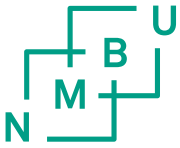
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ABSTRACT

Rapidly growing cities around the world face complex issues in sustainable urban development. In particular, urban ecological systems and food security are important in ensuring healthy, sustainable cities but they are threatened by population growth. Green roofs are a tool that is increasingly used in urban development due to their ability to control stormwater runoff and lessen the likelihood of flooding and combined sewer system overflow. However, this narrow focus on stormwater limits the ability to use diversely and benefit from their multi-perspective values and causes a scaling-up of green roof development rather than out, so that green roofs have less opportunities to contribute to sustainable urban development and ultimately global sustainability. Therefore, the objective of this research is *to explore what is needed for a city to make green roofs more widely and effectively used in sustainable urban development.*

In order to accomplish this objective, a case study was conducted in Oslo, Norway to explore the human and non-human actors, opinions among stakeholders about local green roof development, and the challenges and opportunities present for achieving an ideal future situation. This research was done within the theoretical frameworks of systems thinking and agroecology, which aim to achieve a holistic comprehension of the problem situation by exploring not only the smaller subsystems and processes but also the overall whole system. Qualitative research methods were used to collect data through participant observations, semi-structured interviews, a focus group, a survey, and through primary and secondary documents. Results were analyzed through a stakeholder analysis and a multi-system evaluation. Green roof development requires interdisciplinary cooperation between stakeholders and needs significant advances in research, demonstration, and financial valuation in order to achieve widespread diffusion and optimally realize the values of ecology, economy, and society.

Keywords

Green roofs, sustainable urban development, systems thinking, multi-perspective

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List of Abbreviations & Acronyms

ANT – Actor network theory
DOI – Diffusion of innovation
FLL – Green roof guidelines of Germany
KMD – Ministry of Local Government and Modernization
MAJOBO – 'Food and Soil Where You Live' Norwegian urban agriculture network
NAML – Norske Anleggsgartnere Miljø og Landskapsentreprenører
NFGT – Norsk Forening for Grønne Tak (Norwegian Association for Green Roofs)
NMBU – Norwegian University of Life Sciences
NTNU – Norwegian University of Science and Technology
NVE – Norwegian Water Resources and Energy Directorate
VAV – Oslo Water and Sewage
WGIN – World Green Infrastructure Network

CHAPTER ONE: INTRODUCTION

Sustainability is a vague, yet loaded word that manages to find its way into the jargon of almost any development project. Though it has a plethora of definitions, the Brundtland Report describes it as development that meets the needs of today without compromising the resources of future generations (WCED, 1987). It must consider the ecological, economic, and social multi-perspectives.

Sustainability is challenged by today's urbanization. Urbanization results in local ecological disasters, like flooding and waterway sewage-contamination during heavy rainfall or the interruption of habitat of endangered species (Gomez-Baggethun & Barton, 2013; Oberndorfer et al., 2007). Urbanization challenges will grow as today's world population expands from 54% located in cities to an expected 66% by 2050 (UN, 2014). An anticipated 86% of the world's growth will occur in Asia and Africa during the next forty years, mostly in cities where even basic services like sanitation and water management, transportation, housing, healthcare, education, and food security can be a problem (UN, 2012). Food security, or the adequate access to nutritious food for all people at all times (UNFAO, 2008), is far from a reality since over one billion people go to bed hungry each night (Ingram, Ericksen, & Liverman, 2010). In turn, the growing pressure that cities place on rural areas to supply enough healthy food may not only have urban-felt effects, like higher food prices, but it can cause an increase rural poverty, pollution, and resource degradation and add to the effects of climate change unless significant, systemic changes are made.

Focusing on improving the urban environment through changes in local food systems and ecological management makes a city more resilient. Localizing food production is one option that reduces the amount of imports needed in cities, in turn impacting the agricultural system that generates approximately one-fourth of today's total greenhouse gas emissions (Shore, 2006). Climate change from these emissions has widespread effects on multi-perspective issues threatening the health and security of the world. In a report of 450 urban areas, 60% of the 1.4 billion people in these cities were at risk for natural disaster (UN, 2012), mostly as flooding risks rise (Cicero, 2009; Getter & Rowe, 2006). Floods not only pose ecological and social challenges, but they harm economic systems via crop and infrastructure damage. This flooding can in part be addressed by green infrastructure as a way to improve the urban environment's resilience. In the systemic problems of climate change and global sustainability, urbanization is an important subsystem. Within the systemic problems of urbanization, green infrastructure presents an opportunity to address challenges in urban ecological, economic, and social sustainability.

Green infrastructure uses an array of 'natural' or human-managed natural spaces to address several issues of urbanization (Bugliarello, 2006). Green infrastructure protects, restores, or mimics the multi-perspective natural ecosystem services, though it typically has a focus on water management adaptations

to climate change (Benedict & McMahon, 2002). One type of green infrastructure – green roofs – have large opportunities to contribute to sustainable urban development by placing green spaces on the rooftops of dense cities.

Green roofs are far from new, first being used in ancient Syria and Babylon but not commonly used in modern cities until around the 1970s (Getter & Rowe, 2006). Today, green roofs typically have a system of synthetic layers that protect the roof while storing and draining water; different levels of soil thickness, defining them as extensive, semi-intensive, or intensive; and different kinds of plant communities (Oberndorfer et al., 2007). Extensive roofs are often comprised of sedums, a hardy and low-input succulent, while intensive roofs can be thick enough to even support trees. Examples of green roofs can be seen below in Fig. 1 and 2.

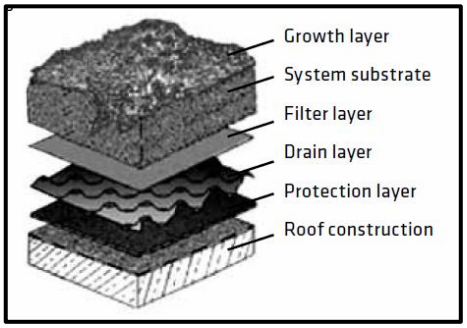

Figure 1 (left) – Layers of a green roof system (Copenhagen, 2012)

Figure 2 (right) – Green roof in Ås, Norway

The multi-perspective values of green roofs are numerous. They control stormwater runoff, sequester carbon dioxide, increase biodiversity, lessen the urban heat island effect, and reduce noise and particulate pollution. Green roofs increase the lifespan of roof membranes, lessen flooding damages, provide employment opportunities, and reduce building energy costs. They also provide educational and therapy opportunities, green spaces for relaxation and urban agriculture, and can strengthen communities (Getter & Rowe, 2006; D. HUI, 2006; Oberndorfer et al., 2007; Stovin, Dunnett, & Hallam, 2007; Susca, Gaffin, & Dell'Osso, 2011; Van der Horst, 2013; L. J. Whittinghill & D. B. Rowe, 2012). These are just a few examples of their ecosystem services, though it is nowhere near a comprehensive list

While it is evident that green roofs can be useful for urban development, but they still have drawbacks. They have high investment costs and insufficient research and experience can cause complications. Some fields are particularly under-researched, like best management practices for diverse kinds of roofs and plant types, material degradation, monoculture impacts, and invasive species (Whittinghill, Rowe, & Cregg, 2013). While sedum-based extensive green roofs and grass roofs are among the most common kinds of green roofs due to their simplicity, this also results in limited multi-perspective opportunities. It is clear that there should be more ways to take advantage of the opportunities of green roofs than what is being realized in practice. An ideal future situation of green roofs in cities allows them to contribute not just to isolated systems in sustainable urban development, but to its entire whole.

Many cities around the world have enacted policies or incentives to encourage green roof construction and narrow this gap (Nagase & Dunnett, 2010; Rømø, 2012). Policymaking requires an understanding of the current situation, technical components, and the identification of a future wanted situation. This necessitates a study grounded in the principles of systems thinking – an approach that explores the roles of, interconnections between, and collective value of parts in a whole (Bland & Bell, 2007). Also,

principles of agroecology – the ecology of food systems – can be realized as a science, practice, or movement through green roofs (Francis et al., 2003; Wezel et al., 2011). Such a holistic approach helps to identify opportunities in scaling-out their quality and subsequent impact on sustainable urban development by encouraging diverse uses and new solutions rather than simply scaling-up the quantity of available knowledge and practices with their related challenges.

