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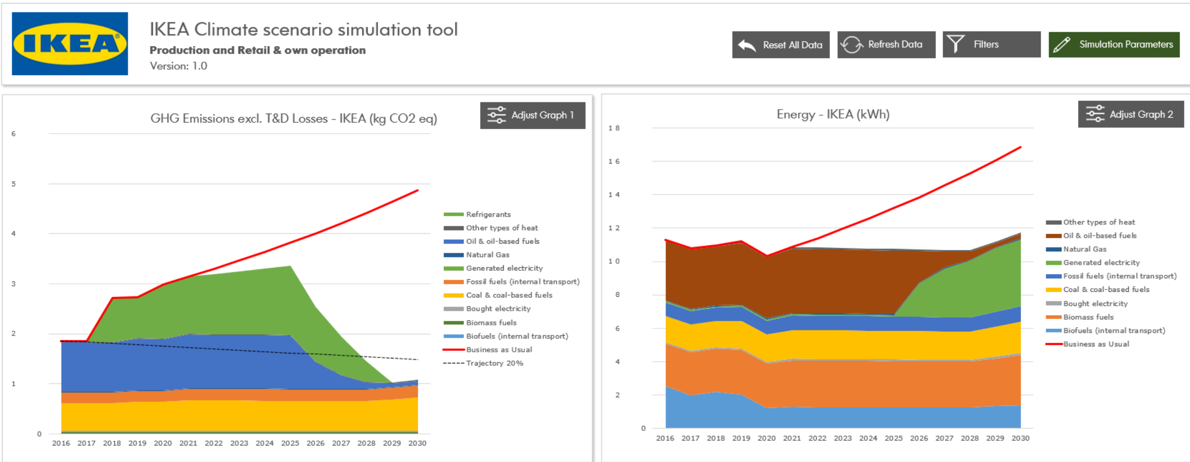

The development of scenario analysis tools to help IKEA set and follow up climate footprint goals

Master’s thesis in Industrial Ecology

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Cover:
The dashboard of the simulation tool developed in this project (dummy data used).

Gothenburg, Sweden 2021

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SUMMARY

IKEA has joined the Science Based Target initiative in an effort to stay in line with what the latest science says is necessary to limit global warming to 1.5 °C. To enable a fact-based approach for setting and evaluating climate targets within IKEA, tools are necessary. The use of scenario analysis has been recognised as a good way to evaluate alternative options for setting climate targets and plans. Scenario analysis can for example be used to evaluate what will be the impact if a supplier purchases electricity from renewable energy sources instead of fossil based. Several scenario analysis simulation tools have already been developed at IKEA. This project has continued the development of these tools.

To understand the needs of the organization and how the existing simulation tool has been used, stakeholder interviews were conducted. The main identified concerns were that the tool was not always available with the latest data, it was perceived as hard to use, it did not always fulfil the need of a certain user, and it was sometimes unclear who had the responsibility of running the simulations.

Based on the interviews, two simulation tools have been developed as part of this project. One will be used to set and evaluate climate targets for tier 1 suppliers and the IKEA stores, and the other tool is intended to be used for food ingredients. The main efforts have been put at creating a standardised data structure to allow for a simpler process of updating the simulation tool with new data. The usability of the tool has also been improved.

The project has also investigated the implications of using Attributional Life Cycle Assessment data in a tool for decision making. It was identified as a good approach for improving the environmental performance of the value chain. To make sure unintended consequences are avoided outside the value chain, a number of principles are suggested that should be used in conjunction with the simulation tool.

Keywords: scenario analysis tool, simulation tool, corporate climate targets, decision making, attributional life cycle assessment, consequential life cycle assessment, greenhouse gas emissions, climate footprint.

Acknowledgement

This master's thesis has been written as a final part of my education in Industrial Ecology at Chalmers University. The project has been carried out at IKEA where I have investigated the needs of the organisation and developed scenario analysis tools to set and evaluate climate footprint targets. I would like to express my greatest gratitude to IKEA for letting me take part of your journey of becoming climate positive. It has been such an inspiring experience. All the people I have met at IKEA has been very welcoming and helpful with their knowledge and time.

I would like to direct a special thank you to my supervisor at IKEA, Andreas Ahrens as well as to Patrik Sander. You have devoted a lot of time and effort in providing guidance and expertise to create the best possible outcome.

Furthermore, I would also like to express my greatest gratitude to my supervisor at Chalmers, Tomas Ekvall for providing valuable feedback along the project. I have highly appreciated the discussions we have had on life cycle assessments and sustainability.

Gothenburg, June 2021

Marcus Bernhard

Glossary

Attributional LCA	Determines who and to what extent an actor is considered responsible for environmental impact.
Consequential LCA	Evaluating the environmental consequences of a decision.
Excel UserForm	UserForm is used to build user interfaces within Excel to be able to collect and process user input. Used in conjunction with VBA
Excel VBA	VBA (Visual Basic Application) is the programming language used in Excel to automate tasks and calculations.
Gross biogenic CO_2 emissions	The instant CO_2 emissions occurring when for example burning biofuels. The natural carbon cycle not included.
IKEA climate team	The team within IKEA responsible for the overall climate positive agenda at Inter IKEA Group and the total IKEA value chain, including collecting and reporting the total IKEA climate footprint. More formally called the climate positive team.
Net biogenic CO_2 emissions	The CO_2 emissions when expected absorption is included.
Scenario analysis	Scenario analysis is looking into and evaluating images of the future, or alternative futures.
Scope 1 emission	Direct GHG emissions from sources that are owned and controlled by the reporting company.
Scope 2 emission	Emissions that come from the generation of purchased electricity, steam, and heating/cooling.
Scope 3 emission	All other indirect emissions from sources not owned by the reporting company.
Simulation	The technique of imitating the behaviour of some situation or process.
Tier 1 suppliers	Suppliers who deliver parts and products directly to the company without any middle hand.

Abbreviations

ALCA	Attributional Life Cycle Assessment
BA	Business Area (within IKEA)
BI	Business Intelligence
BOM	Bill Of Material
CA	Category Area (within IKEA)
CHP	Combined Heat and Power
CLCA	Consequential Life Cycle Assessment
CO_2-eq	Carbon dioxide equivalent
GHG	Greenhouse gas emissions
GO	Guarantees of Origin
IEA	International Energy Agency

IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
REC	Renewable Energy Certificates
SBTi	Science Based Target initiate
VBA	Visual Basic Application

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1 INTRODUCTION

This section will provide a general background to IKEA and why scenario analysis is needed to help in the process of evaluating and setting climate targets. It will also present related work before moving into explaining the aim and research questions used in the project. Finally, the scope and limitation will be presented.

1.1 BACKGROUND

IKEA provides a wide range of affordable, ready-to-assemble, home furnishing products based on the vision to “create a better everyday life for the many people”. To enable a long-term success of its business IKEA has developed a sustainability strategy called “People & Planet Positive” (Inter IKEA Systems B.V., 2020). IKEA wants to create a sustainable business model that should have a positive impact on people, society, and the planet. This means that business should grow within the boundaries of the planet and in a better balance with economic, social, and environmental aspects. One of the focus areas of the sustainability strategy is to become “Circular & climate positive”. IKEA has joined the Science based target initiative (SBTi) to set greenhouse gas (GHG) emission reduction targets to be in line with what the latest science says is necessary to stay within the limits of 1.5 °C global warming. In the IPCC special report “Global Warming of 1.5 ºC” it is stated that it is important to stay within 1.5 °C to avoid many of the most severe effects of global warming, such as costal flooding and extreme weather events (IPCC, 2018). In addition to the commitment within this initiative, IKEA is committed to become climate positive by 2030, thus removing more greenhouse gas emissions than the IKEA value chain emits, while growing the IKEA business (Inter IKEA Systems B.V., 2021; see Figure 1). The first step to achieve this is to drastically reduce greenhouse gas emissions in absolute terms from its operations and supply chain – both upstream and downstream. Some activities to reach this goal are to: promoting sustainable choices, transforming into a circular business, striving to 100% renewable energy across the IKEA value chain and by using more sustainable materials. This is estimated to reduce the climate footprint by at least 15% by 2030 for the entire IKEA value chain (corresponding to about 70% reduction per product, in relative terms).

To further reach net zero IKEA aims at storing carbon in land, plants, and products. The methodologies for these are currently under development within IKEA and are not included in this project.

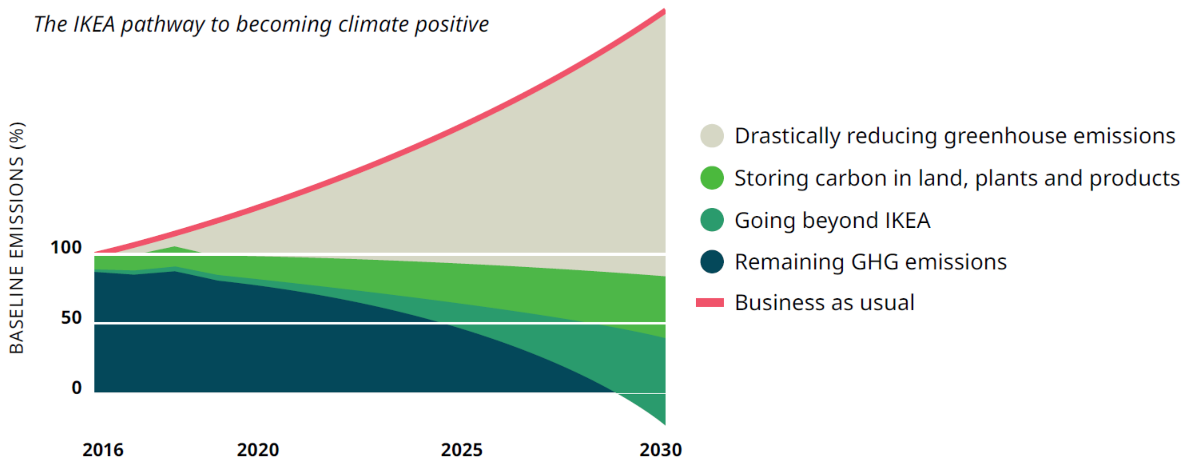

Figure 1. The IKEA pathway to becoming climate positive (Inter IKEA Systems B.V., 2021).

Within the SBTi, IKEA has set an overall ambition for the organisation. But how should these targets be reached? What actions are necessary and are those enough to reach the targets? To have a fact-based approach when setting and following up climate goals and actions, tools are necessary. Today, tools are available for climate performance follow-up, but IKEA wants to develop its capabilities for scenario analysis and simulation to be able to evaluate the impact of plans and future actions. Several scenario analyses tools have previously been developed and used within IKEA for evaluating and setting climate targets. These tools covered emissions related to production, food, product use at home and to some extent materials. This project has continued the development of these tools with the initial ambition to cover more parts of the IKEA value chain.

1.1.1 Emission areas at IKEA

IKEA calculate and report their GHG emissions in eight activity areas. These are materials, food ingredients, production, product transport, IKEA retail & other operations, customer travel & home deliveries, products use at home and product end-of-life. The climate footprint (the GHG emissions of the IKEA operations) for each area for the financial year 2020 is presented in Figure 2. As seen in the figure, the biggest footprints are from material, product use at home and production. In this report the terms climate footprint data and climate data will be used interchangeably.

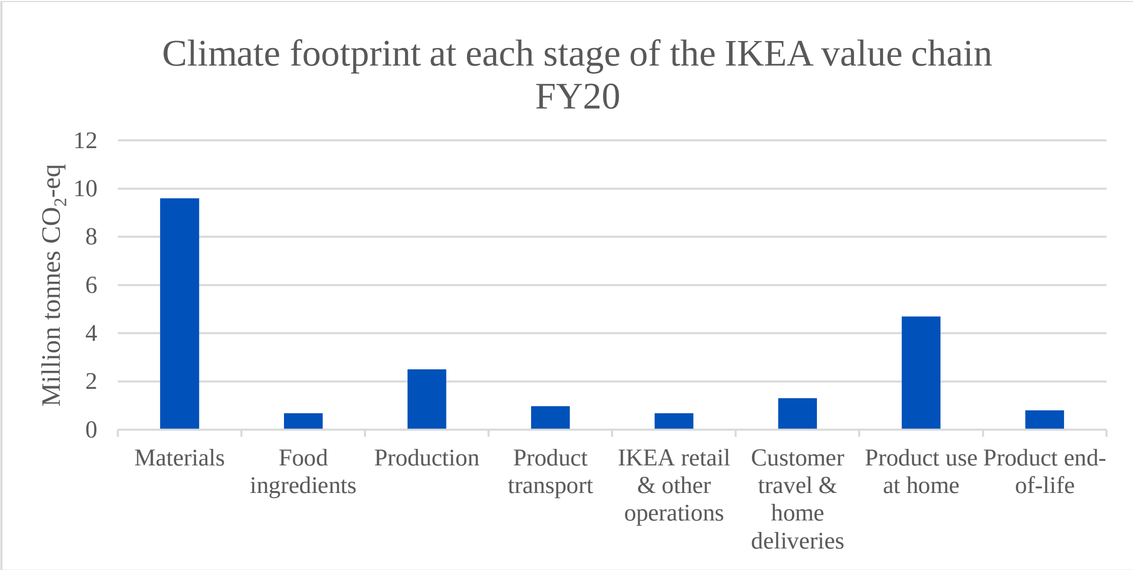

Figure 2. The yearly climate footprint at each stage of the IKEA value chain for the financial year 2020 (September 1st, 2019 to August 31st, 2020) (Inter IKEA Systems B.V., 2021).

A more detailed description of what is included in each emission area is presented in Table 1.

Table 1. The emissions areas included in the IKEA climate footprint (Inter IKEA Systems B.V., 2021).

CATEGORY	EXPLANATION
Materials	By far the biggest contributor to the IKEA climate footprint (45%). Includes emissions from raw material extraction and processing of materials up to the entry gate of tier 1 suppliers (suppliers that provides parts and products directly to IKEA). The calculations are mainly based on estimation which results in large uncertainties in the numbers.
Food ingredients	3% of the total climate footprint. Includes emissions from raw material extraction and processing of ingredients up to the entry gate of tier 1 suppliers.
Production	The third biggest contributor to the IKEA climate footprint (12%). Includes scope 1, 2 and to some extent scope 3 emissions from tier 1 suppliers. Includes both external suppliers, IKEA Industry, and IKEA Components for the supply of home furnishing products, food, components, and print. The footprint is reported on supplier level and not on product level.
Product transport	5% of the total climate footprint. Includes emissions from upstream product transport (home deliveries not included)
IKEA retail & other operations	3% of the total climate footprint. Emissions from the IKEA stores, offices, and similar operations.
Customer travel & home deliveries	6% of the total climate footprint. Includes emissions occurring from customer traveling to the stores and for customer home deliveries.
Product use at home	The second biggest contributor to the IKEA climate footprint (22%). Emissions occurring during the use phase of sold products. Can be products such as lighting, appliances, and candles. The emissions come mainly from the consumption of electricity used by the products.
Product end-of-life	4% of the total climate footprint. The estimated emissions related to end-of-life treatment of sold products, where a cut-off methodology is applied.

It is within these emission areas the scenario analysis capabilities need to be developed. For each area IKEA needs to set a target (if not already done), and to set and evaluate plans to see if they are in line with the target. Which emission areas that are included in the project is described in scope and limitation, section 1.4.

1.2 RELATED WORK

This project builds on the work done by Sander & Skoog (2017). They developed a simulation tool for IKEA to be able to do scenario analysis to support decision making when setting climate targets. The following research questions were explored in their study:

1. Which are the emission drivers relating purchased goods and services, and use of sold products in the IKEA scope 3 emission system?
2. Which parameters can be applied to allow steering on the emission drivers?
3. How should a simulation tool be designed to address and capture the behaviour and characteristics of the emission drivers in the scope 3 emissions system?

The focus of the study was to capture scope 3 emissions from the IKEA value chain. More specifically the authors looked at emissions from raw materials, food ingredients, production, and product use at home. A big part of the study was to identify the emission drivers for the different emission areas, meaning what causes the GHG emissions. This was done by conducting workshops with relevant stakeholders within business control and sustainability functions, as well as external experts. These emission drivers were implemented into a simulation tool developed in Excel. They concluded that the tool did provide good support for decision making. However, the simulation model did not include uncertainties for the GHG inventory and for assumptions made in the model. The tool did also have a very basic user interface and the user experience was thus limited. The authors recommends that feedback should be collected from the users of the tool to make sure it is operational and fulfils its purpose.

The simulation tool developed by Sander & Skoog (2017) has been further developed within IKEA after the projected was finished, with a focus on creating a graphical user interface. Most of the effort has been directed to simulation tools for production and food ingredients, with less effort spent on materials and product use at home. The emission drivers developed by Sander & Skoog will be used in this project and will be elaborated upon in section 5.5.

1.3 AIM AND RESEARCH QUESTIONS

The aim is to expand on the existing scenario analysis tools to enable a facts-based approach to climate goal setting by analysing the climate footprint of different scenarios. The tools will be used to support decision making. Also, a clearly defined collection and storing data format should be developed to allow for a standardised data management and a more automated update of the simulation tools.

The following research questions will be elaborated upon during the project:

- When expanding on the existing scenario analysis tools, what are the priorities and user needs for IKEA?
- To what extent can these priorities and user needs be realised/operationalised?
- How should a new data format be designed to allow for a more standardised data management for the emission areas production, IKEA retail, and other operations?
- Is it legitimate to use Attributional Life Cycle Assessment (ALCA) data as input data in a decision support tool? What are the implications of such a choice?

1.4 SCOPE AND LIMITATIONS

A considerable amount of data related to GHG emissions are needed to construct relevant simulation tools. IKEA yearly collects environmental performance data, and it is this data that will be used throughout the project. It is thus out of scope to collect more data than already exists within the organisation.

The time horizon used within the simulation tool is from the baseline year 2016 up until 2030.

The initial ambition was to cover all activity areas of the IKEA value chain. In the beginning of the project, a prioritisation was developed in collaboration with the supervisor at IKEA to decide what area should be implemented first. The prioritisation was as follows: production; IKEA retail & other operations; food ingredients; materials; product transport; customer travel & home deliveries; product use at home; and product end-of-life. However, due to time constraints the parts that ended being included in the project are production, IKEA retail & other operations, and food ingredients. The included activity areas will now be further explained.

Production

IKEA yearly collects sustainability data such as energy & GHG data, water usage and waste amounts from tier 1 suppliers. The GHG emissions related to the ingoing material to the tier 1 suppliers is captured by the material emission area (see Figure 2) and is therefore not included here. The climate footprint calculations for each supplier are based on the provided energy and GHG data. As part of the energy & GHG data, the suppliers provide information regarding electricity, fuel usage for production and building, fuels for internal transport, refrigerants and sold renewable electricity and heat. IKEA is using the emission factors provided by the Greenhouse Gas Protocol (GHG Protocol, n.d.-b) and the International Energy Agency (IEA) to calculate the GHG emissions based on the provided activity data (IEA, n.d.). The biggest drivers of the GHG emissions are the emission from purchased electricity and from onsite use of fuels for production and heating.

IKEA retail & other operations

Similar to production, IKEA collects sustainability data from all stores, offices, warehouses, and other operations.

Food ingredients

There is a product information system, including a bill of material, connected to all food products. With this information it is possible to find all ingredients of a product and their weight. The information from the bill of material is combined with sales data and emissions factors from the Ecoinvent LCA database to calculate the GHG emissions. The food emission area does only include emissions related to raw material extraction and processing of ingredients up to the entry gate of tier 1 suppliers. Emissions from tier 1 processing is included in the production emission area. The main emission driver is the emissions from meat, especially beef.

2 THEORETICAL BACKGROUND

2.1 SCENARIO ANALYSIS AND SIMULATION FOR DECISION SUPPORT

Simulations has been used for a long time to forecast the behaviour of a system, such as the economy, environmental pressures, and resource constraints (Swart, Raskin, & Robinson, 2004). An early implementation of such a model was “Limit to growth” where present trends in economic and technological growth was used to anticipate the trespassing of ecological limits (Meadows, 1972). These are forecasting models that based on historical data tries to predict the future. The outcome of these models can be used to steer business decisions. It was however recognised that the business decisions themselves affected the outcome and thus needed to be taken into consideration in the model (Huss, 1988). There was also a need to not just to create accurate forecasts but in assisting in the planning for the future. Scenario analysis was introduced to incorporate the possibility for business management to not just react to future conditions, but to evaluate different scenarios and then develop strategies to change the conditions themselves (Huss, 1988).

The terms simulation and scenario are sometimes used interchangeably. Looking at the definition of simulation it is defined as “the technique of imitating the behaviour of some situation or process” (Oxford University Press, n.d-a). Scenario on the other hand is defined as “a postulated or projected situation or sequence of potential future events” (Oxford University Press, n.d-b). The IPCC further defines scenario as “scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might unfold” (IPCC, n.d).

Moon (2015) conducted a literature review into how simulation modelling has been used within the area of sustainability. As sustainability is a wide area, the reason of using simulation differs a lot depending on the final application. Moon listed typical usage of simulation modelling as, (1) to develop a better understanding and gain insights of a system, (2) to compare various plans and scenarios before implementation, (3) to predict behaviours of a system, (4) to aid decision-making processes, (5) to develop new tools for investigation and (6) for training. The interest for this thesis is to use simulation modelling to aid decision-making (5) by comparing scenarios before implementation (2).

An example of an environmental scenario analysis is the emission scenarios developed by the IPCC (IPCC, 2000). They used advanced modelling and developed different scenarios depending on how society might progress in the coming century. This model incorporates the complex interplay between the social, economic and the nature aspect of society.

2.1.1 The simulation modelling process

As described in the previous section, a simulation tries to imitate the behaviour of a system. A system is generally defined as a collection of entities (Law, 2015). Law presents two ways to study a system. Either run an *experiment in the actual system* or an *experiment with a model of the system*. If it is possible and cost-effective it is generally recommended to run the experiment on the actual system. However, this is rarely the case, and in such situations, it might be more feasible to do an experiment on a model. To do an experiment with a model of the system there is a need for a *physical model* or a *mathematical model*. A physical model is used to run physical experiments on objects such as a model car. A mathematical model represents the logical and quantitative relationships between entities. The mathematical model can be used to answer the question under investigation and can be solved by either an analytical solution or a simulation. A simplified representation of the modelling process is presented in Figure 3 (Sargent, 1981).

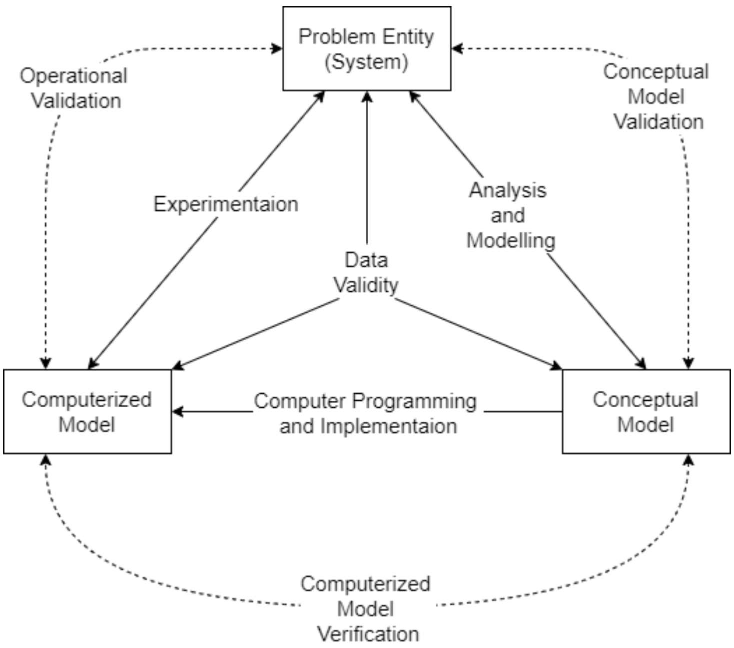

Figure 3. A simplified version of the modelling process (Sargent, 1981)

The problem entity is the real-world system under investigation. In this project that included activities and process that give rise to GHG emissions. The conceptual model is the mathematical representation of the problem entity. It is developed in the analysis and modelling phase. If the conceptual model is implemented on a computer, it is called a computerised model. During the phases of the modelling process there is a need for validation and verification (V&V) to ensure the model behaves as expected. Sargent (2010) defines model verification as "ensuring that the computer program of the computerised model and its implementation are correct". He further states that model validation is normally defined as "substantiation that a computerised model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model".

