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MS thesis
in Environment and Natural Resources

Iceland‘s Circularity Index

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FACULTY OF LIFE AND ENVIRONMENTAL SCIENCES

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Abstract

With a growing global population and growing consumption, the extraction of raw materials from natural resources has become unsustainable. One way to reduce the extraction of raw materials is to use materials again. Numerous nations around the world have declared that they will make their economies more circular in that way, in accordance with the principles of the circular economy. Iceland is among those nations. However, a useful measurement of how circular an economy is at any given time has been lacking. This thesis provides a comprehensive assessment of Iceland's circularity, by use of Economy-Wide Material Flow Accounting. The assessment is done within the methodological framework of four recent national circularity reports of other European nations. This monitoring framework provides policymakers and other stakeholders with a measurement of circularity in the form of a National Circularity Index and a National Circularity Gap. According to this study, the Icelandic economy is 8,5% circular. This means that while fulfilling their needs within the economy the habitants of Iceland use secondary or cycled materials in 8,5% of all materials used. This is Iceland's National Circularity Index. Accordingly, Iceland's Circularity Gap is 91,5%. This makes Iceland very much a linear economy, as opposed to a circular one. Suggestions are made on how circularity can be increased, and different scenarios, including more circular consumption of biomass, fossils, and construction materials, are assessed. An analysis of this kind has not been performed before in Iceland. The information provided should be useful for future decision-making and might increase circularity.

Útdráttur

Með vaxandi fólksfjölda í heiminum og aukinni neyslu hefur nýting náttúruauðlinda orðið ósjálfbær. Ein leið til þess að minnka hráefnisöflun úr náttúrunni er að nota efni aftur, í hringrás. Fjölmörg ríki heimsins hafa lýst því yfir að þau stefni að innleiðingu hringrásarhagkerfis, Ísland þar á meðal. Mælikvarða á árangur slíkar innleiðingar hefur hins vegar skort. Í þessari ritgerð er lagt mat á það hversu yfirgripsmikið hringrásarhagkerfið er á Íslandi með notkun efnisflæðireikninga. Nýlegar rannsóknir á efnisflæðihringrás fjögurra annarra Evrópuþjóða eru hafðar til hliðsjónar og sömu aðferðum beitt. Þessi aðferðarfræði gerir stjórnvöldum og hagaðilum kleift að sjá hlutfall efna sem notuð eru aftur, af heildarefnisnotkun þjóðarinnar, annars vegar í formi hringrásarhlutfalls og hins vegar sem hringrásarbil. Samkvæmt þessari ritgerð er hringrásarhlutfall íslenska hagkerfisins 8,5%. Það þýðir að til þess að uppfylla allar þarfir sínar innan hagkerfisins nota Íslendingar endurunnið eða endurnotað efni, sem fer í hringrás, í 8,5% af heildarefnisnotkun. Að sama skapi fer 91,5% efnis ekki í slíkan hring, og er sú tala hringrásarbil Íslendinga. Íslenskt hagkerfi einkennist því af línulegri efnisnotkun, fremur en hringrás efnis. Í ritgerðinni er lagt til hvernig hækka má hringrásarhlutfall Íslendinga og nokkrar sviðsmyndir ræddar, eins og hvernig auka má hringrás lífmassa og byggingarefna, og minnka áhrif jarðefnaeldsneytis. Rannsókn af þessu tagi hefur ekki verið gerð áður á Íslandi. Hún gæti nýst sem grundvöllur frekari stefnumótunar til að innleiða öflugra og víðfemara hringrásarhagkerfi á Íslandi.

In memory of my father

Preface

The hot tub at my family´s summer house is a green, square plastic tank, fitting up to 15 people, and holding approx. 2000 liters of warm water from the nearby hot spring. It used to be a tank at an aquafarm, for growing salmons. It went out of business, so my father got the tank for a minimum price. Instead of being disposed of, it has served the family and friends as a hot tub for almost thirty years. People maintain it is the best hot tub they have ever been into. Some have tried searching for a similar one at the hot tub market, but it doesn't exist. Furthermore, the pipes that deliver the water from the hot spring into the cabin and the tub, are old, used municipality water pipes, that were supposed to be thrown away some decades ago. In the countryside, they still serve a good purpose. And the cabin that shields the water pump is made of old posts for telephone cables. Such cables are now out of use, but the large poles make excellent material for a log cabin. And the summer house itself is made from used timber from British army bunkers from WWII.

So, I have developed an interest in circularity, and it has grown on me. Reusing materials is a wonderful idea, inspired by nature itself, where everything moves in a circle. And it can help save the globe from a climate catastrophe.

This thesis represents an attempt to estimate how much material is reused in Iceland, or — figuratively speaking — how many hot tubs that used to be aquafarm tanks there are in the country.

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Abbreviations

CE - Circular Economy

GHG - Greenhouse Gasses

NCI - National Circularity Index

NCG - National Circularity Gap

MFA - Material Flow Accounting

EW-MFA - Economy-Wide Material Flow Accounting

RME - Raw Material Equivalents

SDG - Sustainable Development Goals

DE - Domestic Extraction

IMP - Imports

IMP_RME - Imports in Raw Material Equivalents

DMI - Domestic Material Input

RMI - Raw Material Input

DMC - Direct Material Consumption

RMC - Raw Material Consumption

EXP - Exports

NAS - Net Addition to Stock

DPO - Domestic Processed Output

SM - Secondary Material

LCA - Life Cycle Assessment

EE-IOA - Environmentally Extended Input-Output Analysis

Acknowledgements

I wish to thank my supervisors, Brynhildur Davíðsdóttir and Jón Geir Pétursson, for excellent consultation, and inspirational meetings. At Statistics Iceland, Þorsteinn Aðalsteinsson proved to be an invaluable source of data and wisdom concerning this subject, especially concerning the complications of raw material equivalents. For additional data, concerning waste and recycling, I wish to thank Rakel Kristjánsdóttir at the Environment Agency of Iceland and Freyr Eyjólfsson at the waste management company Sorpa. For surviving countless discussions and monologues on my behalf concerning the Circular Economy, and offering valuable insights, I would like to thank Andri S. Björnsson, Hildur Harðardóttir, and my cousin Dagfinnur Sveinbjörnsson. My family deserves endless gratitude on my behalf for being there, especially my mother for her support, and my wife, Alexía, who constantly nourishes me with circular love and strength.

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1 Introduction

1.1 The Challenge

In 1970 the worldwide extraction of raw materials — biomass, non-metallic minerals, metallic ores, and fossil fuels — amounted to approx. 31 billion tonnes. In 2019 this number had grown to 96 billion tonnes (calculations based on numbers from materialflows.net). Those numbers, showing a 211% increase in raw material extraction in half a century, indicate a trend. The global exploitation of natural resources is growing exponentially. By now it has most likely, given the growth rate, reached over 100 billion. Recent forecasts predict that the demand for raw materials will have further increased by almost 70%, to 167 billion, by 2060 (OECD, 2018) or almost double to 190 billion (IRP, 2019). The growing extraction of resources has exceeded the population growth. Evidently, much more material is now consumed per person compared to half a century ago. In the year 1970 around 8.4 tonnes were extracted per capita, In 2019 this number had grown to 12.5 tonnes per capita (calculations based on global population numbers from worldometers.info).

As environmental concerns have increased in recent decades, the notion of Earth as a limitless provider of goods has been gradually rejected. Influential essays and studies — portraying Earth as a closed spaceship rather than an endless field of possibilities (Boulding, 1966) or defining the ecological limits of economic growth (Meadows & Club of Rome, 1972; Meadows et al., 2004) or stipulating several inescapable planetary boundaries (Rockström et al., 2009) — have increased the awareness of the fact that nature is not a bottomless well. The concept of sustainability, as a proper aim of global and national policymaking, has grown out of these concerns. In the influential 1987 UN report *Our Common Future*, by The World Commission on Environment and Development, led by Gro Harlem Brundtland, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 43). The problem from this perspective is that the global extraction of raw materials is unsustainable. At some point, mankind will have used up raw materials in such abundance that it will affect the livelihood and possibilities of future generations. Another way to put this is by adhering to the concept of the ecological footprint (Wackernagel & Beyers, 2019). By using the methodology of ecological footprint, it can be estimated how much natural capital measured in productive land and water the global population needs to produce the goods it demands for consumption and, subsequently, generating waste. The most recent number is 1,75 Earths (Global Footprint Network, 2022). This Earth, in other words, is not sufficient, and mankind does not know of any other. That is the challenge.

Hence, from different perspectives, the same picture emerges. The human species is consuming too much of nature's materials. In the context of this thesis, the main question is not only where this material comes from, but also what happens to all this material. According to the first law of thermodynamics, or the law of conservation of mass, matter or energy cannot be created nor destroyed. After a transformation, the same amount will always continue to exist. Nothing perishes. Therefore, the obvious concern here, is what happens to the abundance of matter and energy that the world uses. The simple answer is that it becomes waste, in one form or another. In 2018 the world's population generated 2 billion tonnes of solid waste, and this number is expected to reach 3.4 billion tonnes by 2050 (Kaza et al., 2018). However, solid waste is only a fraction of the total annual output of materials. It is only one form of output. Through sewage systems matters are washed into the oceans, some become unregistered waste like plastics in the environment, some are dissipated through various processes, some are used again in some form, and some, like fossil fuels, are emitted into the atmosphere as, e.g., carbon dioxide or other greenhouse gasses. Also, much of the material that is extracted each year is transformed into stock, in construction projects, for building infrastructures such as houses, roads, and bridges. How long it will remain within the stock and what will become of it after, only time will tell.

The problem with the extensive use of resources is not only the scarcity of many of those materials, such as rare metals, that mankind demands. The extraction of materials comes with a cost. The emission of greenhouse gasses into the atmosphere most likely constitutes the greatest threat that the world has ever faced. The effect of global warming, caused by the emission of GHG, is already causing major catastrophes around the globe, and the frequency of extreme weather events because of global warming will almost certainly increase in coming years (IPCC, 2022). The extraction of materials and the combined industries of processing and making something out of those materials are estimated to be responsible for 50% of global annual GHG emissions (IRP, 2019). A further influence on the ecosystem is also devastating. Up to 90% of biodiversity loss and water stress can be attributed to the global extraction of resources and processing of materials (IRP, 2019). On the output side of the equation, further damage is generated. Solid waste management is the fourth largest contributor to GHG emissions in Europe (Eurostat, 2020), and plastic pollution and other kinds of pollution are damaging ecosystems.

The climate crisis is perhaps most accurately described as a waste management problem. The output of immense material consumption is stretching Earth's boundaries. The atmosphere has been turned into a dumpster, with up to 80% of the output of material consumption being GHG emissions, according to some estimations (Behrens, 2016). What becomes of materials — whether it is emitted, wasted, or used again — needs to be adequately considered by policymakers around the Globe. A significant reduction in virgin material consumption needs to happen. A circular economy is an approach that aims to address this challenge, while also maintaining economic development and enhancing prosperity.

1.2 Motivations

A circular economy, in brief, is an approach toward society, which aims to increase recycling, or some form of reuse of materials, together with minimizing the need for extraction of raw materials. The goal is to use materials repeatedly in a closed, circular loop.

It is not altogether clear whether the circular economy, to the fullest extent, is a realistic goal. To what degree is a circular economy possible? Also, it is not altogether clear to what extent circular practices might reduce pressure on the ecosystem since circular practices also require the use of resources such as energy. Those kinds of questions are looming in the background of this thesis. The focus of it is narrower but might provide some useful insights for addressing those broader concerns.

The circular economy, in which nothing is wasted, is not a farfetched idea or an unfamiliar one. It is an appealing notion. Making use of as much as you can, out of as little as you can is a well-known practice both in many households around the globe and in the management of companies, big and small. One can argue that this old-fashioned approach constitutes the main principle of efficiency. To create much out of little is quite desirable.

The concept, therefore, resonates with reality. Many who are now experiencing their adulthood in the early decades of the 21st century have vivid memories of older generations who grew up in a world of somewhat more visible scarcity, some decades ago. Everything was used. Throwing something away as waste was a last resort. A grandmother turning milk packaging into flowerpots or making a soup out of yesterday's supper or boiling the head of a fish to use up every gram of nutrients, was a common sight. Garages were built out of timber from boxes.

However, despite the familiarity of the concept, the global economy is far from representing the circular approach. If one singular concept can be said to fit the economic activity of nations, especially the richest ones including Iceland, it would be this: Wastefulness. Materials, if not used for stock, are consumed, and subsequently, they are thrown away, dissolved, or emitted into the atmosphere.

Those habits come with a massive cost. The pressure on the ecosystem is enormous as the global population increases and consumerism grows, with a growing demand for raw materials. Global warming, due to emissions of greenhouse gasses, can to a very large extent be attributed to the over-extraction of resources and the extensive, linear use of materials.

In this context, the attention of policymakers, scientists, and other stakeholders to the circular economy, as opposed to the linear economy, has been growing considerably. That is also the context of this study. Is Iceland, as one of those nations that aim for a circular economy, on a track toward more circularity?

This thesis represents an estimation. The methodological challenges and the scarcity of accurate data are limiting factors, as will be discussed, but as a first step, it is important to map out those limitations, as is done in this thesis, so that they can be fixed. Given this reality, the key results of the thesis, concerning the Icelandic National Circularity Index, should nevertheless give a fairly accurate picture of how things are and what the status of the circular economy is in Iceland.

1.3 Aim and structure

The aim of this study is to estimate how circular the Icelandic economy is. This is done by analyzing how much of the total amount of material that is consumed within Iceland is cycled, or secondary, material. The analysis is therefore consumption-based, as opposed to production-based. The reference year is 2019. The research question is: How circular is the consumption of materials within the Icelandic economy?

The result is presented as the National Circularity Index (NCI) (CGRi, 2020). The method used to estimate this index is economy-wide material flow accounting (EW-MFA), with materials presented as raw material equivalents (RME). The study reveals the flow of materials through the economy, from imports and domestic extraction of resources, and how the materials split into exports and domestic consumption, from where they are either added to stock or reach end-of-life, as output. By revealing how much of the output enters the economy again and estimating how much secondary material is imported from elsewhere for consumption in Iceland, the NCI is established. The National Circularity Gap (NCG) is also thus established. It shows the percentage of materials, of the total annual consumption, that are not secondary.

An estimation of this kind has not been executed before in Iceland, at least not publicly, so this should count as the first step in that respect. By measuring the circularity in this way, it might become more possible to assess what is realistic, as a goal, when it comes to implementing the circular economy in Iceland.

After this brief introduction, a background chapter is provided, discussing the relevant environmental challenges at hand, the origin and meaning of the circular economy approach, and the current endeavors of nations to implement it. The MFA tool, the concept of raw material equivalents, the National Circularity Index, and recent attempts to measure circularity are also discussed. Then a chapter describing the economic reality of Iceland and Icelandic circular policies is provided, followed by a chapter outlining the methodology and the data used in this study. The thesis then proceeds into results and discussion, in which the general results are discussed and explained, with e.g., a Sankey diagram showing the flow, stock, and circularity of the Icelandic economy. Those results are then split into different types of materials, showing the circularity of biomass, ores, non-metallic minerals, and fossil fuels, separately. Based on the results, suggestions are finally offered on how to increase circularity in Iceland. Several scenarios are evaluated, before proceeding to conclusions and references.