The objective of this study is to explore what is needed for a city to make green roofs more widely and effectively used in sustainable urban development. Green roofs can be useful for many challenges present in cities worldwide. Particularly in European and North American cities, flooding is an increasing concern because of waste water contamination when combined sewer systems overflow into local watersheds. Green roofs reintroduce natural features to the largely impervious urban environment, controlling this stormwater runoff. Simultaneously, there is a growing interest and concern about food system sustainability, particularly with organic and local foods. While the integrity of local sustainable food systems is not a trivial matter even in developed cities, green roofs also have the opportunity to address more fundamental problems in food security around the world by introducing agriculture in dense city environments. Oslo, Norway was chosen as a case study due to its flood-prone environment and high reliance on imported goods such as food. An exploration was made to understand the current situation in order to create successful green roof development in the city. To do so, the following research question was asked, specifically exploring three categories:

What is the current situation of green roofs in Oslo?

- *Non-human actors and projects*
- *The network of stakeholders, their roles, and their opinions*
- *Challenges and opportunities*

With an understanding of the current situation, an overview of possible future action was compiled to assist in facilitation of an ideal and feasible future.

Oslo provides an interesting location to conduct this study due to its current lack of green roofs in light of a variety of factors. Oslo has strong environmental goals, affluence, a reputation as a technology hub in the world, and rapid urbanization (Knutsen, 2007; Oslo, 2013b). It is also visibly experiencing the effects of climate change with heavier rainfall and flooding (Cicero, 2009). Whereas green roofs can help address these issues, there is a very weak and fragmented green roof policy in place by the city administration with few resources allocated to change this. International knowledge has laid a good foundation for development, something that many other European cities have taken advantage of (Getter & Rowe, 2006), but Oslo (and Norway as a whole) still has very limited, slow development. Insight into the Oslo situation can counteract this as well as be of benefit to other lagging cities.

CHAPTER TWO: MATERIALS AND METHODS

2.1 Research methodology

This research was conducted through an exploratory qualitative case study, which aims to define the situation and identify questions for subsequent studies (Yin, 1989). The study uses a systems thinking approach that is helpful in understanding complex systems with conflicting goals in order to promote desirable changes (Ison, 2008). In systems thinking, the interconnectedness of smaller systems is important to understand as well as their interactions together impacting the greater whole. Cycles are a fundamental component within these sub and supra-systems. Systems thinking involves stakeholders from across disciplines to deconstruct the complex situation and create ideal and feasible changes (Bland & Bell, 2007). It is in line with an agroecological approach that considers holistic, multi-perspective issues in a problem, notably within the food system (Francis et al., 2003).

Systems thinking can be criticized for its hugeness and the ensuing possibility of being too lost in the smaller systems to forget to consider the whole. The case study of green roofs can easily be engulfed by the focus on local stormwater management, neglecting other important issues. It is hard to create distinct boundaries in dynamic, holistic problems. In part, this can be counteracted with an approach called 'flickering.' Flickering requires movement between the sub-systems and supra-systems in order to maintain a holistic perspective, bringing with it a level of predictability by recognizing the unpredictable nature of systems studies (Bland & Bell, 2007). This method was implemented in the case of Oslo by exploring individual concepts within the multi-perspective and later reflecting on their application on a wider scale. This helped to understand the phenomenon in the context of the greater whole.

2.2 Theoretical framework

Since green roofs in Oslo are a new tool in urban development, particularly in Oslo, the Diffusion of Innovations Theory (DOI) was used in the exploration process. Innovations fundamentally alter the way that we interact with our environment and their theory helps to identify challenges in uptake, barriers in development, and the natural resistance to change (Oldenburg & Glanz, 2008). DOI discusses the processes by which an innovation can be spread both horizontally among peers and vertically between the different hierarchies of stakeholders (Rogers, 2008). In the Oslo case, information about green roofs lay largely in the hands of academic and industrial technocrats.

DOI has many interpretations, and Gladwell's (2000) book '*The tipping point: How little things can make a big difference*' provided the reference for this study. According to Gladwell, there are three factors that will determine if an innovation will become widely adopted:

1) Influential early adopters or champions are necessary,
2) It needs to have a quality that people find compelling,
3) It needs to fit into the broader physical and social environment.

Within these steps, it must be clear how materials and tools will be distributed, how policies and regulations will have an effect, and a long-term plan (Oldenburg & Glanz, 2008). Target audiences, methods of communication, and knowledge diffusion are essential. For such a technical innovation as a green roof, procedural and technical knowledge is important in achieving each DOI step (Rogers, 2008).

There is a variety elements influencing DOI, including both human and non-human actors like consumers, materials, and funding. These same factors are discussed in the actor-network theory (ANT) (Latour, 1996). Whereas DOI discusses how innovations spread, and consequently the pathways for sustainability transitions, ANT discusses the significance of the connections between human and non-human actors and can in part be accomplished with a stakeholder analysis. Patterns in these connections show larger themes like organizations, social institutions, inequality, and power. ANT supports the comprehension of DOI, and both are useful for analyzing the current situation of green roofs in Oslo and uncovering ways to move forward. This forward movement is called translation and it occurs through the steps of problemization, interest, enrollment, and mobilization (Law, 1986), quite similar to Gladwell's three steps of DOI.

2.3 Elements of the study

Like every city, Oslo has large amounts of impervious surfaces that disrupt ecological systems and processes inside its urbanized zone. Also, like many cities in the world, Oslo does not have a self-sustaining food system and relies upon imports to ensure food security. Whereas all urban areas share these problems, different approaches are taken to address them based off of local conditions and goals. Developing an appropriate local strategy requires gathering knowledge about the situation in order to make informed, ideal solutions.

Oslo

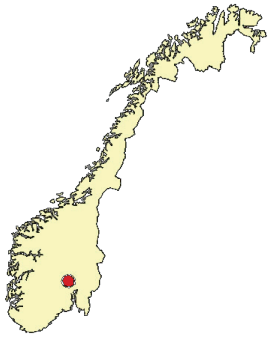

Figure 3 - Location of Oslo, Norway (Oslo, 2013a)

The city of Oslo is located in the eastern portion of Norway at the inlet of the Oslo fjord (Fig. 3). It is Scandinavia's oldest capital city, dating back 1000 years. Oslo has around 600,000 inhabitants and is characterized by its mixture of old and new architecture as well as extensive composition of forests and lakes, as seen in Fig. 4. Only about one-third of the city is developed, the remaining portion surrounded by forests, as will be discussed in Section 3.1. Average mean temperatures range from -3 C in the winter to 16 C in the short summer months. The longest day has 19 hours of sunshine. Oslo's main businesses and industry include shipping; information technology, telecommunications, and multi-media; offshore and engineering activities; and biotechnology and pharmaceuticals (Oslo, 2013a).

Figure 4 - Picture of Oslo (Oslo, 2013a)

A systems approach requires exploring and defining certain criteria: the system of interest, boundaries, connectivity, environment, and networks (Bland & Bell, 2007). The *system of interest* in the Oslo case study focused on the *connectivity* between the *network* of stakeholders and non-human actors related to green roof development. The stakeholders comprised four categories: public authority, private market, independent organizations, and research and academia. The *boundary* for this study was within Oslo, but since this community is so small in Oslo and all of Norway, there was periodic overlap between the city and the country boundaries. Another overlap in the situation was in the distinction between turf roofs, green roofs, and green infrastructure. For this study, turf roofs were considered as separate from green roofs due to their traditional style and social acceptance. Both turf roofs and green roofs represent a type of green infrastructure. Though turf roofs, green roofs, and green infrastructure represent different concepts, they are *connected* to one another. This reinforces the idea that systems thinking *boundaries* can be hard to delineate. There was a much clearer distinction between the overall Norwegian system and the outside *environment*, representing external factors such as imports and research, though it was evident that *networks* within Norway and Oslo *connect* to the green roof systems present in the rest of the world. For the sake of clarity, this study focuses on primarily on green roof development in Oslo, but considers information from the wider systems, as shown in Fig. 3.