Thus, verification is more about that the implementation is correct, with the correct use of formulas and that little to no bugs are apparent. Validation is instead more about that the conceptual model itself is correct and that the results are applicable for its intended users. It might be good to point out that it might not always be possible to validate the model against the actual system (problem entity). Oreskes (1998) splits models into two categories, models that can be validated and models that cannot. For a model to be possible to validate it must: 1) be observable and measurable; 2) exhibit constancy of structure in time; 3) exhibit constancy across variations in conditions not specified in model; and 4) permit the collection of ample data. In the area of sustainability and environmental systems, this is generally not the case. A model of an environmental system will thus generally be evaluated against the scientific knowledge/agreement of how the system works.

Sargent (2010) explains three common ways of integrating V&V into the model developing process. The first approach is to let the model development team themselves evaluate if the model is correct. To avoid bias it is however better to use one of the other approaches. The second approach is to involve the stakeholders and intended users of the model to verify its validity. The last approach is to let an independent party to make the decision if a model is valid, often called "independent verification and validation" (IV & V).

2.2 SCIENCE BASED TARGET INITIATIVE

IKEA is part of the Science based target initiative and have set targets which are in line with the Paris Agreement. The emission reduction targets specified in the SBTi for IKEA are (SBT, n.d.):

- *"The IKEA home furnishing business commits to reduce absolute GHG emissions across the IKEA value chain (scope 1, 2 & 3) at least 15% by FY2030, from a FY2016 base year.*
- *Inter IKEA Group commits to reduce scope 1 and 2 GHG emissions 80% by FY2030, from a FY2016 base-year. For IKEA retail operations (scope 3), the franchisee Ingka Group commits to reduce absolute scope 1 and 2 GHG emissions 80% by FY2030, from FY2016.*
- *Inter IKEA Group also commits to reduce absolute scope 3 GHG emissions from production at direct home furnishing, food, component and catalogue suppliers 80% by FY2030, from a FY2016 base year.*
- *Inter IKEA Group and the franchisee Ingka Group commit to reduce scope 3 GHG emissions 50% per person for customer and co-worker travel and home deliveries by FY2030, from a FY2016 base year.*

- *Inter IKEA Group includes the IKEA franchisor, range development (including food), supply and some manufacturing activities. The target boundary includes biogenic emissions and removals from bioenergy feedstocks*
- *The targets covering greenhouse gas emissions from company operations (scopes 1 and 2) are consistent with reductions required to keep warming to 1.5°C."*

The SBTi encourages companies to set GHG emission reduction targets in line with what the latest climate science considers to be necessary to meet the goals of the Paris Agreement (Science Based Targets, 2021a). The Paris Agreement has a goal to limit global warming to well below 2 degrees Celsius, with the ambition to limit warming to below 1.5 degrees, compared to pre-industrial levels (U.N. Doc. FCCC/CP/2015/L.9/Rev/1, 2015). The SBTi is a collaboration between the World Wide Fund for Nature (WWF), World Resources Institute (WRI), the United Nations Global Compact and CDP. The SBTi issues a number of criteria and recommendations that applying companies has to address (Science Based Targets, 2021b). All the criteria must be meet while recommendations are suggestions for improved transparency and best practice, but not required. It is also stated that companies must report their emissions in compliance with the Greenhouse Gas Protocol (GHG Protocol) Corporate Standard, Scope 2 Guidance, and Corporate Value Chain (Scope 3) Standard.

2.3 GREENHOUSE GAS PROTOCOL

As described in the previous section, companies must comply with the GHG Protocol to be approved by the SBTi. The GHG Protocol is a partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), and is the world most widely used GHG accounting standard (GHG Protocol, n.d.-a). IKEA is using the methodology presented by the GHG Protocol to calculate their GHG emissions. More specifically they are using the Corporate Standard (WRI & WBCSD, 2004), the Scope 2 Guidance (WRI, 2015) and the Corporate Value Chain (Scope 3) Standard (WRI & WBCSD, 2011). The GHG Protocol divides different types of emissions into scope 1, 2 or 3 emissions, see Figure 4. Scope 1 emissions are direct GHG emissions from sources that are owned and controlled by the reporting company. Examples of scope 1 emission are emission from onsite combustion and vehicles. Scope 2 emissions are emissions that comes from the generation of purchased electricity, steam, and heating/cooling. Scope 3 includes all other indirect emissions from sources not owned by the reporting company, such as emissions from material extraction and emissions that occurs in the user phase of sold products.

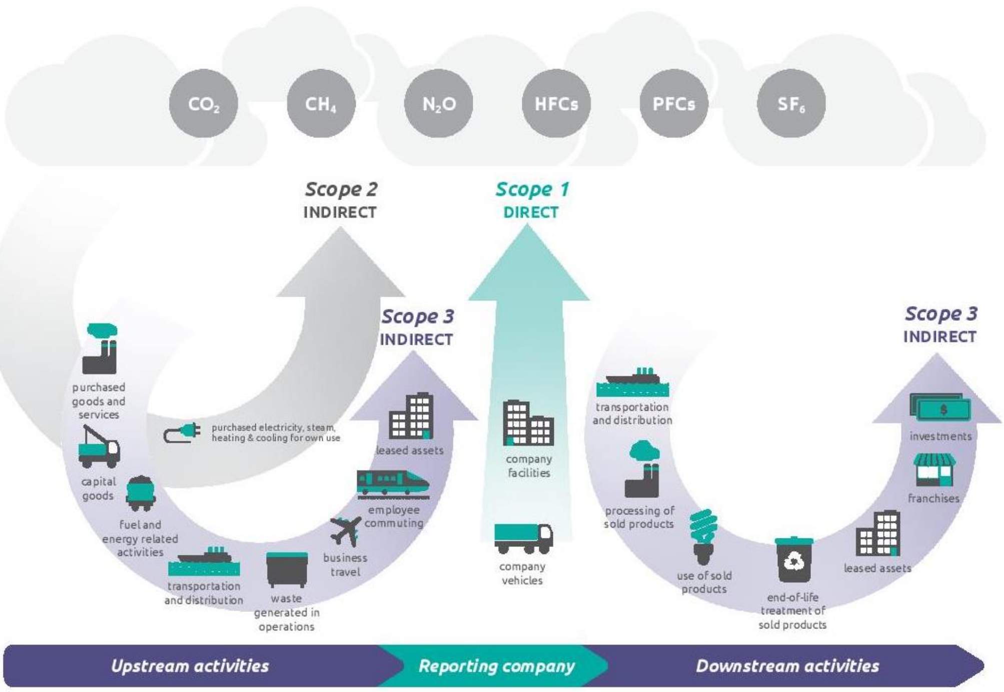

Figure 4. The scopes of the GHG Protocol (WRI & WBCSD, 2011).

2.4 THE USE OF ATTRIBUTIONAL LCA DATA IN A DECISION-MAKING TOOL

There is an ongoing debate within the LCA community on the suitability to use attributional LCA (ALCA) data for decision-making support (Brander, 2017; Ekvall, 2019; Weidema, 2003). The main critique is that attributional accounting does not capture the full consequences of a business decision and might in some cases lead to increased emissions (Brander, 2017; Plevin, Delucchi, & Creutzig, 2014). As described in section 2.3, IKEA is using the GHG Protocol for corporate GHG accounting which is based on the attributional approach (Brander, 2017). The simulation tools developed in this project are in turn using the data collected according to the GHG Protocol with the aim to support decision making. Since the carbon footprint is essentially an LCA limited to greenhouse gases (ISO, 2018), the topic is of interest in this project.

As an alternative to ALCA, consequential LCA (CLCA) has been developed to provide information on the consequences of a decision (Ekvall & Weidema, 2004). Ekvall (2019) explains the difference as; "*an attributional life cycle assessment (ALCA) estimates what share of the global environmental burdens belongs to a product. A consequential LCA (CLCA) gives an estimate of how the global environmental burdens are affected by the production and use of the product.*". The two methods are thus used to answer different questions. Figure 5 visualises the difference between attributional and consequential LCA.

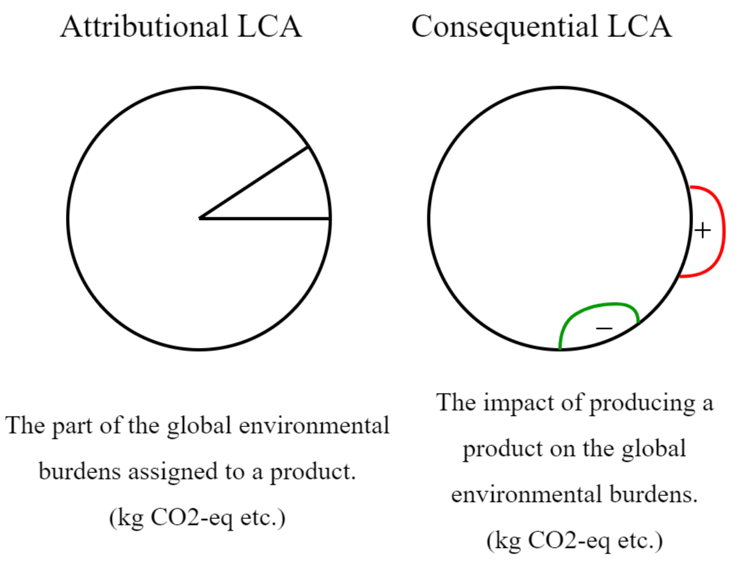

Figure 5. A visual representation of the difference between attributional and consequential LCA. Based on (Weidema, 2003), referred by (Ekvall, 2019).

For example, a company might purchase renewable electricity and using ALCA in an effort to improve its environmental performance. However, it is not certain that such an action increases the production of renewable electricity, just rearranging who takes credit for the "good" electricity. In that case, no environmental improvement will be achieved. CLCA aims at considering the expected consequences of a decision and will only give credit if the renewable electricity system is expected to expand or that dirty sources are expected to decrease (Weidema, 2003). An example when the CLCA will not give any credits is if the renewable energy source is constrained, such as is often the case with hydropower. In order for CLCA to capture the consequences of a decision the system boundary is set to include all parts affected by the change, also parts outside the value chain (Ekvall, 2019). ALCA, generally sets the system boundary in relation to the value chain. CLCA also uses marginal data instead of average data. This as a change in demand is generally affecting the marginal production of a system. Lastly, CLCA is using system expansion instead of allocation in a multi output process.

In the decision of choosing between ALCA and CLCA, Weidema (2003) states that it is important to clarify if the stakeholders are really interested in the environmental impacts of its products, or more in the environmental impact of its supply chain. If the stakeholder is truly interested in ensuring that the global environmental impacts are reduced because of one's decisions, a consequential approach should be applied. This approach will then investigate and include parts affected outside what is controlled by the actor.

From a strict consequentialist perspective, it is stated that a decision-maker should take full responsibility of the consequences of one's actions (Brander, 2019). Brander argues that this is excessive and impractical, and that a normative rule must be applied to delimit what set of consequences an actor should be considered responsible for. This is what is done in attributional inventory boundary-setting. Brander (2017) also lists that ALCA is generally useful for assigning responsibility for environmental impacts, setting carbon budgets, and for setting reduction targets. However, if the LCA should be used for developing actions for emission reductions, CLCA should be used to ensure the action do not have unintended consequences.

As ALCA and CLCA answers different questions, Ekvall (2019) suggests that the practitioner should discuss the goal and scope with the client before deciding on an approach. Ekvall further states that CLCA roughly speaking is more accurate in evaluating the environmental impact of a decision, while ALCA has advantages in more or less all other aspects as it is the most well-known and used approach.

As an interesting note, the GHG Protocol recognises that the attributional approach does not always capture all changes in emissions associated with a decision. It is stated that "*some companies may be able to make changes to their other operations that result in GHG emissions changes at sources not included in their own inventory boundary*" (WRI & WBCSD, 2004). An example of this is the installation of an on-site combined heat and power (CHP) plant that produces electricity and sells excess heat to the district heating grid. If the emission factor of the sold heat is lower than the substituted energy source, this would result in a total reduction of emissions in the system. This is however not captured by the GHG Protocol Corporate Accounting and Reporting Standard. It is instead stated that these reductions may be reported separately.

3 METHOD

The project has been carried out as a case study at IKEA, looking into how scenario analysis tools has been used and what further needs are requested. This was done in a number of steps. Firstly, a literature review was conducted. Then, interviews were performed with stakeholders at IKEA in order to find out the needs of the organisation. From the interviews, a number of requirements were defined. These requirements were later implemented into the simulation tool. Within the implementation phase, a standardised data structure was designed, and functionality was developed to be able to update the simulation tools based on the data structure. These steps will now be explained in more detail.

3.1 LITERATURE REVIEW

A literature review was carried out in the beginning and throughout the project to find literature related to the use of scenario analysis to set and follow up corporate climate targets. The area is rather unexplored, and it is hard to find good and relevant sources. IKEA wants to use scenario analysis to identify and prioritise activities and investments to reach the strategic goals as well as setting fact-based climate targets for each business unit. They are thus not just interested in forecasting, but instead in asking questions such as "what if we do this action, what is its contribution to reach our goal?". The following search phrases was separately used to find relevant sources of information:

"Scenario analysis", "scenario analysis in decision making", "scenario analysis tools", "scenario analysis corporate greenhouse gas emissions", "simulation tool greenhouse gas emissions", "simulation tool sustainability", "decision making attributional LCA", "decision making consequential LCA", "corporate climate targets".

Google Scholar, Chalmers library online search and Google Search was the search engines used in the literature review.

3.2 STAKEHOLDER INTERVIEWS

To develop a tool that is usable and fulfils its purpose it is necessary to balance the need of the user with the business objectives and technical requirements (Knight, 2019; see Figure 6). Therefore, semi-structured stakeholder interviews were conducted with the intention to understand both the user need and the business objectives. Semi-structured interviews were chosen because of the flexibility to have an open-ended exploratory discussion based on predefined questions (Wilson, 2013).

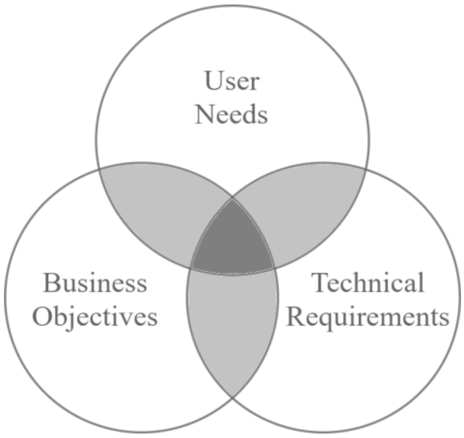

Figure 6. Balancing user needs, business objectives and technical requirements (Knight, 2019).

Each interview had the following phases:

- An introduction was held to provide context and stating the purpose of the interview.
- The interviewee/interviewees were presented a number of questions which were elaborated upon. The interviewer asked for clarification and for further information when necessary.
- Closing comments including the possibility for the interviewee/interviewees to freely share any thoughts or comments

To get meaningful responses during the interview it is important to pay attention to- and develop good questions (Nunnally & Farkas, 2016). The questions were developed based on the master's thesis description and in collaboration with the supervisor at IKEA. The main theme when developing the questions was to understand how different parts of the organisation worked with setting and following up climate goals and how scenario analysis could help. The questions that were developed and asked during the interviews are presented in Table 2 together with the reasoning behind them.

Table 2. Questions that were asked during stakeholder interviews.

QUESTION:	**COMMENT:**
What is your and your department's role within IKEA?	Was asked to get a better understanding of the interviewee and the context that person was situated in.
How do you set and follow-up climate goals and action plans today?	This is a key question to get a good understanding on how they work with setting and following up of goals and actions.
Related to setting and following up climate goals/actions, what problems are there that can be solved with a Simulation tool?	This question focused on problems that could be solved with a simulation tool as it was the scope of the thesis project.
What would enable you to include simulations/scenario analysis in your role today?	There is a general understanding that simulation capabilities are necessary. There are also some tools available today. This question tries to understand what would enable these capabilities to be used throughout the organisation.

What kind of granularity do you need when it comes to simulation parameters and filtering options?	Different users and departments have different needs when it comes to level of granularity and possibilities to filter down on certain aspects. These are important to find out before developing the tool.
There is a simulation tool for some business areas available in Excel today. Have you used it, and does it fulfil some/all of your needs?	Tries to understand how the existing tool has been used and to what extent.

The interviews were carried out with stakeholders within a variety of positions, mainly within business control and sustainability functions. Most interviews were conducted with stakeholders related to the emission area production, followed by interviews with people related to retail & other operations and food ingredients. A more detailed presentation of all interview occasions including date, part of IKEA and stakeholder position is presented in appendix A.

3.3 IMPLEMENTATION, USABILITY TESTING AND VERIFICATION

Two simulation tools have been developed, one combined for production and IKEA retail & other operations, and another for food ingredients. In relation to the simulation tools, two separate tools for updating the simulation tools have been developed. The implementation was carried out in five main steps as presented in Figure 7. Step 2 is mainly connected to the tool developed for production, IKEA retail & other operations. The food tool is using a predefined data format given by IKEA. Each step will now be briefly explained.

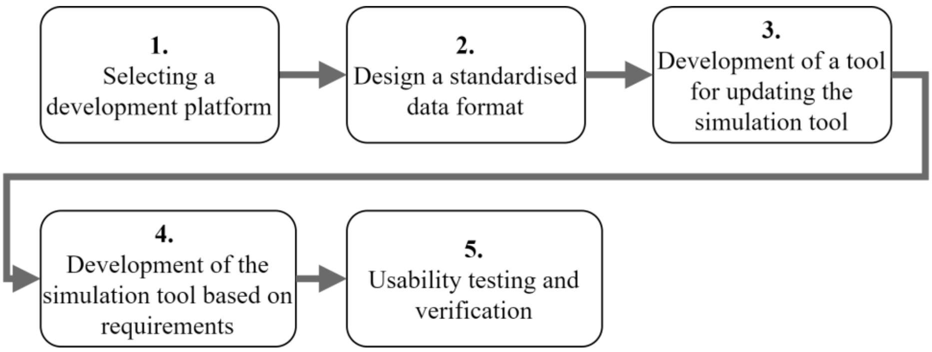

Figure 7. The main steps in the implementation phase.

Selecting a development platform

In the beginning of the project an exploratory investigation to evaluate and find the best tool/platform for the needs of IKEA was carried out. The main alternatives to Excel that was investigated were Power BI or to build a cloud-based web application. More details of this process are explained in section 5.2.

As an outcome of this process, it was decided that the development of the simulation tool will continue within Excel. Thus, Excel has been used together with Visual Basic Application (VBA) and

UserForms. VBA is the programming language used within Excel to implement custom functionality. UserForms are used to build user interfaces within Excel to be able to collect and process user input.

Design a standardised data format

There is a need to standardise the data format used to calculate the climate footprint for production, IKEA retail, and other operation. As the simulation tool should be updated based on the new data format there was a need to define it before moving into the development of the simulation tool. The requirements and needs of the new data structure are explained in section 4.4.

Development of a tool for updating the simulation tool

The new simulation tool should be possible to update based on the new data structure. It should also be possible to use data in the new data format for other applications as well. Therefore, a separate update tool was developed. The development of the update tool is explained in section 5.2

Development of the simulation tool based on requirements

Based on the interviews, a number of requirements of what should be implemented were defined in collaboration with the supervisor at IKEA. A selection of these requirements where then implemented into the existing simulation tools as developed by Sander & Skoog (2017). The requirements are defined in section 4.2 and 4.3 and the implementation process of these are explained in section 5.4.

Usability testing and verification

IKEA wants the developed simulation tool to be widely used in the organization by a multitude of users to set and evaluate climate goals and actions. To be accepted and used it is important to develop a tool with the user in mind and to conduct usability testing (Barnum, 2011). Usability testing gives insights into how the actual user use the tool, what is working for them or not. Usability is defined as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." (ISO, 2013). It focuses on the users, the goals, and the context. The approach suggested by Barnum (2011), "How to Conduct Small Studies" has been used and adopted in the project. The steps carried out in the usability testing was:

- A small introduction on how to use the tool, such as how it looks and what features are available.
- Let the user perform a number of predefined tasks while "thinking-aloud".
- Let the user freely share any additional thoughts or comments.

Participants for the usability testing were selected from the interviewee participants based on if they were considered as users of the tool or not. It was limited to three participants due to the availability of time. Details of the time, part of IKEA and stakeholder position is presented in appendix A. Ideally, further iterations of user testing and development should be performed to ensure what has been implemented are fixing the usability issues. However, only one iteration was performed in this project.

Connected to the verification of the simulation tools, this project builds on the work done by Sander & Skoog (2017). They let appropriate stakeholders, such as external experts and sustainability roles within IKEA, be involved in verifying the validity of equations, parameters, emission drivers and the result of the model. It is therefore expected that the output from the tools developed by Sander & Skoog is consider valid from the perspective of relevant stakeholders. This project is using the conceptual and computerised model by Sander & Skoog. To verify the output from the new tool it has been compared with the output from the tool by Sander & Skoog. In the case where alternations or new features has been added it has been developed and verified with relevant stakeholders.

4 IKEA PRIORITIES - RESULTS FROM THE STAKEHOLDER INTERVIEWS

This section will present the findings from the stakeholder interviews as well as the needs of IKEA when it comes to defining a standardised data format. The findings from the interviews were used to define a number of requirements before moving into the implementation phase.

4.1 FINDINGS FROM THE STAKEHOLDER INTERVIEWS

Interviews has been conducted with a variety of stakeholders from different parts of the IKEA organisation. The needs and problems differ as a lot depending on the role of the interviewee. The existing simulation tool has been used to set climate targets and evaluated action plans. As an example, one category area added expected improvements into the simulation tool until 2030. They added the expected growth, the expected new share of renewable purchased electricity and the expected change in energy sources. It became apparent for them that what was in the action plans were not enough to reach their reduction target. Another category area added the actions that they thought were feasible to implement into the simulation tool. They discovered that it seemed possible to reduce their climate footprint by 80% until 2030 and thus set that as their climate footprint reduction target. The existing simulation tool seems to fulfil its main purpose; however, the users expressed a number of issues and further needs that will now be presented. These has been grouped into four themes, namely, usability and user competence, technical issues and solutions, governance, and further user needs.

Usability and user competence

Some stakeholders expressed that the existing tool was a bit too complicated and hard to use. It was related to the how the user should input the parameters used in simulation. They were sometimes unsure what to enter and in what format to get the intended outcome. Multiple interviewees expressed their wish for a tool that is very easy to use and if possible integrated into the Business Intelligence (BI) solutions they use at IKEA today.

It was expressed by a Sustainability Developer that the existing simulation tool did not fit their working needs. It was stated that to do scenario analysis on supplier level it is possible to use the sustainability collection tool for suppliers and enter alternative numbers and see the outcome. The need for simulations is instead on category area level to answer questions such as, what will be the outcome if we complete all the actions in the supplier action plan? It was however expressed that the existing tool was too general to be able to convert all the supplier action plans into the simulation tool and see the outcome.

One interviewee showed multiple aspects of the tool where the usability could be improved. It included the removal of unused fields and the addition of clarification on what certain functions within the tool meant.

A comment that expresses how they would like it to work is: “The teams do not want another tool, they are already flooded with different tools, they want the functionality to be integrated into the systems they already use”.

Technical issues and solutions

Multiple users reported that bugs regularly appeared when using the simulation tool. When a bug appeared, the users could not save simulation parameters or run a simulation. Sometimes, an error message appeared during execution, but a simulation result was presented anyway. They users could not trust the result in that case.

