Crowdthermal case study Iceland:
Húsavík community greenhouse

Compiled in Spring 2023

by Ottó Elíasson

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857830.

Introduction to the Crowdthermal case study in Húsavík

It is of great importance to reduce climate and evironmental impact to simplify and shorten global food value chains. One way to make food value chains more sustainable, is to increase the share of domestic crops in the local markets. Currently close to 60% of all vegetables consumed in Iceland are imported.[1] By growing more cereal crops, and enhancing greenhouse cultivation the level of sustainability of the icelandic food industry can be elevated.

Eimur participated in the Horizon 2020, EU-funded project Crowdthermal (www.crowdthermalproject.eu).[2] The primary role of Eimur was to shape and design a concept around a community greenhouse in Húsavík, Iceland. The goal of the community greenhouse project is to support innovation in the food industry, enabled by geothermal energy. This was supposed to be a space to foster new ideas, and to ease the creation of new businesses, and introduce the people of Húsavík to the act of cultingvating their own food.

This report is a rough account of the progress of the project, and the community greenhouse concept. It is not a complete account of all activities of Eimur in the project, but the focus is primarily placed on the case study itself. The Húsavík Community greenhouse was a project developed for the Crowdthermal project in the town of Húsavík in NE-Iceland. The aim with the project was to co-develop a concept for a multi-use greenhouse facility in Húsavík. This was carried out through a series of stakeholder interactions, and towards the end of the project a small team of local people joined in pursuing the concept in a very successful open meeting on the project.

Húsavík is a coastal town in the Eastern part of Northern Iceland, with a population of around 2.300 inhabitants. An aerial view of the town is shown in figure 1 (left). The community in Húsavík has a typical age/educational and income profile for a small society. Its main economies have been fishing, fish processing and agriculture, but in the last 20 years or so, it has established itself as a strong hub for tourism. Tourism in Húsavík has mainly been built around fantastic opportunities for whale watching in the bay of Skjálfandi, by which the town stands. The town is well-known in Iceland, and even abroad, as the Icelandic centre of whale watching.[3]

Geothermal energy is abundant in the region, which is located near a volcanically active area. The town is supplied with both hot water and electricity from nearby renewable energy sources. The aim was to use geothermal energy to keep the community greenhouses operational all year round. Alongside geothermal utilisation, the project will benefit the municipality. The gain was however not necessarily financial, but mostly social. The greenhouses could be used for educational purposes, crops for restaurants could be cultivated, and senior citizens could enjoy them. The project could also help raise environmental awareness, and awareness about the importance of local food production.

Geothermal energy is used in the area for bathing, growing vegetables, and for aquaculture. In the high-temperature areas it can be deployed for electricity generation. About 70% of the primary energy that is harnessed in the Northeast part of Iceland goes unused, as is visualised on the Sankey diagram in figure 1. (right). The largest losses occur in geothermal power plants. These valuable resources could without doubt be utilized even better, for the good of the local society. There is especially great potential for food production and processing using the geothermal. The heat could

[1] Erla Sturludóttir og Jóhannes Sveinbjörnsson (2019).
[2] Fernández Fuentes, I et al. (2022).
[3] As a fun fact, Húsavík has become known in pop-culture as the scene of the Hollywood film Eurovision, released in 2020, starring Rachel McAdams and Will Ferrel. The movie featured the song Húsavík, which was nominated for an Oscar award for the best original song.

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Figure 1. Two snapshots of Húsavík. (left) Húsavík is well known for whale watching tourism. (right) An aerial view over the town of Húsavík, a home to about 2300 inhabitants, situated in the North-East of Iceland.

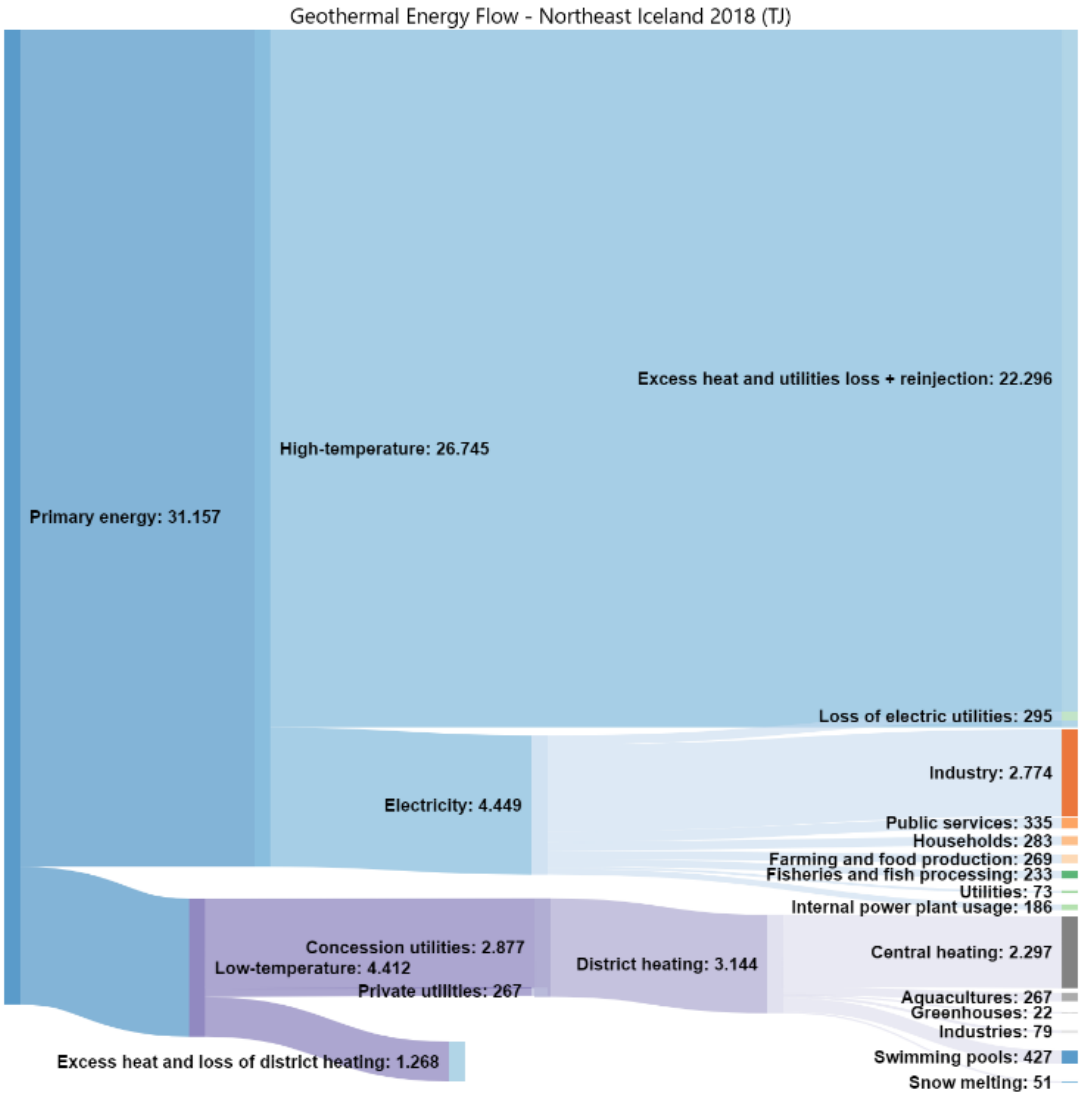

Figure 2. A Sankey diagram, showing the breakdown of the primary energy consumption in the North-East Iceland. Equal portions (about 15%) of the primary energy are transformed to electricity or utilized in district heating systems. About 70% of the primary energy in the region is not utilized, leaving a lot of potential for better resource use.