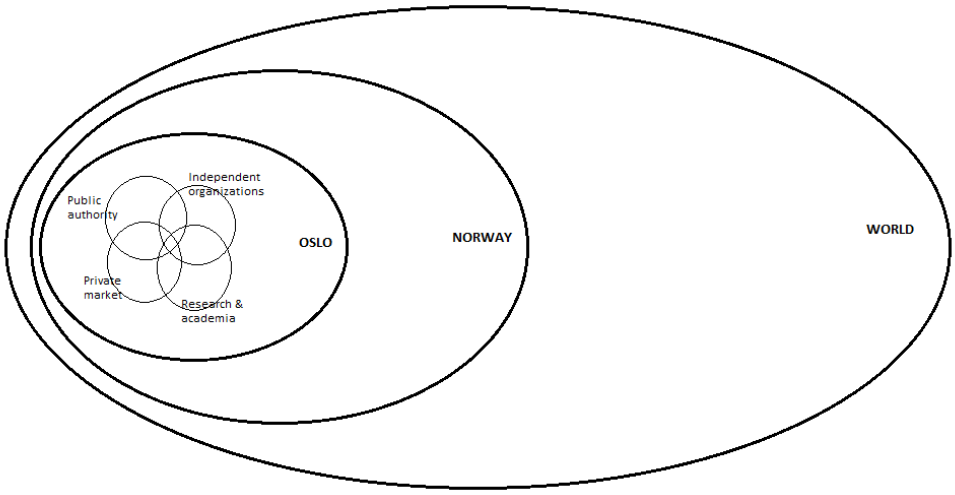

Figure 5 - The green roof system of interest in Oslo in context with its larger boundaries.

For the case study, two projects provided the basis for gathering information and the network of stakeholders. The first was a new green roof project by the City of Oslo atop the Bymilljøetaten building at Strømsveien 102. The second project was the opportunity to help a champion stakeholder in creating a cluster initiative to stimulate the green infrastructure market in Norway. Though this project had wider goals with its focus on green infrastructure in the entire country, its ultimate target group was comprised mainly of businesses working with green and turf roofs around Oslo due to the limited nature of green infrastructure development in Norway as a whole. It focused on the market aspect, providing a contrast to the ecological aspects of green roof development commonly cited by stakeholders through a discussion focused on the economic and social aspects.

Strømsveien 102

The green roof was built by the City of Oslo Bymijløetaten with remnant funds of the national initiative 'Framtidens Byer' (Cities of the Future), a project that addressed issues of sustainability in climate change (Modernization, 2014). Framtidens Byer worked in Norway's thirteen largest cities, seven of which chose to build a green roof with project funds – Oslo, Bærum, Bergen, Drammen, Sandnes, Tromsø, and Trondheim (Bent, interview). Strømsveien 102 primarily involved the person in charge of writing the City of Oslo green roof strategy, a researcher from NVE, suppliers, and me. The purpose of the green roof was to provide a demonstration site for the public authority and to collect certain data like rainfall and runoff to support urban climate research and temperatures for analyzing the urban heat island effect, but no data was collected. I helped in the project by participating in the project planning discussions and I watered the plots during its establishment period in the summer holiday. During this holiday, I took field notes about the weather conditions and made personal observations one to two times per week for the public authority's use.

The green roof had one area of turf grass and one area of sedum provided by five suppliers. One section of the sedum area was commonly designed among the stakeholders, as shown in Table 1. Notes from the planning meeting can be found in Appendix V. At the beginning of the project, the aims were to collect rainfall and runoff data, temperatures for analyzing urban heat island effect, and generating interest in green roofs to support the strategy development. As the summer progressed, no instruments were installed to measure the data and consequently it became a demonstration-focused roof.

	VegTech	**ZinCo**	**Vital Vekst**	**Bergknapp**	**Common**	**Nittedal Torvindustri**
Plant thickness	2.5 – 3.0 sedum	2.0 cm sedum	3.0 cm sedum in coconut mat	3.0 cm sedum	Vital Vekst supplied mat on half of plot (3 cm), hand-scattered sedum on other half	Direct seeding, turf
Substrate	2.5 cm draining mat (XMS 0-4)	4 cm substrate, 1 mm filter cloth, 2.5 cm draining (FD 25-E), 0.4 cm cloth	4 cm substrate, 1 cm draining (Oldroyd 10B)	0.5 cm filter cloth, 2 cm draining mat (Oldroyd SV green 25)	Vital Vekst supplied 8 cm pumice substrate, 1 cm draining	17 cm substrate, draining layer

Table 1 – Template for plots within green roof at Strømsveien 102 including supplier, plants, and substrate

Business and research cluster

The cluster is in its founding phases and aims to create a network that will facilitate green infrastructure development in Norway. Its goal is to stimulate the Norwegian market by uniting fragmented actors, addressing common challenges collectively, and contributing to better conditions for green infrastructure innovations. The initiative was begun by a key stakeholder and I was recruited to help lead it. In May 2014, a stakeholder focus group was held to discuss avenues for cluster development, as was described.

2.4 Research design and methods

The case study was explored through participant observations, semi-structured interviews, context meetings, a survey, and a focus group. Participant observations describe human interactions and behavior through firsthand accounts and field work by combining observations, conversations, and field evidence. The nature of involvement in projects within the study provides a personal contact that encourages a more complete and truthful understanding of the topic of study (Smith, 1990). Semi-structured interviews followed a question guide for topics to be covered but allowed for flexibility and topical trajectories in conversations (Kumar, 1999). The focus group assembled a diverse group of people to participate in a guided discussion (Yin, 1989). It was beneficial in reinforcing themes that were present in the interviews. Following the interviews and focus group, a survey was distributed to members of the public to gain their perspective on key points in the study.

The research question '*What is the current green roof situation in Oslo?'* was comprised of three parts. The first part explored the projects and non-human actors present in the situation. This information was gathered primarily from documents obtained by stakeholders and reports from the City of Oslo and Norwegian government, but data from participant observations, interviews, and independent searches were used when information was insufficient to adequately describe the projects and non-human actors. The second and third parts of the research question were explored simultaneously, investigating the network of stakeholders, their roles, and their opinions about development as well as the challenges and opportunities present. Data for this section was collected through personal observations, interviews, a focus group, and a survey, as will be described.

On a personal note, this study came about due to my personal interests in green roofs. The bias that came with it was addressed through reflections and critical thinking, as described in field notes and interview mind maps, as well as triangulations with data.

Participant observations and exploration

An early exploration was conducted to identify the objective of the study, something that was developed from participant observations and independent research. Throughout the entire process, my participant observations were recorded during meetings, interviews, conversations, and transect walks in a field notebook. It provided the viewpoint with the most subjectivity, but consistent note taking and critical thinking built credibility, as demonstrated in the mind maps available in Appendix IV. Other research findings reaffirmed their value as well. Participant observation allowed for me to engage in the community network, enriching my understanding of the situation while exploring the linked network of

stakeholders and potentially influencing the outcome of minor events. This reduced my capacity to work as an outsider, but provided a clearer perception of the reality. Through participant observations, chains of conversations developed where topics discussed earlier in the research could be included to content of subsequent conversations or the focus group, progressively enriching insight into the situation. The growing narrative of personal observations collected strength and credibility in these ways throughout the study (Yin, 1989).

The primary part of the participant observation process was in attending meetings. The first meeting attended served as the platform for the chain of conversation to begin. It was a planning meeting held by the City of Oslo for constructing a green roof at Strømsveien 102. Seven stakeholders including myself were at the meeting representing the City of Oslo (two environmental consultants and the building caretaker), NVE, Nittedal Torvindustri, Vital Vekst, and NMBU. The meeting discussed logistics such as construction and research method ideas.

The second meeting attended was a seminar titled 'Bioforskning Green Environment / Green Amenity Areas and Ecosystem Services.' It discussed a restructuring of Bioforsk's departments to reflect changing trends in research requests and opportunities. Ultimately, the meeting provided more context relevant information about Bioforsk and was not included the research results.