Regarding the granularity of the data used in the tool the users would like to implement improvements on at least supplier levels into the simulation tool, which is also possible today. It was also expressed that if it is possible, they would like to have the possibility to implement improvements on production unit level as a certain supplier can have multiple production units. A category area specific request was to be able to work with improvements on paper grade level for a certain supplier and production unit.

Related to the existing simulation tool used for food ingredients, one main issue was the file size of the tool which was around 250 MB. Because of this it takes a long time to open, and Excel do sometimes crash when opening the file on less powerful computers. Running simulations takes a long time due to the size of the dataset. The interviewee tried to introduce the tool to more people, but due to the slowness, the file size, and the usability of the tool it was not successful. A large file-size and slow simulations processing has also been experienced on the production simulation tool, but not to the same extent.

Governance

Based on the interviews, it became apparent that the “intended user” of the tool was not clearly defined. From the climate team perspective (the team responsible for developing the previous simulation tool), the intended user was often specified as the person responsible to the climate agenda within for example a category area. However, talking with the sustainability developers within the category areas, it seemed unclear who is responsible for using the simulation tool to evaluate the climate agenda. Some expressed that it was up to the Business Developer to follow up the climate targets and thus use the simulation tool.

When the tool has been used it has mainly been used in close collaboration with the climate team. The tool has contained bugs and was considered non-initiative, and the users needed support to use it properly. It has also been up to the climate team to update the simulation tool every year with new emission data. This is a manual process and has not been done for the production tool for a couple of years. Therefore, it is not uncommon that the tool has been used at only one occasion in collaboration with the climate team. Some expressed that if the tool is available and updated it would be used.

Further user needs

All parts of IKEA are working with improvements but it hard to find out if it is enough and if they reach their goals. IKEA together with the suppliers defines an action plan for making improvements of their operations. They would like to see what the total improvement will be if all actions are implemented. Ideally, they would like to see if they are on track with their climate targets within the tools they use today, such as the action planning tool and the BI system.

Some stakeholders expressed that they did not have any need for simulation capabilities. These were interviewees who had the responsibility for areas that was limited to a few emissions activities. It was clear for them what part that was the biggest emissions source and what kind of improvements that is needed, without the need for simulations. It was mainly interviewees with responsibility over offices and warehouses.

Within food ingredients, the interviewee presented some ideas to extend the functionality of the tool. IKEA is on a journey where they are working on improving the emission factors for their ingredients. One idea was to include the functionality to compose a new dish within the tool. The new dish could then be used to substitute existing products.

Stakeholders related to product development wants to find out, what will be the climate footprint if another material is used in a certain product or if a product is designed in another way. As explained in section 1.1.1, the biggest contributor to the IKEA climate footprint is the material footprint. The initial ambition in the project was to develop simulation capabilities for the use of different materials. But due to time constraints it was later excluded from the project. Therefore, this business need was not further investigated.

4.2 REQUIREMENTS FOR THE PRODUCTION AND RETAIL & OTHER OPERATIONS SIMULATION TOOL

Based on the stakeholder's interviews and prioritisation made together with the supervisor at IKEA the requirements in Table 3 were defined. The requirements are mostly technical, meaning they are aimed at being implemented into the simulation tool. Aspects connected to governance and user competence is further discussed in the discussion section. The main identified issues that are targeted in the requirements are; to more easily update the simulation tool based on the new data format and improve the usability.

Table 3. The requirements for the production and retail & other operations simulation tool. The underlined requirements have been implemented in the project.

PRIORITY	
MUST	• <u>Make the tool less dependent on the climate team. Make it possible to update the tool more easily based on the new standardised data format.</u> • <u>Fix apparent bugs and errors.</u> • <u>Make usability improvements where stakeholders expressed that it was hard to use.</u> • <u>It should be possible to use it with data from retail & other operations. The previous tool has mainly been developed for production. The data is very similar, and the aim is to make sure it works with both production and retail & other operations.</u> • <u>Update the calculation logic for the simulation of energy efficiency.</u>
SHOULD	• <u>If possible, reduce the size of the file and improve the computing time to allow for usage on computers with less computing power.</u> • <u>Make it possible to update the reduction target trajectory within the tool.</u>
WOULD	• Be able to see the impact from each scenario as a waterfall graph. For example, to be able to see the improvement from energy efficiency and separately see the improvement from the change of an energy source, not just the total improvement. • Be able to change the location of a supplier, from one country to another. • Add a name or comment to each scenario added in the tool.
NOT INCLUDED	• From a product develop perspective. To see what the impact will be if the product were developed differently or if another material were used. If developed, it should be part of the tool used for the material emissions area (out of scope in this project). • Be able to see what the total improvement will be if everything in the supplier action plan is implemented. A very common request. It is possible to one by one add these actions into the simulation tool, but some category areas have several hundred suppliers with a lot of action plans per supplier and it will be too cumbersome to add all these to the tool. They would like to automatically see the total improvements within the systems they use today.

4.3 Requirements for the food ingredients simulation tool

The requirements in Table 4 were defined for the food simulation tool. It was mainly defined from the interviews with the Sustainability Development Leader responsible for the food agenda. The main identified aspect of improvement was to reduce the file size and improve the usability.

Table 4. The requirements for the food simulation tool. The underlined requirements have been implemented in the project.

PRIORITY	
MUST	• Reduce size of file. The previous version was 250 MB. • Improve computing times of simulations. • Make the tool use the updated business information and business categories used for food products. • Make it possible to update the tool with new data more easily.
SHOULD	• Improve the usability of the tool. Remove not used fields and add explanations if necessary.
WOULD	• Be able to change emission factors for ingredients more dynamically for certain years.
NOT INCLUDED	• To be able to compose a new dish (product) within the tool and simulate the climate impact.

4.4 Defining a standardised data format for production, IKEA retail & other operations

The simulation tools need to be provided with relevant data. This data needs to be in a predefined format for easy update of the tool but also to make sure that the data is handled and collected in a standardised manner. IKEA has a standardised data format used when collecting GHG data from production (tier 1 suppliers), but it needs to be developed. It has been a part of this project to develop this new format.

Firstly, the new format should use the common identifier for business units as defined in the IKEA Corporate Base Data system. A business unit can for example be a supplier, a store, or an office. This identifier has partly been used before but not in a structured manner and to ensure a standardised way of referring to business units it should be used. Also, IKEA occasionally develops and revise their calculation methods and thus needs to redo the calculations for previous years to get comparable results. To be able to redo the calculations, access to non-aggregated raw data is needed. However, some of the data that has been collected from the business has been provided in an already aggregated format making it hard or impossible to apply the now calculation logic to it. Therefor there is a need to define a collection format that is granular so that it is possible to redo calculations if necessary.

Further, there is a requirement from the GHG Protocol that companies should report their scope 2 emissions both according to the market-based and location-based method (WRI, 2015). Market-based emissions reflects emissions from e.g., electricity that the company has purchased with contractual agreements such as Renewable Energy Certificates (REC). For further clarification, a private consumer can often choose the origin of the electricity, such as wind power, when choosing electricity agreement. This is normally handled with market instruments. However, market instruments do not reflect the actual electricity (electron) that appear in the power outlet of the purchaser. Instead, the instruments generally make sure that the same amount of electricity that is being consumed by the customer is generated into the system, but the actual consumer of the electricity (the electrons) is generally unknown (Brander, Gillenwater, & Ascui, 2018). Renewable electricity from wind and solar energy is intermittent and to maintain a reliable electricity system there is a need for balancing resources (WRI, 2015). It is not uncommon that such balancing resources use fossil energy that in turn releases GHG emissions.

The location-based method tries to reflect these emissions as it uses regional or grid average emission factors (WRI, 2015). To get a more complete picture of the scope 2 emissions companies should report both according to the market-based and location-based method and the newly developed data format should make sure this is possible. The GHG Protocol further states that companies shall (required to) separately report CO_2 emissions arising from the use of biofuels (WRI, 2015). GHG emissions from biofuels are commonly reported as “zero” since it is considered to be part of a natural cycle where the released CO_2 will be captured when new trees grow. But burning biofuels will result in a direct emission of GHG gases and these emissions should separately be reported according to the GHG Protocol. The data structure should allow for the inclusion of biogenic emissions.

Today IKEA capture emissions occurring in production of tier 1 suppliers. One thing that has been omitted in these calculations are emissions associated to material processing at tier 1 supplier, more specifically emissions occurring from glass production. These emissions are likely small in relation to the total IKEA footprint but should nevertheless be included. Glass producers use carbonates such as limestone ($CaCO_3$) as raw materials (IPCC, 2006). When the limestone is heated CO_2 is released and lime (CaO) is formed, see equation 1.

$$CaCO_3(limestone) + heat \rightarrow CaO\ (quicklime) + CO_2 \quad (1)$$

The newly developed data format should be able to capture these emissions. Energy consumption for glass production is already captured in the previous format.

It was also discussed during the design of the new data format to make it possible to collect activity data from Combined Heat and Power (CHP) plants. A CHP plants produces both electricity and heat from the combustion of an energy source such as coal or biofuels. Today IKEA collects the amount of fuel, such as coal or biofuels, that has been used by a supplier, but it is unknown what it is used for. To get a better understanding of the electricity and heat consumption it would be beneficial to know how much electricity and heat that has been generated onsite from a CHP plant. A CHP process is a single input, multiple output process and it is necessary to allocate a certain amount of emission to each product. The GHG Protocol presents several methods for allocating the emissions to either electricity or steam/heat (WRI/WBCSD GHG Protocol Initiative, 2006). These methods are rather straight forward to implement and use. The reason why CHP information was excluded from the new data format was that it will result in a more complicated logic in the simulation tool, with low added benefits. For example, if the user would like to create a scenario where the energy source of electricity from a CHP should be replaced with purchased renewable electricity, how should that be handled within the simulation tool? If you stop producing electricity and purchase it instead, but still need the heat from the CHP, what will happen with the emissions related to heat? This will add extra logic and it was not the priority of IKEA to have this functionality now. It was therefore excluded within this project.

4.4.1 Requirements for the standardised data collection format

The new data format should:

- build on the existing data format,
- use the common identifier for suppliers, stores, and properties etc. as defined in the IKEA Corporate Base Data system,
- make it possible to collect data as granular as possible to be able to redo calculations if necessary,
- be compliant with the GHG Protocol with special emphasis on making sure it is possible to calculate both according to the market-based and location-based method,
- be possible to capture and separately report biogenic CO_2 emissions,
- capture emissions from glass production,
- be able to separate the emissions into scope 1, 2 and 3,
- be able to calculate the footprint not just on the supplier level, but per production plant of that supplier.

5 IMPLEMENTATION AND RESULT

This section will present how the new data format, the simulation update tools, and the simulation tools have been developed. The section starts with explaining the new data format used for production, IKEA retail & other operations. As a next step, the development of the update tool based on the new data format is explained. Before moving into the development of the simulation tool, the selection of an appropriate development platform is presented. Then, the development of the simulation tool is explained followed by showing the resulting simulation tools. The section ends with presenting the findings from the user testing.

5.1 THE STANDARDISED DATA FORMAT FOR PRODUCTION, IKEA RETAIL & OTHER OPERATIONS

The implementation of the requirements for the standardised data format as presented in section 4.4.1 were carried out in the beginning of the project before moving on to the development of the simulation tools. It resulted in both a single table data format and a format with multiple tables based on the relational data model. The main model that should preferably be used going forward is the relational data model. It is this model that has all the fields necessary for being compliant with the requirements in section 4.4.1 and is built to be used in analytical applications. However, to allow for an easy migration from the current data structure used within IKEA for the collection of sustainability data from suppliers, there was a need to develop the single table format as well.

The single table model

The single table data format stores all data in one single table. The Excel based tool used within IKEA to collect sustainability data from suppliers produces a large single table containing GHG data. The new single table data format has a similar structure to allow for easy migration from the old format to the new one. Optimally, the sustainability data collection tool should provide the data in the new single table format as output. The new format is visualised in Figure 8. The part in the middle of the figure shows the whole format, containing business data in yellow and GHG data in green. A part of the business data has been enlarged and shows data such as type and code of the reporting entity, the reporting period, name, and country. The type and code are defined by the IKEA Corporate Base Data system and the type could for example be SUP for supplier, STO for store, and OFB for office building. The Custom key 1 and 2 has been added to allow for further granularity such as on production unit and paper grade level. The key for each entry in the single table format is [Type] + [Code] + [Custom key 1] + [Custom key 2]. There is also a part of the GHG data that has been enlarged and shows the total purchased electricity, the renewable share, and the emission factor of that electricity. It further shows the amount of crude oil used, and what unit it has been specified in. This format allows for each supplier to year by year report their business information and activities leading to GHG emissions. The single table format is easy to share and store in Excel. However, the format is inconvenient to work with to perform more advanced analytics and it takes unnecessary large storage space as it is 141 columns wide. To for example calculate the total footprint of all suppliers and to see what share is allocated to a certain emission source, a relational data model is to prefer.

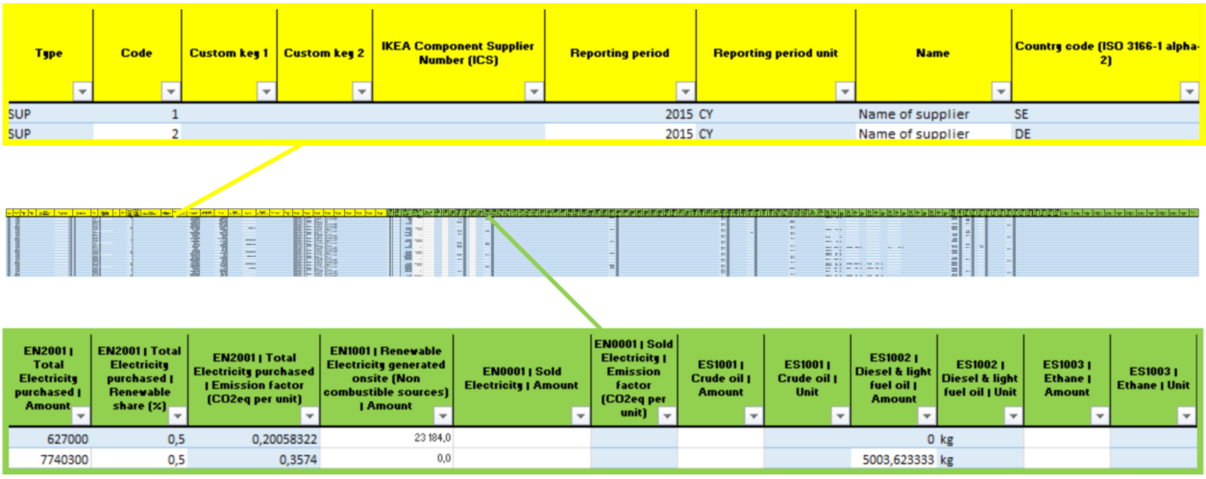

Figure 8. The new single table data format enlarged at two sections (filled with dummy data).

The relational model

A relational data model is the format commonly used by database management systems where related atomic data (data that cannot be decomposed into smaller pieces) are stored in tables and relate to other tables with a relationship (Codd, 1990). In the newly developed relational model, the single table model is broken up and split into separate tables containing similar data, see Figure 9. This model resembles a relational model often seen in databases and the ambition is to create a model that is easy to migrate into a database when such infrastructure is available. The transformation from the single table format to the relational format is done within Excel with Power Query, a tool for combining and transforming data into the wished format (Microsoft, 2020b). This is further explained in section 5.2.1.

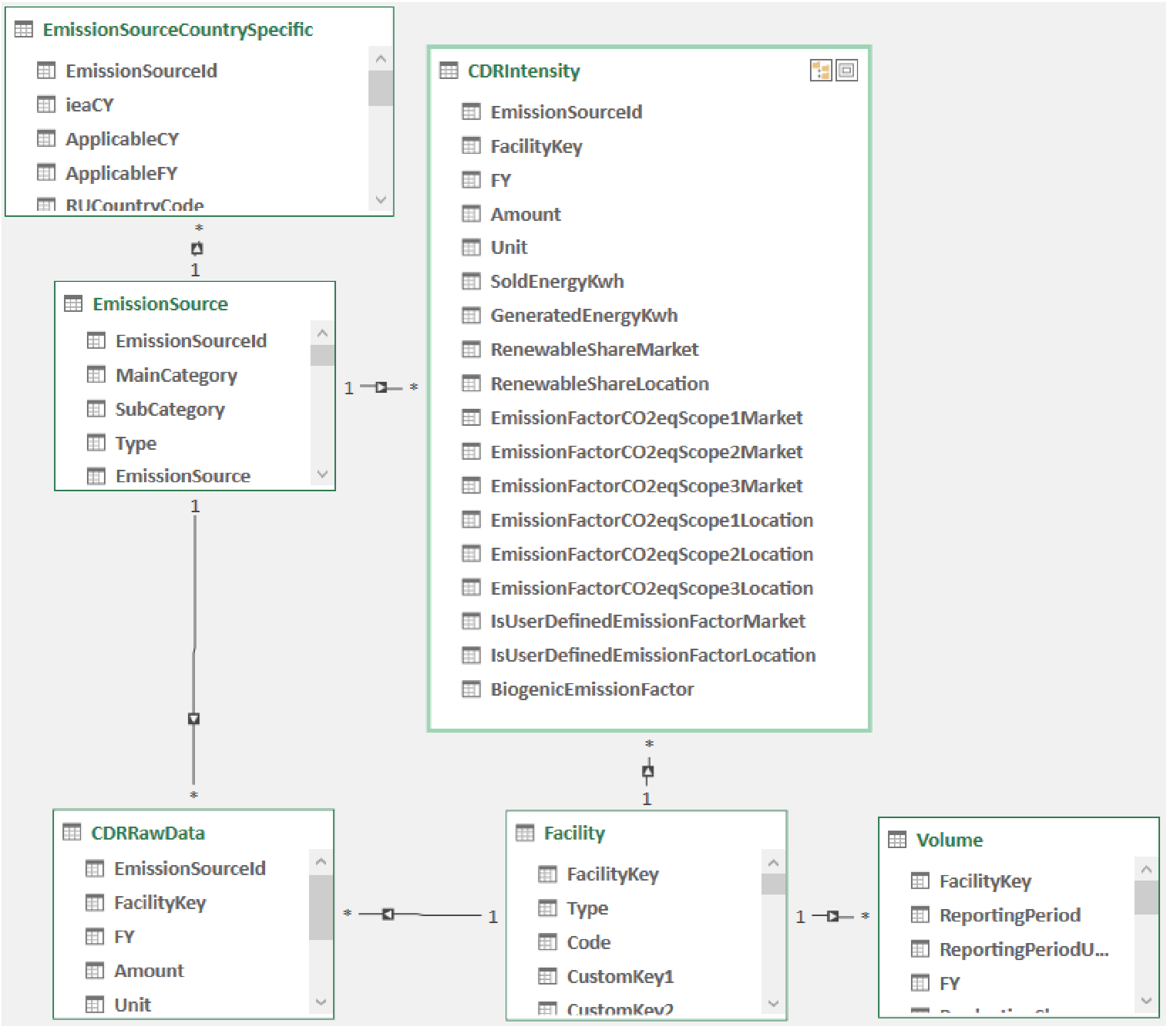

Figure 9. The relationship data model where similar data are grouped together in separate tables and a relation is created to relate to other tables.

The main parts of the model are the CDRIntensity, the facility and the volume entity. CDRIntensity is a made-up abbreviation and stands for "Climate Data Record Intensity". The CDRIntensity entity contains information about the amount of a certain emission source that has been used, and the emission factor of that emission source. A more detailed description of the CDRIntensity entity is presented in Table 5. The Volume entity contains yearly business information connected to a facility. It contains information such as volume and quantify sold, invoiced in Euro, and production share allocated to IKEA for a facility/supplier per year. The facility entity contains information about what supplier, store, or office etc. the emission belongs to, together with data such as location and name. Only one unique Facility can exist for a supplier and multiple [CDRIntensity] and [Volume] can be connected to it. The CDRIntensity entity is connected to the EmissionSource entity with the EmissionSourceId. The EmissionSource entity is a reference table containing emission factors, energy content and density of a fuel/emission source. It is used to populate the emission factors used in the CDRIntensity entity. The emissions from some emission sources are location specific, such as the emissions from purchased electricity. The EmissionSourceCountrySpecific entity contains emissions factors, country by country, for electricity and heat. Detailed descriptions of the fields of each entity are presented in Appendix B.

Table 5. The CDRIntensisty entity with explanation for each field.

EmissionSourceId	The ID of the emission source as defined in the "EmissionSource" table. Could for example be ES1002 standing for Diesel and light fuel oil.
FacilityKey	The key relating to a certain facility. Ex. SUP-1 will relate to a supplier with code 1 as defined in the Facility table.
FY	The IKEA financial year.
Amount	The amount used of the emission source.
Unit	The unit of the amount. Ex. kilograms, litres or kWh.
SoldEnergyKwh	The amount of sold energy is not currently used but there is a wish within IKEA to be able to calculate the "Going beyond IKEA" effect. So, if for example electricity with a low climate footprint is sold to the grid it might substitute a more dirty energy source. IKEA would like to keep track of these numbers.
GeneratedEnergyKwh	The [Amount] field contains information in a variety of units, e.g., kg for refrigerants and kWh for electricity. To easily get the sum of energy used the [GeneratedEnergyKwh] field is created.
RenewableShareMarket	IKEA wants to keep track of the share of renewable energy. Based on the market-based method.
RenewableShareLocation	IKEA wants to keep track of the share of renewable energy. Based on the location-based method.
EmissionFactorCO2eqScope1Market	The scope 1 emission factor in CO_2-eq/[Amount]. Market-based.
EmissionFactorCO2eqScope2Market	The scope 2 emission factor in CO_2-eq/[Amount]. Market-based.
EmissionFactorCO2eqScope3Market	The scope 3 emission factor in CO_2-eq/[Amount]. Market-based.
EmissionFactorCO2eqScope1Location	The scope 1 emission factor in CO_2-eq/[Amount]. Location-based.
EmissionFactorCO2eqScope2Location	The scope 2 emission factor in CO_2-eq/[Amount]. Location-based.
EmissionFactorCO2eqScope3Location	The scope 3 emission factor in CO_2-eq/[Amount]. Location-based.
IsUserDefinedEmissionFactorMarket	TRUE if the market-based emission factor has been given by the reporter at the time of climate reporting. If FALSE, no specific emission factor has been given and the one defined in the EmissionSource reference table will be used.
IsUserDefinedEmissionFactorLocation	TRUE if the location-based emission factor has been given by the reporter at the time of climate reporting. If FALSE, no specific emission factor has been given and the one defined in the EmissionSource reference table will be used.
BiogenicEmissionFactor	The gross CO2 biogenic emission factor. For separate reporting of biogenic CO2 emissions.

The implementation details of a selection of the requirements in section 4.4.1 will now be explained in more detail.

Collect data as granular as possible

The new data format collects and store activity data that gives rise for the GHG emissions together with the unit that has been used when the activity has been reported. As an example, when a supplier specifies diesel usage, they provide the amount and in what unit (e.g., litres or kilograms). Previous versions of the data format recalculated this information into a common unit, namely kWh. The new data format stores both amount and unit without any calculation into a common unit. This allows for complete recalculation based on provided raw data without the need to consider previous calculation logic.

Be compliant with the GHG Protocol

From the data that is provided and stored it should be possible to calculate scope 2 GHG emissions according to both the market-based and location-based method. Further, it should be possible to separately calculate and report the gross CO_2 emissions from biofuels.

The market- and location-based methods applies to the scope 2 emissions of the value chain. This includes emissions from purchased electricity, heat, cooling, and steam (WRI, 2015). Looking at purchased electricity the following approach is followed to evaluate according to the market-based method. The supplier specifies the amount of electivity being purchased. If they have purposely chosen an electricity agreement based on e.g., Guarantees of Origin (GO) or the Renewable Energy Certificate (REC) they should provide the Emission factor and the renewable share for that specific agreement. If no specific emission factor is provided, the country average emission factor will be used. The market-based approach uses this information to calculate the climate footprint.

