ROCKWOOL GROUP

A Circular Economy Business Model Case

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Executive Summary

This report presents a case study of the ROCKWOOL Group and its circular business model, selected by the R2π project along with 17 other cases, due to its position within the construction and building materials sector, which is one of the priority areas of the European Union's circular economy strategy. The objective of the report is to analyse the contextual and business factors affecting the circular business model, as well as to assess the enablers and barriers to implementing such a model and to provide considerations for both business leaders and policy makers.

The construction industry is a rapidly growing and important sector for future global development and yet is currently one of the most resource-intensive and wasteful, accounting for 25-30% of all waste generated in the EU[1]. ROCKWOOL, as a major global player in the industry, was chosen particularly for its "RockCycle" take-back and recycle programme for building insulation materials.

ROCKWOOL provides customers with fire resilient thermal insulation for buildings and houses. The product is made of a natural stone material and has high fire resistance, good thermal properties, long durability and is fully recyclable. During renovation, old insulation material would typically be considered waste and would be discarded in landfills, however, with the RockCycle programme, it is recovered and recycled.

Today, RockCycle is offered in 5 countries, and the company has set goals to replicate the service to 30 countries by 2030. Currently, it is a small part of ROCKWOOL's business with estimates in Germany of roughly 5% of the volume of flat roof insulation sold during 2017 being recovered and recycled. This is, nevertheless, a significant improvement, as the majority of all companies' used insulation is still sent to landfill.

The take-back programme is characterised primarily by three circular economy business model patterns in different parts of the value chain. At end-of-cycle, the material taken back from customers is "resource recovery", and during production, this is combined also with the "co-product recovery" of secondary materials originating from other products or industries to enter a "re-make" process and recycle them back into new insulation material. This combined circular model results in positive environmental and economic impacts over the typical linear model. Outcomes include: reduced materials ending in landfill, lower consumption of virgin materials, financial benefits to customers, revenue to the company as well as image enhancement for the company.

Such a circular business model benefits from certain **enablers** within in its context:

- Global population growth and urbanisation
- Enhanced climate and environmental awareness
- Increased customer demand for energy efficiency (including energy regulations)
- Stronger waste to landfill reduction targets, rising costs to landfill.

However, some other contextual factors can be seen as **barriers**:

- Negative ecological impact of increased growth
- Inconsistency of regulations between European countries
- Lack of infrastructure for recovery, reuse and recycling activities in many countries
- Lack of separate waste codes for different insulation materials (sorted collection based on waste codes not possible)
- Low landfill fees in many countries and little focus on insulation waste
- Uncertainty over long-term EU policy and circular economy strategy.

[1] European Commission (2018). *Construction and Demolition Waste (CDW).* Retrieved from http://ec.europa.eu/environment/waste/construction_demolition.htm

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The incorporated circular business model patterns are deemed replicable and transferable to other companies and other industries. Therefore, the intention of the conclusion of this report is to offer business leaders and policy makers reflections for further discussion on how to utilise the lessons here in the transition to more circular business models and policies in other areas. These general considerations are from the R2Pi perspective and do not necessarily reflect the opinions of the company.

Key considerations for business leaders

- Investigate the entire value chain for opportunities and efficiencies for total lifecycle value
- Collaborate across companies and even across industries to solve system-level issues
- Design for long life, durability, reparability, reusability and eco-design for lowest possible impact on human and ecological health
- Gain competitive advantage by being first, only, best company providing circular models such as resource recovery, re-use, recondition
- Seek highest level on hierarchy of value retention - first, prevent waste, then, re-use, recycle, recover for other purposes - avoid destruction of the value created and do not allow these investments to end in a landfill or incinerator.

Key considerations for policy makers

- Reduce taxes on labour to enable more labour-intensity for separation, recovery, handling, re-using and re-making to retain value of existing products and materials
- Increase taxes on virgin raw materials to incentivise recovery, repair, re-use, recycling and to ensure pricing reflects total costs of entire lifecycles
- Strengthen eco-design standards and requirements across industries and continue to increase targets and standards for energy efficiency
- Require sustainability and circularity criteria in public procurement to create additional demand for circular products and buildings
- Provide financial incentives for re-use, re-make, re-condition and recycling (e.g. zero or reduced VAT on these products) and to discourage landfilling.

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1 Introduction

1.1 Background and context

R2π – Transition from Linear to Circular is a European Union Horizon 2020 project focused on enabling organisations and their value chains to transition towards a more viable, sustainable and competitive economic model in order to support the European Union's strategy on sustainability and competitiveness.

R2π examines the shift from the broad concept of a Circular Economy (CE) to one of Circular Economy Business Models (CEBM) by tackling market opportunities and failures (businesses, consumers) as well as policy opportunities and failures (assumptions, unintended consequences). Its innovation lies in having a strong business-model focus (including designing transition guidelines) as well as in the role of policy development (including designing policy packages).

The ultimate objective of the R2π project is to accelerate widespread implementation of a circular economy based on successful business models and effective policies:

to ensure sustained economic development,

to minimise environmental impact and

to maximise social welfare.

The mission of the project is therefore to identify and develop sustainable business models and guidelines that will facilitate the circular economy, and to propose policy packages that will support the implementation of these sustainable models.

A core part of this project is to work with organisations who are on the journey towards developing circular economy business models, as well as those who have the ambition to do so but have not yet begun. The project has conducted case studies of 18 selected organisations.

The 18 chosen cases covered all five priority areas highlighted in the EU Action Plan on the Circular Economy[2]: plastics, food waste, biomass/bio-based, important raw materials, and construction & demolition. Additionally, the cases were selected to ensure learning in each of the seven business model patterns defined by the R2Pi project: re-make, re-condition, circular sourcing, co-product recovery, access, performance and resource recovery, and these will be discussed in more detail in this report. To gather wide-ranging lessons from differing company sizes and maturities, the following were selected: 7 large corporations, 8 small, medium enterprises, 1 public entity, 1 entire value chain with both public and private organisations and 1 ongoing social project.

This report presents the case of the ROCKWOOL Group. It was chosen due to its role in the construction sector as a large, global building materials supplier and due to its "RockCycle" circular take back model. The next section provides a more detailed overview of the case organisation's business.

1.2 Business overview

The ROCKWOOL Group is world leader in stone wool solutions covering building insulation, industrial and technical insulation for process industry, marine and offshore, customised solutions for industrial applications, wall and facade systems, acoustic ceilings, horticultural substrate solutions, engineered fibres solutions, noise and vibration control.

[2]https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

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FIGURE 1: LOGO OF ROCKWOOL

Industry: Building materials
Founded: 1909
Headquarters: Hedehusene, Denmark
Area of operation: 45 operating facilities in 39 countries, mainly Europe followed by Russia, North America and Asia. The products are sold in more than 100 countries all over the world.
Products: Stone wool insulation and other stone wool applications
Net sales: € 2.374 billion (2017)
No. of Employees: More than 11,000 (2018)[3]

This case study focuses specifically on ROCKWOOL insulation for buildings. This insulation is a rock-based mineral fibre product comprised of basalt rock and recycled materials. Basalt is a volcanic rock (abundant in the earth, 13% of earth's crust), and slag is a by-product of the steel and copper industry. The minerals are melted at 1,500 °C in a furnace and spun into fibres. Binding material and impregnation oil are added to yield a stabilised and water-repellent insulation product.[4]

FIGURE 2: ROCKWOOL'S INSULATION MATERIAL

Photo: https://brandcommunity.ROCKWOOL.com/bilddatenbank/

History

ROCKWOOL was founded in 1909 as a gravel mining company, and in 1937, it purchased a chipping plant for stone in Hedehusene, Denmark and started producing stone wool through a licence from the United States.

[3]ROCKWOOL International A/S (2017, February). *History.* Retrieved from https://www.ROCKWOOLgroup.com/about-us/
[4] DKG Group (2011, November, 7). *The DKG Group presents ROCKWOOL.* Retrieved from https://www.youtube.com/watch?v=n53Zm1kuMu0&t=472s

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Thereafter, the Company changed its focus to the production of insulation material and made innovative changes in the production process of stone wool. In the upcoming years, ROCKWOOL purchased advanced production licences from a U.S. company and gained efficiency while also improving quality by adding binders.

In the 1950s, ROCKWOOL continued expanding geographically with subsidiaries established in Germany and in Norway. From 1959, ROCKWOOL developed further products based on stone wool such as pipe insulation, acoustic ceilings and stone wool as a growing medium for professional horticulture. In the 1960's, the business expanded also through the acquisition of external production plants and the company shares of other stone wool producers.

In the early 70's, ROCKWOOL realised that old stone wool products could be recycled when ground and mixed into briquettes. This process was included into production in Hedehusene by 1979, and in the upcoming years, the recycling of internal wastes was established and recycling schemes were developed to cover external production and demolition wastes.

The 1970's oil crisis led to an energy efficiency testing project for housing in Denmark. It was shown that the energy use of a house could be reduced to one tenth of contemporary standards by good design, workmanship and insulation. ROCKWOOL was a key contributor to the project.

The 1980's led ROCKWOOL to set new standards in fibre production, and it increased the focus on further innovation which led to more specific applications of stone wool for thermal and noise insulation and fire protection. The same decade brought the establishment of more sales offices and further production companies were established in Canada and the US after the foundation of ROXUL in 1988, which grew to become the largest stone wool producer in North America in the upcoming years.

Demand for thermal insulation began to grow rapidly. In 1996, the company became listed on the Danish stock exchange and continued to expand globally.[5] The Kyoto Protocol in 1997 created global awareness of the importance of significant reductions of energy consumption and CO2 emissions.

In 1988, the International Agency for Research on Cancer (IARC of World Health Organisation) classified all mineral wool fibres as "possibly carcinogenic to humans". The EU followed this classification in 1997, but introduced an exemption for fibres fulfilling one of the criteria listed in Note Q proving their safety[6]. ROCKWOOL adjusted the fibre composition of their material around 1996 to meet these exemption criteria. In 2001, the IARC re-investigated many existing health studies on mineral wool in production and use, and as a consequence assessed all ROCKWOOL's fibres for stone wool insulation materials as free from carcinogenetic effects.

After 2000, ROCKWOOL continued expansion through purchases of insulation businesses in Russia, Australia, Malaysia and Poland and building of new production facilities in Mississippi, Croatia, India and Russia. In 2017, ROCKWOOL celebrated its 80th anniversary in stone wool production.[7]

High-level business model overview

ROCKWOOL provides customers with fire resilient thermal insulation for buildings and houses. The product is a natural insulation material with high fire resistance, good thermal properties, long

[5] ROCKWOOL International A/S (2017, February). *History.* Retrieved from https://www.ROCKWOOLgroup.com/about-us/
[6] CLP Regulation (EC) No 1272/2008.
[7] ROCKWOOL International A/S (2017, February). *History.* Retrieved from https://www.ROCKWOOLgroup.com/about-us/

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durability and is fully recyclable. The insulation material is applied to newly constructed buildings or during the renovation of old buildings.

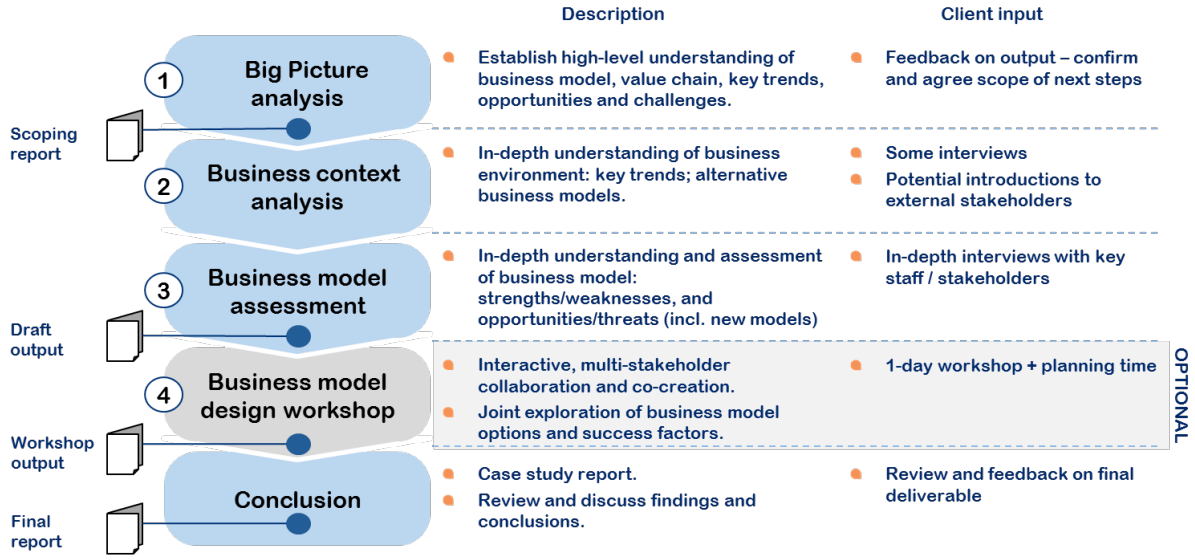
During renovation, old insulation material is typically considered waste and normally ends up in landfills. However, installers can alternatively make use of the "RockCycle" take back program of these materials (if they are stone wool from ROCKWOOL). The RockCycle program differs country by country, based on the local situation. For example, the take back program for flat roof insulation in Germany is offered in combination with delivery of new ROCKWOOL material, so the company makes use of the empty delivery truck runs from the place of delivery (mainly renovation sites) back to their production facilities, where the discarded material is then recycled. The installers pay ROCKWOOL a fee for this take back rather than paying a fee to dispose of the materials in a landfill, so there is a financial incentive as well as the ecological incentive to reduce waste to landfill.

The circular business model "RockCycle" is the primary focus of this case study and will be further described in Chapter 3 below.

1.3 The case study analysis process

The case study process was structured in three main steps, plus an optional workshop, and concludes with this document as the final report (see diagram below). For this case study, factory tours, meetings and interviews were held with multiple ROCKWOOL managers and employees, desktop research was conducted across the entire value chain based on both publicly available information and internal documents provided by the company. The optional business model design workshop was not conducted, due to internal management decisions of ROCKWOOL.

FIGURE 3: CASE STUDY PROCESS



1.4 Report outline

The first chapter introduction has provided a high level overview of the case and case study process. Chapter 2 presents the big picture surrounding the business, showing the context in which it operates and the key external factors. Chapter 3 is an analysis of the business at the building block level of the business model, including the circularity of the business, the financials and the strengths and weaknesses. Chapter 4 draws conclusions about the current state of the business and its future potential.