2 Background

2.1 The Circular Economy – Concept and History

The notion of the circular economy as a systematic approach to environmental and economic challenges has its roots in the growing environmental concerns of the late 60s and the 70s (Blomsma & Brennan, 2017; Winans et al., 2017). The concept has gained widespread attention and support in recent years among governmental and international agencies, companies, organizations, and individuals and has been integrated into many influential public policies around the globe, for minimizing resource extraction and wastefulness. However, the usefulness and clarity of the concept have also been questioned. It has been argued that it is somewhat ill-defined (Korhonen et al., 2018), is inexplicitly connected to the concept of sustainability in multiple ways (Geissdoerfer et al., 2017), or that the concept is best described as an umbrella concept (Blomsma & Brennan, 2017), referring to all kinds of different aspirations to reduce waste, reduce consumption, and increase the longevity of products or create prosperity out of recycling, repairing and reusing.

Figure 1. A schematic representation of the Circular Economy. Raw materials enter the economy from natural resources, products are designed, manufactured, distributed, consumed, collected as outputs, and then preferably recycled so that they can enter the design stage again, and thereby diminish the need for the extraction of resources (Image: European Parliament, 2022).

The circularity approach is often referred to as a zero-waste policy or a closed-loop policy, indicating that the main target of the approach is to increase the secondary use of materials. Instead of throwing things away after use, they should be used again in some form. The general idea is to reduce pressure on natural resources and reduce wastefulness. The European Union has defined the circular economy as a system in which the "value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (European Commission, 2015).

The approach bears liking to other similar approaches, for reducing waste and implementing sustainable consumerism, through some kind of a loop thinking, such as the cradle to cradle approach (McDonough & Braungart, 2002), the blue economy (Pauli, 2010), performance economy (Stahel, 2010), industrial ecology (Graedel et al., 1995), industrial symbiosis (Chertow, 2000) and biomimicry (Benyus, 2002). The circular economy is therefore not an entirely new idea, but rather a concept that grows from other similar attempts, and has perhaps gained a following because of the simplicity that is included in the very name of the concept. A circularity as such is relatively easy to understand.

All those approaches entail a revision of how resources should be used and how things should be produced and consumed, within some kind of a circular loop. What perhaps makes circularity feasible is how it resonates with two major aspects of reality: The efficiency in the use of materials practiced e.g., by older generations, as previously discussed, and secondly, more importantly, the fact that in nature — no matter how thoroughly we look — there is no waste. Everything flows in a circle.

2.1.1 Relevance and practical guidelines

The concept has strong relevance for achieving several of the United Nations Sustainability goals (United Nations, 2022a), including no. 7 concerning affordable and clean energy, nr. 8 about decent work and economic growth, no. 9 concerning industry, innovation, and infrastructure, no. 11 on sustainable cities and communities, and no. 13 relating to climate action. It is however most connected to goal no. 12, which states responsible consumption and production as a goal.

Figure 2. Relevant SDGs. The most relevant for the circular economy is no. 12.

In the most recent UN Sustainable Development Goals Report, it is noted that unsustainable patterns of consumption and production are hindering the achievement of the twelfth goal. Those unsustainable practices are the root cause of a triple planetary crisis of climate change, biodiversity loss, and pollution. It is also stated that the global reliance on natural resources has been increasing considerably in recent years, rising by 65% from 2000 to 2019 (United Nations, 2022b). The circular approach taps directly into this challenge.

According to the Ellen MacArthur Foundation — a pioneering private institution in circular economy theories — a circular economy is based on three principles. The first principle states that every effort should be made to design out waste in the design and production stage of things. At this stage future pollution is mostly decided. Waste should be considered a flaw in the design. Secondly, products and materials should be kept in use as long as possible. This can be done by putting more effort into reusing and repairing the things that are used, and by remanufacturing. Thirdly, natural flows should be regenerated, by returning the nutrients of products back to the ecosystem, enhancing biodiversity, and strengthening natural resources (The Ellen MacArthur Foundation, 2022).

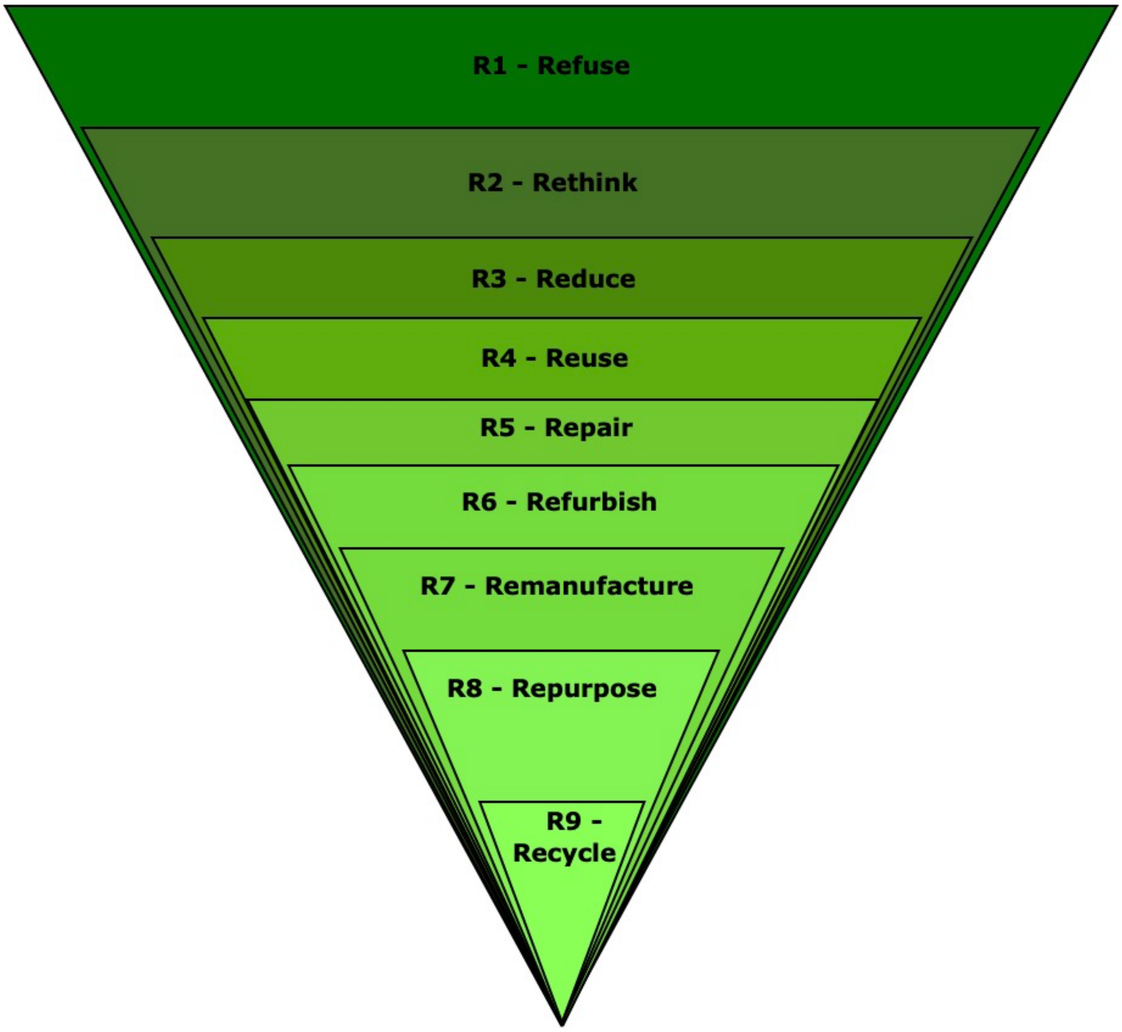

Figure 3. The 9 Rs of the Circular Economy. According to this approach refusing materials is the most preferable method, while recycling is the least preferable.

One way to describe the circular economy in praxis is through the idea of the nine Rs, as put forward e.g. by the European Commission (European Commission, 2020a) and depicted in

Figure 3. The nine Rs represent different methods of fulfilling the demands of the circular economy, that together form a comprehensive web of circular approaches in hierarchical order. First is *R1-Refuse*. By refusing the use of a product it is made redundant or its function is offered by other better means. *R2-Rethink* is the way in which a product can be put to more intensive use for instance by sharing, or some kind of multi-functional reuse. *R3-Reduce* is a key ingredient in the circular economy in which the aim is to increase efficiency in the production of goods by extracting less raw material from resources. Through *R4-Reuse* an attempt is made to use products again, that are in good condition, for their original purpose. *R5-Repair* is a similar approach, through which products are fixed so that they can be used again with their original function, which is also possible through *R6-Refurbish,* where old products are brought up to date and restored. *R7-Remanufacture* is a method by which the parts of a discarded item are used in a new product with the same function and through *R8-Repurpose* such parts are used in a new product, with another function. At last, there is *R9-Recycling,* through which materials from waste are gathered and reprocessed to be made into new products.

The transition from a linear economy to a more circular one can also be conceptualized as an attempt to change how materials flow through a given system. Through material flow accounting (MFA) a system is visualized as a stream of material flows in and out of an economy (Lutter, 2018). From this standpoint, a transition towards more circularity becomes a matter of changing the substance of these flows. As described by Circle Economy (2022), and shown in *Figure 4*, four different approaches are recommended.

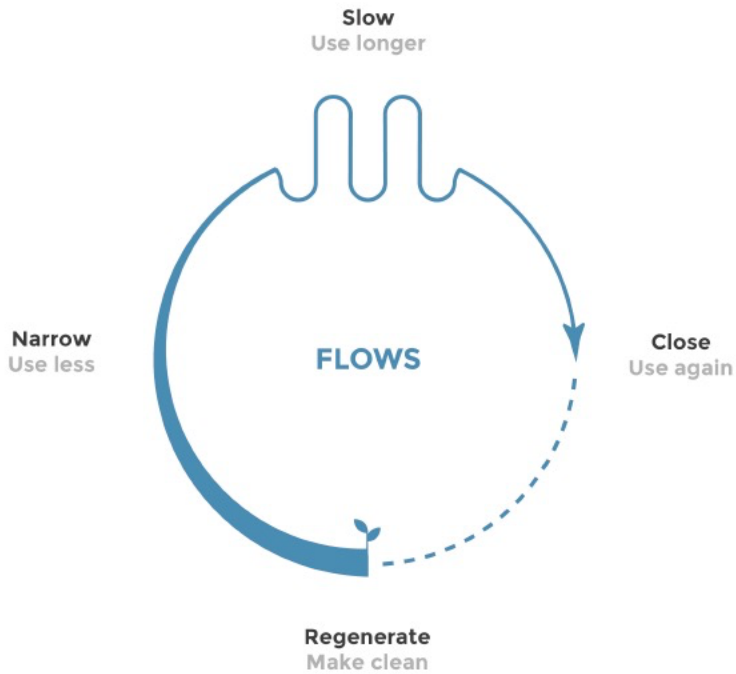

Figure 4. Four different ways for a material flow to be more circular. Image: (Konietzko et al., 2020).

A material flow can be *narrowed*. This means that an effort is made to use less material, for instance by sharing things, increasing multifunctionality, minimizing the need for materials in the production of things, and/or increasing energy efficiency. Secondly, a flow can be *slowed*. This can be achieved e.g. by focusing on longer durability of things, and also by repairing and designing things so that they can be remanufactured or reused in some manner. Thirdly a flow can be *regenerated*. This means that a flow is made clean, by substituting unsustainable linear flows with flows from renewable resources. A change from fossil fuels into renewable, clean energy is an example of this, as well as a transition from unsustainable agriculture into regenerative agriculture. Lastly, a flow can be turned into a *cycled* flow, or *closed*, by increasing the recycling of materials and systematically designing things for recyclability.

2.1.2 Circular economy platforms and initiatives

The circular economy has roots in legislative initiatives in both China and Germany in the 90s (Winans et al., 2017). Because of those initiatives, those nations can be considered pioneers when it comes to the circular economy. The Closed Substance Cycle and Waste Management Act was adopted in Germany in 1996 and Chinese efforts were further boosted with legislation concerning the circular economy in 2005. The so-called Recycling-Based Society in Japan, a policy starting in 2002, is also an early and influential contribution to the notion of the circular economy, in which the aim is dematerialization (Heshmati, 2015).

The United Nations, European Union, and OECD have been influential promoters of the circular economy in recent years. The United Nations Environment Program (UNEP) maintains a circularity platform, where the emphasis is put on the guiding principle of reducing material needs by design (UNEP, 2022). Furthermore, it defines three additional processes, or loops, that should be emphasized in a circular economy, built on the 9 Rs. Those are, in order of importance: 1) User-to-user. Users should, between themselves, refuse products, reduce the need for them, or re-use them. 2) User-to-business. Users should direct their products to businesses, for repairing, refurbishing, or remanufacturing. 3) Business-to-business. Within the realm of businesses, products should be repurposed or recycled.

The EU has also adopted circular economy principles. The European Commission recently published a policy document, *Circular Economy Action Plan*, in which actions are suggested in several fields (European Commission, 2020b). One of the most important aspects of this policy is that its focus is not only downstream — on how to handle the waste generated — but also upstream, on the initial design of things and how waste can be prevented through innovation and new methods. It also, importantly, outlines the legislative framework and platforms for implementation.

Cooperation of stakeholders, incentives for innovation, regulations prohibiting wasteful practices, and promotion of circular methods, along with measures to increase the awareness of the circular approach through information and education, are at the core of the European policy. In this way, it provides a valuable overview of the available policy tools for implementation. Also, the policy is characterized by an awareness of the fact, that to implement a policy a convincing description of its economic benefits might be crucial. The Commission estimates that the Action Plan can potentially create 580.000 jobs within the EU by 2035, hence serving as a strategy for increasing prosperity and welfare within the member states.

For advocating the implementation of the circular economy globally and monitoring its process within its member states, the OECD operates the so-called Re-circle project (OECD, 2022b). This project offers a circular economy policy guidance with a special emphasis on resource efficiency. It aims to provide both quantitative and qualitative studies on the impact of different circular and resource efficiency policies within the member states and emerging economies. The project monitors, with published studies, how material needs are affected by e.g., economic activity, labor market, international trade, and digital innovation, providing nations and cities with useful tools for increasing circularity within their economies.

Several nations, increasingly in recent years, have adopted the principles of the circular economy not only as a sustainable, environmental policy but also as an economic policy. The restructuring of production and consumption, through the roadmap of the 9 Rs, can serve as a way of creating more jobs, new industries, and increasing prosperity. This can already be manifested by focusing narrowly on solid waste only. Solid waste management has been considered an expensive burden. It is often the single highest budget item for local administrations (Kaza et al., 2018). The circular economy offers a radically different approach to waste management. How waste is either reduced or essentially transformed into something that is not waste, means that new resources are created. The circular economy offers new opportunities in the economic design of society. Designing out waste, innovating new technologies and products, and introducing new ways of thinking, can create jobs, increase prosperity, and reduce costs.