The location-based method will only use the regional or country average emission factor to evaluate the climate footprint. Meaning that no matter what is specified as the emission factor according to the electricity agreement, the average emission factor of the country or region will be used.

The gross biogenic CO_2 emissions are a bit more problematic to track. The emission factors of generated electricity acquired from IEA do not include information on the share of biofuels. With this data it is therefore not possible to calculate the biogenic emissions. It is stated by the GHG Protocol scope 2 guidance that if the biogenic emission is omitted for the emission factor it should be documented property (WRI, 2015). However, IKEA do collect data on the use of biofuels onsite. These biofuels are for example used for heating or generation of electricity. It is possible to calculate the gross biogenic CO_2 emissions for these kinds of emissions based on the emission factors from the GHG Protocol (GHG Protocol, n.d.-b). By collecting the amount and type of biofuels used and combine them with the emission factors from the GHG Protocol it is possible to calculate the gross biogenic CO_2 emissions.

GHG emissions from glass production

In the Guidelines for National Greenhouse Gas Inventories for Industrial Processes and Product Use, IPCC defines three methods for estimating the emissions from glass production (IPCC, 2006). If it is possible to collect facility-specific data, they recommend the Tier 3 method as presented in equation 2.

$$CO_2\ Emissions = \sum(M * EF * F) \qquad 2$$

Where:

M = weight of carbonate

EF = emission factor of the specific carbonate in kg CO_2/kg carbonate

F = fraction of calcination achieved

To ensure this information was feasible to collect from the suppliers a Sustainability Developer working with tier 1 Chinese glass producers was contacted. He in turn contacted a number of suppliers to ensure this information was available. It was concluded that the suppliers know the amount of carbonate used (such as limestone). The suppliers did not measure the fraction of calcination achieved but used an industry standard of 0.95 (95%). It is stated in the IPPC guidelines that if the fraction of calcination is not known it can be assumed to 1 (100%) (IPCC, 2006) and it is that assumption that will be used. The emission factors are retrieved from the IPCC guidelines (IPCC, 2006).

5.2 DEVELOPMENT AND RESULTS OF TOOLS TO UPDATE THE SIMULATION TOOLS

Based on the new data format a new simulation update tool has been developed. The following section will explain the development of this tool. It will in part be quite detailed and the target audience is mainly people with the intention to develop similar functionality.

There is a need that the new simulation tool should be updated more easily with new data every year. To make a proper solution the tool should use data from a database (such as a SQL database), and it should be assumed that the data in the database is up to date and correct. If the data is considered to be out of date or incorrect, it should be updated within the database. This do not exist for the climate footprint data of IKEA as of today. Instead, the climate data is mostly collected and stored in Excel files. To make it possible to update the simulation tool in the current situation a special updating tool were developed. The reason why a separate tool is developed, and the update functionality is not built in into the simulation tool itself is that the functionality uses Power Query and the internal data model within Excel to generate all necessary tables from the provided input. And since Excel only allows for one data model per file and that the simulation tool already has one it was feasible and provides the best performance to separate the updating from the simulation tool. Another reason for separating the tools is to be able to use the data in the new format in other tools and for further analysis separate from the simulation tool.

5.2.1 Production, IKEA retail & other operations

The updating tool for production and retail & other operations is based on the new data format as explained in section 5.1. It is within the update tool that the logic of how to transform from the single table format into the relational data format has been implemented. To understand how the relational data model is created and populated from the single table data format an example will now be given.

Table 6. A selection of the single table filled with dummy values.

Type	Code	EN2001 | Total Electricity purchased | Amount	EN2001 | Total Electricity purchased | Renewable share (%)	EN2001 | Total Electricity purchased | Emission factor (CO2eq per unit)	ES1002 | Diesel & light fuel oil | Amount	ES1002 | Diesel & light fuel oil | Unit
SUP	1	627000	0,5	0,20058322		
SUP	2	7740300			5003,623333	kg

Table 6 shows a selection of the single table format that will be used in the example. We will examine how the emission sources EN2001 (purchased electricity) and ES2001 (Diesel & light fuel oil) is transformed into the relational data model. The reporter specifies the amount used for each emission source. If purchased electricity is purchased with for example a Guarantees of Origin (GO), the supplier specific emission factor and renewable share should be specified. If no GO is used, the emission factor and renewable share should be left blank. Purchased electricity is assumed to always be in kWh. For Diesel & light fuel oil, the reporter specifies the unit that the amount is reported in. The single table is converted into a list format similar to the CDRIntensity entity called CDRRawData, see Table 7. By comparing Table 6 and Table 7 it is possible to see that all values have been kept, just rearranged into a new format. Looking at SUP-2 in Table 7, two rows exist, one for emission source ES1002 and one for EN2001. The amount, unit, emission factor and renewable share is kept as previously. FY and CountryCode has been added from the single table format to allow for simpler processing in the next step in the process chain.

Table 7. The CDRRawData entity with data based on the single table.

Emission SourceId	FacilityKey	FY	Amount	Unit	Emission factor (CO2eq per unit)	Renewable share (%)	CountryCode
ES1002	SUP-2	2016	5003,62	kg			PT
EN2001	SUP-1	2016	627000	kWh	0,20	0,5	DE
EN2001	SUP-2	2016	7740300	kWh			PT

The CDRRawData entity is finally transformed into the CDRIntensity format where all necessary fields are populated and defined, see Table 8. This is done by joining (combining the data from two tables) the CDRRawData entity with the EmissionSource entity based on the EmissionSourceId. As previously explained, the EmissionSource table contains reference emission data for different emission sources. Looking at the emission source ES1002 in Table 8, the amount and unit has been converted into kWh. Further, the renewable share and emission factors are populated with data from the EmissionSource table. The emission source ES1002 (diesel) will have scope 1 and scope 3 emissions. EN2001 (purchased electricity) is dependent on which country the electricity has been purchased. It is therefore joined with the EmissionSourceCountrySpecific table where country specific emission is available. As seen in Table 8 for EN2001 and SUP-1, there is a difference between the market-based and location-based emission factors. The reason is that the reporter did specify a site-specific emission factor for the purchased electricity as seen in Table 6.

Table 8. The CDRIntensity entity with data from the single table format. Divided into two rows to be able to visualise the whole table.

Emission SourceId	FacilityKey	FY	Amount	Unit	Sold Energy Kwh	Generated Energy Kwh	Renewable Share Market	Renewable Share Location
ES1002	SUP-2	2016	59765,50	kWh		59765,50	0	0
EN2001	SUP-1	2016	627000	kWh		627000	0,5	0,24
EN2001	SUP-2	2016	7740300	kWh		7740300	0,58	0,58

…

Emission FactorCO2eqScope1Market	Emission FactorCO2eqScope2Market	Emission FactorCO2eqScope3Market	EmissionFactorCO2eqScope1Location	EmissionFactorCO2eqScope2Location	EmissionFactorCO2eqScope3Location	IsUserDefinedEmissionFactorMarket	IsUserDefinedEmissionFactorLocation	BiogenicEmissionFactor
0,2683	0	0,0670	0,2683	0	0,0670	FALSE	FALSE	0
0	0,2006	0,0188	0	0,4907	0,0188	TRUE	FALSE	0
0	0,2833	0,0268	0	0,2833	0,0268	FALSE	FALSE	0

So far, the new data format in the single table and relational data format has been explained. Once the data is in the relational data format it is easy to generate the tables necessary for updating the simulation tool. The new simulation tool needs to be updated with 15 tables containing emission data, filtering tables and reference tables. A simple graphical interface has been developed to ease the update process, see Figure 10. As seen in the figure the update process is done in five steps.

1. Input the data according to the single table format in the INPUT tab.
2. Refresh the data model. This step refreshes the data model within Excel and generates all necessary tables for the simulation tool.
3. Input the name of the simulation tool.
4. Open the simulation tool and press "Export to simulation tool". This runs an VBA scripts that exports all the tables to the simulation tool.

5. Press the button "Reset All Data" within the simulation tool. This recreates all defined ranges and variables within the simulation tool to be based on the newly provided data. The simulation tool has now been updated based on the new data.

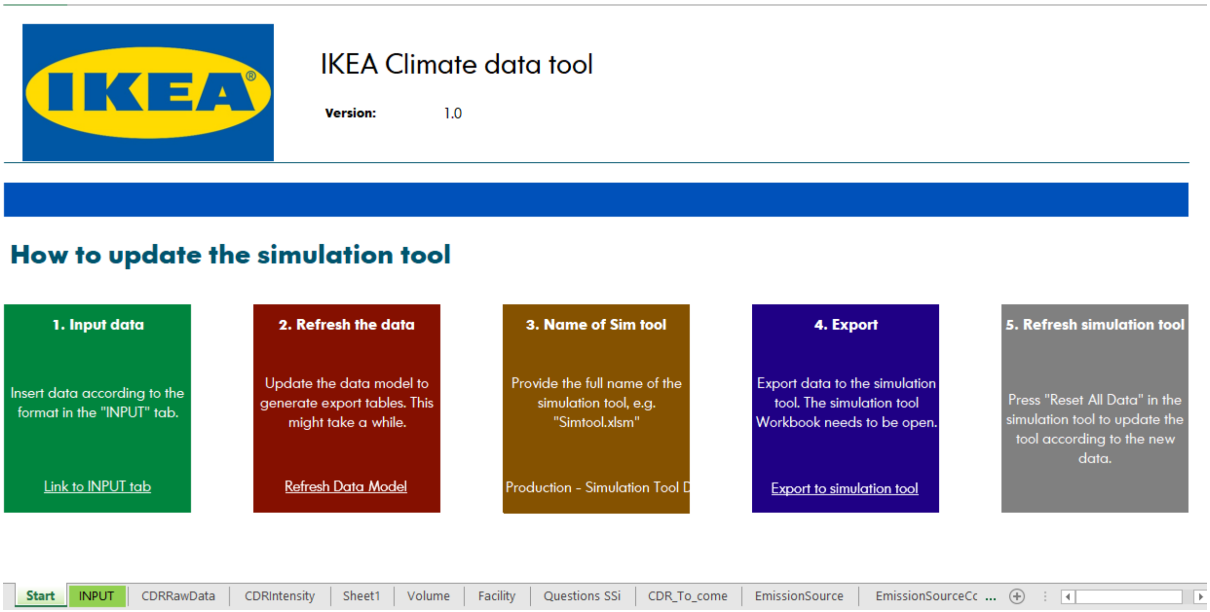

Figure 10. A graphical interface of the tool developed for updating the simulation tool.

5.2.2 Food ingredients

A tool to update the food simulation tool was created in a similar way as the production tool. The new data structure used within the food simulation tool has briefly been explained in section 5.4.2. It is the update tool that generates the new data structure based on the data provided by IKEA. The main input data from IKEA is what is called a Bill of Material (BOM) with associated emissions factors. A BOM is an inventory of raw materials (ingredients) used to produce a product. IKEA also provides sales data for each article as well as classifications for the articles sold. An example of an BOM is presented in Figure 11.

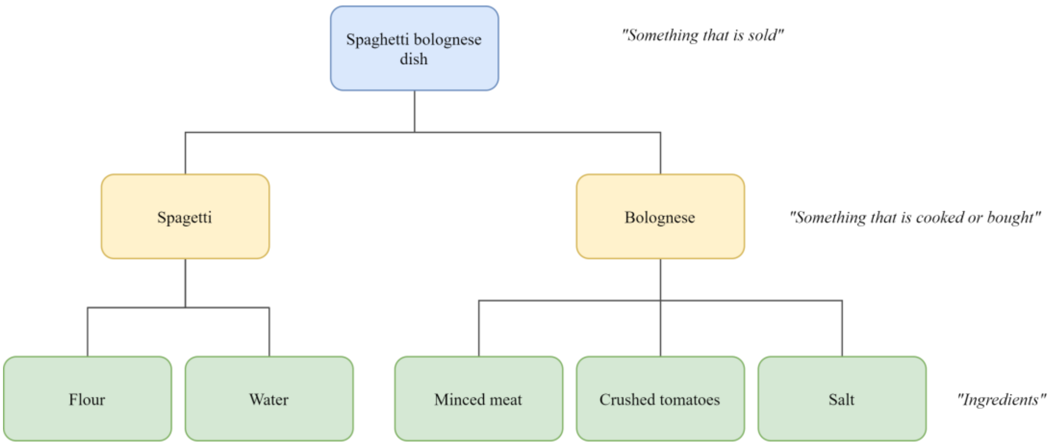

Figure 11. An example of a Bill of Material.

The emission factors are connected on the ingredient level of each article, while the sales data are provided per article. Further, the emission factors are provided per year and can have multiple versions each year. In the update tool, the new data is provided in five tables, the product BOM, the sales data, the ingredient classification, the business area classification, and the category area classification. The data in these tables are used to generate the tables used by the simulation tool as presented in Figure 17. The tool uses the latest available emission factor based on year and version. A similar user interface as for production has been developed for the food update tool as seem in Figure 12.

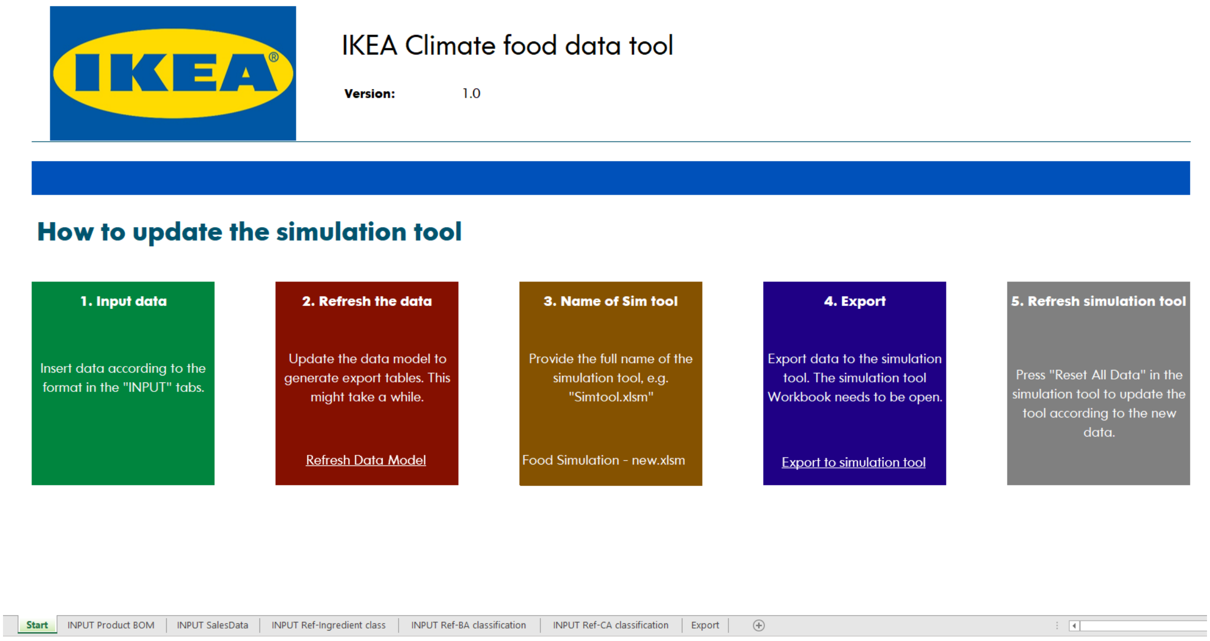

Figure 12. The user interface for the update tool for the food simulation tool.

The logic in the update tool is implemented in Power Query within Excel. The process of generating the necessary tables is somewhat complicated and when running on a large dataset the performance is slow. Using a made-up dataset similar as the one used by IKEA, the processing time is around 1.5 hours.

5.3 Selection of platform for the development of simulation capabilities

From the stakeholder interviews, it was found that there had been some usability issues with the existing Excel based simulation tool. Some of them include non-intuitive user interface, bugs and manual data management leading to data quality issues. Excel is great for single user data management and analysis but as the data grows and becomes more complex and the number of users increases the limits of Excel becomes apparent (365 Data Science, n.d.). To explore alternatives to Excel an exploratory investigation was conducted. During the literature review no apparent tool for evaluating different actions and their impact on the climate footprint of a company was found. Scenario analysis tools and frameworks are available for policy evaluation related to climate change on a society level (Task Force on Climate-related Financial Disclosures, 2017). These are generally not applicable on a company level as they are too generic. One example of a scenario analysis tool is the En-ROADS Climate Solutions Simulator developed by the Climate Interactive (Climate Interactive, n.d.; see Figure 13). It provides the possibility to change parameters such as the energy sources, transportation, buildings energy usage, and growth. The limitation is that is only possible to change these parameters on a global level. IKEA want to be able to change parameters on a higher granularity, such as on supplier level or country level and see the aggregated result of all the individual improvements.

Figure 13. The En-ROADS Climate Solutions Simulator.

A 3rd party simulation solution that is suitable for the needs of IKEA do not seem to be available. The next step was instead to find a suitable development environment where it is possible to implement the simulation capabilities. Three options were investigated, namely, Excel, Power BI, and a web application. A summary of the pro and cons of each alternative is presented in Table 9.

Excel

It is possible to develop the desired simulation capabilities in Excel as it has previously been implemented in the solution by Sander & Skoog (2017). With the use of UserForm and Visual Basic for Applications (VBA) it provides great flexibility in user interface and calculation logic. There are however limitations to Excel that makes it unsuitable for complex multiuser applications. Firstly, if the tool is used by multiple users and there is a need to update the data or the functionality of the tool, the tool must be redistributed out in the organisation again after the update. From this there will be a risk that certain users will continue using the old, outdated version, getting different results than other users. There is also a limitation within Excel that each sheet can contain 1,048,576 rows. If the dataset is larger than that, the data will have to be divided into multiple sheets. Another limitation is that the processing power is limited to the computing power of the user's computer.

Power BI

Power BI is a self-service business intelligence (BI) platform developed by Microsoft (Microsoft, n.d.-a). It is used to visualise and analyse large amounts of data to gain insight for decision making. The great benefit of using Power BI is that it is developed for collaboration. By uploading your data and visualisations to the "Power BI Service" it can be shared with others while ensuring that everyone uses the same data. Out of the box, Power BI comes with rather limited simulation capabilities. It is possible to add "what-if" parameter and integrate that into the calculation logic to alter key values in your report and see the result (Microsoft, 2020a). Power BI uses what is called *measures* to integrate logic into the report. An example of a measure could be to define the income as sold products multiplied with the product price. It is then possible to visualise the income, for example month by month, by using this measure in the report. It is further possible to integrate the what-if parameter into the measure to simulate the change in price and its implication on the income. This is good for rather simple simulation scenarios but is limited for more complex aggregated scenarios. An example of a stacked scenario where this limitation is encountered is presented below. To find out, what will be the final total GHG emissions when running these scenarios on top of each other?

> *Scenario 1: An arbitrarily (chosen by the user at runtime) supplier improve the energy efficiency by 10% until 2025.*
>
> *Scenario 2: An arbitrarily supplier change its energy source from diesel to renewable electricity.*

To be able to run these scenarios it must be possible to:

1. Choose who is affected by the change.
2. Choose what the change will be? E.g., energy efficiency or change energy source.
3. Save result of this change to be able to stack multiple scenarios on each other.

This is not possible in Power BI. There are extensions to Power BI to extend its capabilities. One extension that has the possibility to accept user input and save it back to the data source is Power Apps (Microsoft, 2021). If Power BI is used in Direct Query mode together with Microsoft Dataverse the user can do alternations to the data in Power Apps (integrated in Power BI) that is saved to the data source. As Power Bi is connected in Direct Query mode the report can be automatically updated based on the new data. This solution has potential but the main limitation for not being feasible in this project was its licencing model. All the users must have licences for Power BI Pro or Premium to access the reports (Microsoft, n.d.-b). And if Power Apps is used additional licences are needed per user (Microsoft, n.d.-c). The current price for Power Bi is $9.99 per user/month and for Power Apps $10 per user/app/month or $40 per user/month for unlimited apps. As the wish is that the app should be used throughout the IKEA organisation, possibly by several hundred users, the cost will be high. Especially in comparison to using Excel which comes at no additional cost.

There are other extensions to Power BI with the possibility for scenario analysis capabilities. ValQ is an extension used for forecasting, planning, and scenario analysis within Power BI (Visual BI Solutions, n.d.). It is likely one of the more sophisticated extensions for these capabilities. However, it is questionable if it can fulfil all the needs of IKEA when it comes to climate scenario analysis. It is a premium service and was just evaluated briefly during the project.

A cloud-based web application

A web application provides great flexibility in what can be developed (Okezie, Chidiebele, & Kennedy, 2012). It will be possible to meet the needs of IKEA, but it will require more effort than the other solutions as it will be necessary to develop both the backend server with database management, and a front end for visualisation and user input. This will require more time, have a higher upfront cost and is dependent on the availability of developers. It was not further evaluated in the project as it was considered too extensive.

Table 9. A summary of the pros and cons of the different platform alternatives.

TOOL	PROS	CONS
Excel	Flexible	The maximum number of rows per sheet is 1,048,576 (Microsoft, n.d.-d)
	Easy to get started with.	If Excel is used as a database, it is hard to ensure the quality of the data and implement a decent version control. There is no single point of truth. This is especially problematic if the tool is intended to be used by a multitude of users.
	Available within IKEA.	The processing power is limited by the hardware of the user's computer.
Power BI	Good in processing and visualising large amounts of data.	Limited possibilities for advanced simulation capabilities. It is for example not possible or hard to run a simulation such as changing energy source for a supplier and have stacked/aggregated simulation scenarios.
	Made for collaboration.	Cost. All users need a licence to access the data and visualisation (IKEA is using another BI provider and will likely not pay for one more).
	Simple scenario analysis possible.	

A cloud-based web application	Great flexibility in what can be developed.	Requires more time to implement.
	It is possible to meet the simulation needs of IKEA.	Full stack or front-end + back-end developers must be available for development and support of the tool.

The selected development platform

It was decided to continue the development with Excel. The main reason was that previous functionality had already been implemented within Excel which had to be done again if another platform was selected. The alternatives did also not provide the same amount of flexibility as Excel. However, the limitations within Excel still remain.

5.4 DEVELOPMENT OF THE SIMULATION TOOLS

Two simulation tools have been developed, one that will be used for production and retail & other operations, and another for food. Both tools are developed in Excel and are based on the tools developed by Sander & Skoog (2017). These tools were developed in parallel with the development of a tools for updating the simulation tools as explained in section 5.2.

5.4.1 Production, IKEA retail & other operations

As previously mentioned, the development of the new simulation tool is a continuation of the tool by Sander & Skoog (2017). The goal was to, based on the previous tool implement the requirements for production and retail & other operations as defined in Table 3. There was a need in the beginning of the project to understand how the code was structured, how the logic was defined and how the visual interfaces were laid out. The previously developed production simulation tool had 6266 lines of VBA code (including comments and blank rows) that needed to be understood on a general level. The implementation of the requirements will first be explained. The final tool and its functionality will be presented in section 5.5.

Requirement: Make the tool less dependent on the climate team

The previous tool has been updated manually by the climate team. This is a time-consuming task that has resulted in outdated tools for the users. It was at least 24 tables that needed to be updated, containing climate data, filtering information and support ranges. When the new data had been added to the tool, there was a need to define all the necessary ranges within Excel. A named range is a collection of cells with a name that can be accessed from the VBA code. Then the simulation range can be generated, with data from the present up until 2030. After the simulation range has been generated, it is possible to use the simulation tool. As mentioned, this is a time-consuming and error prone process as all the data needs to be entered in the correct format. It also requires in-depth knowledge of how the simulation tool works to know what needs to be updated. To overcome this a more automatic process has been developed. It resulted in the development of an update tool which is explained in detail in section 5.2. However, there was also a need to adapt the simulation tool itself to make it easier to update. A summary of what has been implemented to allow for a smoother update are:

- Use the new identification of a facility/supplier, namely type and code.
- Reduce the number of tables that needs to be updated from 24 to 15. The tool uses multiple of different tables. Some of them were possible to combine, redo and remove.
- Automatically generate all named ranges
- Simplify the Power pivot data model and reduce the number of measures based on the new tables.
- Adopt the calculation logic to be dependent on the new tables.