Date	Length	Name	Position or Institution	Position or type of meeting	Method or purpose
Mar 3	2 hrs		City of Oslo	Project planning meeting	Planning for Strømsveien 102 green roof installation
Mar 6	2 hrs	***Morten***	Nittedal Torvindustri	Product manager	Semi-structured interview & transect walk
Mar 13	30 min	Ingrid	NMBU	Professor	Semi-structured interview
Mar 14	2.5 hrs	***David B.***	Cluster	Leader	Semi-structured interview & transect walk
Mar 21	45 min	*Erik*	Bioforsk	Senior researcher	Semi-structured interview
Mar 24	45 min	David D. **Einar**	City of Oslo	Environmental consultant & special consultant	Semi-structured interviews
Mar 25	1.5 hrs	***David B.***	Cluster	Leader	Planning meeting for focus group
Mar 26	1 hr	***Bent***	NVE	Researcher	Semi-structured interview
Apr 1	1 hr	***David B.***	Cluster	Leader	Planning meeting for focus group
Apr 25 -26	9.5 hrs total		Bioforsk	Business strategy meeting	Discuss potential changes to Bioforsk's departments to include a new 'urban greening' sector
May 8	2.5 hrs		Cluster	Focus group	Discuss the development of a new organization to facilitate strong growth of green roofs in Norway
May 9	2 hrs		NFGT	Annual meeting	Annual organization meeting including board elections
Sep 1	30 min	Siv	NMBU	Student	Unstructured interview
Sep 2		**Einar**	City of Oslo	Environmental consultant	Semi-structured follow-up interview

Table 2 – Interview and meeting schedule. Bold names identify 'champion' stakeholders in the green roof development situation in Oslo. Italicized names represent interviewees that also participated in the focus group.

Interviews

The second form of data collected was through interviews. The selection criteria for the respondents included having direct work with green roofs in Oslo, a basic understanding of the roles of green roofs, and an interest in expanding the presence of green roofs in Oslo. There was not a large amount of stakeholders fitting these criteria in Oslo, and several potential candidates were unreachable or too busy to participate in the study, limiting the choices. Consequently, the identified 'saturation point' identified by Guest, Bunce, and Johnson (2006) of twelve interviews was not met, but it did surpass their requirement of six interviews to identify metathemes. For this specific study, eight distinct respondents created the saturation point achievable with the given constraints. Four stakeholders played very prominent roles in the green roof development community and can be considered as 'champions,' as shown in Table 2 along with the schedule of meetings, interviews, and the focus group.

Interview candidates were chosen through a 'snowball effect', being referenced by other stakeholders as knowledgeable or relevant stakeholders (Kumar, 1999). All of the interviews except one were semi-structured in nature and purposefully broad to truly gain the respondents' perspectives and to encourage deeper discussions on topics they found to be most compelling. Mind maps were drawn after the first semi-structured interview with each respondent. The questions evolved slightly over time, per the chain of conversations effect, as the interview guides in Appendix III indicate. The one non-semi-structured interview was held after the focus group. It was an open interview with a fellow NMBU student doing her BSc thesis on green roofs and urban agriculture that discussed her experiences with her project. Several interview respondents were met with multiple times, and several participated in the focus group, as shown in Table 2. One follow-up interview was done with the project leader of Strømsveien 102 to inquire further about the policy development after a more complete understanding of the green roof development situation had been achieved. The following topics were discussed during the first semi-structured interviews:

- Demographic information
- Stakeholder's work with green roofs
- Knowledge about green roofs and projects in Oslo
- Opinions about green roofs and urban agriculture
- Opinions about green roof development
- Challenges and opportunities
- Networking

Also, though the interview guide posed a set of questions that were asked to all respondents, several acknowledged a lack of information about certain questions and were not able to provide an answer. This resulted in a few short interviews, though respondent time availability also had an impact on duration. Thorough notes were taken during the interviews, including quotes. By not using an audio recorder for the meetings, it is possible that points could have been missed in my notes. To address this issue, similarly worded questions were asked in the different topics to gain repetition, such as "Who do you work with about green roofs?" and "Does anyone else within your company work with green roofs?" This interview style proved to be both a strength and a weakness because of the intentionally vague nature of the questions. More specific questions could have provided more depth to the results, but providing leads in the questions undermines the stakeholder's ability to address issues that they think were most significant.

Additionally, follow-up interviews with each stakeholder discussing the findings of the preliminary interviews and the focus group would have contributed to the quality of this report.

Transect walks

As a part of several interviews, transect walks were held. With Morten, we visited the Herligheten garden in Bjørvika, the green roof at the Alna Senter, the green roof at the H&M Distribution Center, and a green wall inside the neighboring building. Morten was connected to the projects through his work as well as his extracurricular activities. He participates with MAJOBO, who manages Heligheten and the green roof at Alna Senter, and his company supplied the roof at both the Alna Senter and H&M. David B. gave a ten minute tour highlighting a few private green roofs located in Grønland at the conclusion of his interview.

Focus group

Data was also collected was through a focus group. Together with a stakeholder in the study, a seminar was held to discuss the creation of a business and research cluster supporting green infrastructure development in Norway. This focus group addressed not only questions pertinent to the cluster, but provided insight from private industry regarding the research question of this study:

- What is green infrastructure?
- What are the barriers to market development in Norway? Why is Sweden and Denmark ahead of Norway in the uptake of green infrastructure?
- Do we need a development of public policy and knowledge?
- Can players cooperate and create a win-win market development?
- What is a business and research cluster? And how would it look in relation to green infrastructure?
- How can a business and research cluster be funded?
- What should happen next?

An invitation was sent to 40 stakeholders from the public, private, independent, and research and academia sectors relevant to the wider issue of developing green infrastructure in Norway, 14 of which attended. The goal was to maximize the amount of participation. Stakeholders were identified by interview information 'snowballing' and with extra insight from David B. A list of stakeholders present can be found in Appendix VI, along with the meeting invitation and summary. It was held in Norwegian and led by David B. The focus group lasted for two hours and consisted of a powerpoint presentation about definitions, examples, and social values created by green infrastructure and a powerpoint presentation about industrial stakeholders. A discussion was held about each presentation. It was recorded, transcribed, and summarized by David B. as meeting minutes. A translation of the summary was done via online sources. A Dropbox file was created to share the presentations, contact information of interested stakeholders, recordings and results with participants.

Despite an extensive summary compiled from the audio recording by David B., my understanding of the meeting would have been enriched if the discussions had taken place in English. The summarizations were made from his interpretation of the focus group, adding a different outside perspective and a

valuable dimension to reducing personal subjectivity in the data collection. This focus group was in part strengthened by the wider focus on green infrastructure in Norway but it did detract from the specific focus of green roofs in Oslo in this study, an issue evident in the systemic approach. Critical thinking and flickering between the subsystems and supra-system led to a better understanding of both the smaller and larger issues present in the focus group and study. But, to support this study, the participants of the focus group all worked primarily with green roofs, most of them in the Oslo area though their work extended beyond the boundaries of Oslo. Researchers in the focus group acknowledged their limited roles in the development of a green infrastructure cluster due to the lack of funding for projects on the topic currently.

Survey

Through the meetings, interviews, and focus group, one stakeholder group was not present – the general public. Based off of the data collected throughout the research, the Oslo public did not have a good understanding of green roofs, perhaps not even knowing what they were at all. But in part because of media interest in green roofs and urban agriculture on green roofs, in part because of literature supporting it, in part because of the growing global trends of local foods and rooftop gardening, and in part because of the focus put on ecological values of green by stakeholders, I wanted to see if there was an opportunity being missed. After considerations and input from professors and supervisors, I compiled a short survey to explore the connection between green roofs and urban agriculture or other uses in the perspective of Oslo residents.

The online survey was administered through Survey Monkey, which also analyzed the data. As recommended by my supervisor, I contacted the leader of MAJOBO, who recommended distributing the survey via the group's Facebook page to get the most responses. There were 50 respondents for the survey, 40 of which live in Oslo and were considered in the results. As a result of the group questioned, the results may be skewed to show a higher preference towards urban agriculture use on green roofs. The respondents also may be likely to be more involved in eco-friendly initiatives compared to the general population, angling their preferences as well. Thirdly, the results also may have been skewed due to the order of questions asked. In hindsight, asking about urban agriculture first could have been leading for the results of the subsequent questions focused only on green roofs. Also, rather than providing prompts for reasons to participate, it could have been insightful to gauge people's knowledgeability and unguided opinions but not providing answer options. The survey consisted of the following questions:

1. Do you live in Oslo?
2. Do you currently have a space for urban agriculture?
3. Would you like to have a space for urban agriculture?
4. If you participate in urban agriculture, what are your reasons for doing so?
5. If there is an opportunity to have an urban agriculture space on a green roof, would you be interested in using it?
6. If you were to build or use a green roof, what would you choose to do so?
7. Other comments, questions, or concerns?

Questions 1 through 3, and 5 had yes / no / not interested answers. Questions 4 and 6 suggested a list of commonly recognized beneficial effects, an option for not interested, and an 'other' category in which respondents could leave further reasons.