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2 Business context analysis

2.1 Scope of the business context analysis

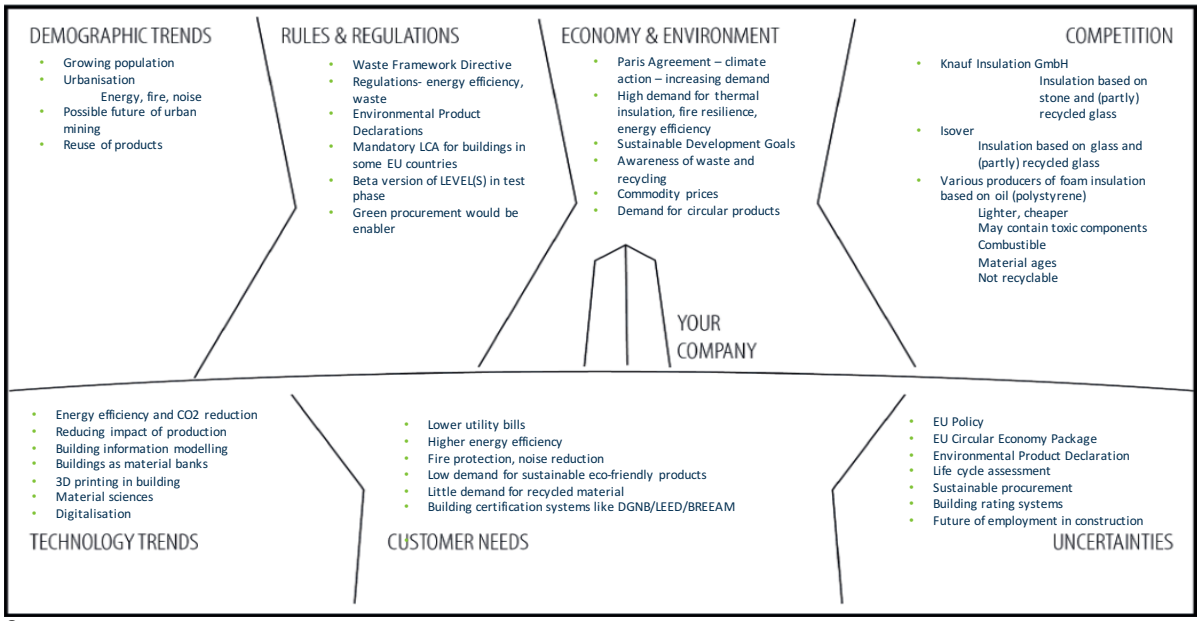
The objective of the context analysis is to identify the main external factors that are to be considered in order to explain the success (or failure) of Circular Economy Business Models (CEBM), as well as their potential role in accelerating the transition towards a Circular Economy.

The business context research was carried out in two stages. In the first stage, the case study team conducted desk research in order to identify the country and sector-specific factors that may potentially affect the business model. In the second stage, the team conducted interviews with relevant key stakeholders of the case organisation.

2.2 Contextual factor analysis

This section identifies the key trends and developments in the business context of building insulation materials in the construction sector and on the dynamics in the value chain of the production, recycling and disposal of mineral-based insulation material. The "Context Map Canvas" was used as a basis for discussion and categorisation of factors (see Figure below).

FIGURE 4: CONTEXT MAP FOR ROCKWOOL



2.2.1 Demographic trends

The increasing global population and ever higher concentrations of people living and working in cities is leading to a much higher demand for infrastructure and buildings, particularly in urban areas. Therefore, planning the supply to meet this growing demand for buildings as living and working places while especially taking into account aspects such as resource efficiency, comfort and affordable prices are becoming key factors in the development of infrastructure for citizens well being. This section explores key demographic factors of:

- Growing population and

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- Urbanisation

that may impact the ROCKWOOL business model through rising demand for renovation, reconstruction and construction of buildings.

2.2.1.1 Growing population

The worldwide growing population, currently numbering 7.6 billion, is estimated to grow to 9.8 billion people by 2050[8]. Additionally, global urbanisation is expected to grow approximately 1.84% per year between 2015 and 2020, 1.63% per year between 2020 and 2025[9]. These are key demographic factors that trigger the need to enlarge city infrastructure and buildings to deliver the necessary living and working space. Even in Europe, the total population of the EU-28 is projected to increase slightly from 505 million currently to 510 million by 2030, also with growing urbanisation[10].

This can be seen as a positive factor for the future growth of the ROCKWOOL Group and its overall sales, however, it presents significant challenges regarding ecological impact and social well-being. In order to grow sustainably, circular business models that reduce waste and reuse and recycle valuable resources will become more necessary. This represents an enabling opportunity for companies to gain competitive advantage through reducing resource costs and developing longer term relationships with customers, thereby meeting society's needs more efficiently.

2.2.1.2 Urbanisation

The world's population is moving inexorably towards the 10 billion mark. This growth will be happening primarily in our cities. The rural population has already stopped growing, but the world's population will add up to 1.5 billion people within the next 15 years[11]. The major move from the countryside into urban areas will evolve even more rapidly in Asia and Africa[12].

The EU-28 currently counts 72.5% of EU inhabitants as living in urban areas, and this is projected to rise to just over 80 % by 2050[13].

Along with the rising demand for buildings in cities, aspects such as the population concentration and the increase of noise pollution requires higher levels of building comfort and safety through sound insulation and fire resilience, as well as energy efficiency through thermal insulation.

Today, cities and urban areas are associated with approximately 70% of total global energy-related carbon dioxide emissions. Cities have a major responsibility in driving climate change mitigation. The awareness of cities on their impact is rising, and solutions and actions towards reduction of green house gas emissions within cities and urban areas are being developed through worldwide alliances[14].

Significant reductions in greenhouse gas (GHG) emissions are expected to be reached through the increase of building standards for new construction, retrofitting building envelopes, upgrading

[8] United Nations (2017, November 28). *World Population 2017*. Retrieved from https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_Wallchart.pdf
[9] World Health Organization (2018). *Global Health Observatory (GHO) data - Urban population growth.* Retrieved from http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/
[10] European Environment Agency (2016). *Population trends 1950 – 2100: globally and within Europe.* Retrieved from https://www.eea.europa.eu/data-and-maps/indicators/total-population-outlook-from-unstat-3/assessment-1
[11] United Nations (2018). *World Urbanization Prospects 2018.* Retrieved from https://esa.un.org/unpd/wup/
[12] United Nations Populations Fund (2018). *Urbanization.* Retrieved from https://www.unfpa.org/urbanization
[13] European Commission (2016). *Urban Europe — statistics on cities, towns and suburbs — patterns of urban and city developments.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs_%E2%80%94_patterns_of_urban_and_city_developments
[14] See https://www.c40.org/

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heating, ventilation, air conditioning and water-heating technology as well as implementing lighting, appliance, and automation improvements[15].

ROCKWOOL sees urbanisation as a key enabler for the demand for non-combustible building insulation products. Stone wool has advantages in fire resilience, thermal protection and noise reduction, and these advantages can be further enhanced by cycling the products in a circular economy business model rather than simply disposing of them as in a linear model. Additional opportunities may be offered by urbanisation in such areas as "urban mining" and "buildings as material banks", which will be further discussed below.

2.2.2 Rules and regulations

The ROCKWOOL Group as an international corporation with activities in more than 100 countries is involved in and affected by numerous international, European and national regulations. The company operates globally, owns physical assets and intellectual property in multiple jurisdictions and is involved in many different contracts on an international and national level. During interviews, the company mentioned its many lobbying activities and involvement in stakeholder conferences on various upcoming European and national legislation issues. In this report, the focus is mainly on:

- Regulations on climate and energy and
- Regulations on waste,

that represent the key enablers and barriers of European and some national policies affecting ROCKWOOL's circular business model.

2.2.2.1 Regulations on climate and energy

The EU 2020 Climate & Energy Package results in binding legislation to set targets to be achieved by 2020. The three key targets are:

- reduction of green house gas emissions by 20% from 1990 levels,
- use of 20% renewable energy inside the EU
- and improvement of energy efficiency by 20%.

The measures for boosting energy efficiency are found in the Energy Efficiency Plan. It contains the Energy Efficiency Directive as a set of rules and obligations for meeting the 2020 targets and measures to make old and new buildings more energy efficient[16].

Energy Efficiency Directive (2012/27/EU)

The Directive (2012/27/EU) establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020 along the whole energy value chain, from production to consumption. Specific measures and policies for member states include 1.5% energy savings per year in energy distribution, the empowerment of energy consumers to manage their consumption, energy audits, procurement of energy efficient buildings, products and services and renovation of 3% (by floor area) of publicly owned or occupied buildings each year. Countries can achieve the energy savings through

[15] McKinsey Center for Business and Environment and C40 Cities (2017, November). *Focused acceleration: A strategic approach to climate action in cities to 2030.* Retrieved from https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/a-strategic-approach-to-climate-action-in-cities-focused-acceleration

[16] European Commission (2018). *2020 climate & energy package.* Retrieved from https://ec.europa.eu/clima/policies/strategies/2020_en

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their own means of favour, for example improving heating systems, installing energy efficient windows or insulating the building envelope. The countries report on their progress annually[17].

In November 2016, a new package of measures to facilitate the clean energy transition was presented. It includes a 30% energy efficiency target for 2030 and measures to update the Energy Efficiency Directive to insure the attainment of the new target.

EU Energy Performance of Buildings Directive

Besides the Energy Efficiency Directive, the Energy Performance of Buildings Directive is the main legislative instrument of the EU to improve energy performance of buildings. They intend to provide a stable environment for investment decisions taken on energy efficiency in buildings.

The current Energy Performance of Buildings Directive defines that all new buildings must be "nearly zero-energy buildings" from 2021 onwards, and for public buildings, this is required from 2019 onwards. The directive requires energy performance certificates for all buildings sold or rented. Each country must set their own minimum energy performance requirements for new buildings, major renovations and replacements of building elements such as roofs, walls and heating or cooling systems. This directive has been further revised to accelerate cost-effective building renovations to reach the goal of a decarbonised building stock by 2050 and to mobilise investments. [18]

Additionally, the EU Commission has published the EU Building Stock Observatory as a database to track the energy performance of buildings in European countries[19]. The Commission also created an initiative on smart finance for smart buildings to release public and private funds for energy efficiency and renewable energy in buildings[20].

These directives can be seen as enablers for ROCKWOOL's general business model and for raising the demand for their insulation products to increase energy efficiency and to enhance the energy performance of buildings. The requirement to renovate and improve efficiency of existing buildings is a potential enabler for the circular business model, offering additional opportunities to take back the discarded stone wool insulation from renovated buildings.

2.2.2.2 Regulations on waste

Waste generation has, thus far, been an ever increasing by-product of economic wealth and growth. This critical link is to be decoupled through regulation on careful material management and conservation of resources. Modern technologies are often seen as enablers for new approaches on the efficient and effective use of materials.

EU Waste Framework Directive 2008/98/EC

The directive is a legal framework on treatment of wastes inside the EU. It strengthens proper waste management, recovery and recycling and reduces pressure on resources and their use. It is designed for protection of the environment and human health. The EU defined the minimum criteria on waste management and treatment for the EU-28 and has applied since December 2008[21]. Some member states have implemented advanced strategies.

[17] European Commission (2018). *Energy Efficiency Directive.* Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
[18] European Commission (2018). *Buildings.* Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[19] European Commission (2018). *EU Building Stock Observatory.* Retrieved from https://ec.europa.eu/energy/en/eubuildings
[20] European Commission (2018). *Smart finance for smart buildings: investing in energy efficiency in buildings.* Retrieved from https://ec.europa.eu/info/news/smart-finance-smart-buildings-investing-energy-efficiency-buildings-2018-feb-07_en
[21] EUR-Lex (2018). *EU waste management law.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:ev0010

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Some key points of the directive are:

- Establishes waste hierarchy: first, prevention, then, re-use, recycling, recovery for other purposes such as energy and lastly, disposal
- Extended producer responsibility, which may include a constraint on manufactures to accept and dispose of products returned by users
- Special conditions apply to hazardous waste, waste oils and bio-waste
- Definition of end-of-waste criteria – expresses the conditions for waste materials to obtain the status of a product or a secondary raw material
- Recycling targets for construction and demolition waste are weight-based with selective sorting requirements for several material fractions (e.g. wood, concrete, ceramics, plaster), however, neither insulation nor stone wool is referred to specifically
- Recycling and recovery targets to be achieved by 2020 for household waste (50% by weight) and construction and demolition waste (70% by weight). [22]

Hazardous wastes

Wastes classified as hazardous require stricter control due to their greater risk for the environment and human health. These wastes are obliged to follow special handling, labelling, record keeping, monitoring and inspection obligations from waste production to final disposal. Mixing of hazardous wastes is banned. The classification into hazardous and non-hazardous waste is based on the system of classification laid down in the Directive's List of Wastes[23].

If insulation waste is classified as non-hazardous (waste code 17 06 04), the Directive allows the mixed collection of insulation wastes, whether they are based on minerals, glass, crude oil or other raw material. Even separately collected fractions are sometimes mixed with other insulation materials. However, all hazardous insulation wastes (waste code 17 06 03*) have to be collected separately and the mixing of hazardous wastes is not allowed.

This is a significant barrier for ROCKWOOL or any company attempting to take back a product or material as they must adhere to different regulations in different countries and situations. Furthermore, it is not guaranteed that stone wool is collected separately. This circumstance makes it much more difficult to take back the stone wool. To improve this condition, there could be a separate European waste code for each insulation material.

Classification of hazardous waste in Germany

In the middle of the 1990s, mineral wool which was not exonerated was classified as potentially cancer causing. Therefore, since 01.06.2000, it is prohibited in Germany to produce or use mineral insulation material which is not approved as defined in the Gefahrstoffverordnung (GefStoffV). Decisive is the bio persistency of the fibres, which depends on the chemical composition and thus solubility behaviour of the fibre dust that could potentially enter the lungs. All German and European producers of mineral wool have developed new fibre compositions and proven them to fulfil the requirements in the GefStoffV and Note Q of the European CLP regulation[24] , with most producers adapting their production around 1996. Therefore, it is common to declare mineral wool produced before 1995 as

[22] European Commission (2016, June 9). *Waste framework directive: Targets and reporting.* Retrieved from http://ec.europa.eu/environment/waste/framework/targets.htm
[23] European Commission (2016, June 9). *Waste: Hazardous waste.* Retrieved from http://ec.europa.eu/environment/waste/hazardous_index.htm
[24] In European reference is the CLP Regulation (EC) No 1272/2008 and Note Q, which states that the classification as a carcinogen need not apply if it can be shown that the substance fulfils certain conditions. These conditions are met by all European manufacturers of mineral wool and controlled by the independent institute EUCEB

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"old" mineral wool and material meeting the requirements of Note Q of the CLP regulation as "new" mineral wool. Even though the WHO/IARC declassified old mineral wool as possibly carcinogenic in 2002, the CLP regulation has not been adopted accordingly, yet.

The Note Q classification applies to Europe. This means that mineral insulation wastes in Europe are classified as hazardous or non-hazardous, depending on age. "Old" stone wool is classified as hazardous, whereas "new" stone wool is non-hazardous. This differentiation is important for the handling (safety-measures during demolition, collection and transportation) and treatment (mandatory melting process of old stone wool to reorganize the fibres) of mineral wool waste. According to the Waste Framework Directive, Member States are allowed to classify hazardous waste as non-hazardous if there are reasons to do so. This is practice in some countries. Different interpretations can complicate cross-border recycling.

Again, the differences in regulations across countries can be a barrier to companies working in multiple countries. In general, the requirement to recover hazardous waste can be seen as positive. Additionally, to melt it, reorganise the fibres and upcycle it to a non-hazardous material offers a market opportunity. However, since this material may be mixed with other types of insulation, it is a barrier to returning it back to its original manufacturer for recycling into their own production. ROCKWOOL, for example, can take back and recycle its own material, due to the chemical composition being suited to its production.

Sorting of wastes

At the EU level, the sorting of insulation wastes differs country by country. Sorting is always driven by the national waste regulations and by economic logic (e.g. metals are always removed before demolition as they have a secondary resale value). Article 10 of the Waste Framework Directive defines, that "waste shall be collected separately if technically, environmentally and economically practicable and shall not be mixed with other waste or other material with different properties". However, these technical, environmental and economical practicability criteria differ by country, and this results in heterogeneous recycling practices - sometimes even within countries.

Denmark and the Netherlands are seen as frontrunners in recycling activities. They apply a principle in their waste policies that any material that is technically and economically feasible to recycle must be recycled and may not be landfilled. In this way, they combine landfill bans and mandatory recycling on the basis of feasibility. Following this principle, it is mandatory to recycle stone wool in Denmark and the Netherlands, which results in better sorting, mostly on-site; no other EU countries demand separate collection on site. Even the municipalities in Denmark are required to have containers for stone wool at recycling facilities as well as at demolition and renovation sites.