Requirement: It should be possible to use it with data from retail & other operations
The newly development data format allows for data to come from a variety of sources if it is provided in the predefined format. The simulation has been developed to work with any of the data provided in the new data format.

Requirement: If possible, reduce the size of the file and improve the computing time to allow for usage on computers with less computing power
The Excel simulation file tended to be fairly large in file size, around 50 MB for production. One of the reasons was that for each facility/supplier, all emission sources were present in the tool, even though it was not actually used. For example, a supplier that did not use any diesel still had an entry in the simulation tool with the amount of 0. As most suppliers generally did not use all emission sources, the file contained a lot of unnecessary data. The reason why all emissions sources were available was to simplify the simulation logic when changing from one emission source to another. To reduce the file size, the unused emission sources were removed and was generated on demand instead. This reduced the file size and improved the general usability of the tool. The drawback is a bit more complicated simulation logic as well as a slower execution of the simulation to change energy source.

Requirement: Update the calculation logic for the simulation of energy efficiency
It was escalated from the climate team that the calculation logic for simulating the energy efficiency improvements was needed to be updated. The old approach was built on the assumption that if the energy efficiency improvement was the same as the business growth, they would cancel each other out. For example, if the business growth and energy efficiency improvement are both 5% the energy amount would remain the same as before. The reason why the logic is updated is because the old approach does not make sense from a product developer (PD) perspective. If a PD express that the efficiency has been improved by 10%, from let say 10 kWh/intensity measure, the PD will expect the efficiency to be 9 kWh/intensity measure. With the old approach, the efficiency would instead be

(1/ (1 + ChangeFactor)) * 10 = 9,09 kWh/intensity measure. The old approach is presented in equation 3 to 4 and the new approach in equation 5 to 6.

The old approach:

$$Efficiency_n = Efficiency_{n-1} * \frac{1}{1 + ChangeFactor} \quad 3$$

$$Energy_n = Intensity\ Measure_{n-1} * (1 + Growth) * Efficiency_{n-1} * \frac{1}{1 + ChangeFactor} \quad 4$$

The new approach:

$$Efficiency_n = Efficiency_{n-1} * (1 - Change\ Factor) \quad 5$$

$$Energy_n = Intensity\ Measure_{n-1} * (1 + Growth) * Efficiency_{n-1} * (1 - Change\ Factor) \quad 6$$

Where:

Intensity Measure = the amount being produced, can for example be in m3 or kg.

Efficiency = represents how much energy is needed per intensity measure, e.g., kWh/m3

ChangeFactor = the energy efficiency improvement.

Growth = the expected business growth

The new approach has been implemented in the new simulation tool.

Requirement: Make it possible to update the reduction target trajectory within the tool

The graphs showing the simulated data within the previous tool had several trajectories showing different reduction targets, namely 15%, 30% and 80%. The trajectories are used to more clearly see if the reduction target has been reached or not. However, different parts of the IKEA organisation have different reduction targets and to allow for a more flexible solution it is now possible to update the trajectory by the user within the tool. This feature is visualized to the right in Figure 19.

Requirement: Fix apparent bugs and errors.

During stakeholder interviews, it was expressed that bugs appeared during usage. Also, during development of the new tool multiple bugs became apparent. Bugs has continuously been fixed as they appeared in the development process. Even though some effort has been directed to fixing bugs, more effort is needed to deliver a more robust and bug free user experience. However, due to prioritisation and time constrains a balance was needed when it comes to quality assurances.

Requirement: Make usability improvements where stakeholders expressed that it was hard to use.

It was expressed during the stakeholder interviews that the previous tool was somewhat advanced and hard to use. It was decided together with the supervisor at IKEA that most things should remain as they were to be able to focus on the development of the other simulation tools. However, it did make sense to do simple low hanging visual improvements to enhance the usability of the tool. Mainly, two changes were made, redesign of the dashboard and adding information boxes (tooltips) to explain certain functionality of the tool.

The dashboard is the main tab for the user of the simulation tool. It provides visual representation of the simulation result and buttons to perform all actions. The dashboard has been redesigned to be simpler and easier to use, and at the same time more visually appealing. This has been done by removing two of the graphs as they were rarely used. Icons and colours were added to the buttons to visualise the intention of the button more clearly. Buttons and graphs were also grouped together for the user to understand what part of the simulation tool that was affected by each button. The previous version of the dashboard of the simulation tool can be seen in Figure 14 and the new version can be seen in Figure 15.

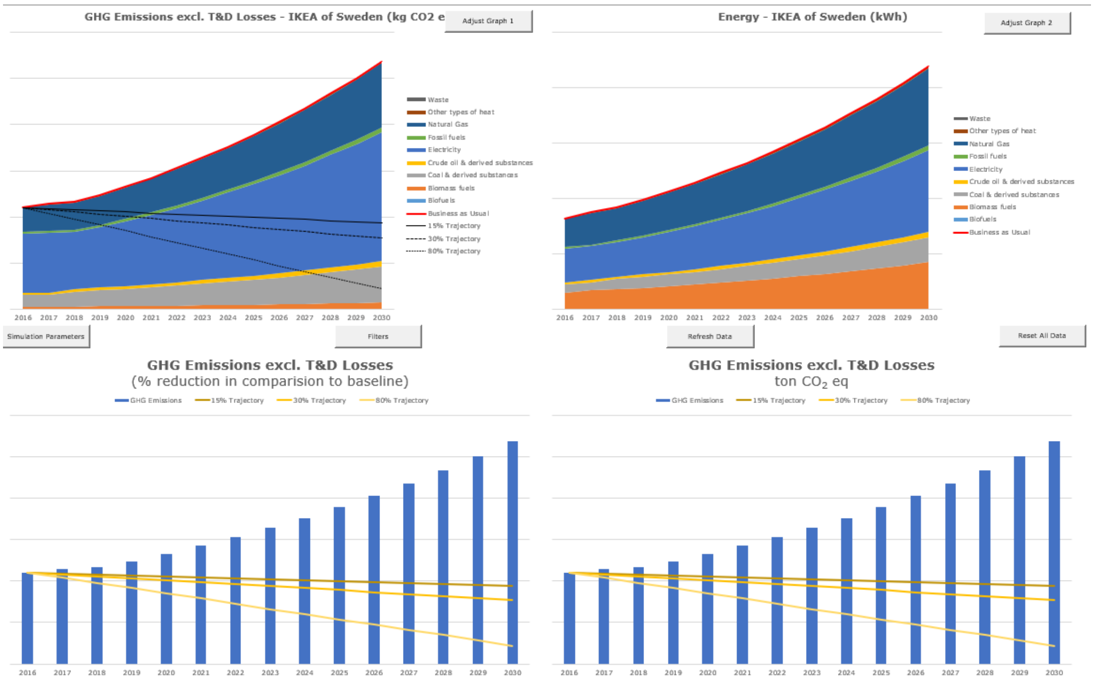

Figure 14. The dashboard of the old simulation tool (axis values has been hidden).

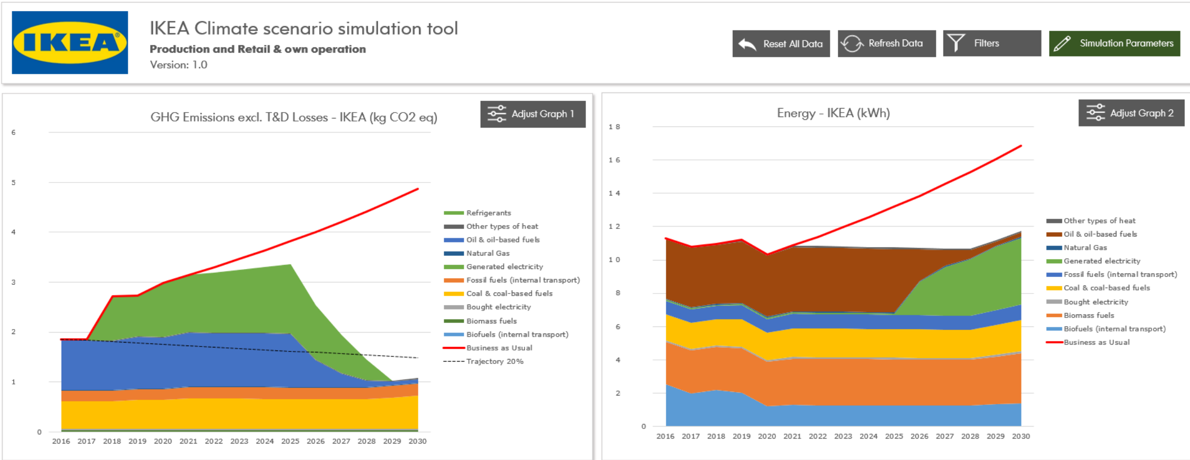

Figure 15. The dashboard of the new simulation tool showing the result of a simulation (dummy data used).

The next improvement was to add info boxes that displays extra information when hovering the mouse above it, see Figure 16. The boxes were added to fields that was expressed hard to understand by the users.

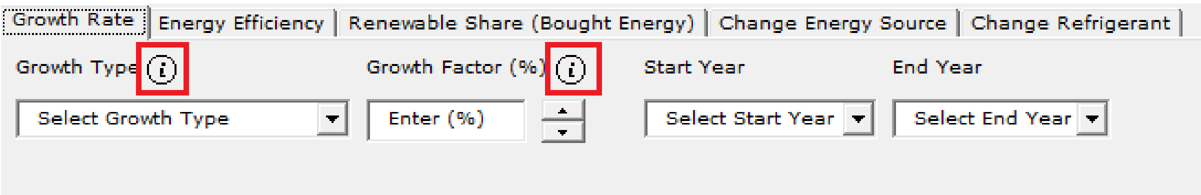

Figure 16. Info boxes were added to fields that was hard to understand.

5.4.2 Food ingredients

Like the production tool the new food tool builds on the previous tool by Sander & Skoog (2017). The implementation for the requirements in Table 4 will now be presented.

Requirement: Reduce size of file and improve computing times of simulations.

The previous tool has a file size of approximately 250 MB. Due to the file size, it takes a long time to open the file and simulations takes a long time to run. Some computers are also not able to run the file due to limited memory resources. The tool is based on two main tables, Article data and Ingredient data. The Article data table contains information about how much has been sold of a certain dish while the Ingredient data table contains all the ingredients used within a dish together with weight and related emissions factor. In a simplified manner, the total emissions are calculated by multiplying the weight and emission factor for each ingredient in a dish with how many times the dish has been sold. The reason why the previous tool was so large was that the Ingredient table was itself large in size. The table had a mixture of fact and dimension data with a result of 44 columns and almost 500 000 rows. Fact tables contains business facts such as how much has been sold while dimension tables contain descriptive fields such as the name of the category that a product belongs to. Dimension tables are often used to filter the data. The problem with mixing fact data with dimension data is that the table ends up with containing a lot of duplicated data. To reduce the size of the table, the dimension and fact data was separated into different tables. The idea is to separate all the business dimensional data into separate tables and add a relation to the fact table. There has also been a reorganization within IKEA that was considered when creating the new data structure. The resulting data structure as taken from the Excel data model is presented in Figure 17. The new structure still contains the ArticleData and IngredientData table, but the dimensional data has been separated into the BA (Business Area), CA (Category Area) and Ref_Ingredient table.

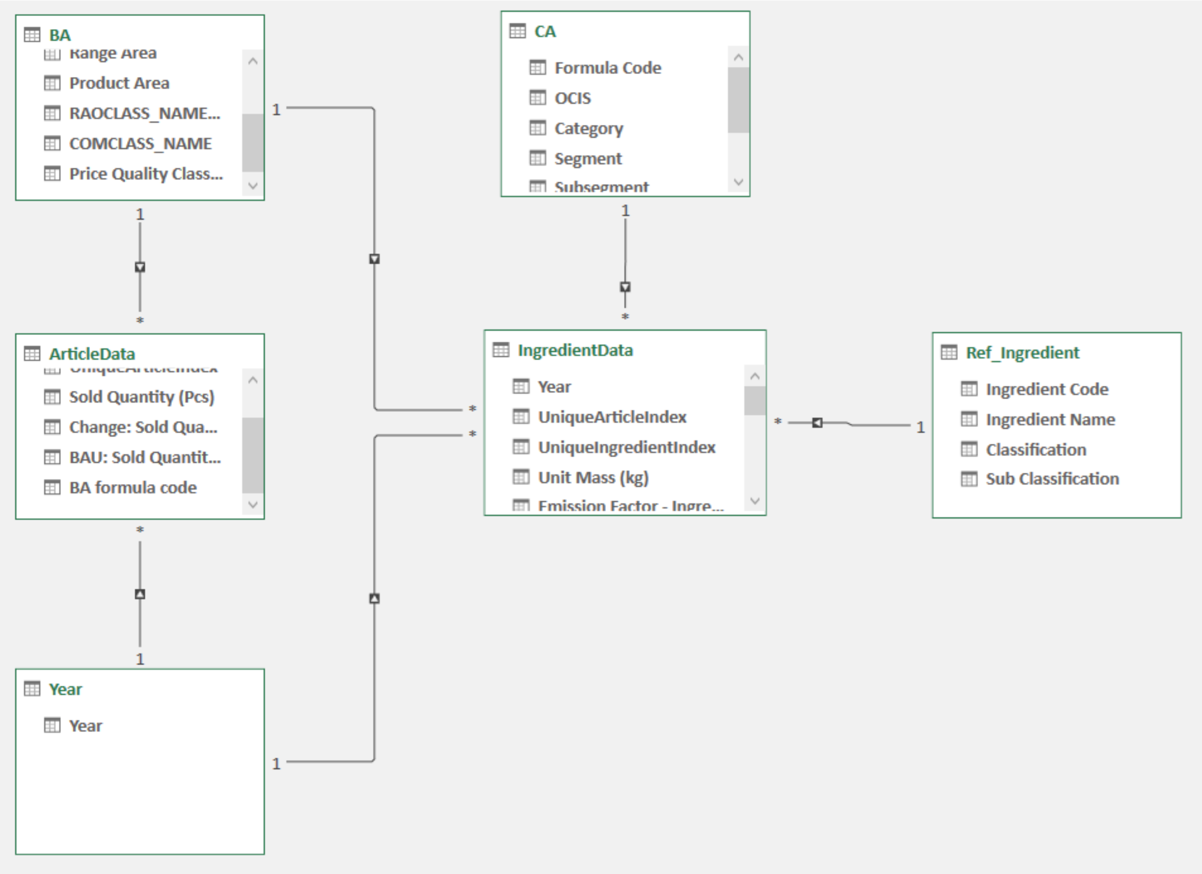

Figure 17. The new data structure for the Food tool.

The old simulation logic was dependent on all the fields in the IngredientData table. It used the dimensional data to determine which rows that should be updated during simulations. In that sense, the logic was simple. Now as the dimension data has moved to separate tables, the logic needed to be updated. The new logic uses slicers that is connected to the data model which filters the rows that should be updated. Also, the filtering and visualisation was rebuilt to be based on slicers and the data model instead of separate filtering tables. These actions drastically reduced the file size and when running a stress test with realistic amounts of data the new tool was around 30 MB. This is almost a tenfold reduction in size.

Requirement: Make the tool use the updated business information and business categories used for food products.

The organisational structures within IKEA has changed since the previous tool was developed. As explained in the previous section the new tool has been developed with this in mind. In addition to that the simulation logic has been updated to account for the new structure, the user interface needed to be updated as well. New fields were added, renamed, and removed within the user interface and all the related variables were updated accordingly. This was a time-consuming process as all the named fields were hard coded with a lot of related hard coded named variables.

Requirement: Make it possible to update the tool with new data more easily.
A similar updating tool as for the production has been developed to ease the update of new data. The development of the update tool was performed in parallel with the development of the simulation tool and the new data structure and is explained more in 5.2.2. The simulation tool itself also had to be adopted to allow for an easier update. The main thing that was done was to implement the functionality to automatically generate the simulation ranges up until 2030 as well as defining the named ranges used by the simulation logic.

Requirement: Improve the usability of the tool.
The food tool was updated in a similar manner as the production tool. A general visual improvement as well as the removal of unused fields and the addition of information boxes.

5.5 THE RESULT OF THE SIMULATION TOOLS

This section will present how the developed simulation tools looks and functions. All simulation options are presented, as well as the general functionality of the tool. The section starts with explaining the tool for production, retail, and other operations, and ending with the tool for food ingredients. Dummy data has been used for all examples and the magnitude of the axis is not realistic and only used for visualisation.

5.5.1 Production, IKEA retail & other operations

The new simulation tool for production and retail & other operations is presented in Figure 18. The new version is anticipated to be easier to update with new data and easier to use. The functionality of the tool will now be explained.

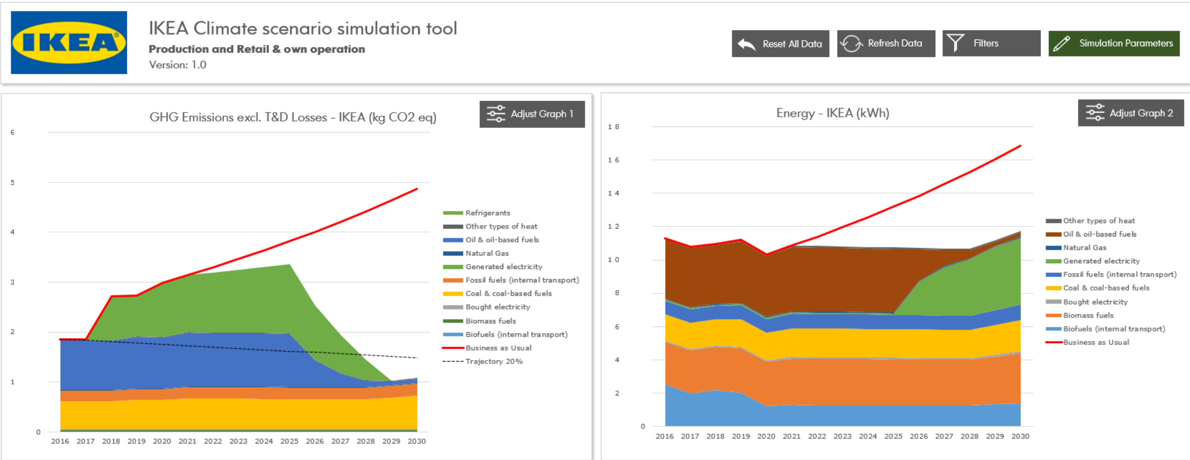

Figure 18. The dashboard of the new production and retail & other operations simulation tool (dummy data used).

The different buttons on the dashboard are explained in Table 10 and Figure 19.

Table 10. The buttons on the production simulation dashboard.

Button	Explanation
Simulation Parameters	Opens a window for input of the simulation parameters and a button to run the simulations.
Filters	Opens a filtering window to be able to filter on e.g., country. The filtering window is presented to the left in Figure 19.
Refresh Data	It is possible to run multiple simulations after each other without refreshing the data model. This saves time as the refresh takes a moment. When all simulations have been executed, the Refresh Data button can be pressed. This button if most often not necessary to use as the refresh is fast enough.
Reset All Data	To reset an executed simulation to the initial state of the simulation tool.
Adjust Graph 1 and 2	Opens a window where it is possible to change the measure/values displayed in the graph as well as the legend. The values can be changed to display for example GHG emission, energy usage, energy efficiency, quantity pieces and renewable share. The legend can be changed to for example see the result per Fuel Category, Fuel, Country, and IKEA unit. This will update the graphs on the dashboard. It is also possible to change the climate target (Trajectory value) within the adjust graph window. See the right part of Figure 19.

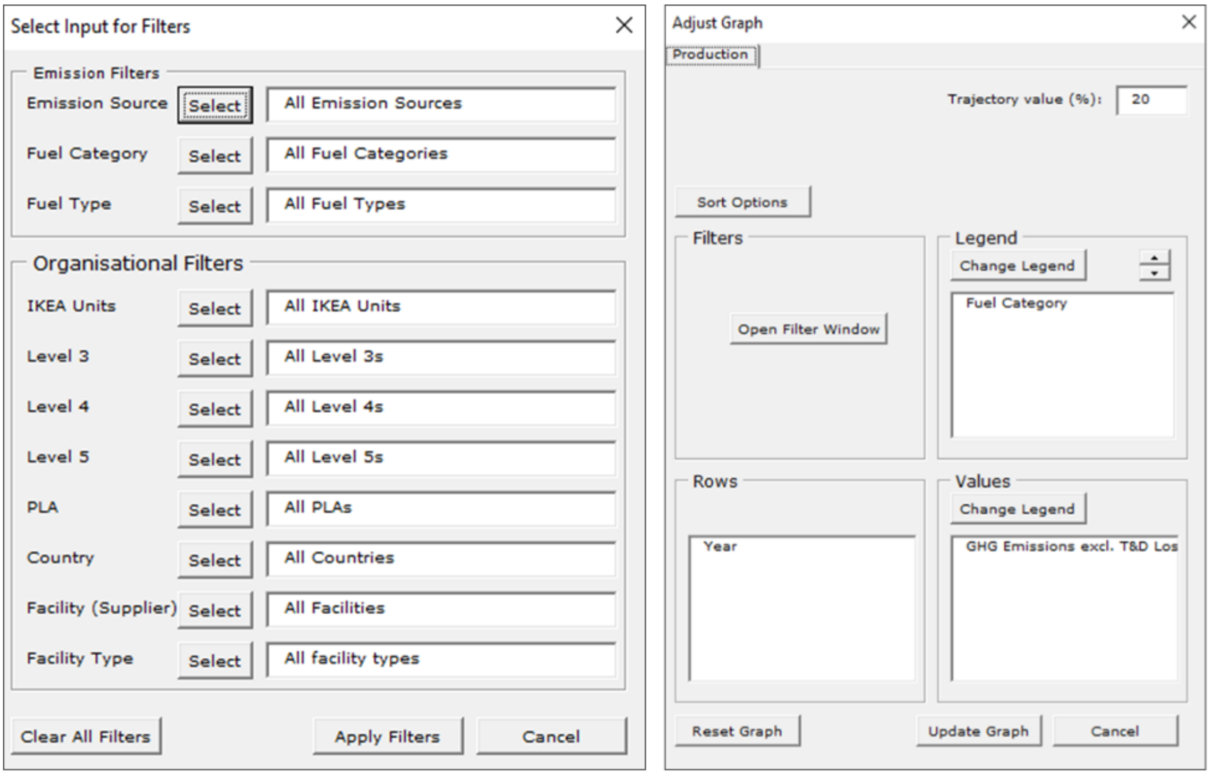

Figure 19. The filtering window (left) and adjust graph window (right).

The main functionality of the tool is to perform climate footprint scenario simulations. By pressing the button "Simulation Parameters", the UserForm dialogue for entering simulation parameters opens, see Figure 20. Five different types of simulation actions are possible to perform; growth rate, energy efficiency, renewable share (bought electricity), change energy source, and change refrigerant. Each simulation option is accessed by navigating between each tab as seen in the top of Figure 20. These simulations options will now be explained in more detail.