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be used for increased production of greenhouse grown vegetables, algae production, and fish farming.[4] In addition, these could be complemented by facilities utilising the heat e.g. for drying of the local produce, either by conventional heat-drying, or even more advanced methods such as freeze drying.[5]

This description gives the context for the project. In the Crowdthermal project three different case studies were operated, this one in Húsavík, the second in Szeged, Hungary, and the third in Madrid, Spain. The Húsavík case study is different from the other case studies in the Crowdthermal project in the aspect that the project as such is not perceived as an energy project in the local community, although the project is enabled by geothermal energy. The Case study is centred around the topic of *sustainable innovation* with a special emphasis on food production and processing, motivated by great unused geothermal resources. Ample freshwater reserves in the area make even more appealing for those purposes.

Acceptance of geothermal and renewable energy projects in Iceland

For the context of the discussion of acceptance of renewable energy and geothermal projects, one must consider Iceland's vast renewable energy resources, and how common their utilization is. Iceland is situated on the tectonic plate boundary between the North American plate and the Eurasian plate, which in itself is a source of geological activity. In addition, there is an excessive upstream of thermal energy due to a mantle plume, localised under Iceland. This leads to heavy volcanic activity which heats up ground water that is present in vast quantities.

Along the tectonic boundaries, which roughly traverse the island from North-East to South-West, there are regions of high-temperature geothermal activity where electricity production is economical. Low temperature geothermal is also utilised directly for house heating across the entire country. Such direct heating has been practiced in Iceland for more than a century, rendering fossil fuels obsolete for that purpose. As Iceland is a geologically active area, earthquakes are common and volcanic eruptions occur multiple times during the course of the lifespan of an Icelandic inhabitant.

The ubiquity of geothermal

As a result of the developments in the past 70 years by and large driven by the Icelandic Energy Fund,[6] a risk mitigation fund for geothermal drilling, currently about 90% of all space in Iceland is heated by geothermal. In 2018 geothermal power accounted for about 64% of Iceland's primary energy usage, with hydropower being the second largest contributor at 18%. Together, these renewable energy sources account for roughly 82% of Iceland's primary energy usage, where the remaining 18% can be attributed to fossil fuels used in the transport sector and industry. A portion of the renewable energy sources are applied for electricity production, which amounted to about 20 TWh in 2019. Thereof hydropower provided 70% of the electricity, and the remaining 30% originated from geothermal sources.[7] Per capita, Iceland is the world's largest electricity producer.[8]

Due to all this, the technical infrastructure and distributions systems for geothermally provided heat and electricity from renewable sources, are readily available. As a result, utilization projects, such as the Community Greenhouse in Húsavík, are not perceived as energy projects. In this case the drilling has already taken place, and the resources required are available through the towns district heating

[4] Dillman (2018).
[5] Fellows, P. J. (2016), kafli 23 og Hrafnhildur Árnadóttir et al. (2022).
[6] Orkustofnun (2023).
[7] Orkustofnun (2021).
[8] Our World in Data (2023).

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system. In general, the population of Iceland is also very accustomed to the utilization of geothermal power, which makes Iceland a perfect location for a project engaging the public and small societies for part-taking in geothermal projects. Here the focus is to a lesser extent on the geothermal, and more on the social engagement and financial tools developed within the Crowdthermal project.

Debates on exploitation of renewable energy in the past and present

In general terms the acceptance of renewable energy projects can be considered high. The energy resources are by and large the key to Iceland's economic prosperity. About 80% of the produced electricity is used for heavy industry, mainly aluminium smelters and silicon metal factories. Naturally debates arise when large projects are initiated, and in the past decades these debates have typically evolved around energy production for heavy industry. The most notable example was that of the Kárahnjúkar hydro-dam project, which came to be Iceland's largest electricity plant, with an installed capacity of about 700 MW. It was constructed for an aluminium smelter in Reyðarfjörður in East-Iceland. The project was highly controversial where its proponents emphasised out the importance of local business development in rural areas and its positive effect on the Icelandic economy, and those against highlighted great ecological loss in relation to the damming and the 57 km reservoir that was created in the process. The impact of the debate was lasting, and the current political consensus is that there is not support for such energy-megaprojects with such vast environmental and societal influence.

Presently there are ongoing discussions on the utilisation of wind energy, which is and unharnessed resource in Iceland. The regulatory framework around wind is not as clear as that for geothermal or hydropower, and no Energy Master Plan is available, as there is hydro and geothermal. Currently advocators of wind energy utilisation face strong local opposition in many places around Iceland, highlighting the importance of stakeholder involvement and community acceptance early on in the planning process.[9] It will be interesting to follow those developments in Iceland, but harnessing wind power for electricity generation is considered one of the key elements for the clean energy transition in Iceland, which will, because of Iceland's unique situation in terms of energy revolve around fossil fuel consumption in the transportation sector.

Acceptance of the Community greenhouse in Húsavík

In light of all this, small projects like the Community greenhouse project in Húsavík, do not face any serious acceptance issues. First of all, it is not perceived as an energy project, but more as a project with a strong social dimension and the potential for enabling new businesses to arise that build on resources readily available. To access the acceptance level of the project, the Case Study Assessment Protocol was shared to the targeted audience of Húsavík. This was mainly done through social media, and local media channels[10], and in that process we received 24 replies to the survey in fall 2020. At that point several stakeholder meetings had been held.

The results of the survey were detailed in deliverables for the Crowthermal project[11], but to the extent that one can trust the results of this survey, the level of knowledge of geothermal and acceptance of the case study remained high in Iceland. However, the survey had its limitations that strongly delimited to which extent the results could be generalised. Because of this shortcoming, ÍZES, a consortium partner, improved the protocol, and this was the topic of discussion in a workshop that was held in

[9] Sunna Ósk Logadóttir (2022).
[10] 640.is (2021).
[11] A list of openly available deliverables can be accessed at the Crowdthermal webpage: https://www.crowdthermalproject.eu/deliverables/.

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Figure 3. Snapshots from an open public meeting in Húsavík, held at Fosshótel in September 2022.

Húsavík fall 2022, with some local stakeholders. An evaluation of the all Crowdthermal case studies is available in deliverable D5.3.[12]

A couple of weeks before the workshop, Eimur along with the local association of municipalities, and Hraðið a local innovation centre, held a public meeting on the greenhouse project. The meeting was generally well received, and in total about 40 inhabitants showed up at the meeting, exceeding the expectations of the planners. With such a crowd present we used the opportunity to survey the perception and acceptance level of the public towards the project, and the potential for the application of crowdfunding in the process of its financiation.

The survey was structured into six questions/themes. An interactive presentation tool Mentimeter[13] was used. A question appears on the slide, and people can through a web browser on their smartphones, enter their answers anonymously. Below the questions are written in italics and comments on the results are written below. A visual snapshot of the results is displayed in Annex 1.

1. ***What type of values/benefits can this project bring to your society?***
   This question was put up in the frame of a Word cloud. Here 36 participants submitted up to 3 words describing the concept. The themes most highly ranked were “sustainability”, “being together” (e.g. with family/Friends), and “knowledge”.

[12] Margarita de Gregorio et al. (2022).
[13] Mentimeter, an interactive presentation software, https://www.mentimeter.com/ (accessed October 2022).

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2. ***How do you want to be involved in the project? I want to ...***
    a. ***co-manage the project***
    b. ***contribute with expertise***
    c. ***contribute financially***
    d. ***be a part of the greenhouse community***
    e. ***grow in my own greenhouse in the community greenhouse***
    f. ***I do not want to be involved***

    Here 34 people replied, and people could choose up to 3 answers. The results were as follows: a. 13, b. 10, c. 12, d. 25, e. 17, f. 0.