ROCKWOOL sees the diversity of sorting regulations as barriers for their business as it means, one, different processes in different countries, and two, decreased opportunities for taking back material in most countries as it is mixed with, and "contaminated" by other materials rather than separated, and three, all regulations are based on weight which make lightweight insulation material a low priority. There is a clear enabler in Denmark and the Netherlands for getting the separated materials back to the corresponding manufacturer.

Waste management in the Netherlands

The Dutch, due to lack of physical space and continuously growing material consumption together with environmental deterioration of land, were forced to take stronger measures to reduce the

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landfilling of waste already in the 1980's [25]. The result is that the amount of waste sent to landfill decreased from 35% in 1985 to 2.3% in 2010[26].

The Netherlands have developed the 2050 Circular Economy Plan, a government-wide programme to move their economy to 100% circular by 2050. It aims at handling all materials more efficiently and moving away from the concept of waste towards all products and materials being considered valuable resources[27]. The Dutch approach is to avoid creating waste as much as possible, to recover usable and valuable materials and, as a last resort, to generate energy by incinerating residual waste.

Landfilling is only allowed for waste streams for which no recovery or incineration is possible. 79% of the Dutch waste is recycled, the remaining wastes are mainly used for energy production. The Dutch banned landfilling any waste streams (currently 35 waste streams) that are suitable for recovery or incineration. Well defined waste treatment standards, planning on a national level in cooperation with local governments, extended producer responsibility (EPR) and intelligent stimulation on prevention and recycling were some of the elements that led the Netherlands towards such a low landfill and high recycling rate [28].

This clearly creates an enabler for circular business models to recover and recycle materials, since it is prohibited to send them to landfill or incineration.

Waste Management in Denmark

The country has a leading role in their landfilling rate (39% in 1985 / 4% in 2014) due to high incineration (26% in 1985 / 36% in 2014). The recycling rate in Denmark increased from 35% to 59% in 2014[29]. Denmark taxes landfilling and incineration of wastes and bans landfilling stone wool as this is a material suitable for recycling [30]. The waste tax gives a financial incentive to shift waste from incineration and landfilling to recycling. The landfill tax and the landfill ban are seen as two of the main drivers for circular economy development in Denmark[31].

Similar to the Netherlands, this combination of taxes and bans in Denmark clearly creates enablers for circular business models to recover and recycle materials.

2.2.3 Economy and environment

The business environment of global players is affected not only by socioeconomic factors like urbanisation, digitalisation and growing population but also by other worldwide economic and environmental trends. In this section, the following trends affecting the business are highlighted and discussed:

- Climate change discourse
- Energy efficiency in buildings
- Sustainable Development Goals

[25] Leonidas Milios, European Environment Agency and ETC/SCP (2013, February). *Municipal waste management in the Netherlands.* https://www.eea.europa.eu/publications/managing-municipal-solid-waste/netherlands-municipal-waste-management
[26] Rijkswaterstaat Environment (2018). *Elements of Dutch waste management.* Retrieved from https://rwsenvironment.eu/subjects/from-waste-resources/elements-dutch-waste/
[27] Government of the Netherlands (2018). *From a linear to a circular economy.* Retrieved from https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy
[28] Rijkswaterstaat Environment (2018). *Elements of Dutch waste management.* Retrieved from https://rwsenvironment.eu/subjects/from-waste-resources/elements-dutch-waste/
[29] Eurostat (2018). *Waste management indicators.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_management_indicators
[30] Danish Ministry of the Environment (2018). *From land filling to recovery – Danish waste management from the 1970s until today.* Retrieved from http://eng.ecoinnovation.dk/media/mst/8051407/Affald_Baggrundsartikel_affald_web_15.01.13.pdf
[31] Dakofa (2018). *Waste regulation in Denmark.* Retrieved from https://dakofa.com/element/test-article-today/

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- Awareness of waste and recycling
- Circular economy
- Urban mining
- Commodity prices.

2.2.3.1 Climate change discourse

Kyoto Protocol

The awareness of and concern for climate issues has grown steadily over the years. One of the key milestones was the Kyoto Protocol, an international treaty signed in 1997 in Kyoto, Japan. Participating states confirmed that global warming was occurring and that is was likely caused by human made CO2 emissions. The participating states agreed on reduction targets for green house gas emissions. The Protocol was also a major milestone in ROCKWOOL's history as it initiated political debates and global awareness on climate change and CO2 emissions. It helped increase demand for building insulation products as the fact that a high share of global energy is consumed through buildings came to light. ROCKWOOL showed that a significant reduction of energy consumption and CO2 emissions could be achieved through thermal insulation and focused their business on energy efficiency.

Paris Climate Agreement

The Conference of Parties (COP) takes place annually in order to discuss global climate efforts. In this regard, in 2015, the COP 21 in Paris is considered a landmark due to the so called Paris Agreement, involving more than 200 countries in the goal to keep global temperatures well below two degrees Celsius above pre-industrial times and to endeavour to limit them even more, to 1.5 degrees. Given this context, the EU has led significant efforts and actions in order to implement its target to reduce emissions by at least 40% by 2030[32].

Therefore, when discussing the reduction of emissions in the EU context, it is significant to consider that buildings are responsible for approximately 40% of energy consumption and 36% of CO2 emissions.[33] To tackle this issue, improving the energy efficiency of buildings and the renovation of existing buildings has the potential to lead to significant energy savings, reduction of CO2 and help achieve climate goals.

According to the UN Environment and International Energy Agency, the energy intensity per square meter of the global buildings sector needs to improve on average by 30% by 2030 (compared to 2015) to be on track to meet global climate ambitions set forth in the Paris Agreement.[34]

On this subject, the European Union set the target to increase Europe's energy efficiency by 20 % by 2020 by improving the energy efficiency of buildings and of a wide array of equipment and household appliances.[35]

Climate and environmental awareness are seen as enablers not only for ROCKWOOL but any company pursuing more sustainable and circular business models.

[32] European Commission (2018). *Paris Agreement.* Retrieved from https://ec.europa.eu/clima/policies/international/negotiations/paris_en
[33] European Commission (2018). *Buildings.* https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[34] UN Environment (2017). *Towards a zero-emission, efficient, and resilient buildings and construction sector - Global Status Report 2017.* Retrieved from http://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf
[35] Eurostat (2017). *Greenhouse gas emission statistics.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

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2.2.3.2 Energy efficiency in buildings

Among the EU's buildings, 35% of them are older than 50 years and 75% of the building stock is energy inefficient. Depending on the country, 0.4 to 1.2% of the building stock is renovated each year. The EU estimates a high potential for reducing total energy consumption by 5-6% through renovation of existing building stock, resulting also in a 5% reduction in CO2 emissions in the EU[36].

ROCKWOOL offers building insulation products worldwide, and the needs for building insulation depend on the climate. Houses have to align with the local climate conditions, and thus differ strongly by region. In warmer regions, houses serve more as a cold storage space during the summers, whereas in colder regions, the houses serve as a heat storage space during the winters. Traditionally, houses in colder regions have thick walls and are thermally insulated to keep them warm during the winter, whereas in warmer regions, they generally have little or no thermal insulation. Today, the thermal insulation of buildings in warmer regions has begun to play a bigger role due air conditioning of buildings and the wish to avoid cooling losses.

The awareness and the desire for greater energy efficiency in buildings is a clear enabler for the insulation business and for circular activities.

2.2.3.3 Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a range of 17 universal goals set by the agreement of 195 countries in 2015 through a United Nations process to provide guidelines and targets for an inclusive and sustainable agenda for future development.

The pillars of the SDGs are comprised of the 5Ps: people, planet, prosperity, partnership and peace. The pillars include areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, among other priorities.

Considering the multi-scalar dimensions and the diversity of contexts of these goals, governments and companies are encouraged to strategically select key goals to be prioritised and embedded in their own agendas.

In the context of ROCKWOOL and the building sector, at least the following four key sustainable development goals are relevant:

- SDG 9 – Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
- SDG 11 – Make cities and human settlements inclusive, safe, resilient and sustainable
- SDG 12 – Ensure sustainable consumption and production patterns
- SDG 13 – Take urgent action to combat climate change and its impacts.

Having a common global vision and agreed goals across public, private and civil society organisations has been highlighted as an enabler by ROCKWOOL for its sustainability activities and for its development of a circular business model.

2.2.3.4 Awareness of waste and recycling

The issues of resource use, excess wastes and the need for recycling has caught the public attention in many ways at least since "The Limits of Growth" in 1972, the first publication of the Club of Rome[37].

[36] European Commission (2018). *Buildings.* Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[37] The Club of Rome (2018). *The limits of growth.* Retrieved from https://www.clubofrome.org/report/the-limits-to-growth/

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Since then, waste management has advanced, mainly driven by regulation, and landfill bans and recycling goals have been pronounced and have continued to develop. The building sector is said to be one of the heaviest resource-consuming sectors, with construction and demolition waste equal to 25-30% of all EU waste generated. This consists of various products and materials, but where many of them could be recycled[38].

Today, overall awareness on the waste problem has reached the mainstream. Lately, the environmental impacts of plastic wastes regularly get broad attention from media and pubic. ROCKWOOL confirmed that the awareness on waste issues have led to increasing demand for materials with recycled content and recyclable materials. The construction sector is, like most industries, still mainly driven by economic decisions though.

The European Thematic Strategy on Prevention and Recycling of Wastes describes key objectives to reduce the overall negative environmental impacts of resource use and insure a higher level of environmental protection through prevention of waste, promotion of re-use, recycling and recovery and establishment of the European recycling society, avoiding waste and using unavoidable waste as a resource whenever possible[39].

The EU Environment Action Programme sets objectives for waste policy in the EU[40]:

- to reduce the amount of waste generated
- to maximise recycling and re-use
- to limit incineration to non-recyclable materials
- to limit landfilling to non-recyclable and non-recoverable waste
- to ensure full implementation of the waste policy targets in all member states.

Today the EU-28 has large differences of awareness across value chains. Leading countries are France, BeNeLux, Germany and the United Kingdom. Eastern Europe and the Mediterranean area are moving more slowly. The trend towards circular products is still new and has not yet reached the mainstream.

These strategies, programs and overall awareness have acted as key enablers for ROCKWOOL to commit to investments in its take-back programme and to set goals to expand this to additional countries. Contextually, this is also an enabler for the entire building materials industry and beyond.

2.2.3.5 Circular economy

Although construction is one of the sectors that most cause the highest impacts on environment - taking into account the estimation that one-third of all global waste is produced in the building sector and most of this waste ends up in landfills[41] - circular and innovative business models in the construction sector have shown that it is feasible to combine the growing demand for materials and new buildings with sustainable value chains.

[38] European Commission (2018). *Construction and Demolition Waste (CDW).* Retrieved from http://ec.europa.eu/environment/waste/construction_demolition.htm
[39] European Commission (2018). *Review of the Thematic Strategy on the prevention and recycling of waste.* Retrieved from http://ec.europa.eu/environment/waste/strategy.htm
[40] European Union (2014). *General Union Environment Action Programme to 2020 - Living well, within the limits of our planet.* Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/1d861dfb-ae0c-4638-83ab-69b234bde376
[41] European Commission (DG ENV) (2011, February). *Service contract on management of construction and demolition waste.* Retrieved from http://ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf

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From the perspective of ROCKWOOL and other businesses that are stakeholders of this project, the circular economy concept has been considered a valuable tool embedding resource efficiency, long term perspectives and sustainable paths into the business agenda of the construction sector.

The Ellen MacArthur Foundation is promoting circularity of materials, and their studies state that the circular economy will cause growth of Gross Domestic Product[42]. "Reuse and high-quality recycling of building components and materials could reduce the need for new materials and decrease construction and demolition waste, if the split incentives created by a fragmented market are addressed. Sharing, multi-purposing and repurposing of buildings furthermore could reduce the demand for new buildings through better utilisation of existing floor space." The annual potential unlocked by 2035 for these opportunities are estimated to be between 400-600 million Euros in Denmark alone[43].

The German Sustainable Building Council (DGNB) certifies buildings which demonstrate a commitment to sustainability objectives. The council has begun to develop a rating system and guideline on the circularity of buildings following the principles of cradle-to-cradle, including a new rating system for demolishing buildings. It is the first system that measures and evaluates circular economy in the building sector. The DGNB system is a market leader in Germany, and not only prestige objects like corporate head offices use such rating systems, but also other building owners make use of these circularity principles.

The 2 largest global sustainable building rating schemes are LEED and BREEAM. Although they assess several waste and resource related aspects and reward recycled content, there is no specific focus on Circular Economy as such.

The concept of circular economy has gained substantial publicity and acceptance and has moved organisations and companies to set new standards, promote new practices and seek better solutions. This has been partly positive for ROCKWOOL and others in the construction sector, yet they are concerned that this might only be a temporary strategy or "flavour of the month" causing a risk for longer term activities.

2.2.3.6 Urban mining

Over the centuries, a massive amount of materials in the built environment such as infrastructure and buildings have been accumulated around the world. These anthropologic material stocks have a high potential to be future sources of secondary materials as they reach their end-of-use status. Urban mining is an approach to recover stocks from existing buildings, make use of these materials and long life products and to decrease the environmental impact of raw material mining and building material wastes. The "mined" materials can either be re-used in similar product applications or enter the secondary materials market to supply production. Landfill mining can be seen as a special discipline of urban mining.

In Vienna, Austria for example, the BauKarussell is already practicing urban mining and is one of the first dismantling organisations focusing especially on re-use of high volumes of building materials. Re-useable components and materials are dismantled and offered to the building market, while recyclable materials are identified, manually separated and directed towards material recycling. The work is executed by social service providers, who educate workers and provide qualification

[42] Ellen MacArthur Foundation (2015). *Growth within: A circular economy vision for a competitive Europe.* Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf
[43] Ellen MacArthur Foundation (2015, November). *Potential for Denmark as a circular economy – A case study from: Delivering the circular economy – A toolkit for policy makers.* Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/20151113_DenmarkCaseStudy_FINALv02.pdf

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opportunities to gain value for the job market. The project is publicly funded, but it demonstrates opportunities, through intelligent dismantling to reuse high volumes of building materials. For example, insulation materials have been recovered in the dismantling of a Coca-Cola factory, and this recovered insulation was then re-used in the Biotope City Quartiers, a building constructed on the same site. The re-use potential in the construction sector in Austria is estimated to be up to 10% by mass, and similar approaches are happening in Switzerland, Belgium, Germany and the Netherlands[44].

Urban mining is clearly not yet a trend, but it represents a new area of opportunity for innovative companies and those who understand the concepts of circular business models. It is not currently an enabler for ROCKWOOL or others in the sector but points to a massive potential of valuable products and material stocks in the built environment as well as offering ideas and examples of how to access that value.

2.2.3.7 Commodity prices

The report "Resource Revolution: Meeting the World's Energy, Materials, Food, and Water Needs" by the McKinsey Global Institute explores the challenge of providing resources to a rapidly expanding world population.

The report depicts the price decline of key resources (energy, food, agricultural materials, metals) seen in the 20th century followed by a sharp increase since the year 2000. The volatility of resource prices was also increasing until 2010, when companies and governments began to realise the diminishing guarantee of cheap supply and energy and that new business models needed to be considered. From 2010, the volatility of the key resource prices seemed to decrease even as the general price level continued to increase.

[44] RepaNet (2018). BauKarussell – Beschäftigung & Kreislaufwirtschaft. Retrieved from http://www.repanet.at/baukarussell/#ErsteBauabwicklung

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FIGURE 5: COMMODITY PRICES OF ENERGY, FOOD, AGRICULTURAL MATERIALS, METALS

Two approaches to solving this resource challenge are proposed in the report:

- Expand the supply of resources available, or
- Use our current resources in a more effective and productive way.