2.2 Measuring Circularity

While the circular economy has gained a following, it has become increasingly important to develop an accepted monitoring framework for circularity. If circularity is an aim, of companies, households, municipalities, nations, or the whole globe, it should be possible to measure progress toward that aim. It has, however, not been altogether clear how circularity should be measured. In a recent study, 63 possible different CE metrics were identified along with 24 features that were considered relevant to CE (Parchomenko et al., 2019). Among those features that can indicate how strong the circular economy is within a society are recycling percentages, the longevity of material use, and the availability/scarcity of materials. It can be argued that there are three main methods for measuring circularity: 1) by analyzing resource efficiency, 2) by mapping through various means the consumption of products, and 3) by studying the stream of materials into and within a system and how materials flow (Parchomenko et al., 2019).

2.2.1 Material Flow Accounting

Economy-Wide Material Flow Accounting (EW-MFA) has been gaining momentum as a proper tool for monitoring circularity within an economic system (UNEP, 2021b). The system can be of any scale, with clearly defined boundaries. A corporation, a household, a municipality, a nation, or the whole globe can all count as such a system. MFA is a globally standardized method for mapping how raw materials flow in and out of a system. It covers all kinds of materials, in all forms, except for water and air. The materials are split into four categories: Biomass, metallic ores, non-metallic minerals, and fossil fuels. Those are split into subcategories in accordance with standardized categorizations. Through EW-MFA the metabolism of a national economy can be analyzed.

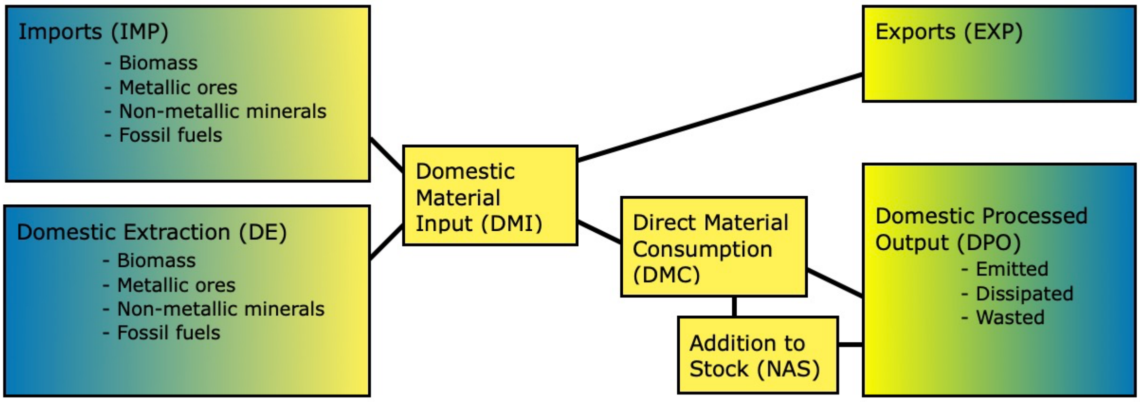

Figure 5. The basic structure of EW-MFA. Imported (IMP) and extracted (DE) materials flow into the economy, out of the blue and into the yellow, where they form the material input (DMI) and are either exported (EXP) or consumed (DMC). Some become stock (NAS), but most materials at some point become an output (DPO) and flow again out of the economy. A circular study, like the current one, adds circularity to this diagram, where materials flow from DPO and into DMI again, becoming secondary materials (SM), and hopefully minimizing the need for more domestically extracted or imported virgin materials from nature.

From an environmental perspective, this approach is important because it shows how an economic system, such as a nation-state, interacts with nature. Materials from nature enter the system, through either domestic extraction (DE) of resources or imports (IMP), the sum of which is the domestic material input (DMI). Those materials are either consumed within the system, through direct material consumption (DMC) or exported (EXP). DMC can be further categorized. Some materials are turned into stock — net addition to stock (NAS) is the relevant index — and others flow through the system. The materials at some stage of production or consumption within the economy become a domestic processed output (DPO). Then the materials enter nature again as some form of waste, be it solid waste from households and industries, materials in wastewater, emissions, or dissipated flows (Eurostat, 2018; UNEP, 2021a).

The data for this kind of analysis is factual, physical numbers from national accounts. One can observe how this kind of accounting is based on the first law of thermodynamics. It is given that matter does not disappear within the system, it can neither be created nor destroyed, only change. So, it flows in and out of the system, or stays within it, revealing the metabolism of the economy and its relationship with nature and other nations. The origin of material flow analysis and accounting can in fact be traced to the biological concept of metabolism, and how it was first applied to society by Marx and Engels around 1860 (Fischer-Kowalski, 1998). This later turned into the notion of industrial metabolism, which enjoyed a growing interest through the environmental awakenings of the 1960s and onwards. This interest in systematically mapping the interaction of materials and energy between nature and economic systems is the basis of EW-MFA (Fischer-Kowalski & Hüttler, 1999). Material flow accounts were introduced as a standardized method by Eurostat in 2001, by the publication of the first methodological guide (Eurostat, 2001). It has since been updated several times. To further spread the method internationally, other institutions have also published guidelines outlining the standardized principles (e.g. OECD, 2008). MFA is compatible with the System of Integrated Environmental and Economic Accounting (SEEA) and fully consistent with the United Nations System of National Accounts (Eurostat, 2018).

2.2.2 Raw material equivalents (RME)

The EW-MFA, as previously described, is based on direct, factual numbers from national accounts concerning imports, exports, and the extraction of resources. For analyzing to a fuller extent the real abundance of materials that economies rely on, the notion of raw material equivalents (RME) has been developed in recent decades. It has been recognized that the products that are transported between nations entail a hidden stream of materials. A car may weigh certain amounts in tons, of which a lot is e.g., aluminum, steel, and plastics, but during the production of the car, a lot more material was used. The material involved in making the car should be accounted for as well. The car, in other words, has a material footprint. There are several ways to estimate a material footprint of a product. A life cycle assessment (LCA) is one such approach, through which all the materials and energy that are required for the manufacturing, consumption, and disposal of a product are accounted for at different stages. An environmentally extended input-output analysis (EE-IOA) is another approach, widely used. These approaches are in constant development, they are in essence estimations and can as such be considerably improved (Lutter et al., 2016). In fact, a universal consensus on how to measure a material footprint of a product is lacking, although the importance of measuring it is widely acknowledged (Matuštíka & Kočí, 2021).

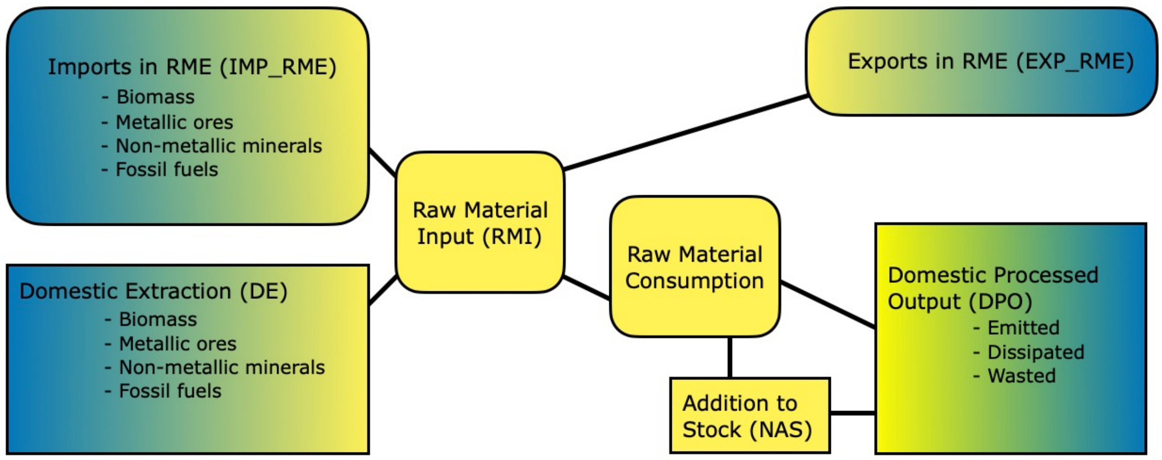

Figure 6. EW-MFA in raw material equivalents (RME). Rounded boxes now represent estimated numbers, acquired using the RME tool. DE still represents direct, physical numbers, and optimally NAS and DPO do so as well, depending on what kind of data is available.

Eurostat has developed the concept of raw material equivalents (RME) as an extension to EW-MFA in an endeavor to grasp the material footprint of products that are produced and/or consumed within the member states of the European Union (Eurostat, 2021a, 2021b). In EW-MFA conducted through the RME model, the physical values of imported goods (IMP), domestic material input (DMI), direct material consumption (DMC), and exports (EXP), are replaced with imports in raw material equivalents (IMP_RME), raw material input (RMI), raw material consumption (RMC) and exports in raw material equivalents (EXP_RME). The calculations for those values are based on environmentally extended input-output modeling, a hybrid approach using input-output tables from the European accounting system to provide material flows in RME of 182 product groups within 51 raw material categories. This approach is under constant development, is specifically targeted for representing the reality of the EU member states, and has been revised considerably in recent years (Eurostat, 2021a).

2.2.3 The Circularity Index

In recent years systematic attempts have been made to measure both the global and national circularity of materials using MFA on a global level and EW-MFA with RME on a national level. It should be noted that since there are no imports nor exports on a global level an RME estimation is not required, and neither is the EW prefix. In essence, the Circularity Index studies add circularity to the flow diagrams. On the output level, the amount of material that is used again is circled back into the RMI. It is suggested in those studies that on a global level, where there are no exports nor imports, the Global Circularity Index (GCI) should be the percentage of secondary materials within the RMI, which is in essence the total number of extracted materials from resources globally. On a national level, where exports need to be subtracted from RMI, the National Circularity Index (NCI) is the percentage share of secondary materials within the domestic raw material consumption (RMC) (CGRi, 2020).

A pioneering effort to estimate the global circularity using MFA was made by Haas et al. (2015). Since 2018 The Circle Economy, an organization based in the Netherlands, has published reports annually, estimating the Global Circularity Index, and the Global Circularity Gap, also by the methods of material flow accounting (Circle Economy, 2018, 2019a, 2020a, 2021, 2022). It has also published reports estimating the National Circularity Index, and the related circularity gap, of four nations — Austria, The Netherlands, Norway, and Sweden — by use of EW-MFA with RME (Circle Economy, 2019b, 2020b; Circle Economy & Circular Norway, 2020; Circle Economy et al., 2022). The methodology of this thesis is adopted from those national and global studies.

This methodology is far from perfect, although useful for obtaining an indication of how circular a system — like a nation-state or the world — is. Some limitations should be noted. The method does not recognize differences within a circular stream of materials, for instance, whether some circularity is more valuable than others. The quality of the recycling, in other words, is not considered. Also, it counts as a limiting factor that the method relies on relative rather than absolute numbers. This means that circularity, as a percentage of total consumption, can increase while the extraction of raw materials for consumption is not necessarily decreasing. A key objective of the circular economy, however, is to diminish the extraction of virgin raw materials.

2.2.4 Results of global circularity studies

According to Haas et al. (2015), the global material consumption in the year 2005 was 6% circular. It was further observed, that since materials are used in vast amounts for energy production and construction — neither creating optimal outputs for reusing — it would be challenging to increase this percentage.

The low degree of circularity was thus mainly attributed to two factors, the first being that an abundance of fossil material was used for energy production, and the second that the need for stocks explained a large share of the material need. Therefore, that study concluded that limited measures for increasing circularity existed downstream, where materials end. Emissions from the burning of fossil fuels were difficult to recycle and if materials were stuck in infrastructure, they were also not available for recycling. Circularity could rather be increased by measures taken upstream, e.g., by the reduction of material need, eco-design of products with reusable material, and a shift into clean energy.

According to the studies conducted by the previously mentioned Circle Economy, the Global Circularity Index has gone from 9,1% in 2018 to 9% in 2019, and 8,6% in 2020. No changes were reported in the 2021 report nor the most recent 2022 report (Circle Economy, 2018, 2019a, 2020a, 2021, 2022). According to this the circularity of global consumption has declined in recent years, despite efforts to increase it.

The most recent report mentions two main reasons for the declining Global Circularity Index. Firstly, it seems apparent that resource extraction is growing faster each year than the global ability to recycle. It is assumed that extraction is outpacing improvements in efficiency and material recovery by a factor of two to three. Secondly, the growing global population is to blame, with an increasing need for construction materials for housing and infrastructure (Circle Economy, 2022).

In the 2022 report, it is estimated that the amount of material that reaches the global economy annually has reached 100,6 billion tonnes, of which 8.6 billion tonnes is cycled material (Circle Economy, 2022). Minerals, mostly for construction projects, are the largest category, with 50,8 billion tonnes extracted, followed by the extraction of 24,6 billion tonnes of biomass, 15,1 billion tonnes of fossil fuels, and 10,1 billion tonnes of metallic ores. According to the report almost half of the total material input, or 48 billion tonnes, goes into long-term stock, such as buildings, all kinds of infrastructure, and heavy machinery. This material can be stuck within those structures for a long period of time, although every year a portion of it becomes available again, as structures are demolished or disassembled. Of the total annual material output, around 17 billion tonnes are materials from such demolished constructions, making gravel, sand, timber, metal, and other waste from infrastructure projects a large, possible component of circularity.

In the reports published by Circle Economy, human consumption is split into seven categories. Of the total material input it is estimated in the 2022 report that the largest share of it, or 38,5%, goes into housing, 21,2% is used for nutrition, 10% for various services, 9,2% for healthcare, 8,7% for mobility, 6,9% for consumables, and 5,5% for communication.

At end-of-use it is estimated that 32,6 billion tonnes of material are collected as waste while the rest is emitted or dispersed into the environment. Of the total collected waste, 24 billion tonnes are deemed lost while 8,6 billion tonnes re-enter the material input as secondary material.

2.2.5 Results of national circularity studies

Interestingly, the four European countries that have received an NCI estimation by Circle Economy and partners, seem to differ considerably when it comes to circularity. The NCI for Austria has been estimated at 9,7%, the estimated percentage for the Netherlands is

24,5%, for Norway, it has been calculated as 2,4%, and for Sweden, it is estimated at 3,4% (Circle Economy, 2019b, 2020b; Circle Economy & Circular Norway, 2020; Circle Economy et al., 2022).

Austria was the first country to receive an NCI estimation in 2019. It was suggested that to boost the country's Circularity Index of 9,7% the national policy should focus on shifting from fossil fuels to renewables, emphasizing the recycling of all recyclable waste, maintaining, as possible, current infrastructure and buildings instead of constructing new ones, and ensuring that imports of goods entail higher portion of secondary materials (Circle Economy, 2019b).

The Dutch circularity percentage of 24,5% is remarkably high compared to other nations and the globe. The report on the Netherlands attributes this relatively high circularity to efficiency in material use and a high percentage of waste recycling, due to a comprehensive public waste management policy. However, it is noted that the high circularity rate is mainly due to waste from construction, which is used again in further construction projects. It is recommended, for increasing circularity, that construction practices — demanding half of all consumed materials — are made more circular, that agriculture and the food system adopt circularity, a shift from fossil fuels to renewable energy is speeded up, and that repairing, remanufacturing, and high-value recycling is boosted (Circle Economy, 2020b).