    The largest part of the participants want to "be a part of the community". This was also the general feeling from us that held the meeting. Naturally, the group that comes to an open meeting is most probably positive toward the concept, so this does not come as a surprise. This is also reflected in the final question, but no one expressed that they would not like to participate. However, we were positive to see that about 1/3rd of the participants answered positively to the first 3 questions, concerning management, expertise contribution and financial contribution. This shows a promising base for a community around the greenhouse.

3. ***In the case of a crowdfunding campaign, I would contribute… [participants were given a range of choices for financial contribution]***
    Here 35 people replied, and most notably, 16 persons said they wanted to contribute between 70 and 140 EUR, 10 between 140 and 360 EUR, and 4 between 360 and 700 EUR. In total, the group contributions would amount to somewhere between 4000 and 8000 EUR. This shows in our opinion a strong will to commit financially and gives a good promise for a successful crowdfunding campaign.

4. ***Would you want to get something instead for financial participation?***
    Here the reply was in the form of a word cloud. Here most people wanted to get access to the greenhouse facilities for their financial contribution, but the second most common reply was that people didn't want anything instead. Here 25 people replied.

5. ***Prioritise the following concepts according to how descriptive you consider them for the project.***
    a. ***Innovation,***
    b. ***Cultivation,***
    c. ***Community,***
    d. ***Geothermal,***
    e. ***Public health***

    Here 35 people replied, and the results are shown in fig. 1 (bottom right). The concepts were ranked in the following manner from top-to-bottom: Community, Cultivation, Innovation, Public Health, and Geothermal. Here it is clear that the sense of "Community" ranks highest, and interestingly "Geothermal" is at the bottom. The project is as such more received as a social and community project, rather than an energy project.

6. ***To which extent do you agree/disagree with the following propositions. Participants were presented with a slider, between "Totally disagree" and "Totally agree" The project...***
    a. ***supports the energy transition***
    b. ***strengthens connections within society***
    c. ***makes society more sustainable***

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d. enhances public health
e. enables new opportunities
f. renders society a more attractive place to live in.

Here 37 participants responded, and towards questions b-f, all were very positive, as shown in fig. 1 (top-right), but the reply to question a, was more mixed.

In the discussion that was spawned among the public following the survey, many useful discussion points came up, concerning light pollution, the possibility of applying for grants to build the facility, and more detailed implementation strategies. There were also discussions on the participation of people from other municipalities.

In summary there is clear support, and the perception of the Community greenhouse concept is very positive as a result of the social engagement work conducted during the Crowdthermal project time. In addition, the project also had the support of the local municipal authorities which agreed that in the case of a successful financiation and construction of the greenhouse they would receive and operate the greenhouse facilities.

Pros and cons of the projects case study

Project development is rarely a lean process. During the process of the development of the case study in Húsavík we encountered several hiccups, even though wind often blew in our sails. Here we discuss what worked well and which aspects were more difficult to handle.

Let us start by listing several challenging aspects.

1. The primary difficulty was that the project lacked a local entrepreneur/project manager, to securely take it over after the development phase. Even though the idea originated within the community, and local people and stakeholders strongly supported it, the actual local drive was missing. We came closer by acquiring a group local “advocators” that participated in the open meeting, but the step towards financiation is a hurdle and requires dedication.
2. The town of Húsavík offers challenges simply due to its size, with only 2.300 inhabitants. Due to its size, the participation of the municipal authorities was deemed to be essential for such a community-oriented project. This was something we partially achieved during the project time, but further steps would be needed to strengthen that participation.
3. The size impacts the conditions of the business model for the concept, which would be easier to work out in a larger society. In a town of 2.300 inhabitants, infrastructure becomes proportionally speaking more costly, and it is more difficult to achieve the financial support needed for such a project to succeed than it comparably would be in a larger society. This will be an obstacle for the crowdfunding process, as we would only be able to collect a portion (estimate 10-20% of the CAPEX). We would need a good sum from the local companies as well to cover the remaining capital costs (see section “Cost estimation for the community greenhouse”).

For the positive aspects of the project. Here the common denominator is social acceptance, and in the context of the “Social licence to operate” framework developed within the Crowdthermal project, we would deem to have acquired an SLO in these first stages.[14]

1. From a geothermal standpoint the project would not require much cost. There is already a geothermal district heating system in place in the town, so no drilling would be required.

[14] A. Barich et al. (2022).

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Geothermal acceptance is also prevalent in Iceland. The project does not require any drilling for geothermal resources. The only aspect that requires some technical work is the connection to the district heating system and the electricity distribution system. As all energy streams are already in place for the project the environmental and technical risks are as good as none.

2. The project has a very strong social angle and has been received very well all along. The cultivation of vegetables has a very positive image in itself, and the emphasis on innovation and the support to local entrepreneurs is also well received.
3. We managed to gather a group of local advocates for the project, which helped to strengthen its image in the community.

One could mention light pollution from the lighting of the greenhouses, but the impact will be minuscule compared to other structures and streetlights. In the case where funding will be secured, Eimur would need to acquire permits from local planning authorities and the local health inspectorate. The boreholes that supply geothermal for the local district heating system are situated around 20 km south of Húsavík.

Eimur has some concerns regarding the funding of the project. The investment capabilities of Húsavík are relatively small, both within the municipality itself as well as and with the public. The financing model will most likely demand the participation of multiple partners. As a result, our primary goal is to find a strategy to get people and businesses to care about the project and get them involved in it for the long term.

The process of conceptualisation of the community greenhouse

The developments for the Icelandic case study started in the fall 2019, simultaneously with the Crowdthermal project. The idea originated within Eimur summer school in 2019, an event where students from Hochschule der Medien in Stuttgart, Germany met up with students from the Icelandic Academy of Arts in a one week idea boot camp, working on improving the utilisation of geothermal in the area.[15] One of the concepts that came out was to transform a warehouse located in the town to a community greenhouse facility accessible for the community.

First concept: The warehouse

The Icelandic case study in the Crowdthermal project is meant to highlight innovative direct use of geothermal energy and the various possibilities its utilization. One objective is to create a platform where good ideas can become a reality with the support of specialists and the community. The focus will be put on how food production and processing can increase the regions level of sustainability and local creation of value. On the basis of this concept the first version/realisation of the community

greenhouse came to be. This was visualised by an architect, Arnhildur Pálmadóttir, and the visualisation is shown in fig. 3 below. The concept was to make a facility consist of three parts:

- *A communal gardening area* to be used by people from the society. Here we would like to encourage experimentation and innovation in the cultivation of fruits and vegetables, to pave the way for an increased variety in geothermally grown vegetation in Icelandic markets.
- *A local brewery*, Húsavík öl run by brewmaster Þorsteinn Snævar Benediktson, aims to cultivate hops to use in their beer brewing in a closed off section of the green house, visible to guests
- through glass walls. There is a strong brewery related innovation scene in Iceland, but hops have never been cultivated in the area. Fresh hops grown indoor in controlled environment and in Icelandic volcanic soil would provide uniqueness to the aroma and flavour of the beer

[15] Eimur (2019).

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brewed from it. Every part of the plant could be fully utilized, oils can be extracted from the leaves and stems of the plants and used as ingredients for various cosmetics or for herbal tea. All leftovers will be composted and used again as a fertilizer.