In the analysis of the survey, I found that a deeper exploration with a wider range of questions would have provided a much better complementary section to the other research. The application of the results was very limited and a further study would be useful for strategy development insight. A further exploration could also look into the value of community involvement in solution finding rather than the reliance upon technocratic solutions.

Data analysis

The first analysis performed was a stakeholder analysis. The stakeholder analysis helps to define their overall influence through their levels of interest and power on green roof development in Oslo. First, a list and description of stakeholders present in the study were compiled, based on participant observations, interviews, and independent research. This description also indicates if they participated in interviews and/or the focus group. Considering that there were stakeholders interested in the focus group but unable to attend, they were given credit for either downloading focus group materials from the public Dropbox file or engaging in a personal conversation with me about the focus group. A network web was drawn representing the interconnectedness of stakeholders and their interest in participating in interdisciplinary problem solving for developing green roofs in Oslo. The second part of the stakeholder analysis was a power analysis, grading stakeholders on their impact in green roof development. Three grading criteria were used – involvement with the Strømsveien 102 project (0 points = no participation, 1 = participation), impact on strategy development (0 = none, 1 = collaboration or advice-giving, 2 = public authority stakeholder), and their perceived power from other stakeholders on the importance in development (1 point for each time referenced). The two analyses were combined to show their total influence, identifying key target groups for development.

The second part of analysis extracted the perceptions and opinions from stakeholders about green roof development. Topics present in interviews and the focus group were grouped into themes and assembled in a chart. To express the prominence of the topic as an issue, the amount that it was referenced by distinct stakeholders was listed. Supporting this analysis, which identified the main themes in challenges and opportunities in green roof development in Oslo, quotes were added in the discussion. The survey was also used to support findings in the discussion.

Future action

Concluding the study, an exploration of approaches used elsewhere to stimulated green roof development was made. It describes strategies and approaches in cities demographically comparable to Oslo from information gathered from journals and the media. This information was used in combination with research results to suggest a feasible and ideal future strategy for Oslo green roof development.

CHAPTER THREE: RESULTS AND ANALYSIS

What is the current situation of green roofs in Oslo?

Green roofs in Oslo have a wide range of factors influencing their development. It is hard to include all of the information from the system into this study. For the scope appropriate for this study, three main non-human actors will be discussed in Section 3.1 – the urban environment, the food system, and Oslo's programs, projects, and policies relevant to urban ecology. Following this, various green roof projects in Oslo are described in Section 3.2, though they are not the only green roofs present in the city. Section 3.3 presents data and results for the stakeholder analysis and section 3.4 describes the results from the interviews, focus group, and survey.

3.1 Non-human actors

The urban environment

Figure 6 – Oslo's forests and green spaces in and around the city center (Oslo, 2013c)

Oslo is very much 'blue, green, and the city in between' (Oslo, 2013b), as shown in Fig. 6. According to Oslo (2013c), 86% of residents visited the northern forested region, Nordmarka, within the past year, and half of residents did it weekly. Since 2009, laws have been in place to protect this forest against development. Other strategies exist to preserve and reinvigorate ecological quality elsewhere in the city. For example, 95% of residents live within 300 meters of green areas larger than 5000 square meters. Ten major waterways pass through the city with their associated greenbelts, providing 280 kilometers of greenways and coastal trails for year-round use. These features comprise the 'blue-green' water and natural infrastructures used to support ecological systems in the city. They not only provide an identity to the city but are critical to urban sustainability by providing ecosystem services like employment, runoff water cleaning, and

wildlife habitat for endangered species (L. J. Whittinghill & D. B. Rowe, 2012). Oslo applied to host the European Green Capital 2016 Oslo, with top ratings in many environmental measures (see Fig. 7). but was ultimately chosen as the runner-up in the contest.

Indicator / Applicant City	Climate change: Mitigation & Adaptation	Local transport	Green Urban Areas incorporating Sustainable Land Use	Nature & biodiversity	Ambient Air Quality	Quality of the acoustic environment	Waste Production & management	Water Management	Waste water treatment	Eco-innovation & sustainable employment	Energy Performance	Integrated Environmental Management
Essen	2	6	4	1	3	1	3	2	2	2	4	4
Ljubljana	5	2	2	4	4	4	5	3	4	5	6	1
Nijmegen	4	4	3	5	8	6	4	5	1	4	2	3
Oslo	1	1	1	3	1	2	1	4	6	1	3	2
Umeå	3	3	7	6	6	3	2	6	5	3	1	6

Figure 7 - Rankings (out of 12) of shortlisted cities in the competition for the European Green Capital Award 2016. Cities were graded on their performance in a variety of environmental measures. (Oslo, 2014b)

In Oslo, the heavily populated inner city is being built up as part of the urban densification plan to focus construction in the urban center so as not to disrupt the neighboring forests (Oslo, 2013c). In the inner city, only 19% of space consists of green areas open to the public. One-fourth of its built-up horizontal space consists of buildings, close to the global average of 32% (Oberndorfer et al., 2007; Oslo, 2013b). In the last ten years, 55% of all homes were built on former industrial sites or similar, mostly in or near the city center (Oslo, 2013c) and in the next 15 years, a projected 100,000 homes will be added as the population grows from its current level of over 600,000 inhabitants to around 800,000 (Oslo, 2014d; Savage, 2014). A map showing the growth of the city during the last decade can be seen in Fig. 8.

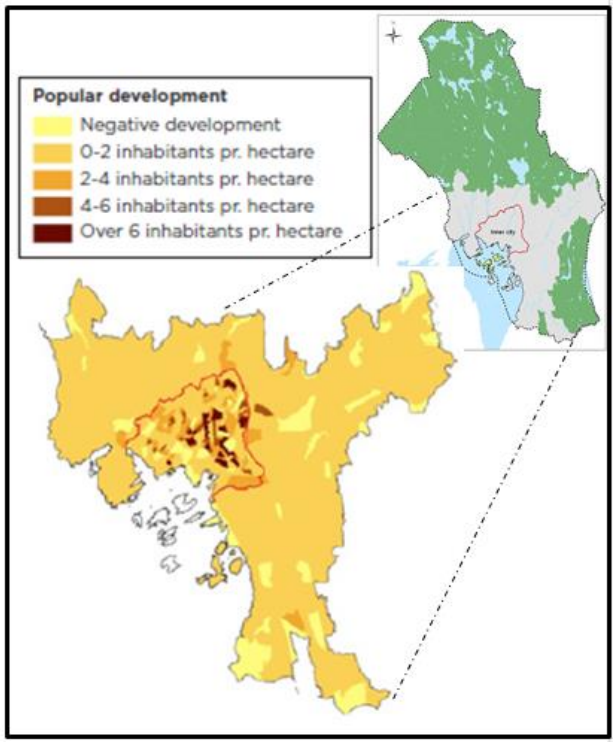

Figure 8 – Population growth (2004-2012) is focused in the inner city in Oslo, with no development allowed in the surrounding forests. The map shows the increase in population density in city by inhabitants per hectare (Oslo, 2013b, 2013c)

One of the biggest ecological challenges for Oslo is its tendency to flood. Overflowing sewer systems can contaminate local waterways and the Oslo Fjord with untreated sewage. One of the most problematic neighborhoods, Grunerløkka, floods every time it rains more than 10 mm/hour (Einar, interview). This problem will increase with climate change if no steps are taken to address it. Norway can expect around 20% more precipitation by 2030 to 2050, compared to the years 1980 to 2000. Eastern Norway, including Oslo, should anticipate even heavier precipitation, mostly during winter, and an increased rainfall intensity (Cicero, 2009).

Oslo is not unique in accruing environmental challenges with urban grown. For this city and many more, flooding problems stem from the use of 'grey' impervious technical structures, as shown in Fig. 9. Grey structures have been the norm in water management, with the idea that they quickly funnel water into underground structures and out of cities. It was a short-sighted practice that led to

Figure 9 - Flooding in Oslo Traffic Ring 2 on 12 August 2013 (Kjersti Flugstad Eriksen, 2013)

water system ecology degradation and flooding (Getter & Rowe, 2006). Large sections of Oslo's waterways were encapsulated in underground culverts, which are insufficient in today's climate (Oslo, 2013d). The city is reopening these waterways to allow for natural ecological systems to occur while also exploring opportunities to support the existing grey infrastructure with other green infrastructures including green roofs (Bent, interview).