Norway's low circularity of 2,4% is mainly attributed to the country's large material footprint. To meet societal needs the nation consumes 234 million tonnes of materials annually or a stunning 44,3 tonnes per capita. Although recycling is widely practiced it cannot hold up to the abundance of the material input, of which approx. half is added to stock. It is maintained that the material footprint could be reduced by 64,8% through various approaches, which would increase the Circular Index to 45,8%. The key factors in increasing circularity are circular construction, transition to clean energy, circular biomass, and stronger repair, reuse, and recycling practices (Circle Economy & Circular Norway, 2020).

Sweden's consumption rate is also high, or 24,8 tonnes per capita, which is almost double the global average. The circularity is also low, or 3,4%. Sweden is, like Norway, a high-income trade nation with a large material footprint. A lot of material is added to stock, making circular constructions a primary goal, and the circularity of biomass is of immense importance since 36% of the material input is biomass. Also, like in the case of the other nations and the globe, fossil fuel — representing approx. 20% of the circularity gap — needs to be replaced by clean, renewable energy.

3 Iceland and Circularity

Iceland is a small country population-wise, with approx. 375 thousand habitants on an island that is 103.000 km2 in size, so the population density is low. The country might be considered one of the greenest economies on Earth since the heating and energy of almost all households and industries in the country are provided through renewable energy resources (Statistics Iceland, 2022b). This reality, based on a policy that was implemented in Iceland during the 20th century — moving Iceland from coal energy into renewables — does considerably affect the social need for materials, mostly fossil fuels. However, Iceland is also a peculiar example of a nation with a high environmental footprint, despite its reliance on renewable energy. Total domestic annual emission of greenhouse gases, without land use, land-use change, and forestry, amounted to 4.72 million tCO_2eq in 2019, or approx. 12,5 tCO_2eq per capita (Keller et al., 2021).

The Icelandic economy is dominated by mainly three export industries: Fisheries, tourism, and aluminum production. Since those are exports, however, the materials required for this production are consumed elsewhere. Those industries do not, therefore, have a huge impact on a consumption-based circularity study like this one, except for the fact that they create domestic buying power. GDP per capita is high (The World Bank, 2022), which might explain high levels of consumerism and a generally rich lifestyle. The annual household consumer-based carbon footprint has been estimated at 10,4 tCO_2eq per capita, mostly due to high imports of goods, food consumption, and transport (Clarke et al., 2017). As for solid waste, Icelanders generated approx. 1,100,000 tonnes of it in the year 2019 (EAI, 2022a). Household waste was 664 kg per capita, which makes Icelandic households the fifth most waste-generating households in Europe (EAI, 2022a). Those numbers indicate that Iceland is one of the most wasteful nations on Earth, in terms of both solid waste and GHG emissions per capita. This huge stream of output must be recycled or narrowed for increasing circularity.

The term *Circular Economy* or in Icelandic *hringrásarhagkerfi* is first mentioned in print in the national media on New Years' Eve 2012, when one of the biggest newspapers, *Morgunblaðið*, republished a short remark from *New York Times* by Ellen MacArthur, in which she advocates a new way of consuming things under the label of the circular economy (MacArthur, 2012). Recycling, however, has been practiced for a longer time in Iceland. In 2019 78% of the solid waste generated was recycled in some way, while 22% was not. Most recycling occurs within the field of construction, with 96% of registered waste generated from construction recycled in 2019. When it comes to households, 39% of the waste was recycled, and 77% of the industrial waste (EAI, 2022a).

A recent study has shown that Iceland lags far behind other Nordic countries and the EU when it comes to reducing landfilling of municipal solid waste and increasing recycling rates of such waste. A landfilling percentage of over 60% of municipal solid waste makes Iceland far from reaching the EU goal of 10% by 2035 (Óskarsson et al., 2022).

This challenge might explain why the circular economy appears to have entered into the public discourse in Iceland with full force mostly in connection with the recycling efforts of municipalities and solid waste management companies. In the public discourse, the concept is dominantly connected to solid waste management. Althingi, the Parliament of Iceland, has adopted new legislation concerning the circular economy, which will take effect on January

1st, 2023 (Althingi, 2021). Although Iceland is not a member of the European Union, a lot of European legislation and policies are adopted in Iceland, mainly because of Iceland´s membership in the European Economic Area (EEA). This legislation is therefore to a large extent based on the European Circular Economy Action Plan, although with a narrower scope. It focuses a lot on solid waste management, while the EU Action Plan has a much broader approach (European Commission, 2020b).

The legislation springs also from previous governmental policy formations, most notably a document published by the Ministry of Environment and Resources in 2021. The stated aim is that Iceland will become a pioneer when it comes to climate-related issues and sustainable use of resources. The implementation of the circular economy is seen as a crucial factor in this, through which the generation of solid waste will be substantially reduced, recycling increased and the landfilling of the waste completely stopped (Ministry of Environment and Resources, 2021). New strategies for reaching these goals will be put into effect by the new legislation.

The presence of the circular ideology can also be felt elsewhere. The Icelandic Ministry of Environment and Resources is legally obligated to publish a waste prevention policy every 12 years. The current policy was published in 2016 and will be in effect until 2027. This document echoes the principles of the circular economy in its general scope. It is stated that the aim of the long-term policy, although not obtained during the time frame of the current strategy, is to prevent all waste and reuse all products (Ministry of Environment and Resources, 2016). In the spirit of the circular economy, some focus is put on increasing efficiency in the use of materials and promoting consuming habits that support such efficiency, like for example offering services instead of products, sharing instead of owning, and repairing instead of throwing away. While some emphasis is put on finding new ways of making greater use of materials, reusing materials, or increasing the lifespan of materials, the most common strategy is rather to reduce the use of materials in the first place, like plastics and paper. Promoting sustainable consumerism is at the forefront of the policy. It is however unclear how this policy is or will be — or has been — implemented, although some aspects of it can be observed in praxis in the society. For instance, plastic bags are no longer used for shopping.

A range of other more limited policies and strategies for enhancing circularity, directly or indirectly, have been put in effect in Iceland, such as green public procurement and management policy (Central Public Procurement, 2022), green initiatives within government and municipalities (City of Reykjavik, 2022), educational projects and events (Landvernd, 2022), promotion of markets with used products (Sorpa, 2022) and various encouragement programs for environmentally sustainable practices. Some efforts have also been made through taxation, rules, and regulations, like implementing a price tag on some types of waste, e.g., from construction and demolition (Althingi, 2021).

GHG emissions, or other forms of output from material use, do not seem to be considered waste in circular policies and initiatives in Iceland. In the context of this study, however, it is important to consider all possible kinds of output, for measuring the circularity gap. Iceland has adopted a comprehensive policy for reducing GHG emissions — which is one form of output — in accordance with the Paris Agreement. The government of Iceland aims to reduce domestic GHG emissions by 55%, compared to 2005 levels, by 2030. This is stated in the most recent national climate policy, with 48 different strategies for reducing emissions (Ministry of Environment and Resources, 2020). These include, for example, carbon capturing and storage through increased forestry and the use of new technologies, decarbonizing transportation, waste taxation, reducing food waste, and banning the landfilling of waste.

As we shall see, it is crucial to consider all output when measuring the Circularity Index. This means that the principles of the circular economy need to be adopted for more than strictly solid waste management if the index is to be increased. The focus on the circular economy in Iceland as a general approach to the fundamental design of the society — as a system change — is perhaps beginning to emerge. However, it still has a way to go. No official detailed roadmap towards a substantially more circular economy exists in Iceland, in the sense that it would considerably reduce the overall circularity gap. That is perhaps not surprising, since the measurement of circularity gaps and circularity index is a relatively new idea.

Such a comprehensive circular policy would need to consider the different impacts of material streams, as is done in this study. Fossils are consumed not only as fuels but also as materials in an abundance of products that enter the economy. Can this stream be regenerated, cycled, or narrowed? The material need for infrastructure projects is gigantic. How can that stream become more circular? Is the share of secondary materials in imported goods considered? How is the food produced, that the nation consumes?

Systematic attention to such questions and more is needed for increasing the circularity of the nation.

4 Methods and Data

4.1.1 The equation for circularity and its variables.

The National Circularity Index, and the related Circularity Gap, are obtained by dividing the amount of secondary material (SM) that is consumed within the Icelandic economy by the total domestic raw material consumption (RMC). As follows:

$$SM = dom\_sm + imp\_sm - exp\_sm$$

$$RMC = SM + DE + IMP\_RME - EXP\_RME$$

$$SM / RMC \ * 100 = NCI$$

Here SM stands for secondary materials, dom_sm is domestically generated secondary material, imp_sm is imported secondary material, exp_sm is exported secondary material, DE is domestic extraction, IMP_RME is imports in raw material equivalents and EXP_RME is export in raw material equivalents. The origin of the data value for these variables is shown in *Table 1*.

Table 1. The variables of the circular equation and the origin of the data. As the table shows, the data is either obtained from official accounts or calculated by the use of the Eurostat RME tool or by other means.

Variable	Refering to	Origin of the data
dom_sm	Domestic secondary material. Material that is cycled within Iceland for reuse.	Official waste management numbers
imp_sm	Imported secondary material for consumption in Iceland. Included in the total IMP_RME	Estimation based on the global share of secondary materials in consumption, excluding construction waste, or 2,15%.
exp_sm	Exported secondary material. Included in the total EXP_RME	Found within export data from Statistics Iceland.
SM	Secondary Material that is consumed in Iceland.	Calculated as follows: dom_sm + imp sm - exp sm
DE	Domestic extraction of resources	Data from Statistis Iceland
IMP_RME	Imports in raw material equivalents	Stastics Iceland & Eurostat RME Tool
EXP_RME	Exports in raw material equivalents	Stastics Iceland & Eurostat RME Tool
RMC	Raw Material Consumption	Calculated: (DE+IMP_RME+dom_sm) - EXP_RME = RMC

4.1.2 The use of the Eurostat country RME Tool

The Eurostat Country RME Tool, October 2021 version, revised on 20 December 2021 was used in this study, for estimating the values of IMP_RME and EXP_RME, and the derivative RMC. The relevant, and existing, national data, that the tool requires was obtained from Statistic Iceland. The reference year is 2019. Materials are categorized into biomass, non-metallic minerals, metallic ores, and fossil fuels.

Table 2. List of data-input worksheets of the Eurostat RME tool. Section I requires data input at a country level, while Section II is valid for all EU countries and is prefixed in the tool. (Table obtained from (Eurostat, 2021a))

Section	Worksheet of the country RME tool	Description
I. Data input country-level	I-1-COMEXT-182	**Comext**: Imports, exports by intra and extra-trade in EUR and tonnes. Data converted to RME182 classification
	I-2-Tot IMP EXP Nat Acc	Data of national accounts on total imports and exports of goods and of services
	I-3-IMP SUPPLY 64	Data of supply table of national accounts for imports and supplies by 64 product groups
	I-4-EXP 64	Data of use table of national accounts for exports by 64 product groups, basic prices
	I-5-IMP SERVICES	Data of supply table of national accounts for imports of services by intra and extra trade by 43 product groups, basic prices
	I-6-Energy balance IMP EXP	Data of energy balance: imports and exports by product
	I-7-Energy balance: nuclear heat	Data of energy balance on primary production of nuclear heat
	I-8-Bunker fuels IOT concept	Data of EW-MFA on imports and exports of bunker fuels by IOT concept (residence principle)
	I-9-EW-MFA	Data of EW-MFA on DE, IMP, EXP, DMC and DMI by main raw material categories and for nuclear fuel
	I-10-Electricity mix	Data of energy balance on electricity mix.
	I-11-Secondary metal ratio	Data of USGS and other sources on share of secondary metal production to total metal production by metals
	I-12-SBS basic metals	Data of Structural Business Statistics (SBS) on basic metal production
	I-13-Monetary reference figures	Data of national accounts on total GDP, EXP and IMP, chain linked volumes
II. Data inputs EU-level	II-1-EU RME coeff IMP	Annual data from EU model: RME coefficients for IMP, valid for all countries
	II-2-EU RME coeff EXP	Annual data from EU model: RME coefficients for EXP, valid for all countries
	II-3-USGS gold price	Annual data from USGS on gold price, valid for all countries
	II-4 EU Unit prices	EU unit prices from COMEXT data (EU RME Tool) based on monetary value per mass weight

The RME tool is an extensive Excel workbook made of 49 sheets, requiring vast input of data. The tool is based on a coefficient approach. This means that the tool processes the data input through EU-level coefficient matrices for imports and exports defined annually by Eurostat, resulting in outcomes given in raw material equivalents. The tool is under development and subject to regular improvements. It comes with a handbook (Eurostat, 2021b) and a data pool for each EU country. However, since Iceland is not an EU country no such data pool is available.

The tool requires both country-level data and data that is valid for all EU countries. The data that is valid for all countries is pre-entered by Eurostat. It is assumed in this study that this data is also valid for Iceland. The country-level data was entered into the tool. An overview of the data input is given in *Table 2*.

The Comext-182 data, which shows imports and exports by intra-EU and extra-EU-trade, in both Euros and metric tons — converted to the 182 categories of materials that the RME tool requires — was acquired from Statistic Iceland (I-1). The same goes for the value of total imports and exports of goods and services (I-2) and the required data for worksheets I-6 to I-13, including data for EW-MFA, showing domestic extraction (DE), imports, exports, domestic material input (DMI) and domestic material consumption (DMC) in direct, physical weight (Statistics Iceland, 2022a).

New data, however, for supply-use tables (1-3 to 1-5) was not available. This was solved by using the most recent data, which is from 2015. Those values were projected for 2019. It can be argued that this should not affect the result too much, since the general structure of the Icelandic economy did not change considerably between 2015 and 2019, with the three major industries of tourism, fisheries, and aluminum production all in similar shape within this time period. For future circular estimations, this will, however, need to be fixed with up-to-date numbers.

The data is processed through a four-step calculation method, as seen in *Figure 7*. In the first step (sheets III-1 to III-9) monetary imports and exports on a country level are estimated by 182 groups of products. The second step (III-10 to III-16) consists of calculating hybrid (mixed monetary and physical units) trade vectors, which are then multiplied in the third step (III-17 to III-19) with EU coefficients, for calculating country-level RME of imports and exports. In the fourth stage, the RME of imports and exports by the 182 product groups and 51 raw material categories are adjusted for electricity mix and secondary metal ratio.

The output is presented by the tool on four sheets (IV-1 to IV-4), showing the RME of imports and exports in 51 raw material categories, as well as the total RME value of imports, exports, domestic input (RMI), and consumption (RMC), split into the four main material categories.