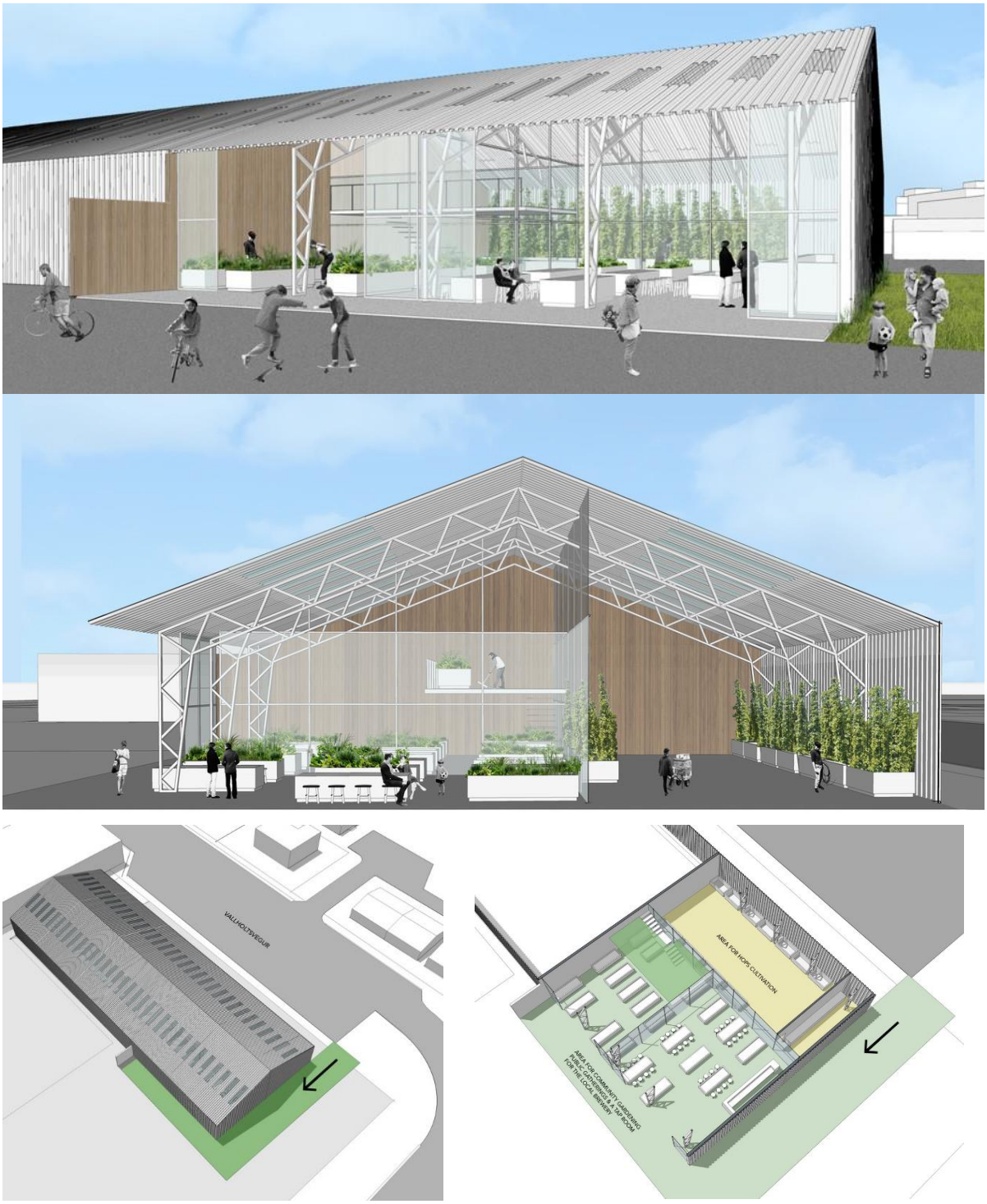

Figure 4. (top and middle). Front and side views of the Community greenhouse in the warehouse on Vallholtsvegur 10, Húsavík. (bottom left) The entrance to the community greenhouse. (bottom right) The facilities are divided into three parts, an innovation facility (area for hops cultivation), area for community gardening, tap room for the local brewery. The drawings were made by architect Arnhildur Pálmadóttir.

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- *A public space* that will be open to all visitors. From here guests may experience the greenhouses and learn about geothermal energy and food production. There will be opportunities for catering, pop-up events, and beer sale with the beer from Húsavík öl.

This triple-use-concept was the theme throughout the entire project but was to be subject to considerable change. This was based on stakeholder meetings held in Húsavík late 2019 and early 2020 with people from the local society.

The interaction between Eimur and the people of Húsavík came however to change drastically due to the COVID-19 pandemic which stormed the planet early year 2020. In Iceland, the first restrictions were introduced on the 16th of March 2020 and were only fully relieved almost 2 years later, on the 25th of February 2022. This imposed great challenges, so for the majority of the project time we had to reside to virtual interaction with the stakeholders in Húsavík.

In the fall 2020 we held an online stakeholder brainstorm meeting where the community greenhouse concept was introduced to selected members of society, and collected feedback from people, working in groups elaborating the concept. As a result of this meeting, we especially worked on the community gardening concept and tried to understand how that could work out.

The first option would be simply to give inhabitants in Húsavík (or the neighbouring area) an option to rent out a crate/booth for cultivating their own crops. In this case many people would need to have access to the area, and a common pool of available tools for cultivation would be preferrable. This concept is in some sense similar to school gardening (ísl. skólagarðar) run by many municipalities, especially in Reykjavík and the surrounding towns. These are, however, only operated during the summertime due to the cold climate in Iceland. For this solution to work out, a person would need to be hired to be around and to maintain the place, at least on fixed hours throughout the working week, and perhaps also on occasions where there would be happenings in the public space.

A second option would be to involve the local schools, either the local primary school or Húsavík High School. This is an appealing option for a few reasons. In the case of the high school, it could be linked to education in botany and other natural sciences, business and innovation. Furthermore, there is an obvious link to a grander theme of sustainability in the 21st century and how well-developed societies like the Icelandic society can tackle the imminent problems faced by mankind. It is slightly unclear how funding would come about, if it would simply need to be added to the operating plan of the educational institution, or if another funding body would need to come to play. That would most certainly be the case for the initial capital investment. If the communal gardening area would rather be linked to the primary school, the education would doubtless be more playful, and perhaps to be linked to the school canteen.

A third option would be that the municipality utilises the area to cultivate flowers, to be used during the summertime around Húsavík. We understood from private communication with Smári J. Lúðvíksson Environmental Manager of Norðurþing that the town spends a considerable amount of money annually for buying flowers, which could be used for growing them instead.

A fourth option would be to give the retired and elderly citizens of Húsavík exclusively an opportunity to grow vegetation, either floral or for consumption. In some municipalities there has been great success in connecting the younger populations and the elderly through activities.

A fifth option would be to couple the local health care services and rehabilitation therapies with the greenhouse environment and the act of cultivation. This is an option that would definitely require some research and innovation, and close cooperation with health care authorities.

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Even though this gives a fine idea about many aspects of the project for the community, some parts are tricky to put together. We followed up on this meeting with several other specific meetings, e.g. with representatives of the schools (both elementary and high schools), where some scepticism was raised concerning the co-existence of a brewing-related facilities and a potential tap-room in the pop-up space, with the presence of educational activities. This is certainly a point that must be taken into account.

After we started looking into the cost of transforming the warehouse, we quickly abandoned that as a viable location for the community greenhouse. We crudely estimated the expenses required for the realisation of the idea > 500 kEUR which is excessive for a small community like Húsavík, even though we would manage to include support e.g. from local businesses. Therefore, we decided to reshape the concept, scale it down, make it more modular and cheaper.