The first approach is classified as not viable due to political and practical difficulties, "*supply chain bottlenecks*", missing infrastructure and further negative environmental impact. The report concluded that the resource productivity approach is more viable and could satisfy 30% of demand by 2030, while at the same time generating up to 25 million new jobs[45].

The price volatility and general increase represent significant risks and barriers to traditional linear business models. Consequently, the proposed solution of resource efficiency and productivity are clear enablers for circular business models. In the case of ROCKWOOL, the main raw material is stone, e.g. basalt, and is not represented in the above study, yet, the concept of resource productivity is a key part of the ROCKWOOL business model.

2.2.4 Competition

In the European market, a small number of major companies are competing with ROCKWOOL in the building insulation market. Knauf Insulation and Isover are identified as major competitors in Europe. ROCKWOOL dominates the market of stone wool insulation material. However, the insulation market

[45] Ellen MacArthur Foundation (2018). *Case studies – Data-backed stories that drive change.* Retrieved from https://www.ellenmacarthurfoundation.org/case-studies/data-backed-stories-that-drive-change

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is also influenced by various producers of oil based insulation material. This section describes some of the major competitors of ROCKWOOL:

- Knauf Insulation
- Isover
- Producers of polystyrene-based insulation

2.2.4.1 Knauf Insulation

The company was founded in 1978 in the USA as a producer of glass fibre insulation and expanded quickly in the USA. Since 2001, it is also producing in Europe, and since 2005, also producing insulation materials based on minerals and wood. The company today is still family owned, has 40 production plants, more than 5,000 employees in 15 countries and creates a revenue of 1.6 billion Euro worldwide.[46]

Knauf Insulation produces insulation based on stone, glass and wood. The company advertises with the natural properties of their product and mention their continuous work on energy and resource efficiency as their task to minimise their environmental footprint. The company states that the energy used for production of their products has the biggest influence on their consumption of resources.

The company also uses secondary materials in production, for example recycled glass and steel slag. It reports that a plant in Slovenia, for example, is reincorporating up to 7% of rock mineral wool trim coming back from customers' manufacturing sites. In Germany, off-cut material from production are also used as secondary materials. Knauf further mentions a focus on reducing water consumption and other production wastes.

Glass mineral wool is made with up to 80% recycled glass, while their rock mineral wool contains recycled steel slag. The company is committed to *"having zero negative impact on resource use"* and states that they are on target to produce zero waste from manufacturing sites to landfill by 2020. The company has already reached their 2020 goal on reduction of discharge of water by 50%, and has achieved a decrease of production waste by 54.8% compared to 2010[47]. The company publishes a sustainability report on a yearly base[48].

2.2.4.2 Isover

The company is now a subsidiary of Saint-Gobain but was founded in 1878 in Germany. It owns 4 production facilities in Germany and has around 1100 employees. The company is a manufacturer of fire resilient insulation materials with products made of glass, stone and polystyrene. Their insulation products and systems are applied for heat insulation, noise reduction and fire protection. In 2016, the company generated a revenue of 359 million Euros[49].

Isover partly uses recycled glass and minerals in their production. 95% of the glass wool product consists of recycled materials such as recycled glass. The company produces in a closed water circle, and the other manufacturing wastes are led directly back into the production process. Isover products are either recyclable or allowed to be sent to landfill like other mineral-based insulation. In packaging, the company is cooperating with Interseroh AG (zero-waste-solutions) to reduce its packaging waste

[46] Knauf Insulation (2018). *Über uns.* Retrieved from https://www.knaufinsulation.de/ueber-uns
[47] Knauf Insulation (2018). *Insulation matters – Knauf insulation sustainability report 2017.* Retrieved from https://pim.knaufinsulation.com/files/download/knauf_insulation_sustainability_report_2017__28de_version_29_5a9e5ac6920d8.pdf?_ga=2.266474958.1713894341.1533119644-1984873393.1523539095
[48] Knauf Insulation (2018). *Nachhaltigkeit ist unsere Verantwortung.* Retrieved from https://www.knaufinsulation.de/ueber-uns/nachhaltigkeit
[49] Saint-Gobain Isover G+H AG (2018). *Isover in Zahlen.* Retrieved from http://www.isover.de/unternehmen/isover-zahlen

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(ROCKWOOL also cooperates with Interseroh on waste solutions). Isover does not publish a sustainability report.

2.2.4.3 Producers of polystyrene-based insulation

In 1949, expanded polystyrene (EPS) was discovered, based on crude oil and a chemical process using pentane to create a polymer with suitable thermal properties to be used as foam insulation. When polystyrene is heated with steam it expands in volume and can consist of up to 98% air and 2% polystyrene.

When polystyrene is used as a base for construction products, it is usually combined with chemical flame-retardants. One example is hexabromocyclododecane (HBCD), which is toxic, bio-persistent, bio-accumulative and already widely spread. The flame-retardant was used in insulation materials for many years and is still prevalent in waste from buildings; it can even be found in wildlife in the arctic region[50]. Since August 2015, HBCD is banned worldwide. The flame-retardant PolyFR is today seen as the more environmentally friendly alternative to HBCD[51].

Various producers of foam insulation are active on the European market and compete with ROCKWOOL in insulation materials for buildings. The oil based insulation materials have very different properties than stone wool, especially when considering the waste management and recycling. “Due to the poor effectiveness of the purification in existing processes and the poor economic viability, high quality recyclates cannot be produced from contaminated EPS waste. For that reason, the main fraction of the waste is incinerated with energy recovery. Only small amounts are processed into milled products for floor levelling compounds and insulation bricks or into polystyrene recyclates for injection molding”; also the use of flame-retardants in EPS demands special disposal[52].

The industry is working on processes that enable virgin quality re-expandable polystyrene to be produced from contaminated EPS[53]. Today, foam insulation materials do undergo mainly incineration. Unlike stone wool, the material ages and is commonly applied by gluing in construction, which also makes it difficult to dismantle, recover and recycle.

Compared to mineral wool, EPS has an even lower bulk density, is able to create better thermal insulation properties and is generally cheaper. Polystyrene-based materials are, however, combustible and are then combined with sometimes toxic, bio-persistent, bio-accumulative flame-retardants when applied to construction, as mentioned above. Especially the flame-retardants in the existing stock make polystyrene based materials less suitable for recycling than mineral based insulation.

For ROCKWOOL and its circular business model, the competitors do not seem to represent either an enabler or a barrier. Most players in building insulation are working to some extent on sustainability, resource productivity and recyclability, however, no other companies have been identified who are operating a circular take-back programme similar to ROCKWOOL. This offers potential competitive advantage and a unique selling proposition for the model.

50 https://www.umweltbundesamt.de/service/uba-fragen/welche-negativen-eigenschaften-hat-hbcd-fuer-umwelt

51 https://www.energieheld.de/blog/weltweites-verbot-des-flammschutzmittels-hbcd/

52 https://www.ivv.fraunhofer.de/en/forschung/verfahrensentwicklung-polymer-recycling/recycling-eps-abfall.html

53 https://www.ivv.fraunhofer.de/en/forschung/verfahrensentwicklung-polymer-recycling/recycling-eps-abfall.html

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2.2.5 Technology trends

As overall requirements, energy efficiency, material productivity and other needs are identified, technology and digitalisation may create enabling tools for different ideas, practices and concepts. These can lead to more detailed planning, modelling, three dimensional (3D) design and new ways of data interaction. This section describes some technology trends in the construction sector:

- Building information modelling
- Building as material banks
- 3D printing
- Communication opportunities through digitalisation

2.2.5.1 Building Information Modelling (BIM)

Building Information Modelling (BIM) is an approach to design the whole building in a 3D-model, where all elements of the different planners (architecture, static, technical installation, furniture, et al) are joined together within the model. The model shows spatial collisions between the elements in the building before it is constructed. BIM delivers visual support and data for decision making processes during the planning of a building. It is mainly a tool interesting for planners and architects leading towards more detailed planning, which can result in fewer mistakes during the construction phase and higher material efficiency.

It is currently not clear what the impact of this may be on ROCKWOOL or other circular business models, however, it may offer opportunities for creating and testing more circular designs. ROCKWOOL mentions that mainly architects currently seem interested in circularity, much more than their other customer groups, and thus, new methods of design may bring new possibilities for circular construction.

2.2.5.2 Building as Material Banks (BAMB)

In the Project BAMB – Buildings as Material Banks, 15 partners from 7 European countries are working on circular solutions for the building sector. BAMB is looking for ways to increase the value of building materials resulting in less waste at the end-of-use phase. The idea is to give buildings the function as depositories of valuable materials, which will be maintained and reused in later stages rather than being treated as waste and discarded. Key tools for enabling BAMB are Materials Passports and Reversible Building Design to ensure the contents of the material bank are both known and able to be recovered later.

ROCKWOOL sees BAMB as increasing in importance for the future and are thinking of possible opportunities in this area. Combined with urban mining above, in the future, building materials may be far easier to track, dismantle, recover and re-use than they are today.

2.2.5.3 3D Printing

According to industry experts, it is likely that 3D printing of building components will be technically and economically feasible in the near future. Labour savings, material savings and positive environmental impact are predicted when managed properly[54].

The approach is still at an early stage, and the impact of the technology on building insulation can not be foreseen at this stage. However, innovative companies will certainly be developing new products and testing new materials, and one can imagine some type of insulation being 3D printed in the future.

[54] https://www.ellenmacarthurfoundation.org/assets/downloads/20151113_DenmarkCaseStudy_FINALv02.pdf

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2.2.5.4 Communication opportunities through digitalisation

Digitalisation is already leading to new communication platforms where, e.g., best practices are shared and new ideas gain wide outreach. The new possibilities in data tracking and communication enable the connection of specific needs with offers and can, for example, utilise matchmaking portals to facilitate previously difficult or expensive transactions. Quick ways of connecting people and second-hand goods for the mass market through exchange platforms are already available, and such platforms for the construction industry can be anticipated.

This trend of digital communication and data exchange has already revolutionised multiple industries but has not yet increased the re-use of building materials. The near future may see new opportunities emerge such as platforms to find and trade used building materials or to separately collect dismantled materials for recycling. Such opportunities will be seized by companies who are motivated enough to recognise new models and flexible enough to implement them.

2.2.6 Customer needs

The customers of building insulation products are primarily interested in energy efficiency and the corresponding lowered costs for heating and air conditioning. Additionally, they are concerned about the fire protection and noise reduction benefits of the material. In recent years, ROCKWOOL has noticed only a slight increase in the call for more sustainable and eco-friendly products, with this generally coming only from some architects and builders interested in meeting special building certification criteria.

The customer need for energy efficiency and lower utility costs is a clear enabler for insulation products. However, there is currently no significant increase in customer demand for return or recyclability of these building materials. In the special case of Germany, there was an increased demand for convenient disposal of roofing insulation, which sparked ROCKWOOL to create the RockCycle programme, and this will be explained in the business model chapter.

2.2.7 Uncertainties

In addition to general uncertainty over the future of EU policy and circular economy strategy, various factors have been identified as currently unclear but with a potential impact on the future success of circular business models and these are described below.

2.2.7.1 Environmental Product Declaration

The Environmental Product Declaration (EPD) declares the environmental performance of the whole life cycle of products and provides data for building design and assessments. EPD started in 1991 and is still an ongoing process with current amendments intended to better align with the European Product Environmental Footprint policy. EPDs deliver important product data for consumers which could influence the market and become enablers for more sustainable products with lower environmental impact.

2.2.7.2 Life Cycle Assessment (LCA)

LCA has become mandatory in some European countries before a building can be designed and built. Assessing the entire life cycle environmental impacts is important in long-term decision making. The leading countries are the Netherlands, Belgium, France, Finland, Germany. Eastern and Southern Europe currently show less interest in this area. Since LCAs are very time intensive, it highly depends on policies and regulations whether LCA will gain further importance in Europe.

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2.2.7.3 Sustainable procurement (public and private)

Public and private procurement plays an important role in the construction sector - "Construction is very conservative - a change will only happen when it is asked for". ROCKWOOL hopes for the implementation of more sustainable procurement systems in Europe. It evaluates the Netherlands, Germany and Finland as front runners in sustainable public procurement for the construction sector. The Netherlands applies green public procurement criteria for buildings and infrastructure. Germany requires the application of the BNB system (Bewertungssystem für Nachhaltiges Bauen) for rating the sustainability of public buildings. Also the demand for DGNB certified buildings is increasing in the German private sector. Finland has started an ambitious circular economy programme in November 2017 which set special requirements for sustainable procurement[55].

2.2.7.4 Building rating systems

The inclusion of rating and certification systems in designing, planning and construction of buildings, such as LEED, BREEAM, DGNB, support the demand for sustainable and eco-friendly products. However, the quality and long-term application of standardisation in buildings is still uncertain. The verification process is executed through auditors, who sometimes interpret rules and criteria differently, which can harm the reputation of such systems and lead to lack of trust in them. It is also unclear whether such certifications lead to increased market value.

2.2.7.5 Future of employment in the construction sector

ROCKWOOL has observed a trend towards lower educated workers in the European construction sector. In Germany for example, public tender processes (with exceptions) require the best price-performance ratio to be awarded the contract, and this leads to a high focus on cost reductions in the labour-intensive sector. The demand for inexpensive labour work pushes construction companies often towards subcontracting firms from countries with lower wages, which leads towards lower quality in the product (building). Also, little awareness of sustainability or waste reduction is cultivated among these less educated workers.

Furthermore, digitalisation and high tech products are finding their way into the construction sector. Some examples are exoskeletons for construction workers, which could make the sector more attractive for physically weaker people[56], or 3D-printing of buildings, where robots execute the physical processes of building and reduce the need for human labour. Such technologies are still in testing, but may be influencing the work environment of the construction sector in the near future.

On the other hand, urban mining may become more important in coming years and could require an increase in the amount of human labour and expertise in specialised areas. In Austria for example, the BauKarussell is developing as the a dismantling company focusing especially on the re-use of existing materials[57].

Predictions in a certain direction on all of the topics in this section can not be made at this time and therefore represent both risks and opportunities for those seeking to invest in circular solutions.

55 https://www.sitra.fi/en/projects/leading-the-cycle-finnish-road-map-to-a-circular-economy-2016-2025/

56 https://www.wired.com/2015/04/try-new-exoskeleton-construction-workers/

57 http://www.repanet.at/baukarussell/

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3 Business model assessment

The business model assessment has been conducted through a combination of publicly available information, interviews with employees and stakeholders of the case organisation and documents provided by the organisation.

The objectives are to gain a deeper understanding of the circular business model and to map out the value chain and interactions in more detail in order to enable an analysis of the strengths and weaknesses as well as to consider the replicability and transferability of such a model to other entities and sectors.

In this chapter, ROCKWOOL's business model and its value chain are described. Thereafter, the circularity is assessed with its financial and nonfinancial outcomes along with the strengths, weaknesses, opportunities and threats associated with the circular business model. Lastly, final assessments and considerations for the company are discussed.

3.1 The business model

3.1.1 Business model overview

ROCKWOOL provides customers with insulation for buildings and houses. The product is made from a natural stone material and has excellent thermal, fire resistance and noise reduction properties, and it is long-lasting and fully recyclable. During renovation, old insulation material would typically be considered waste and would be discarded in landfills, however, with the RockCycle programme, it is recovered and recycled. This circular take-back model has proven economically and environmentally viable and is currently available in Denmark, Netherlands, Belgium, Luxembourg and Germany. Today, it is a small part of ROCKWOOL's business with estimates in Germany of roughly 5% of the volume of flat roof insulation sold during 2017 being recovered and recycled. This is, nevertheless, a significant improvement over the norm, as the majority of all companies' used insulation is still sent to landfill.