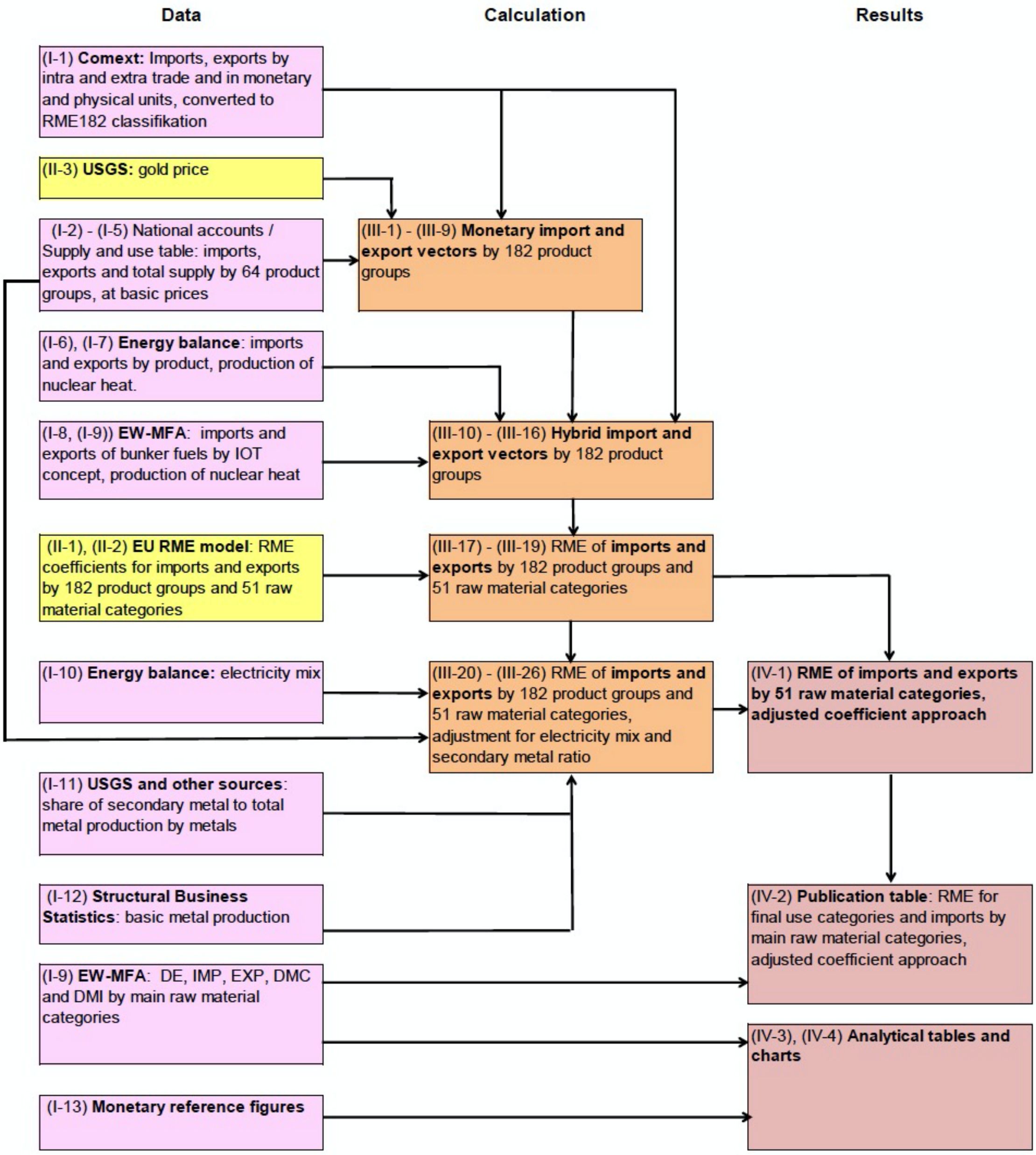

Figure 7. A schematic overview of the Eurostat Country RME tool. The flow of input data into calculations and results is shown (obtained from (Eurostat, 2021a)).

4.1.3 Complications and adjustments

The Eurostat RME tool has not been previously used for Iceland to a full extent by any official body. Preparing and projecting all the necessary economic data into the tool is a relatively complex project, which Statistics Iceland plans to undertake in the near future (personal correspondence with Statistics Iceland). The results of this study are based on the MFA_RME values that were nevertheless acquired by using the tool, despite a certain lack of up-to-date data as described earlier.

Some complications when using the RME tool did pose challenges. The tool is designed with the economic structure of European Union member states in mind. That uniformity has posed challenges in the application of the tool since the countries within the union are quite different from each other (Eurostat, 2021a). This challenge is therefore familiar and Iceland is not an exception. The Icelandic economy is in some ways peculiar. The population is tiny, and two large export industries, fisheries, and aluminum production dominate the economy along with tourism. Raw materials that are imported because of aluminum production make up a huge proportion of the total material input, and the same goes for the fishing industry when it comes to the extraction of resources. Wild fish catch is the largest proportion of DE.

Here complications arise, concerning both wild fish catch and aluminum production. Firstly, the RME tool does not seem to assume that wild fish catch can be such a huge part of an economy. This type of resource extraction does not seem to have received much attention in the construction of the tool (personal correspondence with Eurostat). The RME tool is not applied to the extraction of resources, such as wild fish in this instance, since resource extraction is by definition an extraction of raw materials per se. The numbers in metric tons, therefore, tell the whole story. However when fish becomes an exported commodity the RME tool is applied, since it is assumed that the fish has by then been processed into a product of some kind. In the case of Iceland, the tool gives a skewed picture when it comes to the export of fish products. In short, the tool shrinks the fish export of Iceland into a fraction of what it is in reality. Only further studies can reveal why this is, although some explanations do seem more likely than others at this point. One could be that the European fishing industry is more dependent on aquaculture, and another that some varieties of Icelandic fish products are simply not accounted for within the Eurostat RME tool, and therefore those products do not fall within a category.

Secondly, the RME tool seems to handle the huge share of the aluminum industry within the economy inaccurately. Bauxite and other materials needed for aluminum production are imported in immense quantities. The RME tool, in short, seems to recognize the amount of bauxite that is imported. The aluminum that should be exported, however, does not appear in the exports in the numbers one would assume. It appears that the RME tool makes the aluminum mostly consumed within Iceland, which is not correct — it is exported.

What causes this, remains to be analyzed. For obtaining a realistic RME model of the Icelandic economy, these obvious inaccuracies needed to be fixed. This is done as follows: Both wild fish and aluminum are exported products from Iceland, except for a small fraction of wild fish that is consumed domestically. The aim of this thesis on the other hand is to analyze Icelandic consumption and estimate how circular it is. Products that are imported, processed, and then exported do not directly affect the analysis. Those products are consumed elsewhere and the circularity of their consumption will come into play within a circularity analysis of those nations where they end up being consumed. Therefore in this study, the bauxite required for aluminum production, in RME values, and 95% of wild fish catch were assumed to go in and out of the economy in unchanged numbers.

This kind of adjustment is not unheard of when it comes to applying the tool to national economies. When an economy of a nation is characterized by a large share of re-exports of materials, for instance in the case of the Netherlands, Belgium, and some other smaller European countries, the RME handbook states that it might be appropriate to deduct re-exports (Eurostat, 2021a). For the purpose of this study aluminum and wild fish catch are considered as such re-exports and handled as a flow of materials in and out of the economy.

However, for comparison, the main results are also provided a) without this bypass, with unaffected RME data, and also b) without the RME tool, altogether, simply on the basis of Icelandic EW-MFA.

The EW-MFA data without the RME transition is published annually by Statistics Iceland (Statistics Iceland, 2022a). It should be noted, that when using that data in this study for the purpose of offering results without RME it was noted that the data included a relatively large category of *Others*, for materials that might be somewhat difficult to categorize. However, a closer inspection revealed, that around 90% of this category was comprised of a few products that could with sufficient accuracy be categorized as one of the four types of materials used in MFA. This was done for the purpose of this study. By far the largest component of *Others*, both in import and exports, were carbon electrodes, used in the metal industry, which were categorized as fossils.

4.1.4 The gathering of other data

When the value for RMC was settled by the use of the RME tool as described, domestic consumption was further distributed into seven subcategories of social needs. This has been done in the Global and National Circularity Gap Reports that have hitherto been published, as previously discussed, and is therefore also done here. This categorization, however, does not affect the main results. It only suggests how the material might flow through society and offering this categorization — as factually as possible — does add value to the study. It might give some idea of how circularity can be increased in different fields of society.

Those subcategories of consumption are housing, nutrition, mobility, services, healthcare, communication, and consumables. No specified data is currently available in Iceland which makes it possible to make these distinctions with full accuracy. The nations that have hitherto been subject to a circularity analysis — Austria, Netherlands, Norway, and Sweden — are among nations that are relatively similar to Iceland, being also high GDP per capita European nations, with high consumption levels. The average percentage share of each consumption category of those notions was used as a comparison base for Iceland. Those values were further aligned with Iceland by use of relevant data available, and also by categorizing the materials with as much common sense as possible. Vegetables, for example, most likely fall into the nutrition category. A large share of fossil fuels falls within mobility.

A product is either a *product that flows*, which means that it is consumed soon after the consumer obtains it and proceeds to its end-of-life stage in a short time span, or a *product that stays*, which entails that the materials are put into stock, like houses, bridges, hospitals or other types of infrastructure projects. The share of material that is added to stock is estimated in this study, on the basis of comparisons with other countries, and allocations of the materials themselves, based on their essence. Sand and gravel, for example, are most likely used mostly for construction.

The available data concerning the output is more rigorous. Annual data concerning waste management gathered by the Environmental Agency of Iceland shows how much solid waste from households and industries, and what type of waste, is collected, and how much of it is recycled or in some way reused, or lost (EAI, 2019). No other types of waste – such as from emissions or wastewater — are recycled in Iceland in any significant amounts, so this number in tons represents as accurately as possible the total amount of output that enters circular use. In order to estimate how much of the output from domestic consumption is emitted, the number from the previously mentioned study on the consumption-based carbon footprint, of 10,4kt of tCO_2eq per capita (Clarke et al., 2017), was used and multiplied by the population number. The rest of the output is assumed to be dissipated.

That stream of registered secondary materials (cycled) either enters the domestic material consumption or is exported. If it is exported, it does not account for a secondary material consumed within the economy of Iceland. By going through the export data obtained from Statistics Iceland the exported cycled waste was identified and the amount of it was subtracted from the total cycled waste. In those few and minor instances where exported waste was identified in the export data from Statistic Icelands, and was not accounted for in the EAI waste management data, that waste was added to the total number of domestic solid waste.

It needs to be taken into account, that secondary material can also be imported, which is another source of circularity within an economy. The share of secondary materials in imported goods for domestic consumption is not registered and without such registration, it is almost impossible to find out what this share is. This study relies on the same approach as previous studies of this kind. It is assumed that the share of secondary materials in imported materials is the same as the global Circularity Index during that year. However, it is unlikely that secondary materials from constructions, such as gravel and concrete, which makes up a large share of secondary materials globally, are transported between nations. Therefore the share of secondary materials is assumed to be the same as the global share of secondary materials minus secondary materials from constructions. This percentage is estimated at 2,15%. However, this was not applied to the abundance of bauxite that enters the Icelandic economy, since it can be stated with a fair amount of accuracy that it is not recycled.

5 Results and Discussion

5.1 Key Findings

The share of secondary materials in the total raw material consumption in Iceland in the year 2019 was 8,5%. In 2019 Icelanders imported 665 kt. of biomass, 1.842 kt. of metallic ores, 742 kt. of non-metallic minerals, and 1.897 kt. of fossil fuels in direct, physical numbers. In RME, those numbers are 474 kt. of biomass, 8.245 kt. of metallic ores, 2.629 kt. non-metallic minerals, and 10.133 kt. fossil fuels. Domestic extraction amounted to 1.729 kt. of biomass and 2.489 kt. of non-metallic minerals. Numbers indicate that 785 kt. of waste was cycled back into the economy, while 99 kt of secondary material was exported, and it is estimated that 302 kt. of secondary material was imported. The secondary material (SM) consumed in Iceland was therefore 1.087 kt. The RME of export is estimated at 13.761 kt. This results in a total raw material consumption (RMC) value of 12.725 kt. and an NCI value of

$$(1.087 / 12.725) * 100 = 8,5\%$$

That is the National Circularity Index of Iceland. This means that the National Circularity Gap of Iceland is 91,5%. Of all the materials that Icelanders consume, 91,5% are added to stock, emitted, dissipated, or by other means lost in the environment. The economy is, in other words, linear, not circular.

If the results of the RME calculations are not adjusted, as described in the previous chapter, the NCI decreases to 6,4%. This is because the value of RMC is considerably higher if bauxite and wild fish catch are a part of it. If calculations are done simply with the physical numbers of EW-MFA, and not with RME values, the NCI increases to 11,1%. This is because domestic consumption is lower, if not calculated in raw material equivalents. It can be stated, based on this, that the circularity of the Icelandic economy lies, with a fair amount of certainty, somewhere between 6,5% and 11%, although 8,5% is the result of this study.

Table 3. NCI based on three different methods. Material input and domestic consumption are lower if EW-MFA is given in direct numbers, without RME calculations. Then NCI is 11,1%. When EW-MFA is calculated in RME the material input grows immensely. If aluminum and wild fish are fully considered a part of the domestic consumption (RME unadjusted) the NCI decreases to 6,4%. If RME calculations are adjusted, as is done in this study, the NCI is 8,5%. Numbers in kilotons.

Method	Material Input	Domestic Consumption	NCI
Direct Numbers	10.141	7.965	11,1%
RME unadjusted	26.485	19.193	6,4%
RME adjusted	26.485	12.725	**8,5%**

5.1.1 The material flow of the Icelandic economy

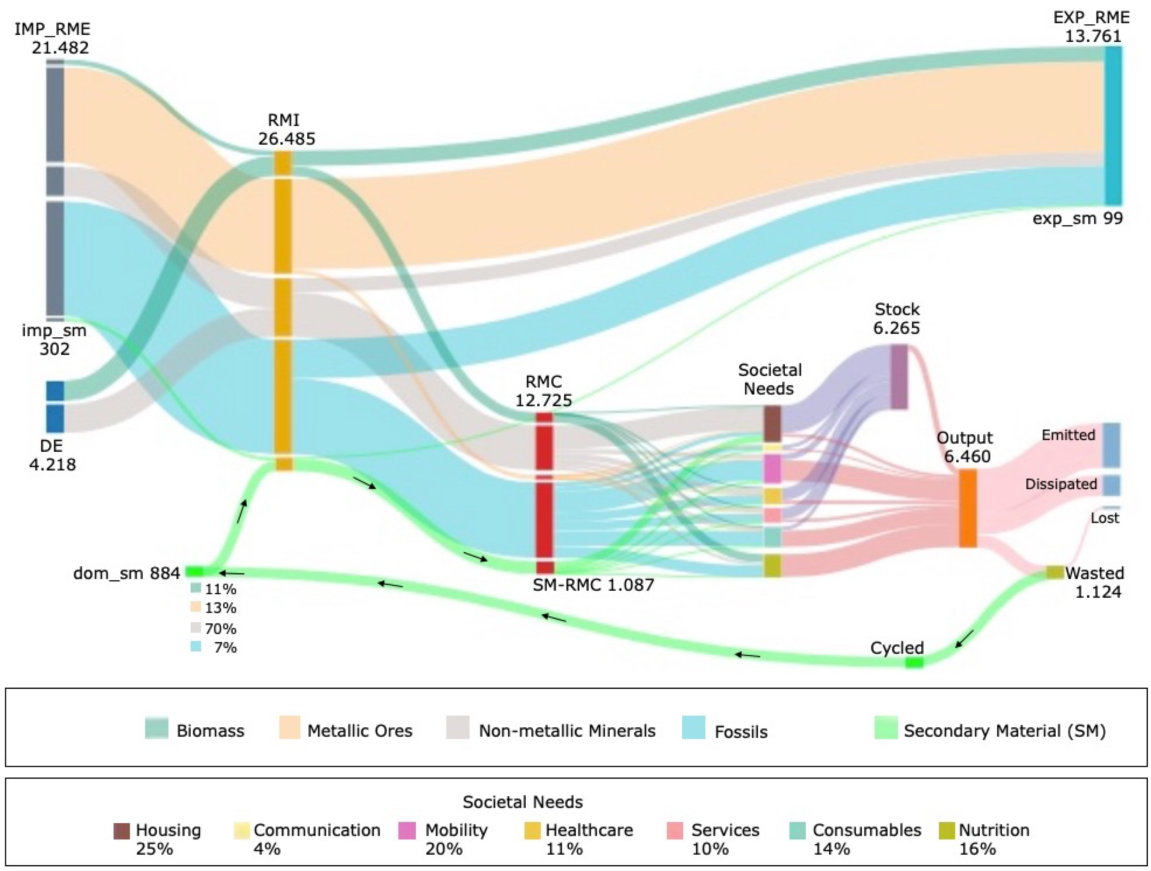

Figure 8. A Sankey diagram of the Icelandic economy. It shows the flow of materials in and out of, and within, the Icelandic economy in the year 2019. In RME the nation imported (IMP_RME) 474kt. of biomass, 8.245kt. of metallic ores, 2.630kt. of non-metallic minerals, and 10.133kt. of fossils. Of the total IMP_RME of 21.482kt., 302kt. is estimated to be secondary materials (imp_sm). Domestic extraction (DE) consisted of 1.729kt. of biomass and 2.489kt. of non-metallic minerals, or 4.218kt. in total. This, along with secondary material (dom–sm) of 884kt. generated from domestic solid waste, resulted in a total raw material input (RMI) of 26.485kt., of which 13.761kt. were exported (EXP_RME). Of the export, 99kt. were secondary materials (exp–sm). The total raw material consumption (RMC) was 12.725kt., of which 1.087kt. was secondary materials (SM-RMC) or 8,5%. The diagram suggests how the RMC, consisting of 7% biomass, 4% ores, 36% minerals, and 53% fossils, flowed into different social needs, and from there into stock (49%) and output (51%), of which 31% was emitted, 11% dissipated, and 9% wasted.