Second concept: The modular greenhouse grove

As an alternative to house the community greenhouse under one large (glass) roof, we could house it under many smaller glass roofs. Such an implementation is modular, and easier when it comes to installation. The number of units will depend on the success of the fundraiser. The total cost is also considerably lower as compared to the previous idea. This type of a community greenhouse area is also flexible in terms of location, which is not definitive, but will be in Húsavík. The Greenhouse grove can be located near schools, retirement homes, restaurants etc. After talking with local stakeholders,

This could also solve a few issues related to the community gardening part, we had encountered talking to our stakeholder groups.

- The issue of overhead is greatly reduced. Transforming a warehouse is a great commitment to the community of Húsavík. The requirement for service is enhanced and thus the need to hire a person (even though it is a partial job) to oversee the premises.
- The issue of space to allocate for the community gardening part. It is somewhat an uncertainty how much great a demand there would be for indoor growing spaces. If we allow for simply adding (and removing) houses according to need, this becomes much easier to deal with.
- Different plants require different growing conditions, and in a single open space it is difficult to create varying climate conditions.
- The potential issue of pest is at least partially resolved. If pest arises in one community garden, it will hopefully be detained and dealt with within the garden.
- Potential risks of conflict due to people's varying notions of cleanliness are also reduced as individual community gardens are sealed off, so to speak.

If there is to be a joint community space, one could of course realise one larger greenhouse. As we find the idea very appealing, we also visualise how such a space could look like and understand its functionality.

Around the time we started thinking about rescaling the concept of the community greenhouse, a new innovation facility, Hraðið innovation centre[16], and a FabLab[17], was being started up in Húsavík. The Húsavík Academic Centre (HAC) that spearheaded that project, was on the lookout for space to host the centre and they among other options also considered the warehouse. Building inspectors however deemed the warehouse unfit for rebuilding for these purposes. Jointly with people from the HAC, we

[16] Cite the webpage.
[17] Write what is a FabLab.

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inspected the option to incorporate/merge the community greenhouse concept into Hraðið, but for the time being that seemed to complicate things quite a lot.

At the time there were two projects in Iceland making small greenhouses for people to put up in their gardens, one called Samfélagsgróðurhús[18] (e. Community greenhouse), and the other Bambahús[19]. We contacted both teams. The former team was making a prototype of a fully equipped, high-tech greenhouse with a climate system and LED-grow lights. This was a very ambitious project that had a start-up grant from the Icelandic technology development fund. During spring 2021, we tried to deploy a demonstration project in cooperation with Samfélagsgróðurhús and Mývatn Geothermal Baths. We intended to put up their greenhouse next to the baths, highlighting the contrast of the barren landscape and the plants growing inside the greenhouse enabled by the natural resources of the region. Unfortunately, we failed to bridge the necessary costs to realise the demonstration.

The other team, Bambahús, makes greenhouses out of used IBC-tanks that are often considered garbage and used in landfills. In this concept the philosophy of a circular economy is prevalent here which had a particular relevance for the theme of sustainability. These houses are very rugged, and cheaper than the other option, which was natural as they did not come with a lighting or a climate system. As a result, we thought they would probably be a more suitable option for the average hobby grower and so they are used in the cost estimations below.

The director of Hraðið, Stefán Pétur, came to like the idea of the community greenhouse very much. As a result of some discussion, we gathered a core group people living in Húsavík to help us at Eimur to co-develop the idea of the modular greenhouse grove further. These were, apart from us at Eimur, Stefán Pétur Sólveigarson at Hraðið, Hildur Halldórsdóttir at the association of municipalities in the North-east of Iceland, Þorsteinn Snævar, the brewer of Húsavík öl and Börkur a restaurant owner. We also came to learn about an ideal location for the project, just east of Húsavík by the road Ásgarðsvegur. There is in fact an old greenhouse. Its shape is however very bad, as it has not been used nor maintained for a long time, see. Fig. 5. The municipality once used the space to grow summer flowers that are planted around Húsavík during the summertime for decoration. Jointly the group presented the idea to representatives of the municipality of Norðurþing (Húsavík is the largest town) and asked for permission to design the idea into the location at Ásgarðsvegur.

We also discussed the option of the municipality receiving a large greenhouse as a gift, in case of a successful fundraising campaign, and employees of the municipality could then participate in its operation, see. Fig. 6. The keys to the premises could e.g. be kept by municipality workers and some basic maintenance could also be carried out by them. The municipality was very positive about that, and agreed to that under the condition that responsibilities would be very clear, and it would not cause a great deal of workload.

In relation to the meeting Stefán Pétur, who is also a graphic designer made a visualisation of the modular greenhouse grove and fitted it into the area at Ásgarðsvegur, as seen in Fig. 7. This visualisation even made it to the news on the web-edition of the national broadcasting service in Iceland, RÚV.[20] Figure 8 depicts three sizes of greenhouses. A group of small houses are on the left in the figure. They could serve as the communal garden. To the right in the figure there are larger individual greenhouses, which could be a suitable option, e.g. for larger groups of people, the local schools, or even for restaurants or small catering services that want to grow their own produce.

[18] Samfélagsgróðurhús vefsíða: https://www.samfelagsgrodurhus.com/
[19] Bambahús vefsíða: https://www.bambahus.is/
[20] RÚV (2022).

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Figure 5. Members of the Crowdthermal consortium and a guest from the East of Moon, inspect the potential location of the greenhouse in September 2022.

Figure 6. The greenhouse team with political representatives and employees of the municipality of Norðurþing.

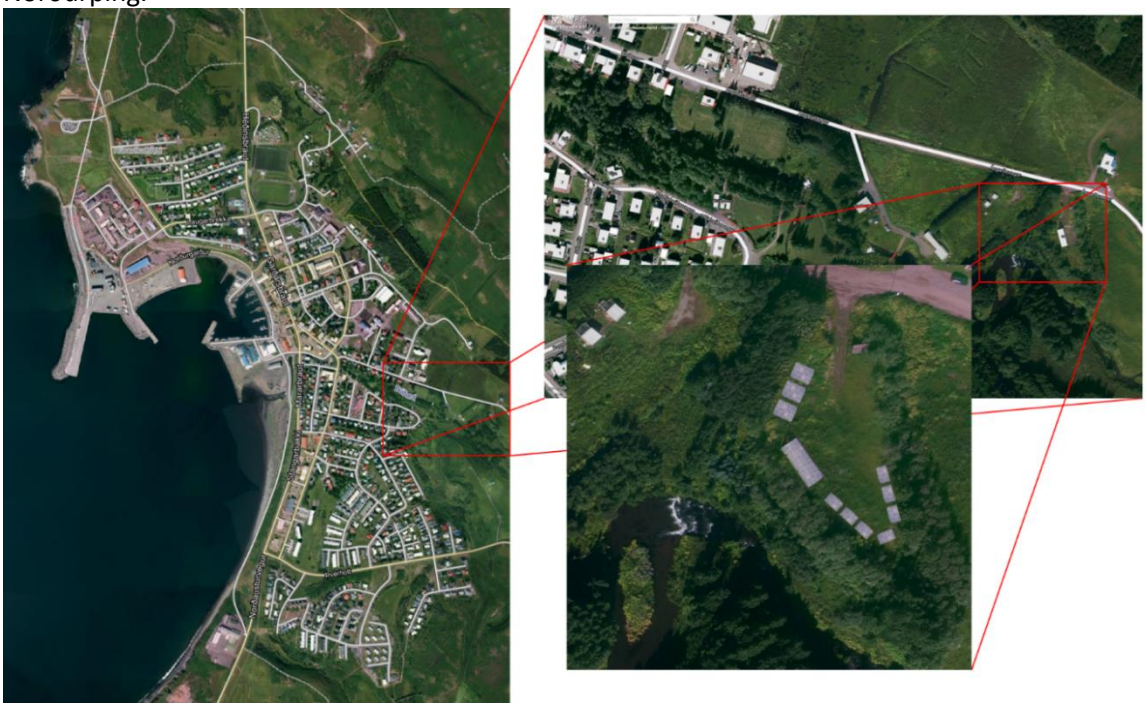

Figure 7. An aerial view of the town of Húsavík. Enlarged is the area into where Eimur and associates designed the concept of the Community greenhouse. The greenhouses are fitted into the tree-enclosed grove in the figure above.

