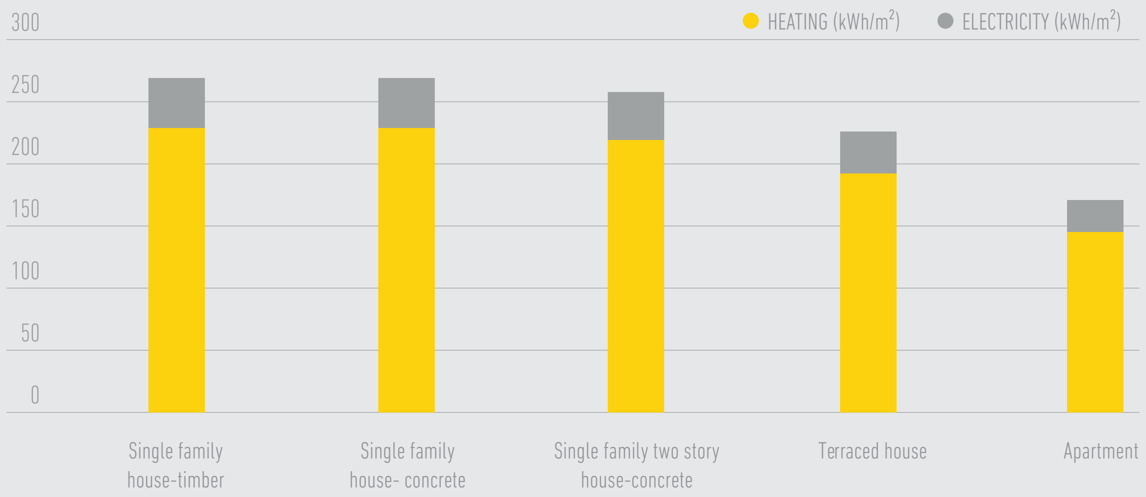
Table 9: Energy use of apartment units according to the calculation model, these properties do not count of economic apartment units

BUILDING TYPE	HEATING (kWh/m²)	ELECTRICITY (kWh/m²)	TOTAL (kWh/m²)
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 10: Energy consumption of apartment units according to the calculation model, built in 2012



Energy consumptions of building types



Energy consumptions of building types

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