How materials flow through the Icelandic economy, and circle within it, is shown in *Figure 8*. Some main characteristics and peculiarities of the Icelandic economy can be observed in that diagram. Domestic extraction of material resources consists solemnly of biomass and non-metallic minerals, the former consisting almost entirely of wild fish (61%) and fodder crops (38%), and the second of stone, sand, and gravel (95%). This picture, though, does not deliver the full story when it comes to resources, since renewable energy resources —

geothermal and hydropower — are not directly accounted for. Its widespread application for heating and electricity reduces the need for material use, mostly fossils, considerably.

However, the economy still relies heavily on fossil fuels and products made of fossils or produced using fossil fuels, thus making fossil material an enormous share of its material footprint. Fossil fuels are directly required for transportation on land, sea, and air — although renewable energy is gaining ground — and fossils are found in an abundance of things, such as plastic goods, and in the material footprint of things, that the nation requires and consumes. It is therefore the single largest stream of raw materials within the raw material consumption. Of the 10.133 kt. of fossils that flow into the economy in RME, 6.797 kt. are consumed domestically while the rest is required for the export industries and becomes a part of consumption elsewhere. Fossils are 53% of the RMC.

The immense share of the aluminum industry is also apparent. Some 7.438 kt. of bauxite calculated as RME flow into the economy and out of it as aluminum. This material stream is 28% of the total raw material input. However, the share of metallic ores in domestic consumption is small, or 448 kt., which is 4% of the RMC. The share of biomass in the consumption is also interestingly small, or 7%. According to this model, the nation consumes 942 kt. of biomass in raw material equivalents. The second largest stream of 4.538 kt., or 36% of RMC, that enters domestic consumption, after fossils, is non-metallic minerals. The largest portion of that stream consists of domestically extracted stones, sand, and gravel, or 60%, while the rest is mostly sand, gravel, limestone, and gypsum required to produce, presumably, mainly imported building materials.

The total RMC of 12.725 kt. shows the intensity of material consumption in Iceland. Raw material consumption amounts to 34 tons per capita, which makes Iceland a high-consuming nation. High consumption is a large factor in the Circularity Index. One of the ways to increase the index is to decrease the consumption of materials.

5.1.2 The origin and amount of secondary materials

The data reveals that in 2019 the Icelandic economy created 1.123.958 tonnes of solid waste, of which 884.166 tonnes were cycled back for further use. Of this cycled material 99.044 tonnes were exported. It is furthermore assumed that 301.938 tonnes of secondary materials were imported, as a part of the total imports of products that the nation requires. This resulted in 1.087.060 tonnes of secondary materials entering domestic consumption (RMC), as shown in *Table 4*.

While the main emphasis of the Icelandic circular policy seems to be on the recycling of solid waste, and all registered domestically produced secondary material is generated from solid waste, it is apparent that solid waste is the smallest stream of material output. It is estimated that most materials, or 49% of RMC, end up as stock, 31% are emitted, and 11% are dissipated. Around 9% of the material that is consumed annually ends up as solid waste, and only 1% ends up as household solid waste. This study reveals therefore how a circular policy, such as Iceland‘s, which focuses primarily on solid waste management, not least from households, is limited when it comes to implementing a more circular economy. Solid waste is only a small fraction of the whole picture.

Table 4: Secondary materials in Iceland in 2019. The table shows how total solid waste, cycled material, imported cycled material, exported and domestically consumed cycled material, splits into material categories, and the share of each category in the total consumption of secondary materials. Minerals are by far the largest category.

Solid Waste	Total	Cycled	Imported	Exported	Consumed	% of sm consumed
Biomass	272.284	99.246	10.198	26.719	82.725	7,6%
Ores	112.761	111.648	17.341	54.854	74.134	6,8%
Minerals	677.781	614.916	56.534	0	671.450	61,8%
Fossils	61.132	58.356	217.866	17.471	258.752	23,8%
Total	1.123.958	884.166	301.939	99044	1.087.061	100%

The secondary material used within the Icelandic economy is dominated by materials from construction, such as sand, gravel, timber, and asphalt. This is, e.g., reflected by the huge share of minerals in *Table 4*. Construction material represents 52% of all solid waste, and recycled construction waste is 64% of all cycled solid waste. If this material was not reused, the NCI of Iceland would decrease from 8,5% to 4,1%.

Earth minerals (such as stone, sand, and gravel) are the largest single category of secondary materials in Iceland, amounting to 382.138 tons. Chemical waste comes second, with a total of 96.996 tons recycled. Third comes soil, with 81.116 tonnes reused. Most secondary materials, or 60% of the domestically cycled materials, are used again as filling material, for e.g. structural foundations.

It is furthermore remarkable that most of the high-profile, so to speak, recycled materials, such as paper and plastic — very much visible in the public discourse concerning recycling and the circular economy — make up a small portion of the secondary materials, and a lot of it is exported. It does not, therefore, increase the circularity of the Icelandic economy.

A further look at how and what materials are reused in Iceland can be obtained by focusing in more detail on each material category separately. This will be done in the following sections.

5.1.3 Circularity of biomass

The analysis suggests that biomass is 8,8% circular in Iceland. The raw material consumption of biomass in 2019 is estimated at 942 kt. or 2,5 t. per capita. The largest share of biomass is nutrients, but consumables such as clothes and healthcare items, such as medicine, are also made of biomass, as well as building materials such as timber. Of the 272 kt. of biomass that ended up as solid waste, 99 kt. were recycled. Based on export data, it can be observed that approx. 30% of this cycled waste was exported (27 kt). That is mostly paper, or 24 kt, which is exported for recycling elsewhere. The result is that 72 kt. of biomass enters the economy again as secondary material. Of this secondary material, compost is the biggest category with 24 kt consumed, while reused timber (16 kt) and paper that is not exported (18 kt) are also large portions of reused biomass. Furthermore, it is assumed that 10 kt of secondary biomass is imported.

The largest share of biomass in Iceland, in the form of solid waste, is not recycled at all, or 64% of it. The biggest portion of this material is mixed household waste, or 130 kt., which is either landfilled or incinerated. The portion of uncycled biomass increases furthermore when other forms of output are considered. It is estimated that the total output of biomass is 819 kt. If 272 kt., or 33% of it, becomes solid waste it can be assumed that most of the rest is dissipated, or 67%. Those 547 kt of biomass are not recycled but are mostly dissolved into the environment through wastewater.

Based on import data and the share of timber, and other durable materials, in the total number of imported biomass, it can be estimated that approx. 123 kt. of biomass is added to stock.

5.1.4 Circularity of metallic ores

The circular index for metallic ores is 16,6%. Icelanders consumed 448 kt of metals in RME in 2019. Numbers indicate that 112 kt were wasted, while 335 kt was added to stock. Almost all the wasted metal, or 99%, was reused, but only around half of these secondary materials, 57 kt, stayed within the economy. The rest, 55 kt, was exported for consumption elsewhere.

The two biggest portions of secondary materials in this category are unspecified iron waste (78 kt), which can be presumed to originate mostly from constructions, and the metal that is found in used cars (16 kt).

5.1.5 Circularity of non-metallic minerals

Non-metallic minerals are 14,8% circular. The RMC of minerals is estimated as 4.538 kt. of which it is assumed that 3.848 kt., or 85%, are added to stock, such as buildings and roads. While some minerals (13 kt), such as those that are found in fertilizers used in agriculture, are dissipated, the rest of the consumed minerals end up as solid waste. Some 678 kt of non-metallic minerals were registered in Iceland as solid waste in 2019, of which 615 kt, or 91%, were recycled back into the economy. The largest category, as previously discussed, is sand and gravel, of which 382 kt are reused.

5.1.6 Circularity of fossils

Fossil fuels are the largest category of imports in RME, and the circularity index of it is low, or 3,8%. This is because only a fraction of fossils turns into solid waste as an output, available for recycling, such as some form of plastics or rubber. Most of it is emitted. Some products are turned into stock. Of the 61 kt of fossil materials that became registered solid waste, 58 kt were cycled back, with 17 kt of the secondary material exported. All the secondary plastic and rubber is exported, according to the export data. The 40 kt of fossil material that is reused within the Icelandic economy is all asphalt, from road constructions, used again for construction projects.

5.1.7 Distribution of materials into societal needs

The distribution of RMC into seven different societal needs is suggested in this study. The plausibility of this speculative allocation is based on an analysis of the materials that enter the economy, and the likelihood of Iceland being similar to other nations, that have been studied in this respect, in the NCI reports previously discussed. It is thereby assumed that 25% of the RMC goes into housing, 4% into communication, 20% is used for mobility, 11% for healthcare, 10% for services, 14% for consumables, and 16% for nutrition.

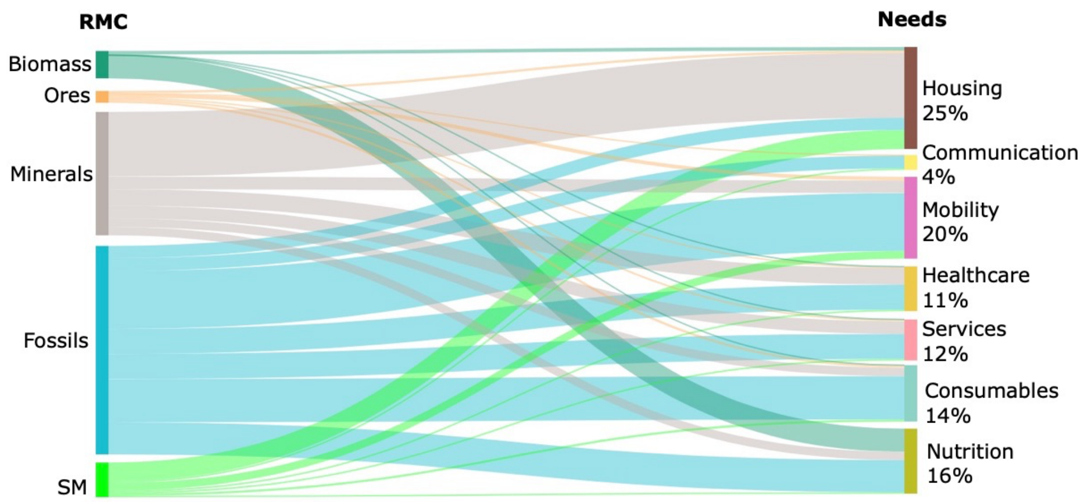

Figure 9. How materials flow into needs. A closer inspection of the Sankey diagram, showing how domestically consumed raw materials, and secondary materials (SM), flow into different categories of social needs.

The construction and maintenance of buildings fall under the category of *housing*. It is assumed that 3.197 kt of materials flow into this category, of which 2.517 kt. are minerals, 458 kt fossils, 133 kt biomass, and 90 kt metal ores.

For *communication*, society requires equipment such as phones and computers. For making those tools, fossil energy and fossil material such as plastics are needed as well as metallic ores. Some 466 kt of materials are ascribed to this category, of which 27 kt are metallic ores and 438 kt are fossils.

Cars, ships, and planes fall under *mobility* together with the energy to power them, and the infrastructure needed. This category is assumed to require 2.565 kt of material, including almost a third of the fossil energy in RME that enters the economy, or 1.861 kt. Furthermore, 126 kt of metals and 578 kt of minerals are assigned to this category.

The share of *healthcare* consists of the need for equipment, medicine, hospital outfitting, and infrastructure. It is assumed that the material footprint of healthcare is mostly comprised of fossils (819 kt), minerals (517 kt) and metals (48 kt) for construction, and biomass (19 kt) for e.g., medicine.

Public and commercial *services*, such as education and banking need materials. It is assumed that the various office equipment and other things required for services leave a material footprint mostly in the form of construction material needed for infrastructure, or 397 kt of minerals, 68 kt of metal ores and 1 kt of biomass, and fossils (819 kt) needed to produce the equipment and supplies.

Within *consumables* fall all kinds of necessities and non-necessities such as clothing, home appliances, cosmetics, toys, and other things that people require for daily life and entertainment. The RMEs required are assumed to be 1.392 kt of fossils, 268 kt of minerals, 87 kt of metals, and 21 kt of biomass.

Food and materials needed for producing food are categorized as *nutrition*. Approx. 80% of the consumed biomass, or 769 kt, is assumed to flow into this category, along with fossil energy (1.008 kt) required for food production and minerals (263 kt) that are e.g., used in fertilizers.

This categorization is hypothetical. However, it does give a rough idea of how materials flow through society. This picture will hopefully be sharpened through further research in the coming years. At this stage, however, it can already be seen how important it is, for instance, to make housing and mobility more circular and/or less dependent on raw material extraction. Also, the suspicion arises, that it might prove difficult to replace or reuse the huge amount of fossil-based material found in every field of society, in things, and in the making of things.

5.1.8 Iceland compared to other nations and the globe

The National Circularity Index of Iceland is in line with the Global Circularity Index of 8,6%. Compared to other countries, Iceland falls in the middle. It is similar to Austria, higher than Norway and Sweden, but is nowhere close to the Netherlands.

Table 5. The NCI of Iceland compared to other countries.