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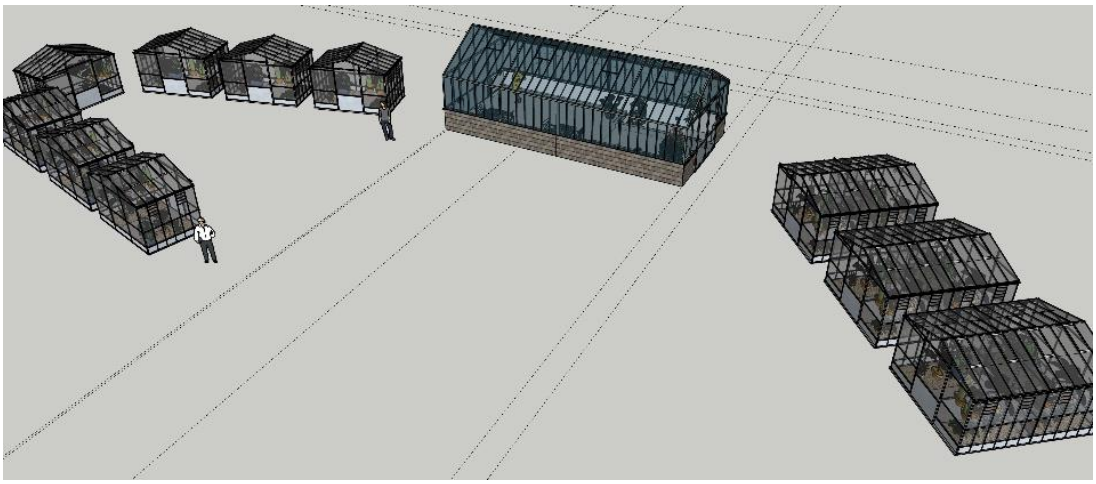

Figure 8. A detailed visualization of the greenhouse grove. Depicted are a few smaller houses to the left, and slightly larger versions to the right, and in the center a large community greenhouse is depicted.

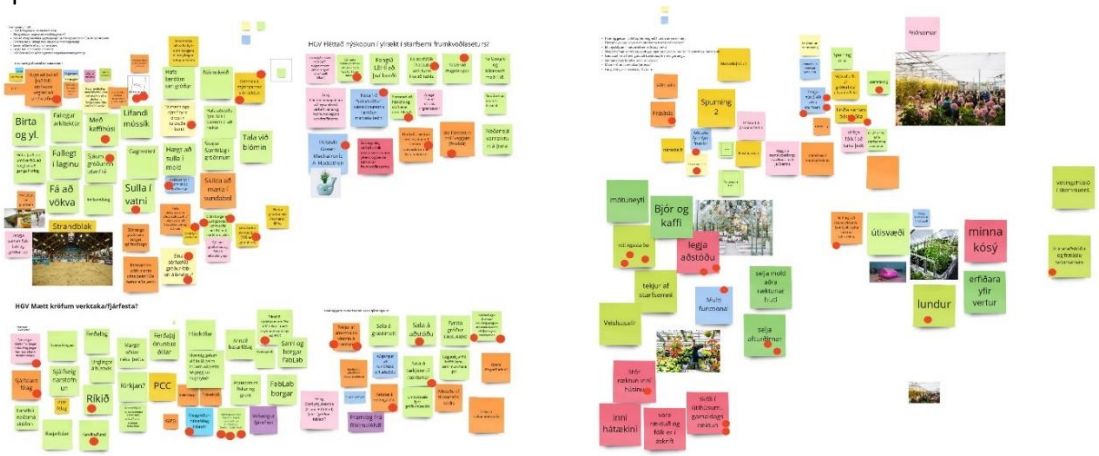

Figure 9. Snapshots from digital brainstorm activities. Multiple stakeholder meetings were held, but many of them had to be conducted virtually, due to the Covid-19 pandemic. We used the digital platform Miro, to facilitate the co-creation.

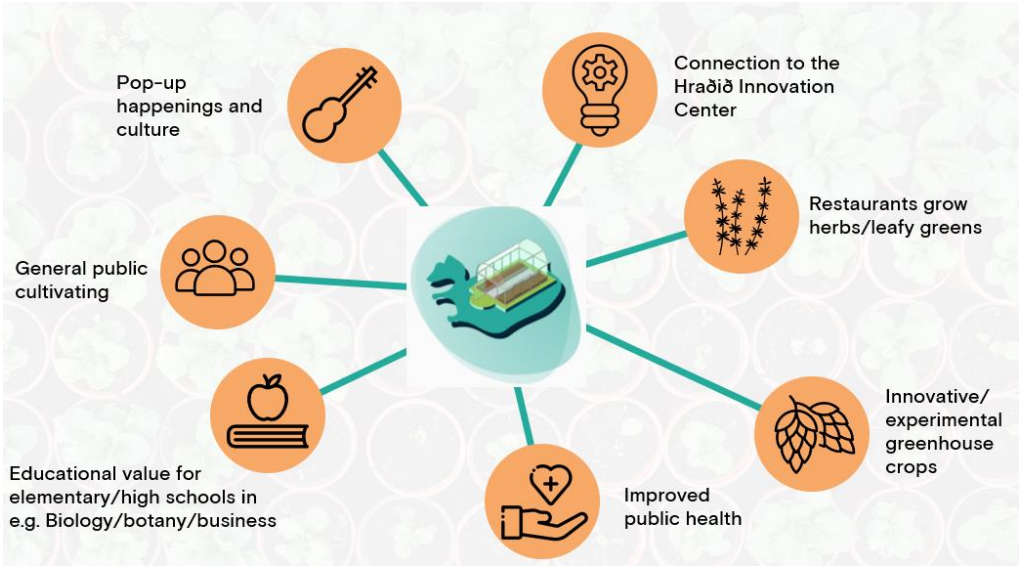

Figure 10. The multidimensionality of the project as identified by local stakeholder groups.

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As described above the concept was co-developed with people in Húsavík through face-to-face meetings and two major virtual brainstorm meetings, and a snapshot of a brainstorm board is displayed in figure 9. There are attempts of the members of the community to bring forth the positive aspects of the project, and also the challenges. As discussed before, the greenhouse concept never faced any opposition.

As one result of this work we tried to identify and highlight the social multi-dimensionality of the project as one of the keys to its success. It is simply an appealing concept to many people, and groups, and could bring many social benefits. We try to represent this multi-dimensionality, or the different interfaces of the project to society, in Figure 10. There are connections to many groups in society; the general public interested in cultivation; schools that could enhance education in biology, botany and even business through such facilities; restaurants growing herbs and greens; or innovators that want to try out new crops for growing, like hops for brewing. There are clear connections to innovation, but cultural event could also take place within the community greenhouse. Perhaps the most important societal benefits that could stem from a community greenhouse facility is improved public health of those who participate in cultivation.

Cost estimation for the community greenhouse

The estimated for the costs around the project have varied greatly throughout the project time. This was mainly because the concept changed a lot throughout the project, and as well because we saw increased prices towards the end of the project due to the value chain and energy crisis following Russia's invasion into Ukraine. Initially when we considered the community greenhouse it to be a part of a warehouse, the cost was in the range of many 10's of millions of ISK (at least > 500 kEUR) for such a refurbishment. Later we learnt that the concept would have been doomed, as the warehouse was deemed unfit for refurbishment.