For more than 20 years in Denmark, the company has taken back material from construction sites, and in 2012, this was extended to also take back from renovation and demolition sites. In an example in Germany, a key issue was raised by installers who renovated large commercial buildings. They had a problem that they should dispose of large amounts of used insulation when renovating a roof, but landfill operators were reluctant to take so much material at one time. Therefore, ROCKWOOL agreed to take back this insulation for recycling, and has since further developed and will expand the programme So, a key enabler came not from a sustainability wish or a regulatory requirement but from a customer problem, which was resolved with a circular solution.

In the Netherlands, there was a similar development. ROCKWOOL was able to recycle stone wool at the end of the last century, and the take back of construction waste has been offered since the early 2000s. An even more pro-active approach was taken in the same period in the Danish programme by offering take-back of both construction and demolition wastes and by cooperating on a structural basis with waste management company RENEWI.

DEPICTING THE BUSINESS MODEL

In order to gather knowledge and understanding on ROCKWOOL's business, the business model canvas framework is applied, which structures the business model into 9 different elements. Each of these have been discussed with ROCKWOOL and are described below.

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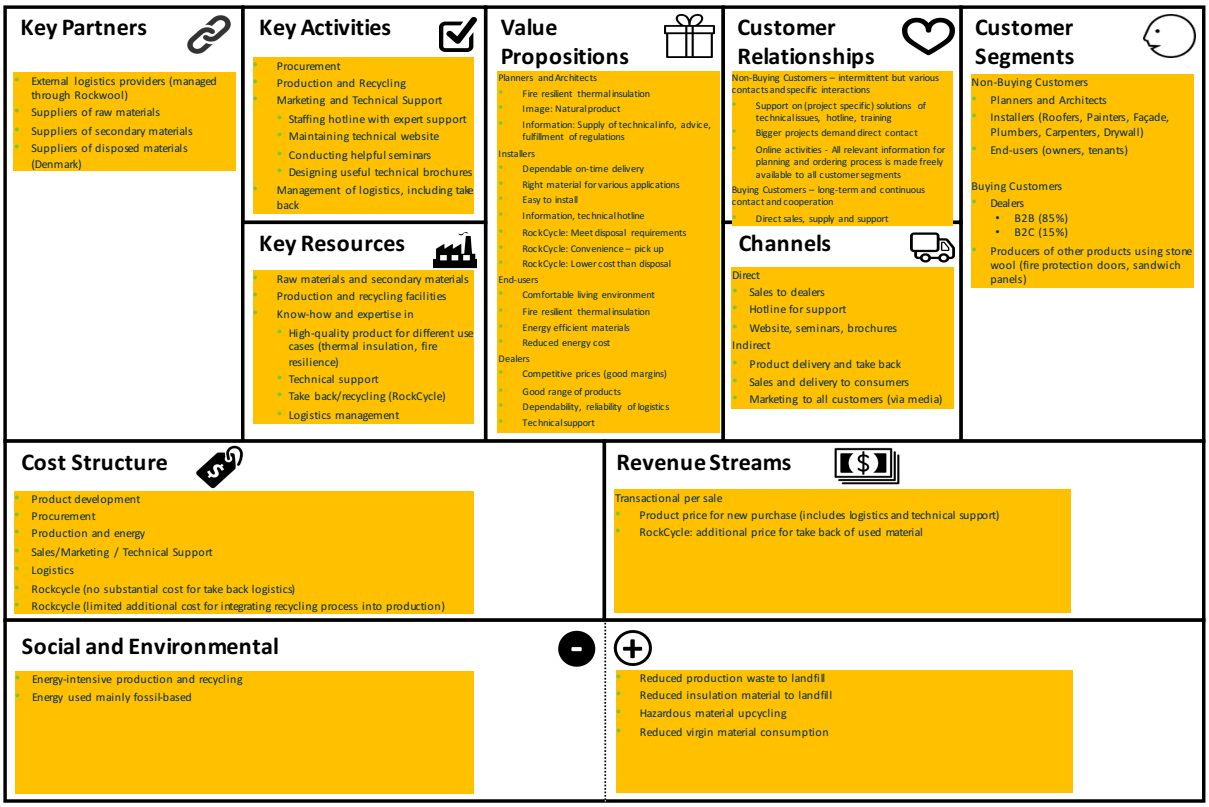
FIGURE 6: BUSINESS MODEL CANVAS OF ROCKWOOL



3.1.1.1 Customer Segments

ROCKWOOL distinguishes between buying and non-buying customers. The dealers (building material wholesalers, do-it-yourself stores) as well as component manufacturers are the buying customer segment. The planners, architects, installers, building owners and users belong to the non-buying customer segment. These non-buying customers are generally the decision makers in the selection of insulation material, but do not have any direct financial value exchange with ROCKWOOL, since the majority of all purchases are handled through the dealers. ROCKWOOL, therefore, must meet the needs of both of these segments.

Non-buying customers

Planners and architects

Planners and architects are major decision makers in the building sector. Planners are always involved in new buildings and are often decision makers in the renovation of existing building stock. They define material specifications in their tenders based upon what architects have created in the building design. Their key needs are:

- To satisfy end users
- Information on regulations to ensure conformity
- Information on available building materials and their properties
- *Sometimes* fulfilment of certification criteria (may include circularity)
- (Currently, no major demand for return-ability or recyclability of materials).

Installers (roofers, drywall builders, facade installers, et al)

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The installers of insulation material are the ones choosing exactly which product to purchase and install based on the specifications from the planners. They have to align their product of choice with requirements defined in the tenders. Their key needs are:

- To satisfy construction companies and inspectors
- Reasonably priced material
- Materials that meet construction criteria
- Dependable on-time delivery
- Speed and ease of installation (technical support when there are problems)
- Safe materials with no health risks during installation
- Easy and inexpensive disposal of cut-off material
- For renovation: Easy and inexpensive disposal of old material
- (Currently, no major demand for return-ability or recyclability of materials).

End users (building owners, operators, residents, tenants)

The end-user is generally the one spending time inside a building for living, working or otherwise utilising the facility. ROCKWOOL has no direct contact with end-users. Their key needs are:

- To satisfy themselves and/or other users
- Safe, comfortable and healthy living environment (non-hazardous, fire-resilient, noise-reducing, thermal insulation supports fulfilment of these needs)
- Building that meets regulatory requirements
- Energy efficiency (lower utility costs)
- Long-lasting materials
- *Sometimes* fulfilment of certification criteria (may include circularity)
- (Currently, no major demand for return-ability or recyclability of materials).

Buying customers

Dealers (building material wholesalers, do-it-yourself stores)

The dealers are the main buying customers, but homeowners can also buy insulation products at do-it-yourself stores. Dealers define sales conditions to installers, manage invoicing and payments and have knowledge on the creditworthiness of the installers. Dealers also offer competitors' products.

All sales, including take-back, go through a relatively small number of dealers. In Germany for example, the majority of sales are covered by the major dealer groups. Some material is delivered to the dealers for on-hand stock, and the majority is delivered directly from the production plant to the installers on construction sites. The key needs of the dealers are:

- To satisfy construction companies and installers
- Competitive prices for installers (with good margins for dealers)
- Good product range to meet various construction demands
- Dependable on-time delivery from ROCKWOOL (so dealer does not have to manage logistics)
- Direct technical support from ROCKWOOL to installers (so dealer does not have to support).

Component manufacturers (companies that use ROCKWOOL insulation in their own products)

ROCKWOOL provides stone wool insulation also to manufacturers of other building components, for example, fire protection doors and sandwich panels (wall elements with thermal insulation for such applications as in ventilation ducts). Their key needs are:

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- To satisfy their buying and non-buying customers
- Material that meets component design criteria
- Low cost
- Dependable on-time delivery.
- Easy and inexpensive disposal of cut-off material
- Sometimes fulfilment of certification criteria (may include circularity)

3.1.1.2 Value Proposition

The company enjoys a good reputation in the building sector as providing high quality products, reliable logistics and excellent technical support. The exact value proposition differs per customer segment.

Non-buying customers

Planners and architects

ROCKWOOL seeks to deliver all necessary product information in convenient ways to support designing and planning. Specific value provided to planners and architects includes:

- Brochures and website providing technical specifications and all regulatory information
- Seminars for planners and architects
- General support and advice through well-educated technical hotline staff
- Specific support for planners in writing product specifications in tenders
- Positive image of natural, non-toxic, stone wool product (for small segment of architects)

Installers (roofers, drywall builders, facade installers, et al)

Even though they are not buying directly from ROCKWOOL, the installers are the ones choosing exactly which product to purchase and install based on the specifications from the planners. Therefore, ROCKWOOL seeks to deliver all information and support necessary to ease purchasing and installation. Specific value provided to installers includes:

- Appropriate material for various specific applications
- Dependable on-time delivery
- Insulation that is safe, fast and easy to install
- Specific support through well-educated technical hotline staff
- Brochures and website providing technical specifications and installation instructions
- Seminars and training classes for installers
- Easy and inexpensive disposal of cut-off material (normally considered waste to landfill, but through RockCycle can be returned for recycling)
- For renovation: Easy and inexpensive disposal of old material (normally considered waste to landfill, but through RockCycle can be returned for recycling)
- Official record of proper disposal (legal requirement)
- **(RockCycle represents convenience and cost savings for installers; there is currently no major demand from installers for sustainable materials).**

End users (building owners, operators, residents, tenants)

ROCKWOOL has no direct contact with the end users, yet ultimately, this is who their product has to serve. Specific value provided to end users includes:

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- Non-hazardous, fire-resilient, noise-reducing, thermal insulation (supports safe, comfortable and healthy living environment for users)
- Energy-efficiency (cost, energy and carbon emission savings[58].)
- Long-lasting material
- Positive image of natural, non-toxic, stone wool product (for small segment of users)

Buying customers

Dealers (building material wholesalers, do-it-yourself stores)

The dealers are the customers, through which the products and services of ROCKWOOL are sold. Specific value provided to dealers includes:

- Good profit margins for dealers (and competitive prices for installers)
- Good product range to meet various construction demands
- Recognisable brand and strong reputation for supporting installers
- Dependable on-time delivery from ROCKWOOL (so dealer does not have to manage logistics)
- Direct technical support from ROCKWOOL to installers (so dealer does not have to support).

3.1.1.3 Customer Relationships

ROCKWOOL fosters different types of relationships with its different customer segments.

Non-buying customers

For planners and architects, ROCKWOOL mainly makes information available through technical brochures and its website. For specific questions, direct contact through their hotline and technical support staff is possible. Additionally, ROCKWOOL offers a wide programme of seminars on various topics, including planning strategies, regulation changes and new product developments, sometimes in cooperation with other building material manufacturers. Most of these seminars are free of charge, and around 10,000 planners and architects attend each year in Germany, for example.

For installers, ROCKWOOL also makes information available through technical brochures and its website, and for specific questions, direct contact through their hotline and technical support staff is often utilised. The company offers training classes on the installation of their products, and installers are also invited to visit the seminars on regulation changes and new product developments, but there is little marketing of RockCycle. For larger projects, installers require a more involved relationship in order to align the delivery schedule with the work process or verify their order and details of the product directly with the manufacturer. The flat roof category, for example, is a project business characterised by regular contact with the roofers/installers and an ongoing relationship during the project.

With the end-user, ROCKWOOL has little or no contact. The company advertises their products on their website and in do-it-yourself stores. The do-it-yourself user can purchase the products either in a store or through online retail portals.

Buying customers

[58] ROCKWOOL Group Sustainability Report 2017 – In addition to utility cost savings, during the lifetime of thermal building insulation, its use can save 85 times the energy and 80 times the carbon emissions that were generated from its raw materials and production.

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With the dealers, ROCKWOOL has extensive direct contact and maintains continuous ongoing relationships with them over many years. In Germany for example, the building material dealers account for the majority of ROCKWOOL sales, while a small percentage is sold through the do-it-yourself stores. About 10 large dealer groups handle the main volume of ROCKWOOL's sales and are, therefore, the key relationships for the company. The ROCKWOOL sales staff is the primary group who maintains the relationships and negotiates terms and conditions for orders, including RockCycle, though this is said to be a low priority. ROCKWOOL accounting departments also maintain relationships with the dealers directly to clarify any invoicing or payment issues.

3.1.1.4 Communication channels

ROCKWOOL maintains both direct and indirect channels of communication with their customers.

The direct channels are:

- Sales to dealers (they in turn sell to installers)
- Hotline for supporting installers, planners, architects
- Website
- Seminars
- Technical brochures and other information/declarations

The indirect channels are:

- Product delivery and take back (through logistics partners and own staff)
- Sales and delivery to consumers (through retail outlets)
- Marketing to all customers (through various media)

ROCKWOOL's primary channel is with the dealers as the main buying customers, and they maintain their own channel with the installers who physically receive and install the product. This poses a challenge for selling RockCycle to installers as ROCKWOOL does not have the direct sales channel, and for the dealers, RockCycle is a new and unusual service offer, so they still have little focus on this.

3.1.1.5 Revenue Streams

ROCKWOOL's revenue from products is transactional per sale and is administered by the dealers who invoice and collect payments from installers. The price includes product, delivery and all customer and technical service.

For RockCycle, the revenue is also transactional per sale for the service of taking back used insulation from renovation sites and is also administered through the dealers. The price includes pick up of old product, required documentation that it has been properly disposed of and customer service. The installer must ensure that the used material contains only ROCKWOOL stone wool and is not mixed with other materials.

For the construction companies and installers, the old material is considered waste and they expect a price for pick up that is lower than sending it to local landfills, which is what they would normally do with all mineral insulation materials.

3.1.1.6 Key Activities

In order to deliver the value needed by the customers, ROCKWOOL must perform many activities, and certain of the key activities are described below.

Procurement

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ROCKWOOL purchases raw materials and secondary materials for its production. The activity involves the economically reasonable procurement of combustion materials to fire the furnace and minerals as the basis for insulation material. The company uses partly virgin materials from raw materials mining and partly secondary materials mainly from the metals industry. ROCKWOOL recycles its own used materials into the production of new materials.

Production and recycling

ROCKWOOL insulation is a rock-based mineral fibre comprised of stones and recycled slag (a by-product of the steel and copper industry). The process is depicted in the diagram below and here explained.

Stones are fed together with coke and anodes as combustibles and briquettes of old material into a furnace, where they are melted at 1,500 °C. A spinning machine processes the fibres into wool, while oil and binders are added to yield a stabilised and water-repellent product. (One cubic metre of raw material delivers about 100 cubic metres of stone wool. The final products are made up of approximately 97% minerals by weight[59], with binding material and impregnation oil being the remaining 3%.) The spun material flies into a wool chamber and then a pendulum forms the wool into the defined density. After optional facing material is added, the final hardening process is done by curing the wool at 200°C. Finally, the insulation is cut and packaged for delivery.

Insulation material returned from the RockCycle programme and from cutting waste is pressed into briquettes and added to the beginning of the process to recycle the material. Stone wool can be endlessly recycled and used as a replacement for virgin minerals, and since stone wool does not deteriorate over time, recycling is not dependent upon the age of the used product.

It is important for the production process to have a stable material flow. Employees have noted that the handling of used material in varying amounts and at various times disrupts the normal production process, yet they are measured upon their efficiency of standard production not on recycling.