Country	Circularity Index
The Netherlands	24,5%
Austria	9,7%
Iceland	8,5%
Sweden	3,4%
Norway	2,4%

From reading the published NCI reports on those nations that are here compared to Iceland, it is not altogether obvious why their circularity rate is so different. A part of the explanation might be found in variations when it comes to material consumption per capita. According to the report on the Netherlands, the Dutch population has the lowest consumption rate measured in raw material equivalents or 12,8 t per person (Circle Economy, 2020b). All the other nations are higher in consumption. Norway's consumption amounts to 44.3 tonnes per person in RMEs (Circle Economy & Circular Norway, 2020). Norway’s low Circularity Index can partly be attributed to its huge imports of processed products that have a high material footprint, measured in RME. Although recycling is widespread it doesn't seem to be able to catch up with consumption. In the Netherlands, in comparison, recycling is also widespread, but consumption per capita is much lower. This might partially explain the difference between those countries when it comes to their circularity rates.

But how do the other nations fit into this picture? Iceland´s consumption per capita of 33,9 t. is high in this comparison. It is higher than the reported consumption of Sweden, which is 25,6 t. per person (Circle Economy et al., 2022), and Austria's, which is calculated at 23,2 t. per person (Circle Economy, 2019b). Austria has less consumption than Iceland, but a similar Circularity Index. In Sweden, on the other hand, the raw material consumption is also lesser per capita than in Iceland, but the NCI is much lower.

It can be observed that the recycling-consumption ratio is different. In other words, within those nations, recycling is not keeping up with consumption at an equal pace. It seems that Iceland is doing much better than Norway in recycling its domestic raw material consumption, and better than Sweden and Austria also. It is, however, far behind the Netherlands. Differences might be explained by differences in what kind of materials are being cycled in those nations. In the report on the Netherlands, it is observed that a dominant share of the recycled material comes from the construction sector (Circle Economy, 2020b). A low consumption per capita plus a high recycling rate of a materially intensive sector might explain the high NCI of the Netherlands. According to this study, Iceland's circularity is also characterized by a high share of construction materials. Its high consumption of processed products, on the other hand, hinders it from reaching the heights of the Netherlands when it comes to the Circularity Index, but rather drags it down toward neighbouring and high-consuming Norway and Sweden.

Those are speculations. It is difficult to state clearly what factors are at play here, that can explain the differences between those nations. Further studies are required, and NCI reports on more nations for further comparison are needed.

5.2 Pathways to Increased Circularity

As prominent current action plans and suggestions for increasing circularity, such as the EU action plan, show, circularity can only be increased through a diversified strategy, that tackles both the need for materials and how they are disposed of. Products need to be designed in such a way that they can and will be used again, consumers and public buyers need to be empowered so that sustainable products are rather bought, and the refusal, reuse, and repairing of products gets more widespread. The manufacturing of goods needs to be circular so that the goal of zero waste is amplified during production, and circular innovations need to be strengthened. All this applies to Iceland. It is apparent that all kinds of efforts can be made to increase circularity, pertaining to both consumption habits and production methods. Streams can be narrowed, slowed, regenerated, or cycled.

5.2.1 General suggestions for increasing circularity

In the special context of Iceland, some approaches will be more effective than others. Before discussing four focus areas, some general suggestions should be made, in no order of importance.

1) *Circular imports*. Since much of the secondary material is exported from Iceland, it should be made into a public policy to increase the share of imported products that are made with secondary materials. It should be recognized, that since Iceland has a small population, and the market for such secondary products for the domestic manufacturing industry is small, then Iceland needs to systematically import circular products. This kind of scenario is considered in the Circularity Gap Report of Austria. It is pointed out that if Austria's imported goods were three times as circular as the global circular average, the Circularity Index of Austria would increase from 9,7% to 20,1% (Circle Economy, 2019b). This policy would have to rely on internationally recognized certifications for recycled content in products. Those exist. The Global Recycled Standard (GRS), e.g., is used to certify the amount of recycled content in a final product, mostly textiles (Textile Exchange, 2014), and the Forest Stewardship Council operates the FSC Recycled label for certifying that paper and timber products are made from 100% recycled material (FSC, 2022). Several ISO standards also exist concerning recycling, providing guidelines for the proper use of secondary materials (ISO, 2022). Using such standards, and by creating awareness among buyers and sellers of goods, the circularity of the Icelandic economy might be increased and its reliance on primary, raw materials decreased significantly. This could narrow the stream of raw material input from nature into the Icelandic economy.
2) *Circular data*. Improved data should be a priority in Iceland. The material footprint of domestic consumption, by use of the Eurostat RME tool or through other methods, needs to be officially evaluated, regularly updated, and published. Also, data concerning domestic consumption, split into different societal needs, should be offered along with an estimation of how much material is added to stock each year. Furthermore, data-collection concerning different recycling methods and different management of the material output, such as the amount of materials in wastewater, could be strengthened. Some improvements concerning environmental indicators, in general, have been made in Iceland in recent years. In a recent report, a special governmental committee made proposals for adopting 39 new indicators for measuring social, economic, and environmental wellbeing (Government of Iceland, 2019). Statistics Iceland, based on these proposals, now collects data for several environmental indicators, such as the share of renewable energy in the economy, and the annual size in ha of new soil reclamation projects (Statistics Iceland, 2022c). Indicators concerning the recycling of household waste and the total annual amount of such waste are soon to be published (Statistics Iceland, 2022c). The Environment Agency of Iceland, however, operates a database concerning waste management from which such information can be obtained, as has been done for this study (EAI, 2022a), and it also collects and presents other important environmental data, such as by the National Inventory Report (NIR), in which the national emissions of GHG are reported to the European Union and the United Nations Framework Convention on Climate Change. More specific data, however, that directly supports the implementation of the circular economy is lacking, and no such indicators were proposed by the above-mentioned governmental committee. A lot of focus has been put on monitoring the progress of the circular economy within the EU, by using several circular economy indicators published by Eurostat (Eurostat, 2022). Among those indicators are, e.g., the share of secondary materials in total raw material demand and investments in sectors related to the circular economy. Iceland might take part in the development of this framework.

3) *Circular innovation*. Iceland could increase circularity by specifically promoting circular innovation in industries and services. As a large food producer, Iceland could further design methods for efficiency within the food production sector. Production processes, e.g., fisheries and the metal industry, can be designed as zero waste processes. Also, innovations concerning the recycling of other waste streams, emissions, and wastewater, should be promoted and adopted. Waste should be considered a resource. A movement toward this kind of thinking has become increasingly prominent in Iceland in recent years. The Government of Iceland now hands out financial grants — a maximum of 20 million ISK each — to circular projects annually, which includes circular innovations initiatives (Government of Iceland, 2022). This should be boosted. Furthermore, possible European grants for circular innovation, such as through the so-called LIFE program (European Commission, 2022), should be actively promoted and proposals for such grants encouraged. Many foreign platforms and initiatives also exist that are useful both as tools for Icelandic circular innovations and models for further efforts. The Excess Material Exchange, e.g., is a digital matching platform that finds valuable options for the reuse of waste materials, aimed at companies (Excess Materials Exchange, 2022), and in Ontario the local Recycling Council that was established in 1978 has now become the Circular Innovation Council, scouting for opportunities to create value out of waste and offering assistance and consultations for increasing circularity through innovation (Circular Innovation Council, 2022). This might be a model for Iceland.
4) *Circular awareness*. Increasing public awareness is important. Icelanders might introduce and integrate the principles of the circular economy at every school level so that a new generation becomes fully accustomed to considering the circular economy as the new normal. This has happened for instance in Finland, where widespread initiatives have been taken in recent years toward a circular economy based on a comprehensive circular roadmap (Sitra, 2016). One of the most successful actions of the roadmap has been the increased awareness of the circular lifestyle within the education system, creating a new generation that considers circularity to be the new normal (Sitra, 2019).
5) *Circular welfare*. More studies need to be conducted concerning the economic opportunities of the circular approach in Iceland. The possibilities for increasing jobs and enhancing prosperity are a prominent part of both the EU circular action plan as well as the Finish roadmap. Iceland should also map those opportunities. It is estimated that within the EU the number of jobs linked to the circular economy increased by 5% between 2012 and 2018, reaching 4 million in total, and by 2030 the net increase in jobs because of circular activities could reach 700.000 (European Commission, 2020b). It has been asserted — although with no scientific evidence cited — that approx. 9000 jobs in Iceland are lost annually because of wasted opportunities for increasing circularity within the Icelandic economy (KLAK, 2022). This should be further analyzed.
6) *Circular frameworks*. Rules and regulations, taxations, and incentives are important steering tools. Those tools need to support reusing, remanufacturing, sharing, and repairing as well as educational efforts, circular innovations, imports and production of products made of secondary materials, and sustainable consumption and lifestyles. How production and services are subsidized —for instance in agriculture — needs to be redesigned, so that circularity is encouraged. The backbone of the economy, small and medium-sized companies, might need support to go circular in their

manufacturing and services. The new legislation for implementing a more circular economy in Iceland, which will be active from the beginning of 2023, is sharply focused on making recycling easier for households and industries and creating financial incentives as well as extended legal duties for the recycling of materials (Althingi, 2021). That is a good start, and will undoubtedly increase circularity, but a broader scope is needed, with further legislation. The EU Circular Economy Action Plan is a good source for more ideas, with its broad emphasis on, e.g., encouraging circularity already on the design stage of products, empowering consumers and public buyers, and creating a market for secondary materials (European Commission, 2020b).

7) *Circular cooperation*. Governmental bodies, municipalities, academia, businesses, unions, and the public need to be on the same page and share the same vision. The government should consider establishing a special panel or a platform for sharing and strengthening the circular vision, or even a special institution — formed by the cooperation of stakeholders and main drivers — that can oversee the implementation of the circular economy, encourage circular innovation, and practices, and strengthen the coordination. Some initiatives already exist. As previously mentioned, the government does offer grants to circular projects, and the new legislation directly aimed at implementing the circular economy certainly counts as a large leap forward. Also, municipalities in Iceland have started cooperation for empowering this implementation (Icelandic Association of Local Authorities, 2022) and within the Nordic Co-operation, consisting of the Nordic Council and the Nordic Council of Ministers, of which Iceland is a part, a working group for the circular economy is operated (NCE, 2022). Based on such initiatives, and by adopting foreign models, a forceful entity for empowering the circular economy might be established. The monitoring of the circular status of Iceland, through the same or similar method as is used in this study, should be among the many responsibilities of such an entity. A model for this might be found, e.g., in Finland's SITRA, which is a fund that was granted its original capital by the Finnish government and operates independently, promoting the circular economy through various means, with annual returns from that capital (Sitra, 2022).

5.2.2 Four additional focus areas for circularity

This study indicates that the pathway towards a more circular economy in Iceland cannot focus almost solemnly on the recycling of solid waste. The recycling of it, however, does certainly matter for increasing the National Circularity Index. If all of the 133 kt of mixed household waste — of which 97% is currently disposed to landfills or incinerated — would be recycled the NCI would increase by one percentage point, to 9,5%. If all registered solid waste was recycled, and nothing was disposed to landfills or exported, the NCI would be 11%. That, however, is the upper limit of how much the recycling of registered solid waste could increase circularity.

The scope needs to be expanded. The recycling of solid waste has received a fair amount of focus in Iceland when it comes to increasing circularity. Now, four additional important focus areas for such a pathway will be suggested. These are 1) the reduction of fossil fuels through energy shift, refusal, recycling and carbon capturing, 2) a circular stream of biomass, 3) sustainable consumption, and 4) circular constructions. It is estimated how successful actions in those areas could increase the NCI of Iceland in percentage points. The purpose of those estimations, however, is only to give a rough idea of what is possible. Knowing what is possible is important for defining goals.

Reducing the impact of fossils

Around a third of the raw materials consumed in Iceland are emitted. Fossils make up approx. half of all the raw materials that are consumed within the economy. The current Climate Policy of the Icelandic government (Ministry of Environment and Resources, 2020), focusing on reducing the need for fossil fuels and reducing emissions, is, therefore, an important policy for circularity, along with the specifically designed Circular Economy Action Plan (Ministry of Environment and Resources, 2021).

The availability of renewable energy is a core strength of the Icelandic economy from an environmental perspective. In 2020 89,7% of heating and electricity for households and industries in Iceland was provided through renewable energy resources (Statistics Iceland, 2022b). This narrows the flow of material input to the Icelandic economy since otherwise, this energy would have to be provided presumably with fossil fuels. The next step is to shift transportation — a major GHG emitting sector — fully into renewable energy. The technology exists and the change is already happening and can be enforced. Furthermore, the fishing fleet needs to shift to renewable energy, as well as airplanes. If transport on sea, land, and air is decarbonized a huge step is taken toward reducing GHG emissions in Iceland. Road transport alone accounts for approx. third of the total domestic GHG emissions (EAI, 2022b). An energy shift in transport is doable, especially if Icelanders manage to use renewable energy resources to create various types of fossil-free fuel, like electricity, methane, and hydrogen. Each might suit a different sector.

However, the impact of such a shift on the Circularity Index is not huge. According to this study, the total elimination of fossil energy for use in transport, and a total shift into renewables, would increase the National Circularity Index by approx. 1,5 points, to 10% in total. However, in this reality, the stream of materials from nature into the economy would narrow considerably, and the pressure on natural resources diminish. The domestic consumption of materials could decrease by 15%. It needs, however, to be considered that a shift from fossil energy comes also with material costs. The need awakens for different energy production, which requires materials for infrastructure and services.

It is interesting to compare this estimation with the indications of other NCI studies. It is estimated, e.g., that the total banishment of all fossil fuels for transport and machinery, and a shift into renewables, in Austria would increase the National Circularity Index of Austria by only 0,2 points, from 9,7% to 9,9% (Circle Economy, 2019b). The reason for the minimal increase is that apart from the use of fossil fuels for domestic energy in transport and elsewhere, an abundance of imported products is made with the use of fossil fuels. Those products are consumed domestically and make up a huge part of the material footprint of the economy.

Because of their widespread use in not only transportation but in the production of goods, fossils as a type of material are an extremely important focus area for increasing circularity. In a world of no consumption of goods made of, or with, fossils the NCI of Iceland could increase to 18%. This is only to illustrate the impact of fossils on circularity. This is, however, an unrealistic goal since presumably the gigantic amount of fossil material in all kinds of products would have to be replaced with a different kind of material. However, some valuable increase in circularity could be achieved by minimizing the need for such products or replacing the material with either secondary material or, in the case of energy, renewable energy. When it comes to reducing the impact of fossil fuels significantly it is apparent that Iceland is very much dependent upon the success of other nations in reducing the use of fossils, in the production of goods and products that Icelanders consume. The nations of the world are interconnected through trade and consumption. The energy shift of other nations decreases Iceland's material footprint and thereby increases circularity.

From a circular perspective, it should also be noted, that the possibilities for recycling CO_2 emissions, through carbon captive technologies, have increased in recent years. Companies based in Iceland, most notably Carbfix and Climeworks, operating on Hellisheiði, have designed Carbon Capture and USE (CCU) technologies for capturing, using, or storing CO_2 on a large-scale (Carbfix, 2022; Climeworks, 2022). Instead of emitting the CO_2 with dire consequences, the CO_2 is transformed into another form of output that doesn't heat up the atmosphere. This is desirable, but it does not increase circularity since the material is by this method not used again within the economy. However, ways of utilizing captured CO_2 from emissions certainly exist and are constantly in development (Huang & Tan, 2014) . Captured CO_2 can e.g. be used for growing vegetables in greenhouses and for growing microalgae, which could turn into a valuable food source in the near future (Torres-Tiji et al., 2020). This kind of utilization of captured emissions has already started in Iceland (Vaxa, 2022). Captured CO_2 can also be used to make methanol, which can be utilized in the production of fuels, chemicals, and various products. An Icelandic company, Carbon Recycling International, has been turning captured CO_2 into methanol on an industrial scale since 2012. It operates several plants around the globe, that can recycle up to 160.000 tons per year of CO_2 into methanol (CRI, 2022). If 100.000 tons of CO_2 would be recycled annually in Iceland, for any kind of production, the Circularity Index would increase by 0.8 percentage points. This is roughly the same as if all household waste would be recycled.