Food system sustainability

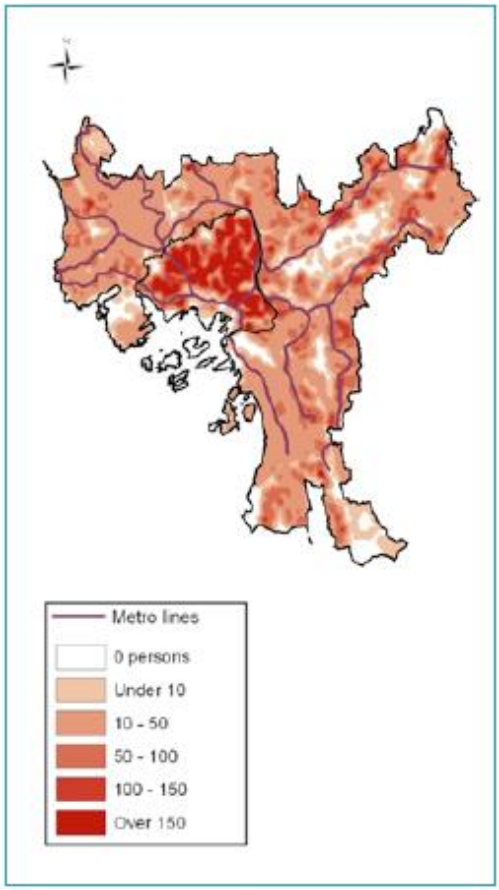

Figure 10 – People per hectare in Oslo as of January 1, 2013 (Oslo, 2013b)

While Oslo has significant flooding challenges, its rapidly growing population also raises questions about the sustainability of its food system. Like other urban areas, Oslo relies upon imports to ensure food security, which has wider effects on global sustainability as discussed. The recent growth in population shown in Fig. 10, interest in urban agriculture, and Norway's White Paper all emphasize the significance of local food security (Agriculture, 1999; Knutsen, 2007). The EU recently finished the action plan URBACT, which was a program promoting sustainable urban development throughout Europe, but was specifically focused on sustainable food in urban communities in Oslo (Oslocontributor, 2012). Various organizations like MAJOBO, an organization that promotes local, organic food production (MAJOBO, 2014), also build support for urban agriculture. Though food security is currently not an issue in Oslo or Norway, urban agriculture can still contribute to sustainability objectives.

Domestic production is limited in Norway by three primary factors – only 3.2% of total land is arable, the terrain is difficult to cultivate, and the growing season is short and cool (Knutsen, 2007). The main agricultural products are dairy (over 100% self-sufficiency), meat (100%), eggs (100%), potatoes (80%), and grains (60%). Additionally Norway produces vegetables (55% self-sufficiency) and fruits and berries (5%). But even factoring in the generous fish supply, the total national Norwegian self-sufficiency level is around 50% (Flaten & Hisano, 2001). In Oslo, with a population density of over 3000 people per square kilometer in its densest regions (Oslo, 2013b), local self-sufficiency is very low. In addition to low urban food production levels, domestic food products can originate from as far away as 2,500 kilometers, roughly the same distance between Oslo and Rome, which contributes to the systemic plight of transport energy use in an unsustainable global food system and climate change.

Fortunately, food security in Oslo isn't a problem today (David D., interview). Norway has strong policies both controlling and providing international imports (Knutsen, 2007). Oslo is among one of the wealthiest and most stable cities in the world. The national GDP per capita is 593,000 NOK, Oslo constituting 40% of the GDP, and unemployment is 3.4% (Oslo, 2013c; SSB, 2014). But, urbanization has undermined the sustainability of Norwegian agriculture, the backbone of Norwegian history. Farm holdings have decreased by 80% since 1949, though the amount of land farmed has remained constant (SSB, 2013), and agriculture employs less than 2% of the population – a 20% decrease between 2000 and 2006 alone (SSB, 2014).

But the government sees value in supporting its agricultural sector – for protecting rural livelihoods and landscapes, environmental conservation, maintaining cultural traditions, and last but not least, for food security. Government support is necessary since production is not profitable. 74% of farmers' incomes come from subsidies, one of the highest rates in the world (Knutsen, 2007).

Programs, projects, and policies

The City of Oslo has a municipal strategy for sustainably developing its ecology, economy, and society. Most relevant to this study, the City of Oslo is developing a strategy for addressing flooding issues (Einar, interview). But while there is a focus on this issue both in Oslo and numerous other North American and European cities (Bloomberg & Holloway, 2010; Braskerud, 2014; Copenhagen, 2012), green roofs can also support other eco-friendly and urban sustainability goals. It is possible to add green roofs into the existing framework as well as create new frameworks (T. Carter & Fowler, 2008). In Oslo, the existing framework starts with the municipal master plan 'Oslo 2030 – SAFE, SMART, GREEN' and its objectives for sustainable urban development (Oslo, 2014d):

1. Grow through compact urban development
2. Protect and develop blue-green structures
3. Be an attractive city with safe and user-friendly urban spaces
4. Become an internationally leading climate-friendly city
5. Create attractive meeting places and make them publicly accessible in the National Cultural Axis (city center waterfront region)

The Urban Ecology Program is auxiliary to this plan and has three main goals – leading by example via eco-efficient city administration; reducing GHG emissions by 50% by 2030; and working together with residents, businesses, NGOs, and the national government to improve the city's condition (Oslo, 2013b). It also includes the following objectives (Oslo, 2014a):

1. Reduce noise levels, air pollution and greenhouse gas emissions
2. Have an eco-efficient transport system
3. Develop Oslo in an environmentally sustainable manner
4. Use a life-cycle approach in waste management
5. Maintain and strengthen its blue-green infrastructure
6. Develop an eco-efficient city administration
7. Work together with its residents, businesses, and government to improve the urban environment
8. Take part in regional, national, and global cooperation to improve the environment

Various action plans and strategies exist to achieve the goals of the Municipal Master Plan and the Urban Ecology Program. Within the master plan and Urban Ecology Program, specific laws, protocols, and guidelines are useful in achieving goals. A list of a few of these can be found in Appendix VII. Though green roofs do not fit into every category, such as eco-efficient transport, they can find space in the remaining objectives of the Urban Ecology Program. The fruition of using existing framework includes possibilities like green building certification points and faster building permit acquisition if constructing green roofs. New framework for stimulating green roof development can also be created including construction guidelines, regulations, subsidies, incentive schemes, awards, and seminars (Falck-Pedersen, 2012).

The City of Oslo has remarked that it should take a bold stance to support its urban development, especially through eco-innovations (Oslo, 2013c):

1) Create breeding grounds for eco-innovations through collaboration and networks to share knowledge and foster new ideas
2) Through funding green R&D and innovations
3) Through purchasing power and green procurement
4) Through bold political decisions that become game changers

This consideration is important for the upcoming policy development.

3.2 Green roof project descriptions

Strømsveien 102

The green roof at Strømsveien 102 is one part extensive sedum and one part semi-intensive turf, as shown in Fig. 11. The original plan included one more roof section but its construction was withdrawn due to budget limits. The portion removed from the plan was meant to be built on the second floor adjacent to the cafeteria and accessible by the entire building. The top floor with the existing green roof is behind a secure access door. Though there were plans to conduct research on the roof, ultimately no data was collected and it was used primarily for demonstration. An analysis of winter survival is expected in spring 2015 (Einar, interview).

Figure 11 - Strømsveien 102 sedum roof (left) and turf roof (right)

The roof at Strømsveien 102 involved both industry and public authority representatives for planning. One plot was mutually decided upon by the five green roof suppliers present. All plots performed well, though one section of the turf roof was not installed by a supplier. The summer was full of tours and interviews and generated public interest, meeting one of its major goals. It also served as a strategy-launching project for the City of Oslo, since it is the first green roof installed by the municipal authorities. There is a request from the politicians to make a green roof strategy for Oslo, but no firm deadline (Einar, David D., interviews).

Bymiljøetaten and NVE have been conducting research in addition to the Strømsveien 102 project to spread interest and support in strategy development (Braskerud, 2014; Falck-Pedersen, 2012; Noreng et al., 2012), but a noteworthy challenge within the City of Oslo is its fluctuations in employees (David B., Einar, interview). Some of the most knowledgeable and influential people regarding green roofs in the city have changed positions, complicating the strategy creation process. Originally, strategy development was meant to begin in October 2014, but it is now estimated to start in early 2015.