[59] ROCKWOOL Sustainability Report 2016

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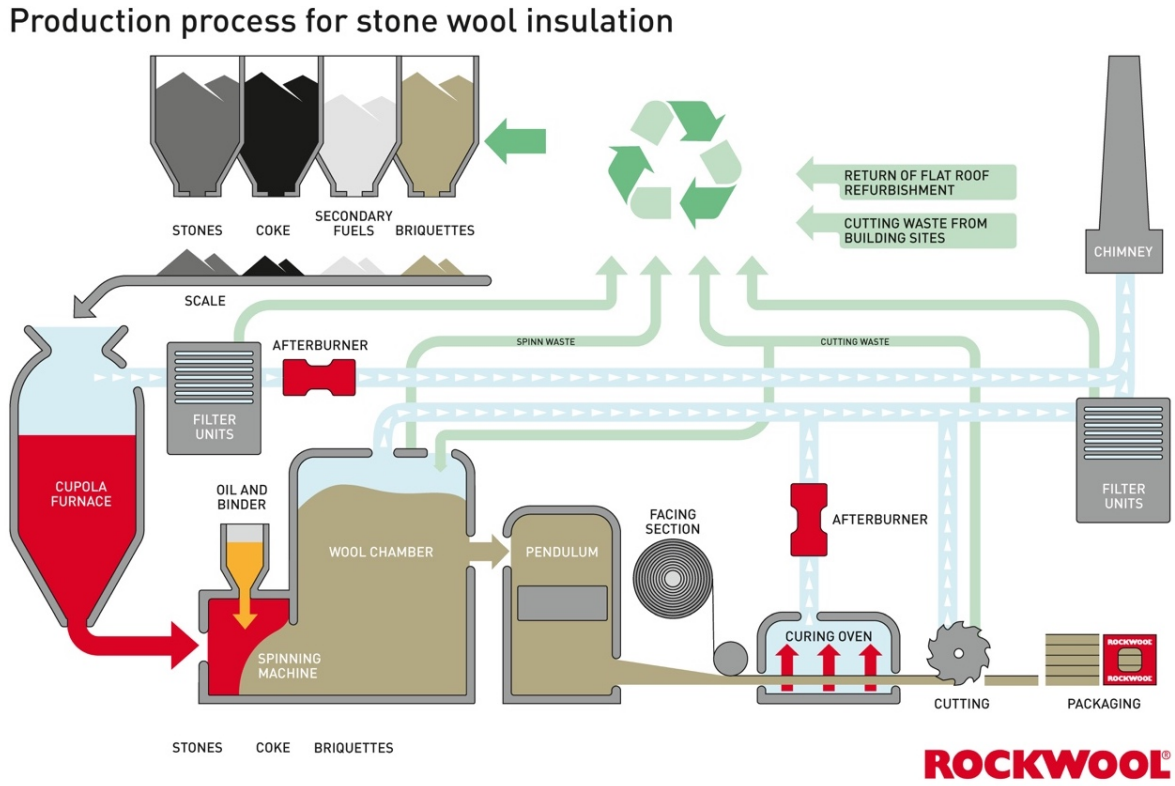
FIGURE 7: PRODUCTION DIAGRAM



Source: ROCKWOOL

Marketing and technical support

ROCKWOOL makes advice and information easily available to all customers and also uses this support as a marketing tool for informing on products and services particularly with the non-buying customers. Their key activities include:

- Staffing hotline with expert support
- Maintaining technical website
- Conducting helpful seminars
- Designing useful (technical) brochures

The marketing and support for RockCycle varies by country (available in Denmark, Netherlands, Belgium, Luxembourg and Germany). Active promotion is done in Denmark and the BeNeLux counties. In Germany, the take back of roof insulation is sometimes a key criterion for the sale of new material. In other cases, the ROCKWOOL sales staff and that of the dealers do not actively market the RockCycle service.

Management of logistics

On-time delivery of the ordered products is important to customers and critical to the work processes on renovation and construction sites. For RockCycle to be efficient and make use of “empty rides” of the delivery trucks, reliable logistics is also critical. The delivery and pick up are outsourced to external logistic partners. The coordination and management of the logistics and partners is a key activity of ROCKWOOL.

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An important note for circular take-back programmes is that in order to be allowed to handle this used material, which is legally considered waste, companies must be specifically authorised as a waste disposal company. This creates additional administrative and cost burdens on the companies, and it highlights how a simple classification of something as a waste rather than as a resource can be a barrier to sustainable and circular behaviour.

3.1.1.7 Key Resources

Key resources are the physical and human resources necessary to carry out the key activities for creating value. Some of the key resources important for ROCKWOOL are listed below.

Raw materials and secondary materials

Certain materials are required for the production of stone wool and they are sourced from both primary (virgin) and secondary (used) sources. ROCKWOOL focuses on recycling wastes and using secondary materials. In 2017, some of ROCKWOOL's stone wool products had a recycled content of up to 50 percent with a global average of 31 percent[60].

The virgin materials used are natural stone like basalt and diabase. Secondary materials originate from production waste, stone wool waste collected in the market and by-products and waste from e.g. the metallurgic industry like slags and by-products from the aluminium industry. These secondary materials are bound with cement into briquettes that can enter the production process of new stone wool. Depending on the type of production process (furnace), stone wool waste can also be recycled directly. Depending on the product, 0.5-5% binder (in most cases made from virgin materials) and 0.1-0.2% mineral oil is added. The furnace uses virgin fossil combustibles such as coke and secondary fuels. Other furnaces use electrical energy.

Production and recycling facilities

Clearly, the factory and its equipment are crucial for the production and recycling, and all parts of the process described above are key resources. ROCKWOOL runs 45 operating facilities in 39 countries, mainly in Europe followed by Russia, North America and Asia.

Know-how and expertise

ROCKWOOL has extensive knowledge and experience in:

- High-quality products for different applications
- Technical support
- Take-back / recycling (e.g. RockCycle)
- Logistics management.

3.1.1.8 Key Partners

Key partners are those that are critical to ROCKWOOL in creating and delivering value to its customers, and these are listed below.

Logistics providers

The logistics service partners are a major key partner for ROCKWOOL's overall business and for RockCycle. They execute the delivery and pick up of products on time and in a dependable manner, which are critical factors for the customers.

[60] ROCKWOOL Group Sustainability Report 2017

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Suppliers of raw materials

Other key partners are the suppliers of raw materials. They produce and deliver the needed commodities (stones, combustibles, minerals and binder) for the production of stone wool.

Suppliers of secondary materials

ROCKWOOL has key partners for co-product recovery in the steel and aluminium industry for the delivery of anodes as a replacer for combustibles and slag as a replacer for minerals. In the other direction, the steel industry makes use of pig iron as a by-product of ROCKWOOL's production.

The demolition industry delivers in some cases old clinker bricks and other mineral wastes as recovered secondary materials for stone wool production.

Suppliers of disposed materials

In Denmark, ROCKWOOL collaborates with waste treatment facilities and recycling centres on sourcing of further secondary materials. This is possible due to Danish regulations on required separation of stone wool as well as on the banning of sending recyclable materials to landfill. A similar situation exists in the Netherlands, and comparable regulations in other countries would enable an increase in resource recovery and recycling.

3.1.1.9 Cost Structure

The costs must cover the entire value chain:

- Product development and approval
- Procurement
- Production and energy
- Sales/Marketing
- Technical Support
- Logistics
- RockCycle (no substantial cost for take back logistics)
- RockCycle (some additional cost for integrating recycling process into production).

The costs for RockCycle logistics can be minimal when the take-back is done with the same trucks that deliver the new material and these then return with used material instead of empty. In other cases, ROCKWOOL cooperates with waste management companies to collect and support take back material. The recycling process incurs some additional costs for pressing material into briquettes but is otherwise integrated into the normal production process, with some disruptions and inefficiencies as noted above. The profit margin for RockCycle is not known, but simple cost versus price calculations seem to show it to be economically viable, with a break-even principle, in existing cases. The company stresses that different local conditions (e.g. landfill fees and legal requirements) can significantly alter the cost and revenue model.

3.1.2 Value network

In order to fully understand the business model, it is important to appreciate how value (both financial and non-financial) is exchanged between the different stakeholders across the value chain.

In the case of ROCKWOOL, the material flow and value flow follow largely the same paths and are thus depicted on the flow map below along with the key partners and other actors across the value network. The black arrows represent the flow of material and value between the stakeholders show in the various boxes, with orange boxes representing the key partners. Since the production and recycling of

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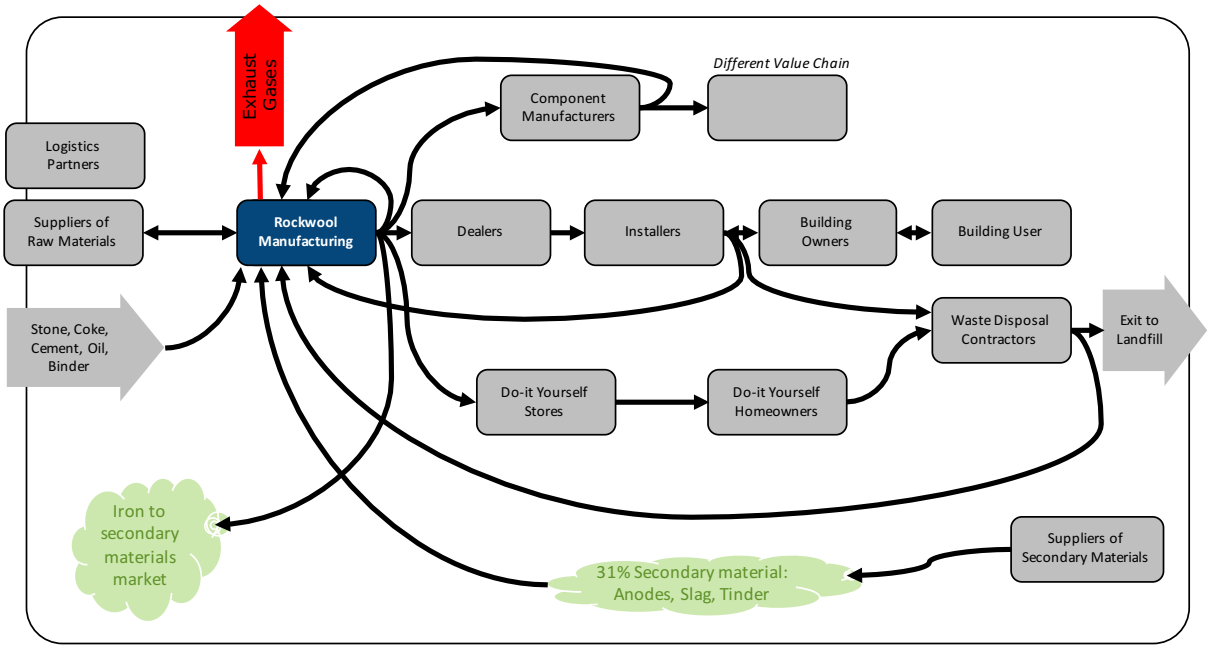
stone wool is very energy intensive, it needs to be pointed out, that the combustion process is currently a linear, non-reversible process with CO2 exhaust emitted to the environment, depicted by the red arrows.

FIGURE 8: MATERIAL AND VALUE FLOW MAP



This mapping shows supplies of raw materials flowing into the manufacturing process to deliver the stone wool products, which are sold to dealers who, in turn, sell them to professional installers. The installer mounts the material in the building, and the ownership of the material is passed on to the building owner. Building users in many cases are not the owners, but they benefit from the applied insulation material. Additionally, the product paths to component producers and do-it-yourself stores are depicted. In case of renovation or demolition, obsolete materials are dismantled by installers or demolition companies, who are legally required to properly dispose of the materials. The circular flows are discussed in the next section.

3.2 Business model circularity assessment

This section provides an assessment of the case organisation's circular business model. It begins with a depiction of the 7 Circular Economy Business Model Patterns identified by the R2Pi project, and describes which of these patterns are utilised by the case organisation. This is followed by the financial and non-financial outcomes of the business model as well as a discussion of its strengths, weaknesses, opportunities and threats, before final assessments are made to close the chapter.

The patterns are shown and described in the following figure:

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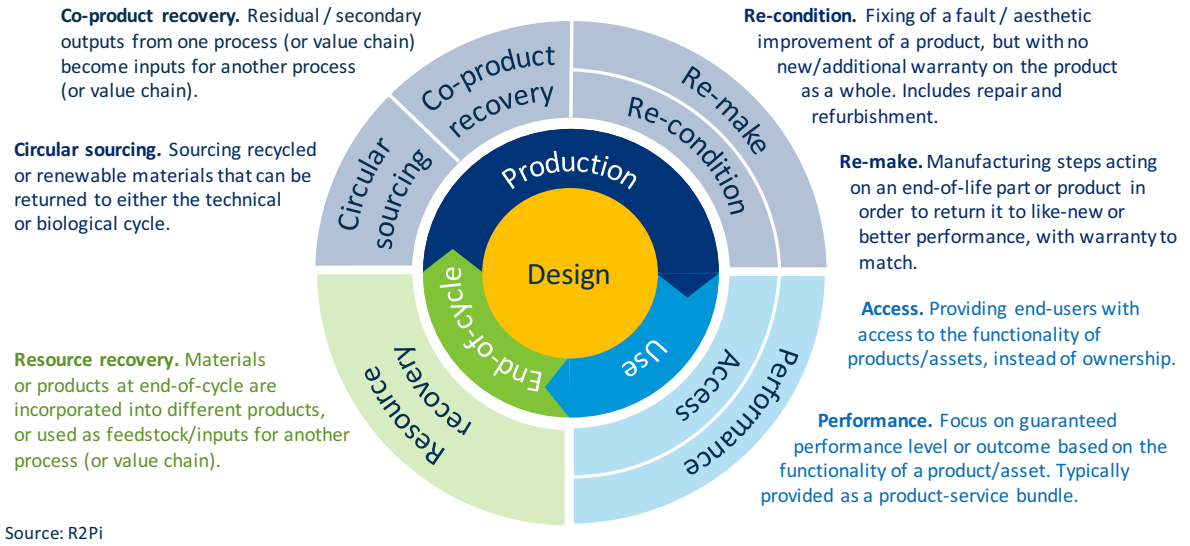
FIGURE 9: CIRCULAR ECONOMY BUSINESS MODEL PATTERNS



Source: R2Pi

ROCKWOOL utilises primarily the patterns of co-product recovery, resource recovery and re-make, and these will be discussed in more detail in the following section.

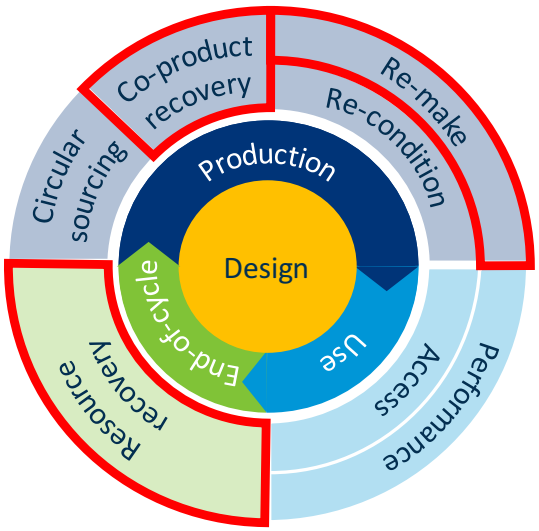
3.2.1 Circularity assessment

Within ROCKWOOL's sustainability practices, numerous ways of recycling and using secondary materials are applied. These activities can be classified by different circular economy business model patterns.

The take-back programme is characterised primarily by three circular economy business model patterns in different parts of the value chain. At end-of-use, the material taken back from customers is "resource recovery", and during production, this is combined also with the "co-product recovery" of secondary materials originating from other products or industries to bring the materials into a "re-make" process and recycle them back into new insulation material.