Recycling carbon dioxide, together with an energy shift towards renewable energy in transport, along with increased recycling of fossil materials and hopefully successful policies for reducing the use of fossils globally could significantly increase the circularity of Iceland — all combined — although a lot of uncertainties are connected to this aim. It is not too optimistic, based on this analysis, to assume that a 3% increase in the National Circularity Index is obtainable through minimizing the impact of fossils with a systematic effort.

Circular biomass

Around 7% of the raw material consumption in Iceland is biomass. Biomass is different from the rest of the materials as it is renewable in essence. A tree dies and another one grows. A person eats a tomato, a tomato grows again. A bird dies in a forest, and its corpse becomes nutrients for other species and the soil.

So why shouldn´t it be reasonable to state that all the biomass that enters Iceland, and is consumed by Icelanders, goes in a circle? That is because the production of biomass, the agricultural methods that are used, is currently leaving the biosystem in worse shape. It is not sustainable. It has been estimated that agriculture, forestry, and other land-use are responsible for 24% of global GHG emissions annually (FAO, 2016) and that it accounts for approx. 70% of water extraction globally, plays an extensive role in water pollution (FAO, 2017) and is a key factor when it comes to soil degradation (Lal, 2015). Furthermore, the use of fertilizers has a damaging effect on ecosystems, and land conversion due to agriculture has led to a large-scale loss of biodiversity (Dudley & Alexander, 2017). In Iceland, massive land erosion has happened on account of agriculture (Arnalds, 2020) and the carbon footprint of Icelandic lamb meat, dairy, and beef production has recently been estimated as among the highest in the world (Arnalds & Gudmundsson, 2020), compared to food production elsewhere.

However, this doesn't have to be this way. Sustainable methods exist in agriculture and regenerative agricultural methods — which may have less environmental impacts or even positive impacts — are gaining support and becoming more widespread (Giller et al., 2021). Some signs indicate that methods in agriculture are improving, with better environmental impacts (OECD, 2022a). There is, to be sure, a long road ahead. Annually the nations of the world spend between 700 to 1000 billion US dollars on agricultural subsidies and supports, while only 1% of this amount is considered to be connected to mitigating environmental impacts in one way or another (Arnalds, 2020). Also, how sustainable agriculture should be defined is not entirely clear — and perhaps never will be, given the wide scope of the issue — and the ideas of how to promote it are accordingly very different (Melchior & Newig, 2021).

However, although hindrances surely exist and global agriculture poses immense and well-documented challenges for the environment, sustainable agriculture — in the sense of being regenerative — can also deliver huge benefits for the environment, in for example mitigating greenhouse gases and in land reclamation, given that the methods are in accordance with environmental standards (FAO, 2021). As stated in a recent report: "Agriculture emits around one quarter of greenhouse gases, but it holds almost half of the solutions to global climate goals" (FAO, 2019, p. 5).

If the biomass consumed in Iceland is provenly produced by sustainable, regenerative, methods, it could be maintained that its consumption is circular. But is this possible and is Iceland on a track towards this?

Carbon-neutral agriculture is a part of the Climate Policy of Iceland and sustainable methods are promoted in both agriculture and fisheries. However, it is not altogether clear whether and how progress toward more sustainability in domestic production of biomass is monitored. This will have to be done, to maintain that its consumption is circular. When it comes to the import of biomass, such as food, efforts need to be made to evaluate the sustainability of those products. This is not impossible. In a recent meta-analysis, data was gathered from over 38 thousand food producers of 40 types of food globally, revealing a huge variety within different categories of environmental impacts of these products (Poore & Nemecek, 2018). Depending on methods and surroundings, the environmental impact of the production, transportation, and consumption of a particular food type can vary up to fiftyfold. This indicates that more sustainable biomass products, with lesser environmental impacts than others, can be systematically targeted and promoted.

On the output end of biomass consumption, further possibilities for recycling also exist. Organic materials in wastewater and solid waste can be made into compost. Nitrogen levels in organic household waste in Iceland have been measured between 1-2% (Jóhannsson et al., 2017). This is sufficient for soil reclamation, which could contribute to carbon capture. Furthermore, it has been estimated that approx 400 tonnes of nitrogen and phosphorus can be recycled from wastewater in Iceland (Gunnarsdóttir et al., 2020).

Possibilities when it comes to circular biomass exist on both ends of the line. If all biomass can be said to be circular — which is surely what is aimed for although perhaps optimistic — the NCI, with everything else unchanged, would increase by 6,5 points, to 15%.

Sustainable consumption

As previously discussed, since a lot of Iceland‘s secondary material, apart from construction materials such as sand, gravel, and asphalt, is exported, an extra effort should be made to secure that imported goods are made of secondary materials. If the smallness of the society doesn‘t allow much recycling for its own use, then it might sound sensible to systematically turn it into a national circularity policy, to let the recycling occur abroad, and then import the secondary material for domestic consumption. This could be done for example through incentives.

While this might be an important part of a national policy for more sustainable material consumption, a strong emphasis should also be made on minimizing the overall consumption of goods and products. As previously discussed, the consumption-based environmental footprint is high in Iceland and material consumption is high per capita (Clarke et al., 2017). Measures for diminishing the overall consumption of goods should be forcefully promoted. Information concerning how durable things are, like electronics and textiles, need to be widely available. Unnecessary packaging needs to diminish. By promoting sharing instead of owning, people should be more able not to own things. Merchants should be required to offer repairs. Products that can be repaired or remanufactured should be labeled and promoted. Canals for remanufacturing and reusing, like marketplaces with used things, should be strengthened. Through such efforts, the stream of materials can both be narrowed and slowed, as well as cycled.

Such policies are an important part of the EU circular action plan. The plan, e.g., emphasizes that a stronger duty for manufacturers to repair their products is an essential part of a circular policy (European Commission, 2020b). In the Netherlands, it is estimated that a stronger repair industry could boost the Circularity Index up 4,5 points, from 24,5% to 29% (Circle Economy, 2020b). In Norway, it is estimated that a more robust repair and recycling industry could increase the NCI from 2,4% to 5,4% (Circle Economy & Circular Norway, 2020).

A lot is at stake here when it comes to increasing circularity. If domestic consumption in Iceland is reduced through these various means by 20% the NCI increases by 2,2 points, to 10,7%, with everything else unchanged. Also, if products made of secondary materials become 10% of all imported materials, the NCI could increase by 8,5 points.

Circular constructions

Since approx. half of all the materials that are consumed in Iceland are added to stock, the circularity of buildings, roads, power plants, and all other sorts of infrastructure is a crucial factor in how circular the society is and can be. Eco-design, by which structures are designed from the start with circularity in mind, should therefore be actively promoted. Of course, only time will tell how circular the current stock is, but current numbers give some reason for optimism. According to the 2019 waste management data, almost all (98%) waste from construction sides and demolishing was reused.

Because waste from construction is such a large share of cycled materials, in Iceland and elsewhere, the reduction of such waste can actually decrease the Circularity Index. Less material would be cycled. In the Netherlands, it is, e.g., estimated that if all buildings were used to their uttermost possibilities, buildings were designed for sharing and multipurpose usage, no buildings were demolished, and no new buildings were constructed, this would decrease the circularity rate from 24,5% to 16%. The material input, however, would decrease dramatically (Circle Economy, 2020b).

That scenario is unrealistic. Although less construction significantly diminishes the pressure on nature´s resources, given the share of the construction industry in material use, it is apparent that nations need infrastructure, roads, and houses. However, to reduce pressure on resources constructions can also be built with the use of secondary materials. The Green Building Council of Iceland, an organization of major public and private drivers of the domestic construction industry, which is part of the World Green Building Council, has published criteria for what counts as circular construction. When rebuilding old constructions at least half of the materials should be cycled and obtained locally. Also, 10% of the materials can be imported secondary material and at least 10% should be material that is reusable. When constructing new buildings, at least 20% should be secondary material and 20% reusable material (Green Building Council Iceland, 2021).

Those are standards created by the construction industry itself, in international cooperation. If those standards are met, the impact on circularity could be significant. It is realistic to assume, based on this study, that if 20% of materials used for stock were secondary materials the National Circularity Index would increase by 10 percentage points.

These evaluations here presented are raw, and they are offered as a perspective on what likely matters most when increasing the NCI of Iceland. Perhaps there is a long way to go, but this overview illustrates nevertheless, that various possibilities do exist for increasing Iceland‘s circularity.

5.3 Limitations of this study

Some limitations of this study should be mentioned. As previously discussed the Eurostat RME tool will need to be adjusted in order to fit Icelandic reality better. However, it has to be kept in mind also that such tools will never give a fully accurate picture of any reality of any nation since they are in essence always models, and will have to be thought of as such. The RME tool, in which the goal is to find raw material equivalents of goods and processes that fit the reality of many different nations simultaneously, will always serve only as an estimation, and that is what this study is: An estimation.

Secondly, it needs to be said that this study does not evaluate different forms of secondary use of materials. There are many ways to recycle or reuse, some better than others, as seen e.g. by the 9 Rs. Burning plastics for energy is perhaps not the ideal secondary use of materials, but it counts if the energy efficiency is high enough. Using the waste management hierarchy it is assumed that all waste that is not landfilled or incinerated with less than 60% energy efficiency, is used again as secondary, cycled material. This is in accordance with the categorization as it appears in the official data. In connection to this, it is also important to keep in mind that the study does not evaluate whether other methods to increase circularity, such as circular design, increasing repairs, sharing, or reduced buying of new products have become more widespread or not. This should however have an impact on the input of materials, and therefore on the total raw material consumption, which is a key number.

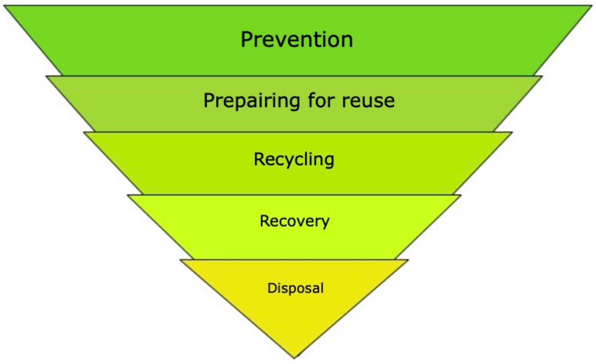

Figure 10. The waste-management hierarchy. This study considers everything above disposal as secondary material.

Thirdly, this analysis is based on the data available. It can be speculated that perhaps more is recycled or reused than the numbers show. Something might be unregistered, and something might not be considered waste management in any strict sense. Farmers use manure for growing, all kinds of things are reused, like furniture and clothes, within families, between friends, or within the unregistered market of used products, and new methods for recycling are being tested and developed without those efforts being accounted for in any records. This study does not attempt to grasp the possible share of this kind of activity, although further possibilities for cycling have been discussed.

Fourthly, the case of biomass needs to be stressed. Since the production of things out of biomass, like food, clothes, and building material, is not generally executed sustainably, as previously discussed, procedures can hardly count as circular. However, regenerative food production, or sustainable production of other kinds of biomass for consumption, surely exists and is perhaps growing — in Iceland and elsewhere — and can serve as a significant method for increasing circularity. This study does not estimate in any way how circular this production already is.

Fifthly, it should be emphasized that the allocation of material consumption into stock and output, and into different societal needs, is not based on official numbers, since such data is not available. Those are estimations, as much based on factual evidence as possible.

6 Conclusion

This study aimed to estimate how circular the Icelandic economy is, by posing the following research question: How circular is the consumption of materials within the Icelandic economy?

The answer is 8,5%. That is the percentage of consumed materials that are secondary or cycled. The Icelandic economy is therefore 8,5% circular, which is akin to the circularity of the globe.

A National Circularity Index of 8,5% means that Iceland is not a circular nation currently. This number means that 91,5% of the domestic consumption is linear. That is Iceland's Circularity Gap. Resources are exploited so that things can be consumed and then disposed of or put into stock. That is the main characteristic of Icelandic consumption as it is.

Along the way toward this conclusion, several discoveries were made, and insights were born. Firstly, it soon became apparent that a lot of data is lacking, concerning the Icelandic economy, domestic consumption, and how materials flow through the society, fulfilling different societal needs. A lot of work is needed for improving this picture. Most important for future circularity studies like this one is to improve the calculation of national imports, consumption, and exports in raw material equivalents with up-to-date numbers for using the Eurostat Country RME tool. Also, further research is needed to establish how accurate this tool is when applied to Iceland and what adjustments are required when using it, so that the material footprint of the Icelandic society is as accurately presented as possible.

The many questions that arose while doing the study should be valuable for future endeavors of this sort. Those questions indicate what pieces of the puzzle are lacking to complete a fuller picture of Icelandic circularity. What is the real share of secondary materials in Icelandic imported products, as opposed to an estimated share? What percentage goes into stock annually? How do the materials fulfill different needs? What is the status of the repairing industry, how much is shared, reused, or remanufactured in Iceland? How circular is the Icelandic production of biomass, given the methods that are used within agriculture and fisheries? How much material in other outputs apart from solid waste — emissions and wastewater — is or could be recycled?

On the other hand, the conclusion of the study, based on the available data, revealed several important aspects of the Icelandic economy when it comes to circularity. Those should be relevant for future decision-making.

The study showed that Icelandic circularity is overwhelmingly marked by the circularity of sand and gravel and other waste from construction, which is reused for construction. This is not peculiar to Iceland. High-profile waste, so to speak, dominant in the public discourse in Iceland concerning the circular economy, such as plastic and paper, is a minor portion of circularity as it is. A lot of that material, furthermore, is exported for recycling elsewhere.

An over-emphasis on the recycling of solid waste, although important, is not the correct pathway, singularly, toward a more circular economy in Iceland. Recycling of solid waste is immensely important, but there is a low upper limit to how much the recycling of all registered solid waste would increase circularity. The focus of the circular policy needs to be wider, with more emphasis on other aspects of the economy, such as reducing and changing overall consumption, shifting into clean energy, promoting regenerative biomass production, recycling other forms of output such as emissions and wastewater, increasing the share of goods made of secondary materials in imports, and increasing circularity in constructions.

Furthermore, public awareness concerning circular consumption habits needs to be increased and the repairing and remanufacturing of products promoted, along with an increase in recycling. The cooperation of relevant parties should also be systematically enhanced and developed, circular innovations empowered and the social and legal framework for circularity strengthened.

Iceland can become more circular. This study suggests that a systemic focus on several important fields of action can increase the Circularity Index substantially.

This is undoubtedly challenging, but possible. A lot is at stake, and a lot of work is needed. When heading somewhere it is always good to know where you are. This thesis gives an idea.

So let’s go.

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