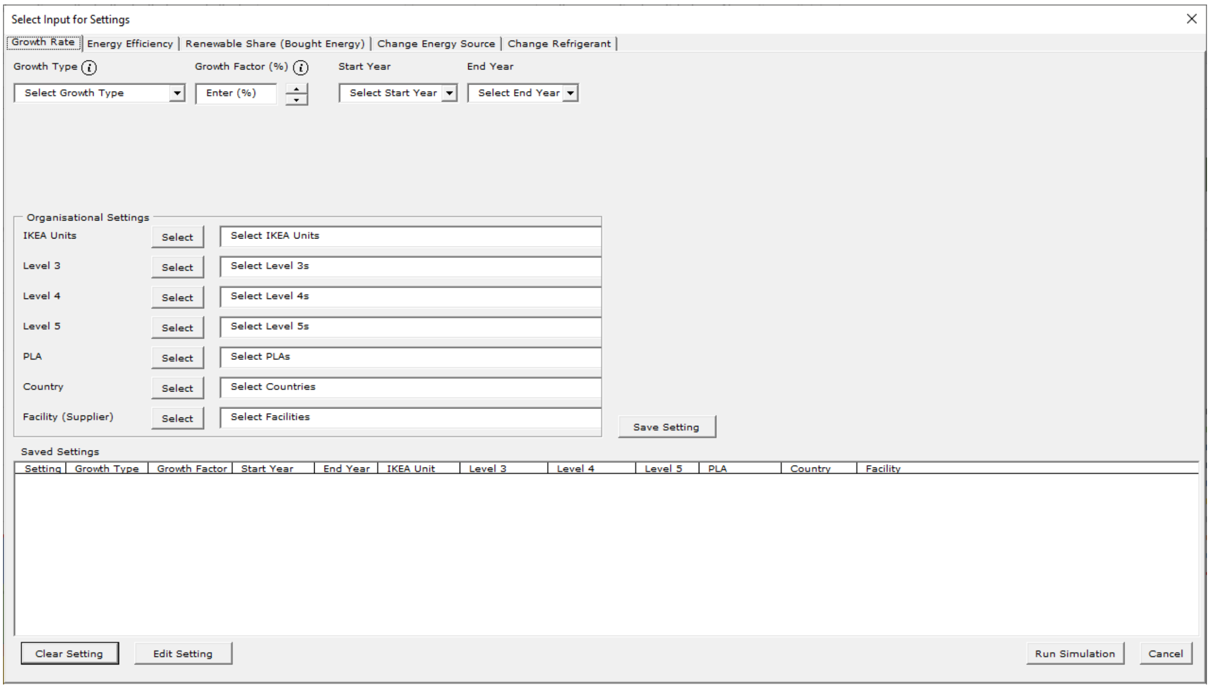

Figure 20. The simulation parameters window.

Simulation option: Growth rate

The growth rate simulation option is used to simulate the expected growth of the business. If no other actions are performed the emissions are assumed to be growing with the growth rate of the business. The growth rate is simulated by selecting the growth type, growth factor, start year, end year and what part of the organization that will be affected. Table 11 provides explanations to each parameter.

Table 11. Explanations for the growth rate simulation parameters.

PARAMETER	EXPLANATION
Growth type	Growth type can either be annual or absolute. If annual is selected, the growth factor will be applied every year. If absolute is selected, the provided growth factor will be the total growth until the end year.
Growth factor	How much the business is expected to grow in percentage.
Start year	From what year should the growth rate start.
End year	Until what year will the growth rate be valid.
Organisational settings	What part of the organisation is affected by the growth rate.

When all parameters have been set, the settings should be saved by clicking the "Save Setting" button. The saved settings will then appear in the "Saved Settings" box as seen in Figure 20. The saved setting can be edited by clicking on the "Edit Setting" button. If necessary, more scenarios can be added affecting different parts of the organisation with different growth rates. All scenarios will be added to the Saved Settings box and when the simulation runs it will be executed in the order they were added. To run the simulation, the "Run Simulation" button is clicked. This will open a dialogue asking which of the five simulation options the user would like to run. The user can select to run one simulation option at a time or to run multiple or all options at the same time. The default growth rate has been set to the arbitrary value of 5% within this report. For use within IKEA, the expected growth rate of the IKEA business is used as the default growth.

Example:

The result of running a growth rate simulation is shown in Figure 21. The left graph shows the initial values and the right one shows the result after the simulation has been performed. In the simulation parameters the growth type was set to annual, the growth factor to 2%, the start year to 2020 and the end year to 2030. All parts of the organisation were chosen to be affected by the simulation. As seen in the right graph, the slope is not as steep as the graph to the left.

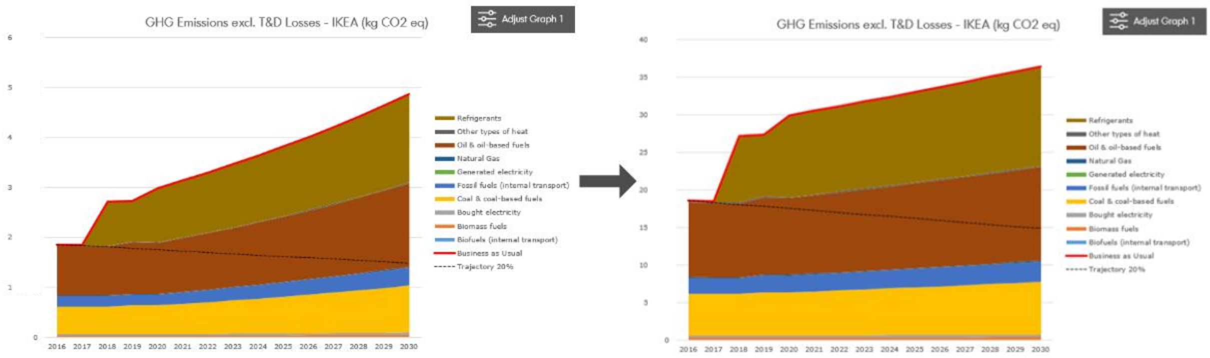

Figure 21. Running the growth rate simulation with 2% annual growth rate. The left graph shows the initial values (5% default dummy growth rate), and the right graph shows the result after the simulation has been performed (dummy data used).

How the growth rate is calculated is presented in equation 7 and 8.

$$Intensity\ Measure_n = Intensity\ Measure_{n-1} * (1 + Growth\ factor) \quad (7)$$

$$GHG\ emissions = Intensity\ Measure_n * Efficiency * Emission\ factor \quad (8)$$

Where:

Intensity Measure = the amount being produced, can for example be in m^3 *or kg.*

Growth factor = the expected annual business growth

Efficiency = represents how much energy is needed per intensity measure, e.g., kWh/m3

Emission factor = the emission factor in kg CO_2*-eq / kWh*

GHG emissions = the total GHG emission in kg

Simulation option: Energy efficiency

The energy efficiency simulation option simulates potential energy efficiency improvements. A process with improved energy efficiency provides the same output, but with less energy.

The parameters presented in Table 12 needs to be provided for the energy efficiency simulation.

Table 12. Explanations for the energy efficiency simulation parameters.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The potential energy efficiency improvement in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
Emission source	The affected emission sources.
Fuel category	The affected fuel categories.
Fuel type	The affected fuel types.
Organisational settings	The part of the organisation affected by the change.

Example:

The simulation results of an energy efficiency simulation is presented in Figure 22. The parameters were set to an annual improvement of 3%, from 2020 to 2030 for all energy emission sources and for all part of the IKEA organisation. The simulated result can be compared with the “Business as usual” case as represented as a red line in the graphs. As seen, the energy efficiency only affects energy sources. Therefore, GHG emissions from refrigerants are unchanged.

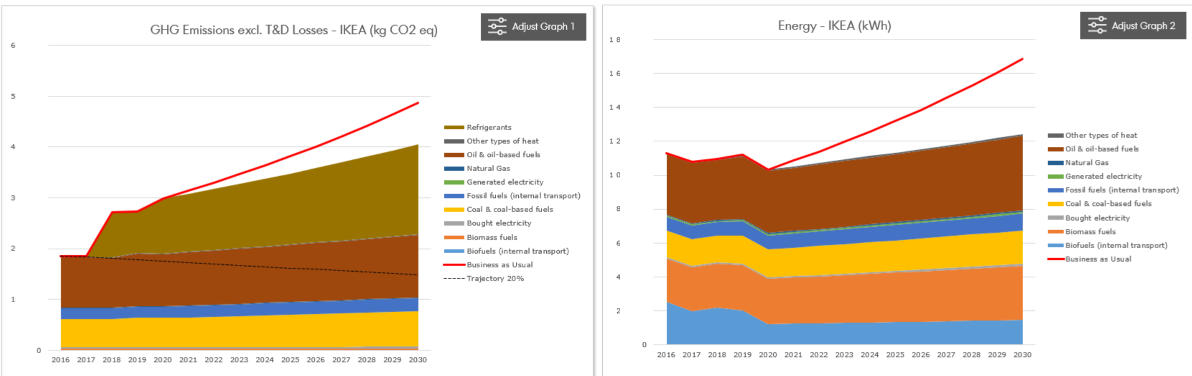

Figure 22. Running the energy efficiency simulation with an annual improvement of 3% (dummy data used).

The logic of the energy efficiency has previously been explained in equations 5 and 6. The GHG emission are calculated in the same way as in equation 8.

Simulation option: Renewable share

The next simulation option is to change the renewable share of the bought energy (electricity and heat). It builds on the assumption that if the energy is bought from 100% renewable sources, the GHG footprint is 0 kg CO_2-eq/kWh. The tool uses linear interpolation to change the renewable share and associated GHG emission from the initial value up to the provided value. The logic of the interpolation and the reasoning behind the assumption are further explained in the report by Sander & Skoog (2017). The parameters for renewable share simulation are presented in Table 13.

Table 13. Explanations for the renewable share simulation parameters

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The change in renewable share.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
Emission source	The affected emission sources (only bought energy).
Fuel category	The affected fuel categories (only bought energy).
Fuel type	The affected fuel types (only bought energy).
Organisational settings	The part of the organisation affected by the change.

Example:

The change factor is set to 100% with an absolute change type. The start year is set to 2025 and the end year is set to 2030, the emission source is set to only affect purchased electricity (not purchased heat), and the change will affect the whole IKEA organisation. The result is presented in Figure 23.

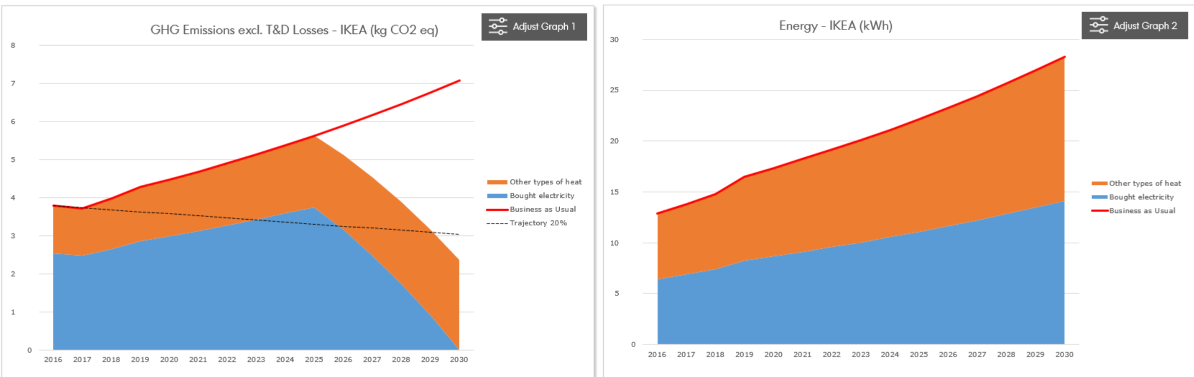

Figure 23. Running the renewable share scenario with 100% renewable electricity by 2030 (dummy data used).

Equations on how the renewable share is working is presented in equation 9 and 10. The total GHG emission are calculated in the same way as presented in equation 8.

$$Renewable\ share_n = Renewable\ share_{n-1} * (1 + change\ factor) \quad 9$$

$$Emission\ factor_n = Emission\ factor_{n-1} + \frac{(Emission\ factor_{n-1})}{1 - Renewable\ share_{n-1}} \dots$$

$$\dots * (Renewable\ share_n - Renewable\ share_{n-1}) \quad 10$$

Where:

Renewable share = the share of renewable energy for the emission activity.

Emission factor = the emission per intensity measure

Simulation option: Change energy source

The option to change energy source simulates the climate footprint when changing one energy source to another. The parameters that can be changed is explained in Table 14.

Table 14. Explanations for the change energy source simulation parameters.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The potential energy efficiency improvement in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
From - Emission source	The emission sources that should be changed.
From - Fuel category	The fuel category that should be changed.
From - Fuel type	The fuel type that should be changed.
To - Emission source	The emission sources that should be changed to.
To - Fuel category	The fuel category that should be changed to.
To - Fuel type	The fuel type that should be changed to.
Organisational settings	The part of the organisation affected by the change.

Example:

The result of the simulation changing 100% of the oil and oil-based fuels to renewable electricity is presented in Figure 24. The change factor is set to -100% with an absolute change type. The start year is 2025 and the end year is 2030. The from fuel category is set to “Oil & oil-based fuels” and the to fuel category is set to “Generated electricity”. As seen in Figure 24, the graph showing the energy used by IKEA shows that the oil-based fuels have been replaced by the generated electricity. The graph showing the GHG emissions shows a reduced GHG footprint.

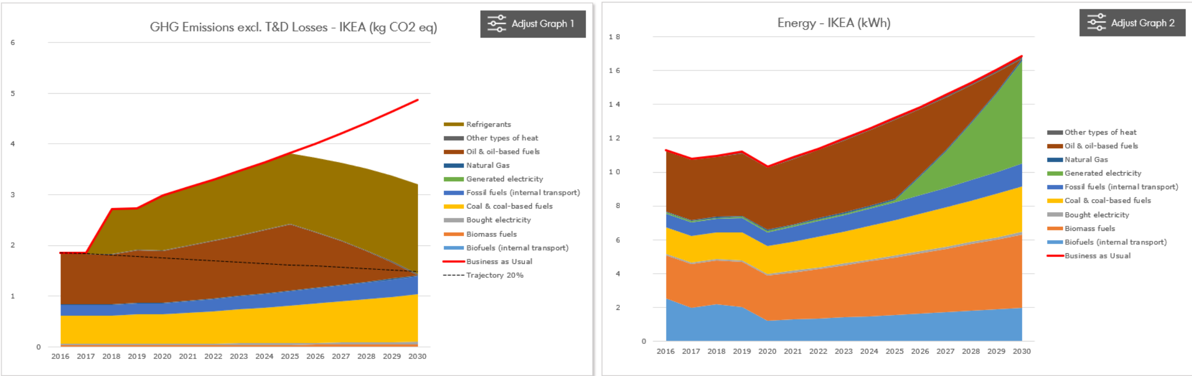

Figure 24. The result when changing 100% of the oil-based fuels to renewable generated electricity (dummy data used).

The general logic of changing energy source is presented in equation 11 to 15.

$$Energy\ share\ from_n = Energy\ share\ from_{n-1} * (1 + Change\ factor) \quad 11$$

$$Change\ energy = Total\ energy\ (kWh) * (Energy\ share\ from_n - Energy\ share\ from_{n-1}) \quad 12$$

$$Energy\ from\ (kWh)_n = Energy\ from\ (kWh)_{n-1} - Change\ energy \quad 13$$

$$Energy\ to\ (kWh)_n = Energy\ to\ (kWh)_{n-1} + Change\ energy \quad 14$$

$$Energy\ share\ to_n = \frac{Energy\ to\ (kWh)_n}{Total\ energy\ (kWh)} \quad 15$$

Where:

$Energy\ share\ from/to$ = the initial share of energy allocated to a certain energy source (per supplier and year)

$Change\ energy$ = The change amount that is subtracted from the from energy and added to the to energy.

$Total\ energy\ (kWh)$ = The total energy amount, per supplier and year.

Energy from (kWh) = The energy amount of the from energy source

Energy to (kWh) = The energy amount of the to energy source

Simulation option: Change refrigerant

Similar to change energy source, it is also possible to change the type of refrigerant being used. The parameters for change refrigerant are presented in Table 15.

Table 15. Explanations for the change refrigerant simulation parameters.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The potential energy efficiency improvement in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
From - Refrigerant type	The refrigerant that should be changed.
To - Refrigerant type	The refrigerant that should be changed to.
Organisational settings	The part of the organisation affected by the change.

Example:

The result of changing all refrigerants to a refrigerant with an emission factor of zero CO_2-eq is presented in Figure 25. Note that this is likely not a realistic simulation case but only for visualisation. The change type is absolute, with the change factor of 100%. The start year is 2025 and the end year is 2030. As seen in the left graph the climate footprint is reduced between 2025 and 2030.

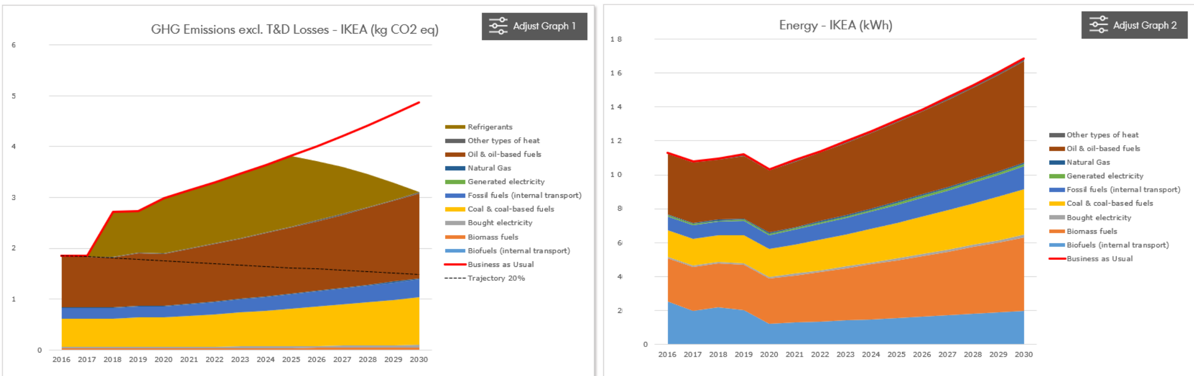

Figure 25. The result when changing all refrigerants to a refrigerant with 0 GHG footprint (dummy data used).

How the change refrigerant is calculated is presented in equation 16 to 20.

$$Volume\ share\ from_n = Volume\ share\ from_{n-1} * (1 + Change\ factor) \quad (16)$$

$$Change\ volume = Total\ volume * (Volume\ share\ from_n - Volume\ share\ from_{n-1}) \quad (17)$$

$$Volume\ from_n = Volume\ from_{\ n-1} - Change\ energy \quad (18)$$

$$Volume\ to_n = Volume\ to_{\ n-1} + Change\ energy \quad (19)$$

$$Energy\ share\ to_n = \frac{Volume\ to}{Total\ volume} \quad (20)$$

Where:

$Total\ volume$ = *The total refrigerant volume in kg, per supplier and year.*

$Volume\ share\ from/to$ = *the initial share of volume allocated to a certain refrigerant (per supplier and year)*

$Change\ volume$ = *The change amount that is subtracted from the from volume and added to the to volume.*

$Volume\ from$ = *The volume of the from refrigerant*

$Volume\ to$ = *The volume of the to refrigerant*

5.5.2 Food ingredients

The new food simulation tool is presented in Figure 26. It is very similar to the production tool in design, but the simulation functionality and filtering options are different. All the simulation examples below are executed on made up data.

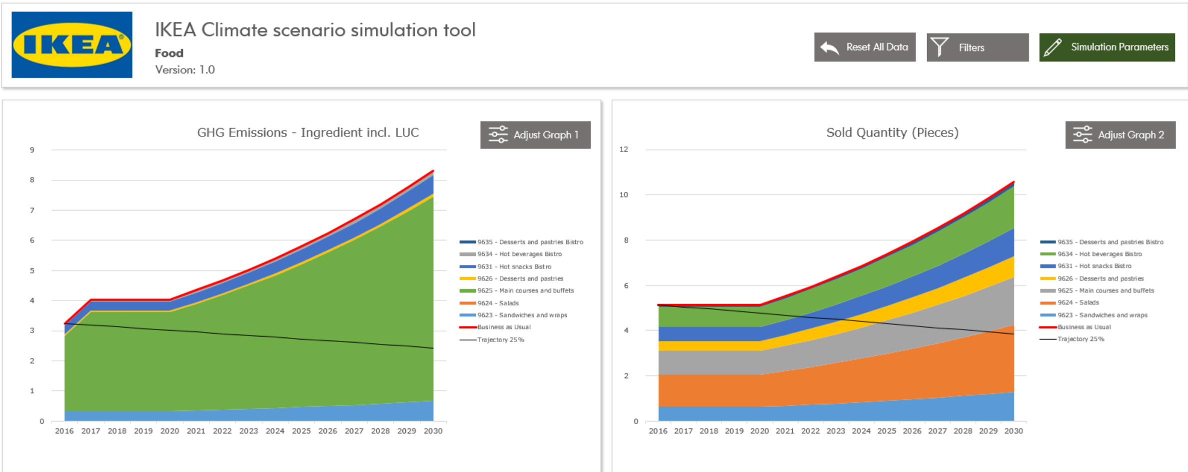

Figure 26. The updated food simulation tool (dummy data used).

The "Simulation Parameters" button open the simulation window, see Figure 27. Six types of simulations are possible to run; growth rate, change emission factor, change ingredient, change articles, sourcing option beef, and sourcing option cocoa. Generally, the simulation logic has been kept from the tool developed by (Sander & Skoog, 2017). It has however been adapted to work with the new data structure.

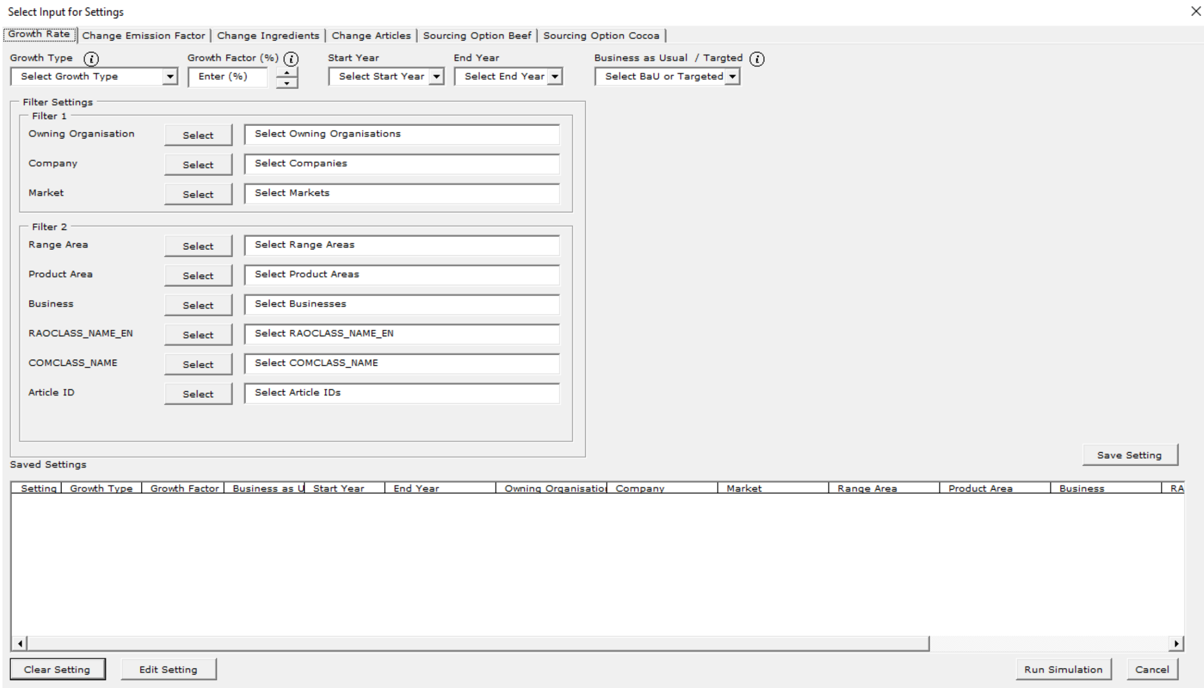

Figure 27. The simulation parameters for the food tool.

Simulation option: Growth rate

Used to simulate how much the business is expected to growth, together with associated emissions.

The simulation parameters are presented in Table 16.

Table 16. The simulation parameters for the food growth rate simulation.