The circular economy business model patterns primarily utilised by ROCKWOOL are highlighted in red below:

FIGURE 10: CIRCULAR BUSINESS MODEL PATTERNS USED BY ROCKWOOL



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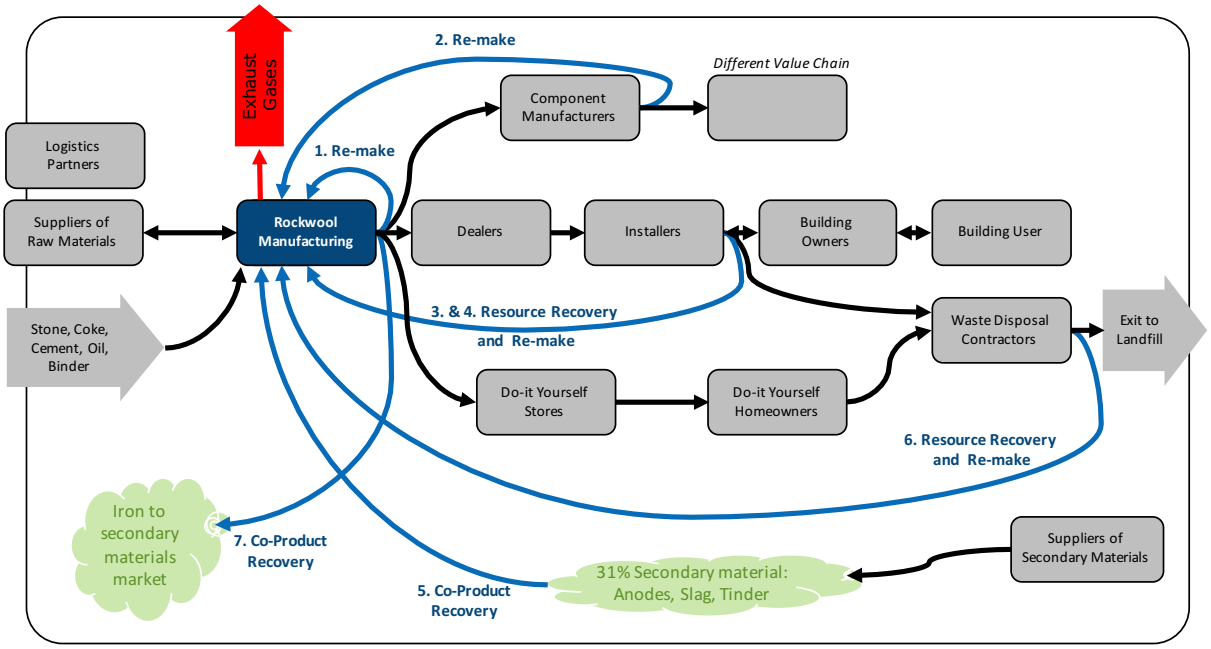
Looking at ROCKWOOL's material and value flows, these patterns can be identified. Within the following diagram, the seven circular activities and three circular business model patterns are identified and labelled in blue arrows and text. Each is then further explained below.

FIGURE 11: FLOWS AND CIRCULAR BUSINESS MODEL PATTERNS



3.2.1.1 Re-make: Internal production excess material

ROCKWOOL recovers all internal production cut-off and excess material and feeds it back into the wool chamber to re-make into new material. ROCKWOOL is not aware of the exact amount of the recovered internal material. A calculation of this recycling tonnage is currently ongoing but not yet available.

3.2.1.2 Resource recovery and re-make: External production excess material

ROCKWOOL delivers insulation products to producers of other components such as fire protection doors, sandwich panels and insulation for chimneys. ROCKWOOL offers take-back of cut-off and excess ROCKWOOL insulation from that production. Due to the risk of impurities of the recovered resource, it is not put back into the wool chamber but rather is processed into briquettes and put back into the furnace for the re-make of new material.

3.2.1.3 Resource recovery and re-make: Excess material from construction sites (RockCycle)

For installers of insulation material, e.g., roofers, facade installers and dry-wall builders, ROCKWOOL offers take-back of cut-off and excess material which is leftover from the installation. The installer has to insure the separated collection and transportable packaging of the material. ROCKWOOL supplies collection bags on the first delivery of new insulation, which are filled by the installers during their work. On the next delivery of new insulation, the filled bags are taken back and transported to recycling plants where the recovered resource is processed into briquettes to re-make material in the ROCKWOOL furnace.

Insulation material based on commodities other than stone such as polystyrene or glass can not be recycled by ROCKWOOL. They prevent the recycling process from producing the needed fibre chemistry.

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FIGURE 12: TAKE BACK OF EXCESS MATERIAL

Photo: https://brandcommunity.ROCKWOOL.com/bilddatenbank/

3.2.1.4 Resource recovery and re-make: Take-back of used insulation at end-of-use (RockCycle)

RockCycle was expanded to incorporate renovation and demolition of buildings, including large-scale, commercial roofing renovations. The company takes back stone wool of all ages, whether it is originally from ROCKWOOL or not, and in some cases, this is in combination with the purchase of new ROCKWOOL products.

In Germany, the programme has been used most extensively in flat roof renovations. Due to the higher density of flat roof insulation material, it is logistically most efficient and provides clear benefit to installers who have to dispose of large volumes of material within a few days while at the same time installing new insulation material. In some cases, this offer is the unique selling point to close a deal for ROCKWOOL new material.

The insulation exchange on site usually involves two teams working on the same roof, where the first team removes the old material and the second team mounts the new material. When the crane lifts the new material from the delivery truck onto the roof, the old material is taken down and loaded onto the truck. This procedure is convenient for the installers, since the construction site stays free from large amounts of discarded materials, and they need not deal with a second disposal company. After the delivery of the material to the construction sites, the logistics partner makes use of what would normally be “empty rides” and transports a full load of used material. This recovered resource is taken to a recycling plant, where it is processed into briquettes to re-making as raw material in the cupola furnace.

For other ROCKWOOL insulation products, the take-back programme is more individualised and may be less efficient for products other than large-volume flat roof insulation. In Denmark, for example, the company cooperates waste management companies that collect material from demolition sites, and from public municipal waste collection centres to recover stone wool disposed of by the public.

Resource recovery and re-make is ecologically and economically sustainable on a local or regional scale, i.e., when new material is delivered from a local factory to a local renovation site and the used

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material is taken back to the same factory for recycling. However, this model would no longer be sustainable on a global scale, given current infrastructure.

FIGURE 13: FLAT ROOF INSULATION

Photo: https://brandcommunity.ROCKWOOL.com/bilddatenbank/

3.2.1.5 Co-product recovery: Combustibles

ROCKWOOL purchases used anodes, which is a by-product of the aluminium industry. The anodes replace virgin coke to fire the furnace. Before putting some recovered co-products into the cupola furnace, the material may have to be granulated and formed into briquettes.

3.2.1.6 Resource recovery and re-make: Minerals

Discarded mineral materials can replace virgin mineral commodities, the natural stones, depending on the composition. These can be various kinds of minerals, like mineral dusts or granulates. As stated before, by-products and wastes from the metallurgic industry like slags, are also used to replace virgin natural stone. The externally recovered materials have to be granulated and processed into briquettes before feeding them to the furnace for the re-make process.

3.2.1.7 Co-product recovery and re-make: Use of ROCKWOOL's by-products by external companies

ROCKWOOL produces pig iron as a by-product of its process. The iron is used as recovered co-product or secondary material by the steel industry. This practice reduces what might otherwise be sent by ROCKWOOL as waste to landfill. ROCKWOOL's goal for 2022 is to decrease its waste to landfill from production by 20% compared to the baseline year 2015.

3.2.1.8 Potential to Re-use or Re-condition Products

Due the long-lasting and durable nature of stone wool, there is a large potential for re-using or re-conditioning the insulation material to retain higher value for much longer. As opposed to destroying value through an energy-intensive re-make process, it may be possible to re-use insulation as is or to re-condition it for re-use and maintain its value for multiple use phases.

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Given the current system of demolition and the culture of older materials being considered only wastes rather than resources, re-use is largely impractical at the moment. Nevertheless, as mentioned, the Baukarussell project in Austria has already proven that re-use of insulation is possible and no re-making activities were required[61]. This is an example for ROCKWOOL and others to consider even higher-level circular business models for the future.

In such cases, the re-use of insulation material is feasible and economically viable. Companies can recover and temporarily store used insulation and then offer it to customers for renovation or new construction. This service would require higher labour effort for careful dismantling. Such activity could be performed by an external company, perhaps requiring the future role of a "dismantling" expert rather than a demolition expert. The critical points will be to maintain the quality of the material during dismantling, and then to match the recovered materials with the needs of local or regional buildings through planners and installers. This can be enabled by ongoing advancements in information technology, building information modelling, materials passports, etc. Enhanced communication technologies can enable trading platforms for second-use building materials.

Currently, insulation products are not generally designed for re-use due to their long life spans and the traditional culture of linear models and waste. However, it makes sense to adjust the design and construction of buildings to further enable recovery and re-use. ROCKWOOL is already involved in a Danish project called Circle House, where all building components are designed for disassembly and reassembly into other buildings with solutions for sustainable, flexible, reusable, social housing construction[62].

ROCKWOOL has collaborated to develop a compact wall system for housing to be launched in 2018 in Denmark, Belgium, Netherlands and Luxembourg. The wall system is made of stone wool, wood framing and steel fixtures, where ROCKWOOL is delivering all stone wool components. It is designed for high energy efficiency and easy assembly and disassembly (mechanically fixed instead of glued). Due to the design and durability of the products in the Circle House, the expectation is to disassemble and re-use up to 90% of the components without losing substantial value.

3.2.2 Financial and non-financial outcomes assessment

This section discusses various outcomes of ROCKWOOL's sustainability and circularity activities.

3.2.2.1 Reduction of internal production waste to landfill

Compared to 2015, ROCKWOOL reduced their worldwide waste to landfill by 4.1% in 2017. This was achieved through such measures as internal co-product recovery and re-make where production material such as pig iron is used as a secondary material in the steel industry and moving towards zero-waste factories. The company already runs 9 factories with zero waste to landfill. ROCKWOOL's goal is to decrease waste to landfill by 40% by 2022 and to 85% by 2030.

3.2.2.2 Reduction of insulation material to landfill

In 2017, 20,600 metric tonnes of building insulation, including some packaging, were reclaimed by ROCKWOOL and thereby, did not enter landfills as would normally be the case (up from 18,110 tonnes in 2016 and 14,200 in 2015)[63]. By recycling the recovered construction resources, the amount of virgin raw materials needed for new production was also reduced.

61 http://www.repanet.at/baukarussell/

62 https://www.orbicon.com/project/circle-house

63 ROCKWOOL Group Sustainability Report 2017, page 35

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3.2.2.3 Convenience to customers

Installers and construction sites benefit from the take-back as a convenient option to handle the renovation material at the same time as installing new material, and as described above, avoid landfill waste. BeNeLux and Denmark are leading countries in tonnage taken back, and ROCKWOOL plans to extend the programme from the current 5 countries to 15 countries by 2022 and to 30 countries by 2030[64].

3.2.2.4 Hazardous material upcycling

When ROCKWOOL takes back older pre-1995 material that is classified as hazardous according to the regulations and changes its chemical composition during melting and production process, it is upcycling the material to a non-hazardous state for new applications. Those hazardous materials would also normally be sent to landfill.

3.2.2.5 Financial benefit for customers and revenue for ROCKWOOL

ROCKWOOL generates some revenues through the RockCycle programme. The company says that it prices the service with a break-even principle, since they offer it as a differentiator in the market and as responsible business conduct. Exact figures were not immediately available from the company, but for the sake of showing the potential business model for the R2Pi project, all of the following estimations are based on publicly available German information and serve only as examples to illustrate the viability of the business model.

In Germany, the take back of one "big bag" (1,5 m3, which contains up to 250kg) of new cut-off material, costs €117.08, including the delivery. For the take back of old insulation material, ROCKWOOL charges €250 per metric tonne[65]. Of course, prices differ per country, but to seek an extrapolated example, using the 20,600 metric tons reclaimed in 2017, a revenue of somewhere between 2.4 million and 5.2 million euros could have been generated. According to ROCKWOOL's break-even principle, these costs cover transport and waste handling (often outsourced) and internal waste handling in the ROCKWOOL factory. Again, these publicly available numbers do not represent actual revenues of the company but serve only to illustrate the economic viability of the business model.

In Germany, the disposal costs for landfilling such materials vary widely. The price ranges from 200 to 900 euros per metric tonne. The financial benefit for installers, thus depends on the landfill prices in their local area. For example, at Seibel Entsorgung in Wuppertal, Germany, the disposal of one metric tonne of non-hazardous insulation material (waste key 17 06 04) costs 400 euros[66]. Therefore, an installer in this example could save between 150 and 283 euros per tonne by using the take-back service. In this case, RockCycle is not only a convenient and eco-friendly solution but also clearly an economically-advantageous solution for the customer.

3.2.2.6 Reduction of virgin material consumption through secondary materials

The use of recovered anodes as combustibles results in a reduction of virgin coke consumption but exact estimated amounts were not available. The use of co-product recovery of minerals such as clinker bricks and slag cause a reduction of virgin mineral commodities consumption. In total for 2017,

64 ROCKWOOL Group Sustainability Report 2017

65 ROCKWOOL Preisliste Flachdach ab 01.02.2018

66 www.seibel-entsorgung.de

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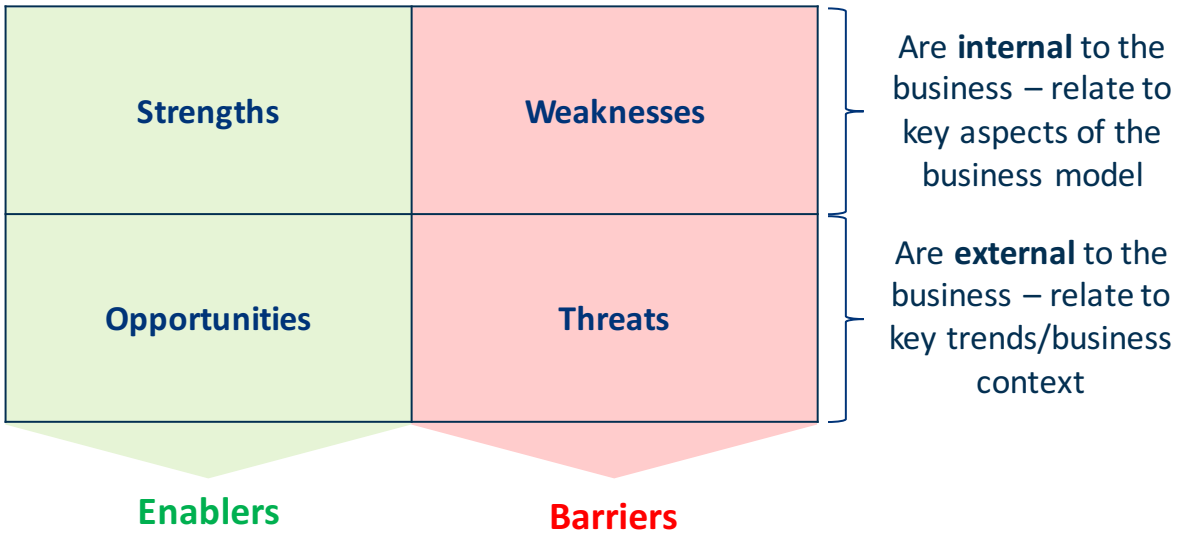
ROCKWOOL managed to implement 30.9% secondary raw materials (including reclaimed materials from the take-back program) per tonne of stone wool into their products[67].