Alna Senter

The Alna Senter is a pilot project demonstrating local and organic food production that began in 2012, as seen in Fig. 12. It is a collaboration between building owners, MAJOBO, Nittedal Torvindustri,

Figure 12 - Green roof at Alna Senter (MAJOBO, 2014)

Framtidens Byer, the City of Oslo, and the social entrepreneurial company Kompass & Co., (Dæhlen & Ortiz, 2013; Kjersti F Eriksen, 2013; Vestreng, 2013). The roof is accessible from the outside and visible from the parking lot, due to its slope. It is popular among shoppers and valued the property owner, who sees noticeable summer energy savings. (Morten, interview). The roof had twenty large boxes containing vegetables and herbs as well as bees that produced 40 kg of honey in 2013 (Vestreng, 2013). But, in 2014 the project encountered funding problems, limiting the vegetable and herb section of the roof. MAJABO kept the beehive project going, but the vegetables and herbs were not able to be taken care of (Einar, interview).

Bjørvika Barcode District

Figure 13 - Bjørvika green roof (Vekst, 2014)

The new Barcode district of Oslo (see Fig. 13) was a pioneering sustainable development project. 50% of its roof space was required to be greened. But, the project leaders either did not know or did not correctly implement information about technical details. Strong winds on the roof pushed the substrate to accumulate on one side of the roof (David B., Morten, interviews). The building drainage system was decreased by the proportion that green roofs should reduce stormwater, but the effects of soil saturation were not considered (which is normal during prolonged rainy weather in Oslo) and flooding ensued.

Veolia

A research project was carried out by the SINTEF, UMB, and the City of Oslo studying stormwater runoff at the environmental recycling center Veolia as well as three other sites in Oslo (Noreng et al., 2012). The Veolia green roof is very large – 28,000 m2 – and won the 2008 Scandinavian Green Roof Award (Ødegård, 2008). Despite this publicity and its use in case studies, it is not well known, not even to building employees. The company receptionist was not aware of its existence when called to request a visit (Siv, interview).

Sagane and H&M Distribution Center

The borough of Sagene in Oslo intended on building a green roof for vegetables. The project faced resistance from the building owner due to misunderstandings about the maintenance and impacts, leading to project cancellation. To contrast this example, the building manager at the H&M Distribution Center was initially very hesitant to allow a green roof to be installed, citing pest issues. After an hour of

conversation with the green roof supplier, the manager completely changed his mind to support it and is proud of his roof today (Morten, interview).

Oslo City Hall

A green roof was planned to be installed atop the Oslo City Hall in 2009, supplied by Nittedal Torvindustri and free of charge for the City of Oslo. After the Anders Behring Breivik terrorist attack, City Hall didn't want large groups of visitors coming to building that would be hard to control. Consequently, the green roof plan was completely cancelled with no discussion (Morten, Ingrid, interviews).

3.3 Networks and connectivity

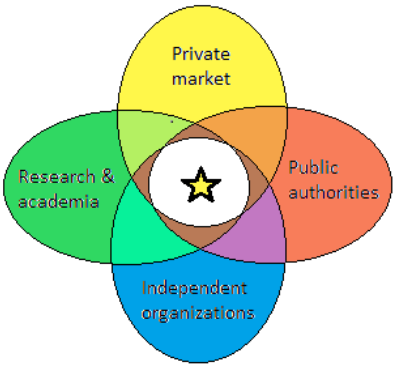

Figure 14 – Helix of cooperation between stakeholders in a systemic problem

Understanding stakeholders' objectives and involvement is needed in understanding the current situation of green roof development in Oslo. The support of stakeholders is critical to building successful organizations, policies, plans, and programs (Bryson, 2004). Stakeholders can be divided into four categories: public authorities, private market, research and academia, and independent organizations, as seen in Fig. 14. The structure for this is borrowed from Rømø (2012) and adapted to include independent organizations in order to meet the situation of Oslo. It emphasizes the importance of interdisciplinary work, a cornerstone of systems thinking and agroecology, and critical in creating an ideal and feasible future for green roof development. A description of the stakeholders present in the study is listed in Tables 3 through 6. Following the stakeholder descriptions, the diagram in Fig. 15 shows the interconnections between stakeholders, reflecting their interest in the problem situation. Stakeholders with high interest levels have twelve or more connections in this study, representing the nearest whole number to the median.

Public authority		**Interview**	**Focus group**
Stakeholder	**Description**		
Oslo Bymiljøetaten (Urban Environ-mental agency)	Manage the following areas of urban development: sport and leisure, wildland, nature, environment, traffic and transport, and projects (Oslo, 2014a).	X	
NVE (Norwegian Water and Energy Directorate)	Ensure the integrated and environmentally sound management of the country's water resources, promote efficient energy markets and cost-effective energy systems and contribute to efficient energy use (Sanderud, 2009).	X	X
VAV (Oslo Water and Sewage agency)	Supply Oslo's population with drinking water and wastewater handling (Oslo, 2014b).		/
KMD (Ministry of Local Government and Modernization)	Responsible for a wide array of matters including management tasks under the Planning and Building Act relating to urban development, municipal land-use planning, environmental impact analyses and county planning, and national mapping and geodata policy (Modernization, 2013).		/
Politicians	Eight political parties work in Oslo: Høyre, Arbeiderpartiet, Sosialistisk Folkeparti, Fremskrittpartiet, Venstre, Kristelig Folkeparti, Rødt, and Miljøpartiet De Grønne (Oslo, 2014c).		
Innovation Norway	Instrument for innovation and development of Norwegian enterprises and industry (Norway, 2014)		/
City of Bærum	Governing body of the Bærum Kommune		/

Table 3 - Public authority stakeholders present in study. X = participation in an event, / = expressed an interest in the result.

Private market		Interview	Focus group
Stakeholder	**Description**		
Nittedal Torvindustri	Largest supplier of materials for turf roofs in Norway	X	X
Vital Vekst	Supplier of sedum green roofs		X
VegTech	Supplier of urban greening projects		X
Bergknapp	Supplier of sedum green roofs		X
ZinCo	Supplier of green roofs		X
Naturtorv	Supplier of grass roofs in eastern and western Norway		X
Hallingtorv	Supplier of turf roofs		X
COWI	An international sustainability consultancy group with a philosophy of 360 degree thinking (COWI, 2014)		X
Reiersøl	Producer of forest plants, including sedums, and focuses its business on southern Norway		
Icopal	Supplier of technical roofing components		/
Anlegg og Utemjiljø	Landscape architects working with green infrastructures		/
Sweco	Consulting group for sustainable engineering and design		/
Protan	Supplier of roofing membranes		/
Bærekraftig Investering AS	Consulting group for sustainable water resources management, and planning and investment on long-term solutions for renewable energy (Kraft, 2012)		X

Table 4 – Private market stakeholders present in the study. X = participation in an event, / = expressed an interest in the result.

Research and academia		Interview	Focus group
Stakeholder	**Description**		
Bioforsk	Research institute for agriculture, food production, plant, environment and resource management that also focuses on research-based innovation and value creation (Bioforsk, 2014)	X	X
SINTEF	The largest independent research organization in Scandinavia that develops innovative technologies (SINTEF, 2014)		X
NMBU	Norwegian University of Life Sciences	X	X
NTNU	Norwegian University of Science and Technology		
Nofima	Research institute for aquaculture, fisheries, and food science		

Table 5 – Research and academia stakeholders present in the study. X = participation in an event, / = expressed an interest in the result.

Independent organizations		Interview	Focus group
Stakeholder	**Description**		
NFGT (Norsk Forening for Grønne Tak)	Independent professional organization that promotes green roofs in Norway (NFGT, 2014)		X
Research and business cluster	Start-up cluster supporting the market development of green infrastructure in Norway	X	X
Blue-green Network	A multidisciplinary network promoting blue-green infrastructure (byer, 2014)	X	X
MAJOBO	Norwegian network organization that promotes localized and urban organic food production (MAJOBO, 2014)	X	X
NAML	Organization for businesses within the green sector (NAML, 2014)		/
Standard Norway	Private and independent member organization that creates standardizations for a broad array of products and services (Norge, 2003)		
GBA (Norwegian Green Building Alliance)	Environmental network of the largest real estate players in Norway to develop environmental efficiency (Byggallianse, 2014)		/

Table 6 – Independent organization stakeholders present in the study. X = participation in an event, / = expressed an interest in the result.