PARAMETER	EXPLANATION
Growth type	Growth type can either be annual or absolute. If annual is selected, the growth factor will be applied every year. If absolute is selected, the provided growth factor will be the total growth until the end year.
Growth factor	How much the business is expected to grow in percentage.
Start year	From what year should the growth rate start.
End year	Until what year will the growth rate be valid.
Business as usual /targeted	Does the growth rate represent the expected future growth? If that is the case, business as usual should be selected. That means that the red line in the resulting graph will follow the growth. Or do you want to simulate the impact of a business decision that will impact the growth? For example, a business decision might favour plant-based food and disadvantage meat-based food. This will in turn impact the anticipated growth of the different types of food. This will then be a targeted growth and will not affect the red line in the resulting graph.
Filter settings	What part of the organisation or which articles will be affected by the growth rate.

Example:

The food growth rate simulation works like the production growth rate simulation. This has previously been presented and explained in relation to Figure 21.

Simulation option: Change emission factor

The change emission factor scenario is used to simulate how an improved emission factor will affect the result. Can be used to for example simulate the anticipated emission factors improvement for dairy products. The parameters settings are explained in Table 17.

Table 17. The simulation parameters for the food change emission factor simulation.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The anticipated change improvement in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
Emission Factor Type	Which emission factors should be affected? Can be set to “Ingredient excl. LUC” and/or “Ingredient LUC”. LUC stands for Land Use Change.
Filter settings	What part of the organisation, which article, or which ingredients should be affected by the change.

Example

Figure 28 show the result when running a scenario where the emission factor for beef has been improved. The change factor was set to 30%, the change type as absolute, the start year as 2025, the end year as 2026, the emission factor type was set to all (both “Ingredient excl. LUC” and “Ingredient LUC”) and the Ingredient Code under Filter settings were set to the ingredient code of beef. As seen the emission from beef ingredients are reduced from the year 2025.

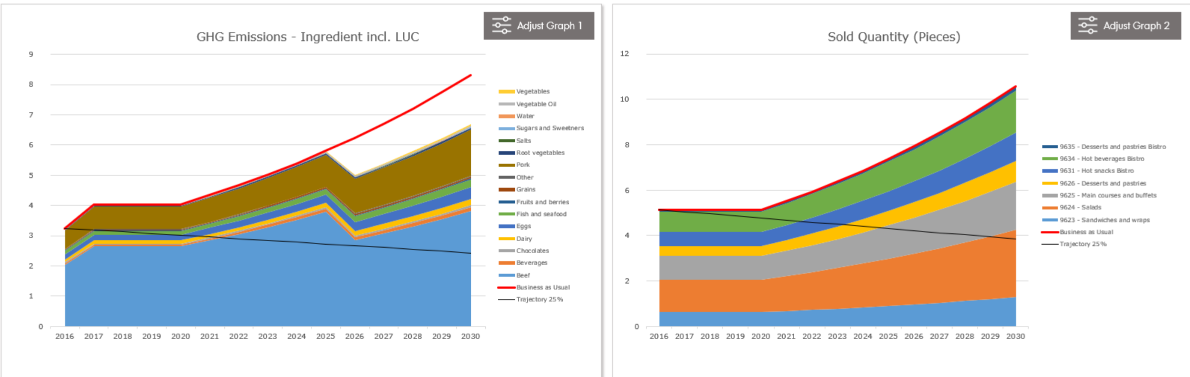

Figure 28. The result when improving the emission factor for beef (dummy data used).

The change emission factor calculation logic is presented in equation 21.

$$Emission\ factor_n = Emission\ factor_{n-1} * (1 + Change\ factor) \qquad 21$$

Where:

Emission factor = the emission factors for an ingredient.

Simulation option: Change ingredient

The change ingredient scenario can be used to simulate the impact of changing one ingredient to another. The simulation parameters are presented in Table 18.

Table 18. The simulation parameters for change ingredient.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The anticipated change in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
From ingredients: Filter settings	What part of the organisation, which article, or which ingredients should be changed from.
To ingredients: Filter settings	What part of the organisation, which article, or which ingredients should be changed to.
Affected share: From ingredient	Default 100. For more advanced scenarios. "Affected share To Ingredients" can be used for example to let 100% of meatballs go into 50% of plantballs and 50% of vegetables.
Affected share: To ingredient	Default 100. For more advanced scenarios. "Affected share To Ingredients" can be used for example to let 100% of meatballs go into 50% of plantballs and 50% of vegetables.

Example:

The result of changing beef ingredients to root vegetables ingredients are presented in Figure 29. The change type is annual, the change factor -5%, the start year 2022, the end year 2030, the from ingredient classification is set to Beef, the to ingredient classification is set to Root vegetables, the from affected share is set to 100%, and the to affected share is set to 100%. As seen in the figure, the overall emissions and more specifically the emissions from beef are reduced compared to the business-as-usual scenario.

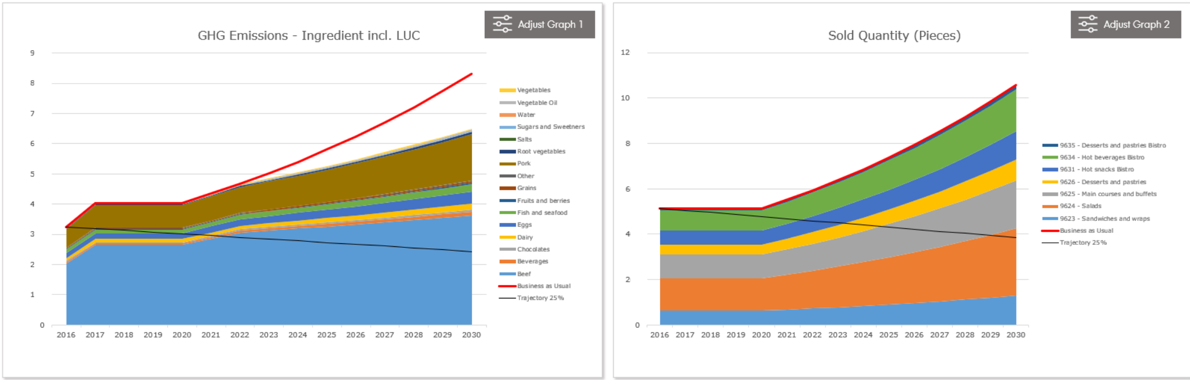

Figure 29. The result of changing the ingredients from beef to root vegetables (dummy data used).

A simplified presentation of the calculation logic is presented in equation 22 and 23.

$$Quantity\ from_n = Quantity\ from_{n-1} * Affected\ share * (1 + Change\ factor) \quad 22$$

$$Quantity\ to_n = Quantity\ to_{n-1} + (Quantity\ from_{n-1} - Quantity\ from_n) \quad 23$$

Where:

Quantity from = The amount in kg of the from ingredient.

Quantity to = The amount in kg of the to ingredient.

Affected share = The specified amount that is expected to be affected by the change (for advanced usage).

Change factor = The specified change in percentage.

Simulation option: Change article

The change article scenario can be used to simulate the impact of changing one article to another. It works similar as the change ingredient scenario, but instead of changing a specific ingredient the whole article (product or dish) is changed. The simulation parameters are presented in Table 19.

Table 19. The simulation parameters of change article.

PARAMETER	EXPLANATION
Change type	The change can either be annual or absolute. If annual is selected, the change factor will be applied every year. If absolute is selected, the provided change factor will be the total change until the end year.
Change factor	The anticipated change in percentage.
Start year	From what year should the change start.
End year	Until what year will the change be valid.
From article: Filter settings	What part of the organisation and which article should be changed from.
To article: Filter settings	What part of the organisation and which article should be changed to.

Affected share: From article	Default 100. For more advanced scenarios. Can be used for example to let 100% of a meatballs dish go into 50% of a plantballs dish and 50% into a vegetables dish.
Affected share: To article	Default 100. For more advanced scenarios. Can be used for example to let 100% of a meatballs dish go into 50% of a plantballs dish and 50% into a vegetables dish.

Example:

The result of changing a dish with beef to a dish without beef is presented in Figure 30. The change type is annual, the change factor -5%, the start year 2022, the end year 2030, the from article is set to a dish containing beef, the to article is set to dish without beef, the from affected share is set to 100% and the to affected share is set to 100%. As seen in the figure, the emissions is reduced compared to the business as usual scenario.

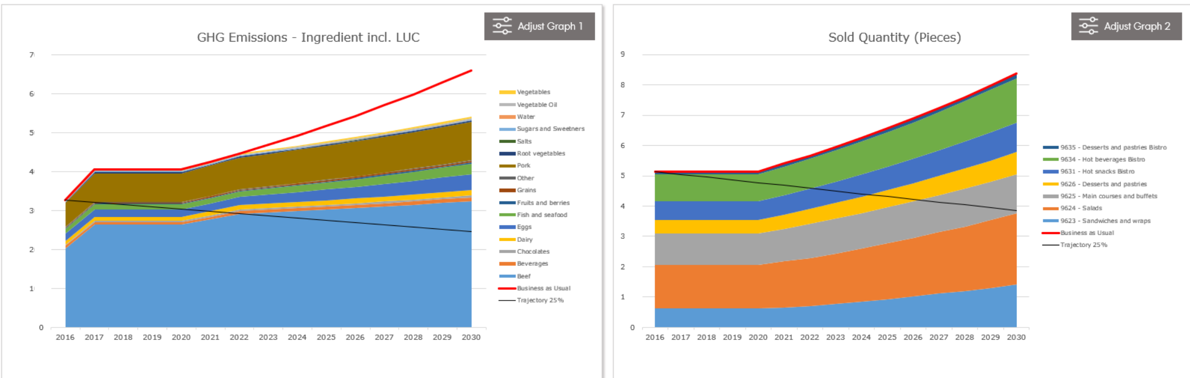

Figure 30. The result of changing a dish with beef to a dish without beef (dummy data used).

Once again, a simplified presentation of the calculation logic is presented in equation 24 and 25.

$$Quantity\ from_n = Quantity\ from_{n-1} * Affected\ share * (1 + Change\ factor) \quad 24$$

$$Quantity\ to_n = Quantity\ to_{n-1} + (Quantity\ from_{n-1} - Quantity\ from_n) \quad 25$$

Where:

$Quantity\ from$ = *The sold amount of the article changed from.*

$Quantity\ to$ = *The sold amount of the article changed to.*

$Affected\ share$ = *The specified amount that is expected to be affected by the change (for advanced usage).*

$Change\ factor$ = *The specified change in percentage.*

Simulation option: Sourcing option beef

Can be used to simulate the impact of sourcing beef meet from different countries as well as changing the type of cattle being used in the beef production. Figure 31 shows how the simulation parameters can be changed. When selecting the sourcing country and sourcing option, the new emission factor for beef is calculated based on predefined emission factors for the different countries and sourcing options. When the simulation is executed, all the beef ingredients are updated with the new emission factor.

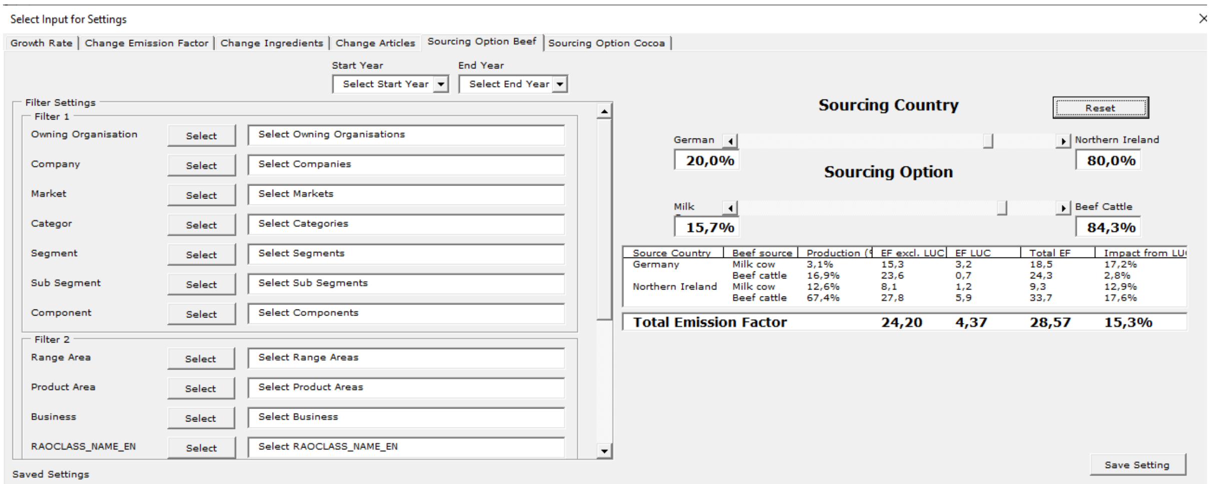

Figure 31. Sourcing option beef simulation parameters.

The simulation parameters are explained in Table 20.

Table 20. The simulation parameters of sourcing option beef.

PARAMETER	EXPLANATION
Start year	From what year should the change start.
End year	Until what year will the change be valid.
Sourcing country	The share of the country that the beef should be sourced from, German or Northern Ireland.
Sourcing option	The share of what type of cattle that has been used for the beef, milk or beef cattle.
Filter settings	What part of the organisation and which articles should be affected?

Example

The result of changing the sourcing country to Germany and that only milk cows are used in beef production is presented in Figure 32. The start year was set to 2025, the end year 2030, the sourcing country to 100% Germany, the sourcing option to 100% milk and all IKEA products were affected. As seen the emissions from beef is reduced from the year 2025.

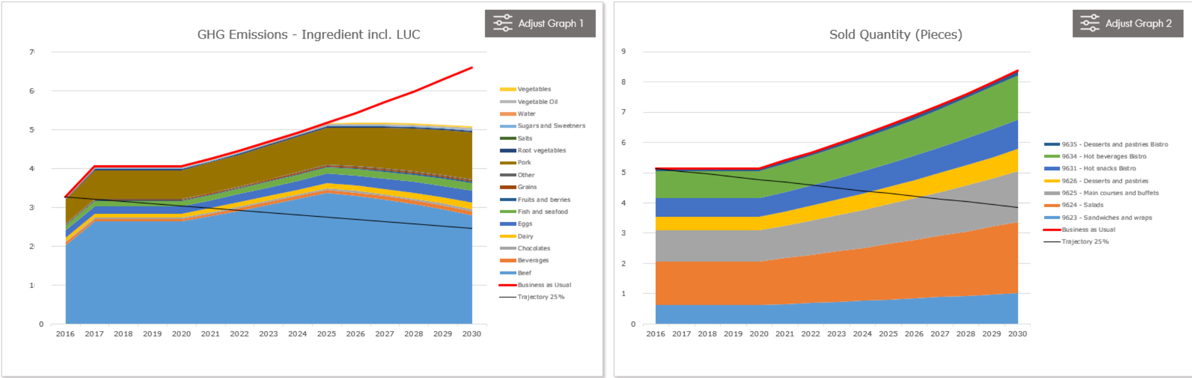

Figure 32. The result when changing the sourcing country of beef to Germany and milk cows (dummy data used).

Simulation option: Sourcing option cocoa

Can be used to simulate the climate footprint when the sourcing country of cocoa is changed, see Figure 33. When selecting the sourcing country, the new emission factor for cocoa is calculated based on predefined emission factors for the different countries. When the simulation is executed, all the cocoa ingredients are updated with the new emission factor.

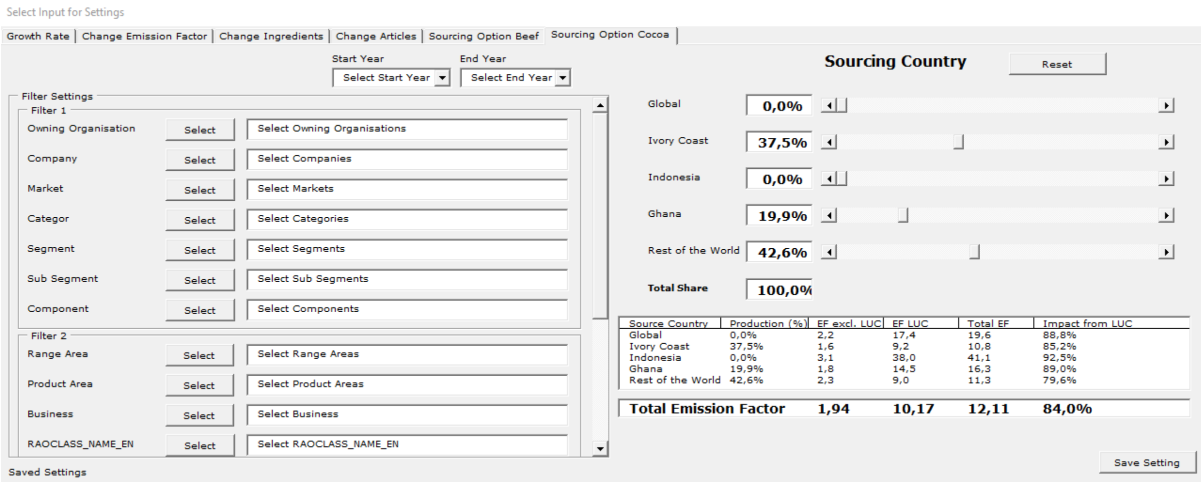

Figure 33. The simulation parameters of sourcing option cocoa.

The simulation parameters are presented in Table 21.

Table 21. The simulation parameters of sourcing option cocoa.

PARAMETER	EXPLANATION
Start year	From what year should the change start.
End year	Until what year will the change be valid.
Sourcing country	The share of the country that the beef should be sourced from, German or Northern Ireland.
Filter settings	What part of the organisation and which articles should be affected?

Example

The result when changing all sourced cocoa to Indonesia is presented in Figure 34. Only products containing chocolate is presented for easier visualisation. The start year was set to 2025, the end year to 2030, the sourcing country to 100% Indonesia, and all IKEA products are affected. As seen in the figure the emissions have been reduced for products containing chocolate.

Figure 34. The result when changing the sourcing country to Indonesia (dummy data used).

5.6 FINDINGS FROM THE USER TESTING

Three user testing sessions were performed for the production and retail & other operations tool. During the session, the user got a general introduction of the tool and was then given instructions on different actions to perform. The main findings from the user testing will now be presented.

Two of the users thought that the tool will be useful in their daily tasks for creating scenarios connected to their climate agenda. The third user was unsure if the tool was usable from his perspective, this since the user had an internal tool specially developed for their purpose.

The tool is still a bit hard to use without detailed descriptions on how to use it. A few examples when the user misunderstood the behaviour of the tool are; the user clicked on run simulation without saving the simulation parameters, the user tried to reset the filtering by clicking on Reset all data (this will reset the simulation result but not the filtering), the user entered “10%” instead of “10” when specifying the energy efficiency, the user entered “100” instead of “-100” for the change factor for changing the energy source.

Further, one user avoided clicking on the “Simulation Parameters” button because he thought that would directly start the simulation. The reason was that the icon used for the button looked like a “play” icon. Afterwards, the button was updated with a “pen” icon to make it clearer that it will open an edit-window. Another user would like the possibility to see what is filtered on when performing the simulation as this is not included in the current version. The third user had some problems with the scaling of the buttons of the simulation tool. They became smaller than the intended size. While still being usable, the tool looked a bit strange. The issue was not possible to reproduce on other computers and was not apparent by other users.

Based on the findings from the user testing some minor changes were made to the tool, including the update of the “Simulation Parameters” button and verification of the user input for the change factor.

6 DISCUSSION

From the stakeholder interviews a number of aspects were identified as relevant for the success of using a scenario analysis tool. These aspects have been grouped into categories: usability and user competence, technical issues and solutions, governance, and further user needs. This project has mainly worked with improving the usability and the technical aspects of the simulation tools. However, developing the user competence and making sure that the governance is defined and understood (who is responsible for what) is equally important. All four aspects are discussed in this chapter based on the IKEA needs. This discussion will cover what has been implemented and what further improvements are needed. The chapter will end with a discussion on the use of attributional LCA data in a decision support tool.

6.1 USABILITY AND USER COMPETENCE

One critical area for the success of using a simulation tool appears to be that it is easy to use. Multiple interviewees seemed somewhat hesitant to use the previously existing simulation tool since they consider it hard to use. Low hanging usability improvements have been implemented in this project but during the usability testing it became apparent that the tool can still be considered hard to use as multiple users had trouble performing some of the actions in the tool. This is problematic as it might result in that the tool not being used at all. If a user feels that the tool is hard to use, he or she will likely be hesitant to use the tool and will also not help in spreading it in the organisation. It is also likely that the user will find or develop a new separate procedure for achieving similar results, resulting in many different approaches being used throughout the organisation. Another aspect is that the user might not trust the result of the tool if the user has been unsure about how to insert the simulation parameters. If the result cannot be trusted it will likely not be used for decision-making, and the benefits of using scenario analysis will not be realised.

To avoid the most critical usability issues within the current tool, a user guide should preferably be developed, and the users should be trained in how to use the simulation tool. A user-guide may help improving usability to a certain degree, but it should preferably be combined with further usability improvements of the simulation tool. It is recommended that further iterations are being made between user testing and development. This to find usability issues, make improvements and evaluate if the improvements are solving the issues. This will be a rather time-consuming process but is necessary to secure the usability of the tool. An alternative could also be to looking into platforms other than excel where it might be easier to create a better user experience. One such alternative could be Power BI (see section 5.2), however, appropriate licensing must in that case be worked out.

6.2 Technical issues and solutions

One of the most requested needs from the interviews was that the simulation tool itself should be available and updated with the newest data. This is one of the areas where most effort has been spent in this project as it relates to the development of the new data structure, the update tool, and the adaptation of the simulation tool to allow for easy update. The initial idea was that the developed functionality would allow the user of the simulation tool to update the tool themselves with new data. The update tool as presented in section 5.2.1 and Figure 10 was developed with this ambition. It was however recognised that it will most likely be too hard for the end-user to make sure that the data is provided in the correct format to allow for a correct update. The format that the user has to provide the data in is 141 columns wide and the user must make sure that the content of each columns is correct. To provide an example, the received data to be used in the production simulation tool contained errors (NaN), unreasonably high numbers, percentages over 100% when it should not be allowed, emission sources not previously defined, and more. As a developer of the tool, it is possible to capture and understand these errors, but as an end-user it is very hard to understand what went wrong. The tool itself can capture some of these errors and correct them, but it is hard to know and capture them all.

The underlying problem seems to be connected to the way climate footprint data is handled and processed within IKEA. Excel is the most used tool within IKEA to collect, process, and transfer climate data and it seems rather common that human induced errors are introduced into the data. If Excel is used to store data, there are multiple aspects that are important to be aware of that might compromise the quality of the data. By default, there is no guarantee that duplicate rows do not exist in the data set. Each cell does also allow any type of data to be stored meaning that for example a text value can be stored where it is supposed to be a number. Measures can be developed within Excel to counter these issues. However, as the data is often forwarded and further processed by multiple stakeholders there is a risk that these measures are not always implemented.

One problem with the manual management of data is for example if the user of the simulation tool finds errors in the data, such as incorrect values for the electricity use for a supplier. Then the data should optimally be updated in the base data of where it is collected. All the manual processing and transferring of the new climate data must then be performed again in order to make sure the data is updated throughout the organisation. If this occurs multiple times, there is a risk that certain procedures and measures are missed due to the human factor leading to incorrect data.

Another issue is that the process is rather people dependent. Each stakeholder needs to know and have sufficient knowledge of how the processing of the data should be performed. If a person is replaced by another it must be ensured that the new person is processing the data in the same way. Inherent in this, there will be a risk that certain measured and processing steps are missed with a negative effect on the data quality. If incorrect data is used it might deceive the decision-maker into taking actions that are either not enough or unnecessary to a reach a goal.