Introducing the modular concept that consisted of a single larger house and several smaller houses simplified the concept and reduced the prices. Below we consider the larger house and smaller houses separately. This is done because in principle they could be realised independent of one another. The larger house has a more emphasis on the multi-purpose aspect of the space, e.g., also for events, and groups etc. The group of smaller houses brings in a greater emphasis on the social aspect of cultivation and the formation of a community around that concept.

In this section we use the exchange rate 1 EUR = 150 ISK for the currency conversion.

Utilities and resource distribution

Since geothermal is an essential feature of the project, we would need to connect to local utilities, hot and cold water and sewage system (overseen by Húsavík utilities), and secure access to electricity (overseen by RARIK). We contacted both parties and the cost for this term is estimated to be about 1 million ISK for the former term and about 300.000 ISK for the latter. The Húsavík utilities expressed that they would be willing to absorb a portion of the cost for connections to hot and cold water, in support of the project (about 1 million ISK). For the sewage system, they recommended to place a sceptic tank, as the area considered for the project is still outside the land-use plan of Húsavík. The total cost for such a solution is estimated to be about 1.2 million ISK.

To house

- an inlet for the utilities,
- a common storage space for the greenhouse community
- and possibly a toilet,

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a small house/tool shed would be built, a "common utilities house". The house is in principle not visualised in figure 7, but one could foresee replacing one of the smaller greenhouses with such a house. The cost of a 15 m^2 pre-built insulated house is close to 1 million ISK. The necessary groundwork and estimated cost to put up a toilet facility inside the house is in the vicinity of another 1 million ISK. If the larger greenhouse would be built, a part of that could of course house toilet, utility inlets etc. However, as the greenhouse square meter is considerably more expensive than the square meter of a tool shed, it could be preferrable to be able to fully use the greenhouse for events and cultivation activities.

Table 1: Cost estimation for utilities and common utilities house

Cost term	**Cost ISK**	**Cost EUR**
Connections to water utilities (hot and cold)	1.000.000	6.667
Connection to electricity (100 A)	300.000	2.000
A sceptic tank solution for sewage	1.200.000	8.000
A toolshed for utility inlet, toilet and storage	2.000.000	13.333
Total for utilities and common house	**4.500.000**	**30.000**

Larger house

The cost for the larger house depends of course greatly on the way it's built. As we focussed a lot on the multi-use purpose of the house, i.e., it could be used to house events, just as gardening we realised that it would need to be rather larger than smaller and aimed for a 100 m^2 house. We contacted NPK, an Icelandic company importing greenhouses, and they estimated the cost (in august 2022) to be no less than 200.000 ISK/m^2 (3000 EUR/m^2). This was obviously going to be the largest expense-term. The intention is also to split the house in two parts, one larger (85 m^2) for joint events, and a smaller space (15 m^2) for innovators to come in and pursue growing experimental crops. In the first round this part would be suitable for the growing of hops, where Húsavík öl (the local brewery) would experiment with cultivating hops. This part requires extra features, such as lighting and climate control, rendering this portion of the space a bit more expensive. We estimate the cost of that part 50% higher than that of the common facility.

The floor of the house itself could be grass, gravel, wood, concrete, or tiles. As the intention is to pass the house over to the municipality, we aimed for the concrete floor as that would require least maintenance in the long run. If the space is to be able to house events, we would need to install toilet facilities, either in the greenhouse itself, or alternatively to build a second smaller house/shed, that could also serve as a storage space. The secondary toilet house/and storage space is used in the estimates below.

In the table below these different terms for the capital expenses are enlisted, assuming a 100 m^2 multi-purpose greenhouse. In summary the costs for such a house lie in the vicinity of 200.000 EUR, which is after all a considerable amount.

Table 2: Cost estimation for large greenhouse with innovation facility

Cost term	**Cost ISK**	**Cost EUR**
Greenhouse common space (85 m2)	17.000.000	113.333
Greenhouse innovation space (15 m2)	4.500.000	30.000
Cemented floor with heat installed (150 m2)	4.000.000	26.667
Total large greenhouse	**25.500.000**	**170.000**

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Smaller houses

Here we use greenhouses from Bambahús, an Icelandic innovation and a recycling company that makes greenhouses out of used IBC tanks. The houses themselves are modular, with the basic unit being 6.6 m^2. They can then be doubled, tripled or even quadrupled. Here we work with the smallest 6.6 m^2 version. The price of a single house is about 400.000 ISK.

In this case one would also require access to hot and cold water. A part of the concept is to heat up individually each house. We assume to take in the utilities in a common utilities house as described above. From the utilities house, hot water pipes would need to be led to each greenhouse. To secure from issues with freezing, the hot water pipes would need to be dug 70-100 cm into the ground. It would also be preferrable to add a layer of rockwool insulation into the ground below each house, about 10.000 ISK for material cost for each house. We estimate the material costs for plumbing for each house to be about 50.000 ISK, and two days of plumbing work about 200.000 ISK.

Table 3: Cost estimation for five small (6.6 m2) IBC tank greenhouses

Cost term	**Cost ISK**	**Cost EUR**
Five IBC tank greenhouses	2.000.000	13.333
Groundwork for five houses	500.000	3.333
Floor insulation for five houses	50.000	333
Plumbing for five greenhouses (material+work)	450.000	3.000
Total five heated greenhouses	**3.000.000**	**20.000**

Operation of the community greenhouses

The preferred way of operating the community greenhouses would be to forming a cooperative or a non-profit organisation (ísl. félagasamtök), that would oversee operation and expenses. There will always be some expenses, mostly related to (a) energy and utilities, and (b) maintenance cost. With a reasonable monthly fee for membership in the organisation these monthly expenses should be easily taken care of.

If the larger greenhouse would be realised the possibility arises that the community would need to employ a person partially (10-15% occupation) to oversee the premises. This can become a costly term, so the role of the person would need to be clearly defined. The annual pay including all costs of an employer lies between somewhere between 10-12 million ISK. A 10-15% occupation thus yields a cost term between 1-2 million ISK on an annual basis, and a higher level of complexity for the operation.

Summary

In summary we estimate the cost of the total concept to be 33 million ISK or 220.000 EUR. Here the larger greenhouse is the bulk of the cost, as displayed in table 2 above. It would of course be possible to realise only what is listed in table 1 and 3 above, i.e., not to build that larger greenhouse, as its high cost renders it difficult for crowdfunding. That option would amount to a cost of about 50.000 EUR, a much more manageable prize for a community like Húsavík. With support from local companies in addition to a crowdfunding campaign (see Crowdfunding prospects as probed in the open meeting, sec. “Acceptance of the Community greenhouse in Húsavík” above) this should be quite feasible.

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The project has a very strong social angle, but in fact a much lesser business angle. At some point in the development procedure, we attempted to frame it into the Business model canvas[21], and put it into context with the finance schemes for geothermal energy developed within the Crowdthermal project.[22] These attempts always suffered from the limitation that we found it difficult to create the revenue streams needed to run such a project and were afraid that we would not be able to get enough people to participate, such that it would work out. Of course, one could foresee renting out greenhouses to create revenue streams, but we deem the risk of not getting enough costumers, too high in such a small society. This model could probably work better in a larger society, like Akureyri, the largest town in the North-East of Iceland.