3.2.3 SWOT analysis

This section contains an analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) associated with the circular business model. It is important to note that this is primarily an assessment of the attributes of the business model itself and only secondarily of the specific attributes of the individual company. As is customary in SWOT analyses, the Strengths and Weaknesses are INTERNAL to the case organisation's business model. Whereas, the Opportunities and Threats are EXTERNAL to the case organisation, coming from the context in which they operate (exemplified in the diagram below).

FIGURE 14: SWOT ANALYSIS FRAMEWORK



The following table summarises the strengths and weaknesses that have been discussed in Chapter 3 and the opportunities and threats as discussed in Chapter 2.

67 ROCKWOOL Group Sustainability Report 2017

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FIGURE 15: SWOT ANALYSIS

Strengths	Weaknesses
• Company recognised customer need based on a "waste" problem and met need with a "resource" solution - (take-back not disposal) • Increasing customer demand for energy efficiency and lower utility costs • Financial benefit to customers through lower price of take-back than disposal price • Financial benefit to company through additional source of revenue • Co-product recovery (during production) reduces internal and external materials sent to landfill and reduces need for virgin materials • Resource recovery (at end-of-use) reduces internal and external materials sent to landfill and reduces need for virgin materials • Re-make upcycles hazardous material to non-hazardous material, creates value • Re-make recycles non-hazardous material that would be discarded, retains value • Convenience benefit to customers • Potential for re-use, re-condition of products. • Competitive advantage as only company currently taking back insulation • Excellent material properties – thermally efficient, long-lasting, reusable, recyclable • Reliable logistics partners for efficient take-back • Strong, long-term relationships with dealers • Some zero waste to landfill factories.	• Re-make (recycling) is lower on hierarchy than re-use or re-condition • Re-make process is energy intensive and uses mainly fossil fuels • Recovery and re-make unsustainable at global scale (with current infrastructure) • Added value of re-usability, return-ability and recyclability not clear to customers • Added value of certification of sustainable materials / buildings not clear to customers • Uncertain financial benefit to company in different countries and situations • No direct sales channel with installers as primary beneficiary of take-back • No relationships with end users (owners / tenants) as primary beneficiary of efficiency • Insufficient marketing of RockCycle according to interviewees (new product) • Employees may consider re-make as disruption to production process and as conflict with other goals.
Opportunities	**Threats**
• Population growth and urbanisation • Climate and environmental awareness • Increased customer demand for energy efficiency (including energy regulations) • Waste to landfill reduction targets • Rising landfill fees • Massive growth in built environment • In some countries, DK, NL – ban on landfilling of recyclable materials • Sustainable public procurement • Beginning of re-use and urban mining • Sustainable Development Goals • New technologies and digitalisation.	• Ecological impact of increased growth • Inconsistency of regulations between European countries • Lack of infrastructure for recovery, reuse and recycling activities in building sector • Uncertainty over long-term EU policy and circular economy strategy • Take-back requires authorisation as a waste disposal company • Waste regulation based on weight (makes lightweight materials low priority) • Lack of separate waste codes (sorted collection not possible).

3.2.4 Final assessment

For ROCKWOOL, their sustainability efforts, in general, and their RockCycle take-back and recycle programme, in particular, have proven to be both ecologically and economically viable. These efforts have shown significant improvements over linear models and "business as usual" as exemplified by the positive financial and non-financial outcomes listed previously. There are always both strengths and weaknesses to any business model, and having listed these above, the company can consider several ways to move forward and continue their journey towards circularity. Some of these are listed below:

- Seek to move to a higher level of value retention and explore additional ways to re-use insulation and give the product multiple use phases
- Transition to renewable energy, electric furnaces and means of production that reduce energy intensity in both new products and recycled products
- For replicating take-back and especially for global customer base, seek solutions to re-use insulation locally and when not possible, to recycle material locally
- Increase marketing and education across multiple channels to increase awareness of and demand for take-back; consider special incentives for dealers to increase RockCycle sales and to increase competitive advantage as only company taking back insulation

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- Engage employees more in sustainability and circularity efforts and align target setting and performance evaluations also with these activities
- Pursue cross-industry cooperation to overcome system issues and build the necessary infrastructure for increasing recovery, reuse and recycling of building materials.

Having looked in detail from ROCKWOOL's perspective, the next chapter will discuss the potential for replicating or transferring such a circular business model to other entities or sectors and suggest considerations for business leaders and policy makers.

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4 Discussion & Conclusions

This report has presented and assessed the circular business model of a leading building materials manufacturer, the ROCKWOOL Group. They have combined co-product recovery, resource recovery and re-make activities into their circular model. Although this is only one case study as an example of circular business model patterns, the lessons here may prove valuable to other businesses and sectors.

The intention of this chapter is to offer business leaders and policy makers considerations for further discussion and work on how to transition to more circular business models and policies. These considerations are from the R2Pi perspective and do not necessarily reflect the opinions of the ROCKWOOL Group.

The above implemented circular business model patterns seem replicable and transferable to other entities and other sectors and offer substantial potential for positive environmental and economic benefits. Companies and industries must, of course, reflect carefully on their specific context and product design when choosing which circular models to pursue.

Considerations for business leaders

- **Investigate the entire value chain for opportunities and efficiencies for total lifecycle value**
- **Collaborate across companies and even across industries to solve system-level issues**
- **Design for long life, durability, reparability, reusability and eco-design for lowest possible impact on human and ecological health**
- **Gain competitive advantage by being first, only, best company providing circular models such as resource recovery, re-use, recondition**
- **Seek highest level on hierarchy of value retention - first, prevent waste, then, re-use, recycle, recover for other purposes - avoid destruction of the value created and do not allow these investments to end in a landfill or incinerator**
- Design with high value materials that are abundant, robust, reusable and recyclable
- Transition to renewable energy and means of production that reduce energy intensity in new, re-used and recycled products
- Develop circular models that provide extra value to customers, such as convenience, fulfilment of legal requirements, reduced cost over landfill
- Ensure take-back logistics are sustainable both economically and ecologically - make efficient use of resources, e.g., take-back in combination with delivery rather than empty rides
- For replicating take-back on a global scale, design solutions to re-use locally and when not possible, to recycle locally
- Increase marketing of sustainability and circularity activities to increase awareness of and demand for circular products
- Engage employees in sustainability and circularity efforts and align target setting and performance evaluations with these activities.

Considerations for policy makers

- **Reduce taxes on labour to enable more labour-intensity for separation, recovery, handling, re-using and re-making to retain value of existing products and materials**
- **Increase taxes on virgin raw materials to incentivise recovery, repair, re-use, recycling and to ensure pricing reflects total costs of entire lifecycles**

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- **Strengthen eco-design standards and requirements across industries and continue to increase targets and standards for energy efficiency**
- **Require sustainability and circularity criteria in public procurement to create additional demand for circular products**
- **Provide financial incentives for re-use, re-make, re-condition and recycling (e.g. zero or reduced VAT on these products) and to discourage landfilling.**
- Ban landfilling or incineration of any materials that are feasibly reusable or recyclable and invest in new technology to ensure more materials become feasibly reusable or recyclable
- Further reduce waste to landfill targets and increase taxes to landfill and incinerate
- Invest in secondary materials markets to enable recovery, re-sale and re-use of used materials
- Require additional separation of materials to enable more efficient take-back and recycling
- Set distinct targets and waste regulations based on volume rather than weight for lightweight materials (such as insulation)
- Prioritise distinct waste reduction and recycling targets based on environmental impact and feasibility
- Ensure consistent resource ("waste") regulations across EU countries
- Invest in urban mining projects and infrastructure for this resource recovery
- Create clear and consistent long-term goals on circular economy to enable and boost further investments in circular infrastructure and business models.

As part of the continuing work of the R2π project, this report will be combined with the 17 other case studies, synthesised to gain cross-case lessons and discussed with other business and policy experts in the European Union, to then finalise and deliver Policy Packages and Business Guidelines. These are intended to enable organisations and their value chains to transition towards more viable, sustainable and competitive economic models that will ensure sustained economic development, minimise environmental impact and maximise social welfare.

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References

Adam Rogers (2015, April 28). *We try a new exoskeleton for construction workers.* Retrieved from https://www.wired.com/2015/04/try-new-exoskeleton-construction-workers/

Danish Ministry of the Environment (2018). *From land filling to recovery – Danish waste management from the 1970s until today.* Retrieved from http://eng.ecoinnovation.dk/media/mst/8051407/Affald_Baggrundsartikel_affald_web_15.01.13.pdf

Dakofa (2018). *Waste regulation in Denmark.* Retrieved from https://dakofa.com/element/test-article-today/

DKG Group (2011, November, 7). *The DKG Group presents ROCKWOOL.* Retrieved from https://www.youtube.com/watch?v=n53Zm1kuMu0&t=472s

Ellen MacArthur Foundation (2018). *Case studies – Data-backed stories that drive change.* Retrieved from https://www.ellenmacarthurfoundation.org/case-studies/data-backed-stories-that-drive-change

Ellen MacArthur Foundation (2015). *Growth within: A circular economy vision for a competitive Europe.* Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

Ellen MacArthur Foundation (2015, November). *Potential for Denmark as a circular economy – A case study from: Delivering the circular economy – A toolkit for policy makers.* Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/20151113_DenmarkCaseStudy_FINALv02.pdf

European Commission (2018). *2020 climate & energy package.* Retrieved from https://ec.europa.eu/clima/policies/strategies/2020_en

European Commission (2018). *Buildings.* Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

European Commission (2018). *Construction and Demolition Waste (CDW).* Retrieved from http://ec.europa.eu/environment/waste/construction_demolition.htm

European Commission (2018). EU *Buildings Database.* https://ec.europa.eu/energy/en/eu-buildings-database

European Commission (2018). *Construction Products Regulation (CPR).* http://ec.europa.eu/growth/sectors/construction/product-regulation_en

European Commission (2018). *Energy Efficiency Directive.* Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

European Commission (2018). *EU Building Stock Observatory.* Retrieved from https://ec.europa.eu/energy/en/eubuildings

European Commission (2018). *Paris Agreement.* Retrieved from https://ec.europa.eu/clima/policies/international/negotiations/paris_en

European Commission (2018). *Review of the Thematic Strategy on the prevention and recycling of waste.* Retrieved from http://ec.europa.eu/environment/waste/strategy.htm

European Commission (2018). *Smart finance for smart buildings: investing in energy efficiency in buildings.* Retrieved from https://ec.europa.eu/info/news/smart-finance-smart-buildings-investing-energy-efficiency-buildings-2018-feb-07_en

European Commission (2016). *Urban Europe — statistics on cities, towns and suburbs — patterns of urban and city developments.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs_%E2%80%94_patterns_of_urban_and_city_developments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

European Commission (2016, June 9). *Waste framework directive: Targets and reporting.* Retrieved from http://ec.europa.eu/environment/waste/framework/targets.htm

European Commission (2016, June 9). *Waste: Hazardous waste.* Retrieved from http://ec.europa.eu/environment/waste/hazardous_index.htm

European Commission (DG ENV) (2011, February). *Service contract on management of construction and demolition waste.* Retrieved from http://ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf

European Environment Agency (2016). *Population trends 1950 – 2100: globally and within Europe.* Retrieved from https://www.eea.europa.eu/data-and-maps/indicators/total-population-outlook-from-unstat-3/assessment-1

European Union (2014). *General Union Environment Action Programme to 2020 - Living well, within the limits of our planet.* Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/1d861dfb-ae0c-4638-83ab-69b234bde376

EUR-Lex (2018). *EU waste management law.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:ev0010

Eurostat (2017). *Greenhouse gas emission statistics.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

Eurostat (2018). *Waste management indicators.* Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_management_indicators

Fraunhofer Institute for Process Engineering and Packaging IVV (2018). *Recycling of EPS waste to re-expandable polystyrene – EPS loop.* https://www.ivv.fraunhofer.de/en/forschung/verfahrensentwicklung-polymer-recycling/recycling-eps-abfall.html

GGM Gütegemeinschaft Mineralwolle e.V.. (2016, March). *Health assessment of mineral wools on the basis of bio solubility.* Retrieved from https://www.ral-mineralwolle.de/tl_files/Downloads/PDF/Artikel%20Bioloeslichkeit%20auf%20Website_deutsch.pdf

Global Insulation (2014, December 1). *European EPS and XPS portfolio switched to PolyFR ahead of REACH deadline.* Retrieved from http://www.globalinsulation.com/news/item/968-european-eps-and-xps-portfolio-switched-to-polyfr-ahead-of-reach-deadline

Government of the Netherlands (2018). *From a linear to a circular economy.* Retrieved from https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy

Knauf Insulation (2018). *Insulation matters – Knauf insulation sustainability report 2017.* Retrieved from https://pim.knaufinsulation.com/files/download/knauf_insulation_sustainability_report_2017__28de_version_29_5a9e5ac6920d8.pdf?_ga=2.266474958.1713894341.1533119644-1984873393.1523539095

Knauf Insulation (2018). *Nachhaltigkeit ist unsere Verantwortung.* Retrieved from https://www.knaufinsulation.de/ueber-uns/nachhaltigkeit

Knauf Insulation (2018). *Über uns.* Retrieved from https://www.knaufinsulation.de/ueber-uns

Leonidas Milios, European Environment Agency and ETC/SCP (2013, February). *Municipal waste management in the Netherlands.* Retrieved from https://www.eea.europa.eu/publications/managing-municipal-solid-waste/netherlands-municipal-waste-management

McKinsey Center for Business and Environment and C40 Cities (2017, November). *Focused acceleration: A strategic approach to climate action in cities to 2030.* Retrieved from https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/a-strategic-approach-to-climate-action-in-cities-focused-acceleration

Orbicon (2018). Circle House. Retrieved from https://www.orbicon.com/project/circle-house

RepaNet (2018). BauKarussell – Beschäftigung & Kreislaufwirtschaft. Retrieved from http://www.repanet.at/baukarussell/#ErsteBauabwicklung

Rijkswaterstaat Environment (2018). *Elements of Dutch waste management.* Retrieved from https://rwsenvironment.eu/subjects/from-waste-resources/elements-dutch-waste/

ROCKWOOL International A/S (2017, February). *History.* Retrieved from https://www.ROCKWOOLgroup.com/about-us/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

The Club of Rome (2018). *The limits of growth.* Retrieved from https://www.clubofrome.org/report/the-limits-to-growth/

Saint-Gobain Isover G+H AG (2018). *Isover in Zahlen.* Retrieved from http://www.isover.de/unternehmen/isover-zahlen

The Finnish Innovation Fund Sitra (2018). *Leading the cycle – Finnish road map to a circular economy 2016-2025.* Retrieved from https://www.sitra.fi/en/projects/leading-the-cycle-finnish-road-map-to-a-circular-economy-2016-2025/

Umwelt Bundesamt (2016, Juli 25). *Welche negativen Eigenschaften hat HBCD für Umwelt und Gesundheit?.* Retrieved from https://www.umweltbundesamt.de/service/uba-fragen/welche-negativen-eigenschaften-hat-hbcd-fuer-umwelt

UN Environment (2017). *Towards a zero-emission, efficient, and resilient buildings and construction sector - Global Status Report 2017.* Retrieved from http://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf

United Nations (2017, November 28). *World Population 2017*. Retrieved from https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_Wallchart.pdf

United Nations (2018). *World Urbanization Prospects 2018.* Retrieved from https://esa.un.org/unpd/wup/

United Nations Populations Fund (2018). *Urbanization.* Retrieved from https://www.unfpa.org/urbanization

UrbanNext (2018). *Circle House: Materials and Systems for a Circular Construction.* Retrieved from https://urbannext.net/circle-house/

World Health Organization (2018). *Global Health Observatory (GHO) data - Urban population growth.* Retrieved from http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

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