The best way to avoid these problems is to automate the process as much as possible as well as to put the climate footprint data in a centralised relational database. This will allow for an easier update and availability of the simulation tool. Using a centralised database will have several benefits: for example, all tools will use the same source of data (both performance follow-up and simulation tools), the data needs to be corrected only in one place, and improved data quality as the database can set constraints not allowing invalid data to be inserted. Ideally, a corporate climate footprint database should be designed storing all GHG emitting activities. All different type of emission areas should be stored as different entities but still allowing for them all to be aggregated into one climate footprint. The centralised storing should preferably not be Excel based, but in a relational database system. A way forward could be to look more into using Microsoft Dataverse as explained in section 5.2. The need of the IKEA climate team and the explanation by Microsoft matches very well (Microsoft, 2020c):

> "*Building out the data infrastructure to enable business insight can be both time consuming and expensive. The data originates from a variety of devices, applications, systems, services, and software as a service (SaaS). This large and growing number of sources often consists of multiple data technologies that store different types of data, expose different APIs, and use a mixture of security models. The developers needed to create these technologies can be expensive and hard to find. Developers often must have a deep understanding of how to deploy, configure, manage, and integrate these different data technologies.*
>
> *Dataverse addresses these concerns with an easy to use, easy to manage, compliant, secure, scalable, and globally available SaaS data service. Dataverse empowers organizations to work with any type of data and any type of app, and use the data within it to gain insights and drive business action."*

Looking more into Microsoft Dataverse might be the most feasible approach for finding a flexible data storage solution for the IKEA climate data. Microsoft Dataverse is closely connected to Power BI and should optimally be used together.

Another issue that was expressed as problematic during the stakeholder interviews was the appearance of software bugs. The identification and fixing of bugs should ideally be part of the usability testing and implementation iterations as discussed in section 6.1. It is important that enough time is directed at improving the quality of the tool as users might be hesitant to use the tool if too many bugs appear. One learning from this project is that it is important to have enough time for user testing and debugging when setting the timeline for a project. Also, as the existing tool had very limited code documentation it was sometimes hard to understand its functionality before implementation. Therefore, a lot of trial and error was performed when implementing new features, often resulting in new bugs being introduced.

There are measures that can be applied to reduce the number of bugs in a software such as Test-Driven Development (TDD). In TDD, tests of how the software should perform are defined before the implementation of the functionality. These tests are then run every time the code changes, making sure the functionality is still correct. Unit tests are often used in TDD. This is an automated test, testing a specific unit/functionality. It is not possible to do unit testing within Excel without 3rd party extensions and has thus not been included in this project. It might be a good approach to look into going forward. Management and stakeholders must also be aware of that quality assurance will take some time. The more stress and the tighter the deadlines, the more bugs will appear, leading to a reduced trust and usability in the tool.

6.2.1 Uncertainties of the simulation model

It is important that the output of the simulation tool is reasonable, can be trusted in and provides a good basis for decision-making. In worst case it might mislead the decision-makers in making decisions that turn out to worsen the environmental impact. To give an example, hydropower is generally considered to be associated with low GHG emissions, but a recent study suggests that the emissions from hydropower might be much higher than anticipated, especially in tropical regions (Scherer & Pfister, 2016). Potential future discoveries such as these adds to the uncertainty of the model and might result in decisions being made that turns out being unfavourable.

In the process of model development, several assumptions are made that can be considered more or less accurate, especially in future conditions. These assumptions will affect the result and must be considered when interpreting the output of the simulation tool. Depending on the nature of the assumption, the uncertainty differs. For example, burning 1 kg of fossil diesel fuels will likely emit the same amount of GHG emissions in 10 years as today, while other emission factors are more dependent on technological advances. Activities with emission factors that are more uncertain are for example the use of electricity, heating, and biofuels. The time horizon of the scenarios is important as the uncertainties increases as the time goes. The developed tool within this project has a time-horizon until 2030 which is only nine years into the future. It is for example unlikely that the energy system will radically change in this period. However, if the time-horizon would have been until the year 2050, the uncertainty would have been much larger since energy systems might have radically changed and new technologies has been invented.

The use of scenario analysis itself is a way of handling uncertainty as the user of the tool can change certain parameters and evaluate different scenarios. For example, an estimate of future business growth exists within IKEA and it is the growth that will determine the expected growth in GHG emissions. Within that expected growth, there is a certain degree of uncertainty and it might in reality be lower of higher. To cater for this the user can run multiple scenarios in the developed simulation tool, one with the expected growth rate, one with a lower rate and one with a higher rate and see how the climate impact is affected. This will add an extra layer of assurance as the decisions to be made can be tested on multiple scenarios.

6.3 GOVERNANCE

As found out during the interviews, it was hard to find the intended user of the tool. All stakeholders thought it was important and relevant to do these simulations, but few considered themselves spontaneously having the responsibility for doing them. Therefore, there might be a need to clearly define roles to make sure the simulation capabilities are being used. There are three main responsibilities, (1) the one responsible for providing the tool and support, (2) the one responsible for the climate agenda within the specific area and (3) the one responsible for running the simulation tool.

The one providing the simulation tool will have the responsibility to provide a tool that is usable and functional, with the newest available data. This does likely include the need to continue the development of the simulation tool as the needs and structure of the organisation changes. There is also a need to provide support to the users of the simulation tool in the case it does not behave as expected. It falls rather natural that the one who has developed the tool should also provide the necessary support. This since the developer have in-depth knowledge of the tool. This is however not strictly necessary if sufficient training is conducted to the one giving the support.

There is generally a stakeholder responsible for how a certain part of the organisation performs in relation to set targets at IKEA. This is often tracked with Key Performance Indicators (KPIs). There should thus be a person responsible for following up the climate footprint performance (which is also often the case within IKEA). Based on the interviews it seemed rather uncommon that the one responsible for the KPIs was the one using the scenario analysis tool.

Additionally, there should be a person that is responsible for running the scenario analysis within the simulation tool. This can be the same person that are responsible for the climate performance, as described above. If that is not the case, it needs to be clearly delegated. It should preferably be delegated to a person within a sustainability function in order for a better understanding of the climate issue. It was sometimes recognised that a person working within sustainability was performing the scenario analysis and provided the input to the one responsible for the climate performance. This seems like a good approach.

Based on what has been decided in this project it will likely be the climate team that will update the simulation tool and provide the updated simulation tool to the users. This is not the most optimal solution as it will add on to the workload of the climate team and that some of the dependency of the climate team will still exist. If the data is provided in the correct format, the tool is however much easier to update than before thus the workload of the climate team should be reduced. As the resources within the climate team are limited there is a risk that the tool will not be updated regularly. If this is the case, the tool will likely not be used and the benefits of using scenario analysis will not be realised. To ensure that the new tool is available for the organisation the climate team must clearly define when the tool should be updated and who is responsible for doing so. To allow for this kind of support, the climate team might need to grow.

6.4 FURTHER USER NEEDS

As laid out in section 4.1, one of the most requested functionalities from the interviews was to be able to see the improvement within a certain part of the organisation if all action plans were implemented. This is possible to do in the existing simulation tool, however, as stated by one of the interviewees it has been considered too cumbersome and unfeasible to do so. The reason is that it has been considered too hard to "translate" the actions into one of the simulation options. On top of this, some areas have more than hundred suppliers, each with multiple actions, and it has not been considered doable to insert these into the simulation tool. It was decided in collaboration with the supervisor at IKEA that this project should put no effort into this as there is a parallel ongoing project within IKEA that has this issue in mind. Therefore, the simulation tool can be used to see the improvement if all action plans are implemented, but the process of adding these to the simulation tool can still be considered cumbersome and unfeasible. To give an example, an action plan might state that some parts of the purchased electricity and heat should be replaced by an onsite CHP system. To be able to add this in the tool today, numerus assumptions must be made, something the user of the tool might be uncomfortable making. If similar assumptions must be made for every action, it will be a lengthy process and the user might not trust the result of the tool.

6.5 THE IMPLICATIONS OF USING ATTRIBUTIONAL LCA DATA AS A BASIS FOR DECISION-MAKING

This section elaborates on the fourth research question "*Is it legitimate to use ALCA data as input data in a decision support tool? What are the implications of such a choice?"*

The goal of IKEA is to reduce the GHG emissions that are emitted because of their business. They use the guidelines provided by the GHG Protocol to create an indicator of their climate footprint. The use of the GHG Protocol is also a requirement by the Science-Based Target Initiative. The aim is to reduce this impact and eventually reach zero GHG emissions. The GHG Protocol corporate standard is attributional in nature as it tries to decide which emissions can be attributed to which process. As stated in section 2.4, the use of attributional LCA data for decision making has been questioned as it does not capture all the consequences of a decision. This is nevertheless what is happening in this project, attributional climate footprint data is being used in the simulation tool to support decision-making.

IKEA aims at having a responsible value chain with low or even net-negative GHG emissions. It is however not certain that the global emissions will be reduced as a consequence of the planned actions to reduce the GHG emissions of the value chain. For example, if biofuels (which is a limited resource) is used to reduce the climate footprint, it might happen that another actor on the market need to use another source of energy which might result in GHG emission occurring elsewhere. Likewise, if electricity is only purchased from hydropower (which is a limited resource) with the use of guarantees of origins, it might push another actor to purchase more dirty electricity. IKEA, and other responsible companies do likely want to have as few negative consequences as possible because of their decisions (they want to have a real positive change). That is for example why IKEA is looking into securing additionality when purchasing renewable electricity. This means that when purchasing renewable electricity, they want to ensure that new electricity generation is installed, avoiding the risk of just rearranging who is purchasing the already existing renewable electricity.

So, how can a company work with lowering the emissions associated to the value chain while avoiding having negative consequences because of their decision and plans? Weidema, among others, argue that CLCA should be used in decision-making to capture the full consequences of a decision (Brander, 2019; Weidema, 2003). If CLCA data should be used in the simulation tool, IKEA would have to not only collect the normal GHG inventory, but also collect data based on the CLCA methodology. If that is the case, they would have to set a relevant system boundary, including actors outside the value chain, use marginal data and system expansion to avoid allocation for every action. This will be a rather time-consuming process. In reality, it is likely not feasible to do so for every decision being made. A more practical approach is to use the ALCA data already collected in the GHG inventory. This could be used in conjunction with a number of principles to avoid having unintended consequences. Examples of these principles could be “reduce the use of energy and materials as much as possible”, “avoid renewable energy sources where the resource base is very limited” and “strive for additionality from the purchased renewable energy”. However, the true consequences of one’s decisions will be unknown.

One part of the GHG Protocol methodology that makes it more robust is the requirement to report both according to the market-based and location-based approach. According to the market-based approach, a company might purchase all electricity from renewable and clean sources and receive an emission factor of zero or close to zero. However, the location-based approach always uses the average emission factor of a region or a country, independently on what electricity has been purchased with the help of market instruments. The reporting of both the market- and location-based method side by side provides a more complete picture of the situation.

7 CONCLUSION

There is an apparent need for decision-supporting tools to aid the setting and following up of climate footprint goals within the IKEA organisation. The use of a scenario analysis tool seems to be a helpful tool for this purpose. A number of concerns were identified from the users of the previously existing simulation tool. These included that the tool was not always available with the latest data, it was perceived as hard to use, and it was sometimes unclear who had the responsibility of running the simulations. Also, the tools did not always meet the need of certain users. For example, multiple stakeholders requested the possibility to see the estimated GHG emission reduction if all planned improvements were implemented by all suppliers within a specific part of the organisation. This was considered unfeasible to do within the existing simulation tool.

Based on the previously existing tools, two simulation tools have been developed in Excel as part of this project. One will be used to set and evaluate climate targets for production, IKEA retail & other operations, and the other tool is intended to be used for food ingredients. The new simulation tools are easier to update with new data based on the new standardised data structure. This will increase the likelihood of the tool being updated and made available when new data becomes available. The graphical interface and the simulation logic of the tools has also been improved, allowing for an enhanced user experience. Even though improvements have been made, the tool is still dependent on manual processes for updating the tool with the latest data and the usability could be further improved. As a specific user need, it will be possible to add all planned supplier improvements into the simulation tool, but if there are many suppliers and many planned actions it will likely still be considered cumbersome by the user to do so.

In an effort to improve the data management of the GHG inventory, a new standardised data format has been developed for production, IKEA retail, and other operations. In the new data structure, associated data has been grouped together and is stored in separate tables. The data structure is using the IKEA defined common identifier for business units and is compliant with the GHG Protocol. The main table of the data structure is the “Climate Data Record intensity” table containing the amount used and correlating scope 1, 2, 3, market-based, location-based, and biogenic emission factor for each emission source, supplier, and year. By separating the business facts, such as measurements and numbers, into fact tables and descriptive fields into dimension tables, redundancy is avoided, creating a data structure that is suitable to be used for data analytics such as in a simulation tool. The new data structure is built and implemented into Excel but should preferably be used within a centralised database.

The use of attributional LCA data is useful as decision-support when improving the environmental performance of a value chain. There might however appear consequences outside the value chain not captured by the ALCA data. To minimize the unintended consequences, decision making should be strengthened by complementing scenarios/simulations with a set of principles to secure a true impact in society. Recommended principles include, but are not limited to: "to reduce the use of energy and materials as much as possible", "to avoid renewable energy sources where the resource base is very limited" and "to strive for additionality from any purchased renewable energy".

7.1 FURTHER RECOMMENDATIONS

To further improve the data management, it is recommended that the GHG inventory data should be located in a centralised database. This will allow for analytical tools to always use the latest available data without the need of manually updating the tool and redistribute it in the organisation.

It is also recommended that the responsibility of each stakeholder is clearly defined. Firstly, someone should have the responsibility to provide the simulation tools updated with the newest data. The same unit will likely also provide support to the users. Secondly, to make sure the scenario analysis capabilities are being realised, there should also be a clearly defined person responsible for running the simulations within each part of the organisation.

Another key area of improvement is to continue working on the usability of the tool. Even after improvements done in this project, the users experienced difficulties with the simulation tools. As a first step, a user guide should be developed, and training should be conducted with the users. Ideally, more iterations should be carried out between development and user testing to further refine the usability.

An obvious further recommendation is to continue developing scenario analysis tools to cover the remaining 5 parts of the IKEA value chain. The next area of focus should preferably be the emissions related to the use of material, as this is the biggest single emission area. The management should be aware of that a considerable effort will be needed to develop, provide support, and make sure all tools are relevant when new data becomes available and as the organisation evolves. As far as possible, future versions of the simulation tool(s) should be integrated into other systems for performance follow-up to limit the number of systems end-users need to operate to drive the climate agenda in their respective parts of the organisation.

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APPENDIX A – OCCASIONS AND PARTICIPANTS OF THE STAKEHOLDER INTERVIEWS AND USABILITY TESTING

Table A1 presents the date, emission area, part of IKEA and the participants for each interview occasion. Table A2 shows similar information but for the usability testing.

Table A1. The stakeholder interviews that were carried out during the project.

Occasion	Emission area	Part of IKEA	Interviewee
2021-02-10	Production	Core Business Range, IKEA Communication	Sustainability Specialist
2021-02-12		Core Business Supply, IKEA Industry	Sustainability Manager
			Project Engineer
			Environment Coordinator
			Project Engineer
2021-03-04		Core Business Supply, IKEA Components	Process Developer
			Range and Engineering manager
			Range Navigator
			Project Leader
			Sustainability Developer
2021-02-18		Core Business Supply, IKEA Components	Sustainability Developer
2021-02-09		Core Business Supply, Purchasing Development, CA Wood	Sustainability Project Leader
2021-02-17		Core Business Supply, Purchasing Development, CA Wood	Sustainability Developer
2021-03-03		Core Business Supply, Purchasing Development, CA metal, plastic, float glass	Sustainability Developer
2021-02-23		Core Business Supply, Purchasing & Logistics Areas, Business Information	Business Navigator
			Business Information Purchasing
2021-02-09	Retail & Own operations	Core Business Franchise	Business Performance Leader
2021-02-19		Core Business Franchise	Sustainability Performance Developer
2021-02-19		Core Business Supply, Supply Chain Operations	Sustainability Developer
2021-03-15		IKEA Property	Property Manager
2021-02-18	Food	Core Business Range, Sustainability Development team	Sustainability Development Leader
2021-03-05		Core Business Range, Sustainability Development team	Sustainability Development Leader

Table A2. The occasions for the usability testing.

Occasion	Part of IKEA	Interviewee
2021-04-08	Core Business Supply, IKEA Industry	Project Engineer
2021-04-09	Core Business Supply, Purchasing Development, CA Wood	Sustainability Developer
2021-04-23	Core Business Franchise	Sustainability Performance Developer

APPENDIX B – RELATIONAL DATA MODEL, ENTITY DESCRIPTIONS

The appendix contains tables with explanations to each field of the relevant entities in the relational data model for production and retail & other operations.

VOLUME ENTITY

Table 22. The Volume entity with explanation for each field.

FacilityKey	The key relating to a certain facility. Ex. SUP-1 will relate to a supplier with code 1 as defined in the Facility table.
ReportingPeriod	The reporting period of the of the volume and correlated climate data. E.g., 2020.
ReportingPeriodUnit	If the reporting is per Calendar Year (CY) or Fiscal Year (FY). Different units are used throughout IKEA. The aim is to use financial year.
FY	All reporting should be converted into financial year to allow for a standardised comparison. The original [ReportinPeriod] is kept as a reference for potential recalculations.
ProductionShare	How much of the production and its emissions are allocated to IKEA for a facility/supplier. Represents how big share of a facilities total invoicing in Euro that goes to IKEA. If a supplier does not want do disclose e.g., total energy used, the supplier can set 100% and make sure to only report energy and emissions related to IKEA.
VolumeSoldM3	How much volume of products has been sold by the supplier.
WeightSoldKg	How much in weight has been sold by the supplier.
QuantitySoldPcs	How many quantities has been sold by the supplier.
SalesOrInvoicedEUR	How much has been sold or invoiced in Euro.
FloorAreaM2	How large is the floor area. Mainly relevant for stores and offices.
IsNewFacility	To keep track if the supplier is new or not.
MeasuredEstimated	If a facility does not report their emissions for a certain year it is possible to estimate the emissions based on previous years data. Then it is set to Estimated, otherwise Measured.
IsGeneratedICS	IKEA Purchasing and IKEA Components sometimes has the same suppliers, and it is reported at the same time. The new data format splits

	the reporting based on the SUP (supplier code) or ICS (IKEA Component Supplier code) and the production share set for each part. If it is split, [IsGeneratedICS] is set to TRUE.
Comment	The possibility to add a general comment.

FACILITY ENTITY

Table 23. The Facility entity with explanation for each field.

FacilityKey	The key of the facility. Is created from [Type] + "-" + [Code] + "-"+[CustomKey1] + "-" + [CustomKey2]
Type	The type of the facility, such as SUP for supplier and OFB for Office Building
Code	The code of the specified type.
CustomKey1	Added [CustomKey1] for the possibility to report on a higher granularity, such as Production unit.
CustomKey2	Added [CustomKey2] for the possibility to report on a higher granularity, such as Paper grade.
TypeFullName	The full name of the Type. For SUP the Full name will be "Supplier". For easier visualisation and filtering when using the data.
Name	The name of the facility/supplier.
CountryCode	The 2 letter Country code of where the facility is located, in the iso 3166-1 alpha-2 format.
CountryName	The full name of the country.
City	The city of where the facility is located.
Latitude	The longitude of the facility (optional).
Longitude	The latitude of the facility (optional).
IndustryOrComponents-FactoryCode	IKEA Purchasing do purchase from suppliers owned within the IKEA sphere. If they purchase from IKEA Industry or IKEA Components factory, the factory code of that supplier should be added here. To avoid double counting when summing all emissions as the factories have their own emission reporting.
IsIndustryFactory	If a Factory (Type FCT) reports their emissions, we need to know if the factory belongs to IKEA Industry or IKEA Components. If the factory code belongs to IKEA Industry, the [IsIndustryFactory] is TRUE.
IsComponentsFactory	If a Factory (Type FCT) reports their emissions, we need to know if the factory belongs to IKEA Industry or IKEA Components. If the factory code belongs to IKEA Components, the [IsComponentsFactory] is TRUE.
IsGeneratedICS	IKEA Purchasing and IKEA Components sometimes has the same suppliers, and it is reported at the same time. The new data format splits the reporting based on the SUP (supplier code) or ICS (IKEA Component Supplier code) and the production share set for each part. If it is split, [IsGeneratedICS] is set to TRUE.
BusinessInfo1	To allow for a flexible reporting format, a facility can have up to 10 custom fields. Can contain information about which Category Area or which Purchasing and Logistics Area (PLA) a certain supplier belongs to.
BusinessInfo2	Custom field similar to BusniessInfo1.
BusinessInfo3	Custom field similar to BusniessInfo1.

BusinessInfo4	Custom field similar to BusniessInfo1.
BusinessInfo5	Custom field similar to BusniessInfo1.
BusinessInfo6	Custom field similar to BusniessInfo1.
BusinessInfo7	Custom field similar to BusniessInfo1.
BusinessInfo8	Custom field similar to BusniessInfo1.
BusinessInfo9	Custom field similar to BusniessInfo1.
BusinessInfo10	Custom field similar to BusniessInfo1.

EMISSIONSOURCE ENTITY

Table 24. The EmissionSource entity with explanation for each field.

EmissionSourceId	The IKEA internally defined EmissionSourceId
MainCategory	The main category the emission belongs to, e.g., "Electricity" and "Other Fuels for Production & Building"
SubCategory	The subcategory the emission belongs to, e.g., "Bought electricity" and "Biomass fuels"
Type	The type of the emission, can at the moment be Energy, Refrigerants and Process emissions
EmissionSource	The name of the emission source, such as Crude oil and Generated renewable electricity.
Scope	Which scope do the emission belong to, scope 1, 2 or 3.
FossilBasedFuels	If the fuel is based on fossil fuels TRUE/FALSE
BioBasedFuel	If the fuel is based on biofuels TRUE/FALSE
RenewableShare	The renewable share of the energy source
ReferenceUnit	Reference unit, kWh for energy, kg for refrigerant and process emissions
EmissionFactorCO2eqScope1	The scope 1 emission factor for the emission source. Based on [kgCO2PerKgFuelNet] + [kgCH4PerKgFuel] + [kgN2OPerKgFuel].
EmissionFactorCO2eqScope2	The scope 2 emission factor for the emission source
EmissionFactorCO2eqScope3	The scope 3 emission factor for the emission source
SoldEnergy	Some emissions sources represent sold energy, such as Sold electricity. Set to TRUE if emissions represent sold energy.
LocationSpecificEmission	Is the emission location specific. E.g., Purchased electricity depends on which country or region the electricity was purchased from. If TRUE, the table [EmissionSourceCountrySpecific] will be used to find the emission factor for a certain country.
DensityKgPerLitre	Density of the fuel to allow for conversions.
DensityGasKgPerM3	Density of the gas to allow for conversions.
kWhPerKgFuel	The energy content in kWh of the fuel to allow for conversions.
MJPerKgFuel	The energy content in MJ of the fuel to allow for conversions.
kgCO2PerKgFuelGross	The Gross CO2 emissions for a certain fuel. Relevant for Biogenic fuels.
kgCO2PerKgFuelNet	The Net CO2 emissions for a certain fuel. Relevant for Biogenic fuels. For fossil-based fuels, the net and gross emission factors will be the same.
kgCH4PerKgFuel	The CH4 (methane) emissions for a certain fuel.
kgN2OPerKgFuel	The N2O (nitrous oxide) emission for a certain fuel.

DataSource	The data source of where the data has been found.
DataSourceYear	The year of when the data was acquired.
SSILabel	The label of the emission source as used in the sustainability collection tool.
Comment	The possibility to add a general comment.

EMISSIONSOURCECOUNTRYSPECIFIC ENTITY

Table 25. The EmissionSourceCountrySpecific entity with explanation for each field.

ApplicableCY	What calendar year is the emission source information applicable.
ApplicableFY	What financial year is the emission source information applicable.
RUCountryCode	A special 2 code country code used within IKEA.
CountryCodeISOAlpha2	The 2 letter Country code, in the iso 3166-1 alpha-2 format.
CountryName	The name of the country.
ContinentCodeISOAlpha2	The continent code, in the iso 3166-1 alpha-2 format.
ContinentName	The name of the continent.
RenewableShare	The share of renewable energy in the grid mix for the applicable year and country.
ReferenceUnit	Reference unit, kWh for energy.
EmissionFactorCO2eqScope1	The scope 1 emission factor for the emission source.
EmissionFactorCO2eqScope2	The scope 2 emission factor for the emission source.
EmissionFactorCO2eqScope3	The scope 3 emission factor for the emission source.
Comment	The possibility to add a general comment.

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