Conclusions

In conclusion, we have formed a concept around a community greenhouse in Húsavík and estimated the cost of building such facilities. In addition, we have probed the social perception of the project through interaction with local stakeholders, which also have taken part in realising the community greenhouse. The main effect of the project was to spawn discussion of the concept in the local community. Several local stakeholders in Húsavík saw great benefits in the it, and there was a consensus that it would add a lot to the society if the concept would be realised. However, as it in such an early stage, it is hard to quantify or point to any significant, or permanent effects it has had on the community. As the project has gained local support, Eimur will continue working on its realisation it and aims to pursue a crowdfunding campaign in 2023.

The community greenhouse facilities could greatly benefit society by:

- Enhancing people's connection with the environment and local resources.
- Bringing food production and knowledge thereof closer to people, encouraging a greater level of sustainability in the local community.
- Providing access to local schools, such that the greenhouses could be utilised for educational purposes in multiple STEM related subjects.

The project could form a pillar in the local innovation eco-system, along with Hraðið, the local innovation centre, Fab Lab Húsavík a maker space, and STEM Húsavík, a network for enhancing STEM education on local premises, and Húsavík Academic Centre. These entities could all link their operation to the community greenhouse in one way or another by providing courses botanical and technological aspects of cultivation.

In our opinion, the most viable approach would be to do it entirely on the premises of the society and people's interest in cultivation. The financiation strategy would focus on the common utilities house and e.g., two additional smaller greenhouses that would be given to the local schools, kindergarten and elementary school. The total sum for this project would be somewhere close to 40.000 EUR. In this case we would primarily seek donations from local companies, like PCC the silicon smelter and other larger companies. In addition, we would top it up with a crowdfunding campaign from the local community, if necessary. Simultaneously we would offer local companies, and the people of Húsavík to put up their own geothermally heated greenhouse in the grove at Ásgarðsvegur.

[21] A. Osterwalders Business Model Canvas is available through Strategyzer's webpage: https://www.strategyzer.com/canvas (accessed spring 2023).
[22] Fernández Fuentes, I. et al.(2022).

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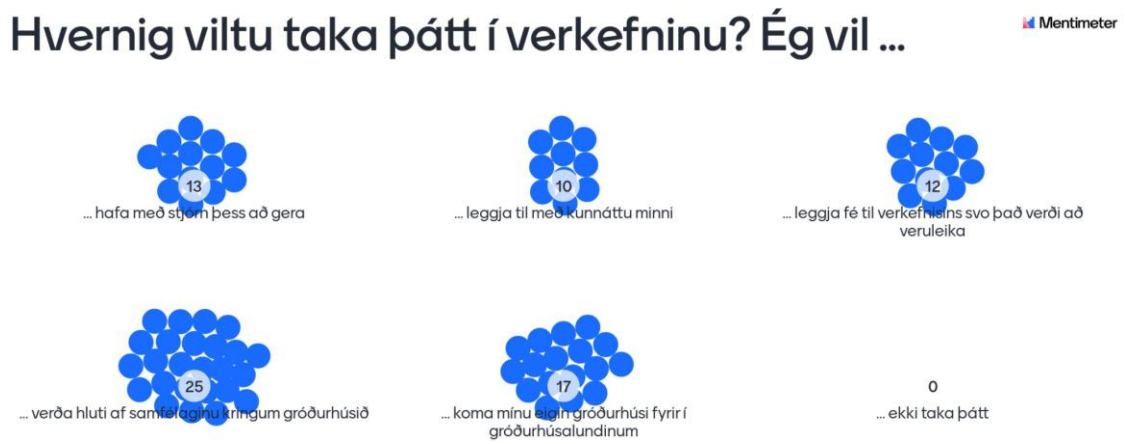
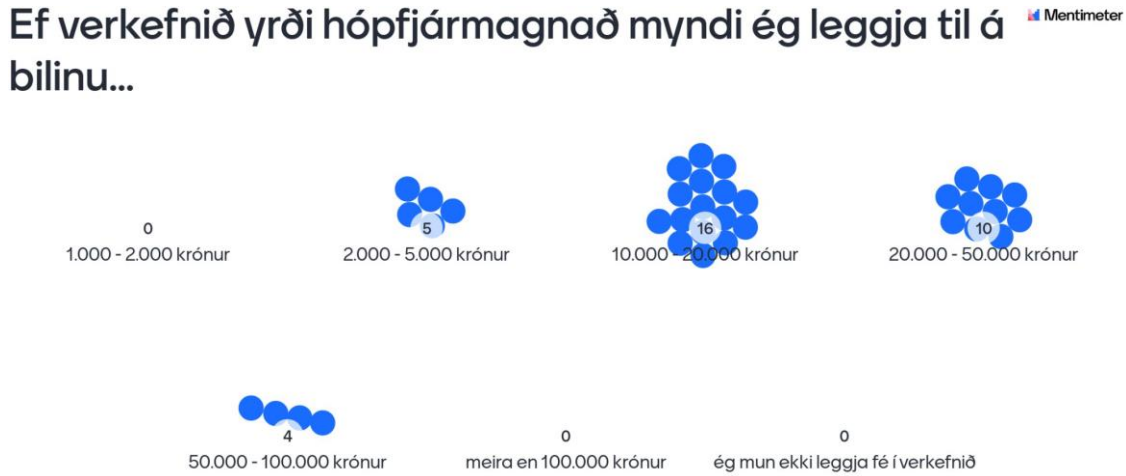
Annex 1 – results from open meeting survey 5. of September 2022

An open meeting was held on the 5th of September to introduce the concept of the Community Greenhouse. About 40 people attended the meeting that was held in Fosshótel in Húsavík. Below are raw results of a survey we conducted live with the crowd, utilising the Mentimeter presentation software, see section "Acceptance of geothermal and renewable energy projects in Iceland" above.

What type of values/benefits can this project bring to your society?



How do you want to be involved in the project? I want to ...



In the case of a crowdfunding campaign, I would contribute…

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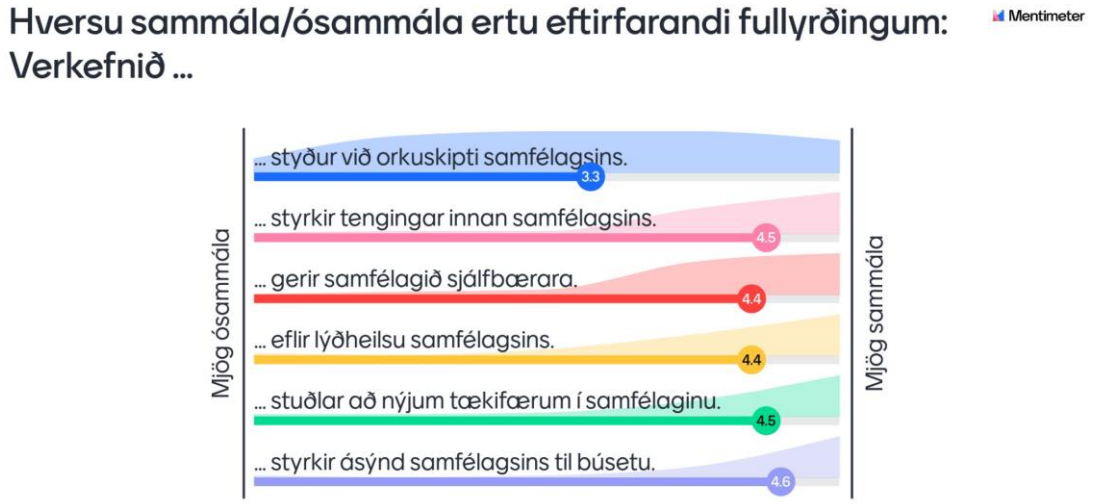
Would you want to get something instead for financial participation?

Prioritise the following concepts according to how descriptive you consider them for the project.



To which extent do you agree/disagree with the following propositions. Participants were presented with a slider, between “Totally disagree” and “Totally agree” The project...

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