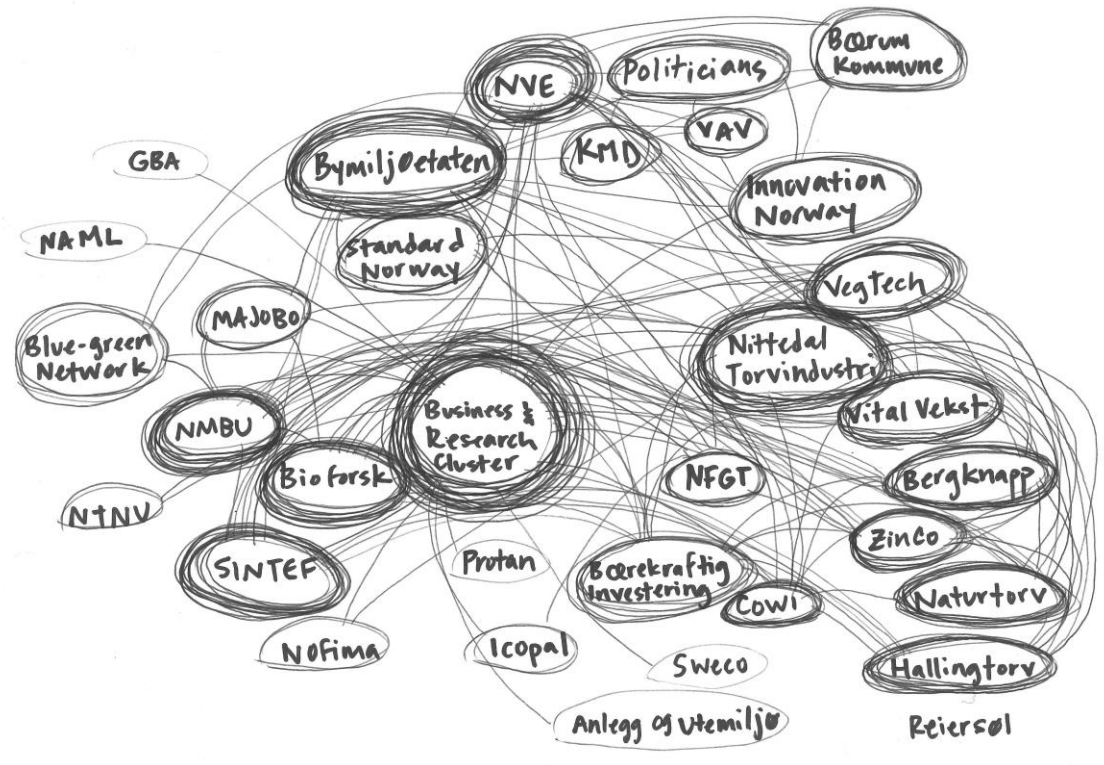

Figure 15 - Stakeholder interest diagram. Lines indicate direct interactions between stakeholders present in the study and subsequently their interest in interdisciplinary solution-making for developments in green roofs in Oslo. Circles around stakeholders indicate their quantity of interactions, bolder circles exhibiting more relationships and more interest.

Both interest and power are important components in influence, an important classification of a stakeholder analysis (Bryson, 2004). Power in this study comes from the stakeholder's prominence in the green roof community as well as their power over policymaking. The following analysis grades the power of stakeholders present in the study, as shown in Table 7. High scoring power groups were defined as having a score of four or more and are highlighted. Four represented the whole number closest to the median total points of stakeholders.

Stakeholder	1	2	3	Total
Bymiljøetaten	1	2	5	8
NVE	1	2	6	9
VAV	0	2	2	4
KMD	0	2	1	3
Politicians	0	2	2	4
Innovation Norway	0	2	1	3
City of Bærum	0	2	3	5
Nittedal Torvindustri	1	1	4	6
Vital Vekst	1	1	2	4
VegTech	1	1	0	2
Bergknapp	1	1	1	3
ZinCo	1	1	1	3
Hallingtorv	0	0	0	0
Naturtorv	0	0	0	0
COWI	0	1	0	1
Reiersøl	0	0	1	1
Icopal	0	0	0	0
Anlegg og Utemiljø	0	0	0	0
Sweco	0	0	0	0
Protan	0	0	0	0
Bærekraftig Investering AS	0	0	0	0
Bioforsk	0	1	4	5
SINTEF	0	1	3	4
NMBU	1	1	4	6
NTNU	0	1	2	3
Nofima	0	0	1	1
NFGT	0	1	0	1
Cluster	1	1	0	2
Blue-Green Network	0	1	2	3
MAJOBO	0	1	4	5
NAML	0	1	2	3
Standard Norway	0	1	4	5
GBA	0	1	1	2

Table 7 - Stakeholder power. Category 1 shows the involvement in the Strømsveien 102 project (0 = no participation, 1 = participation). Category 2 shows the impact on strategy development (0 = none, 1 = collaboration or advice-giving, 2 = public authority). Category 3 shows their perceived power from other stakeholders on their importance in development (1 point per each reference in interviews).

The influence of a stakeholder comes at the intersection of power and interest. Depending on the levels of power and interest, it is possible to categorize stakeholders into four subcategories – crowd, subjects, context setters, and players (Bryson, 2004), as shown in Fig. 16. Placing stakeholders into these categories shows which stakeholders to expand relationships with for current development and which groups to target for improving either their interest or power in order to optimize green roof development. This categorization was done for the stakeholder in Oslo and is shown below.

Players: high interest, high power
- Bymiljøetaten
- NVE
- Nittedal Torvindustri
- Vital Vekst
- Bioforsk
- SINTEF
- NMBU

Context setters: high power, low interest
- VAV
- Politicians
- Bærum
- Standard Norway
- MAJOBO

Subjects: low power, high interest
- VegTech
- Zinco
- Bergknapp
- Cluster
- Hallingtorv
- Naturtorv
- COWI

Crowd: low power, low interest
- KMD
- Innovation Norway
- Bærekraftig
- Reiersøl
- Nofima
- Icopal
- Anlegg og Utemiljø
- Sweco
- Protan
- NTNU
- NFGT
- Blue-green Nework
- NAML
- GBA

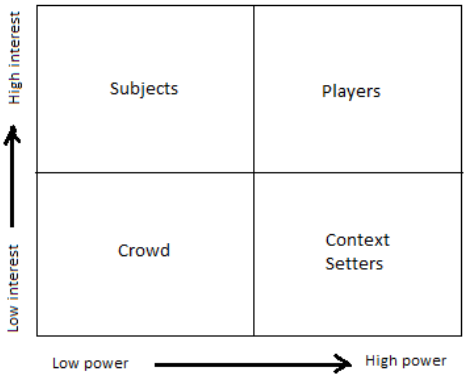

Figure 16 - Influence diagram (Bryson, 2004)

3.4 The opinions of stakeholders and the challenges and opportunities in development

Interviews

The opinions of stakeholders represented their perspective on the challenges and opportunities present in the development of green roofs in Oslo. In the interviews, there were four main challenges that were discussed by over half of the respondents, as shown in Table 8.

- In Oslo today, green roof projects have a limited realization of multi-perspective values.
- Money drives the system and funding opportunities do not necessarily match the research needs.
- There is a lack of local information, experience, and leadership.
- The Nordic climate is not well understood in relation to green roofs and results in unexpected problems.

Qty	**Challenges**
6	*Limited realization of multi-perspective values*
	Ecology
4	*Climate*
	Economy
6	*Money drives the system and funding opportunities do not necessarily match research needs*
2	Building weight bearing capacity limits and project budget underestimations
1	Territorial markets decrease desire for collaboration
	Society
5	*Lack of local information, experience, and leadership*
3	Failure of projects
3	Slow development and resistance to change
3	Fluctuations of employment in City of Oslo
3	Safety and use concerns
2	Norwegian romantic relationship with turf roofs
1	People harbor too much individually
1	Age and demographics of public for interest
1	Ample Norwegian wilderness makes it more difficult for consumers to see green roofs as necessary
1	Threatens to reduce the need for ground-level planning of urban green space
1	Quality in materials and handling may be low due to lack of research and knowledge

Table 8 - Challenges for green roofs in Oslo from the perspective of key stakeholders. Qty (out of 8) represents the amount of respondents that discussed the topic in their interview.

Similarly, there were five main opportunities discussed by over half of the respondents, as shown in Table 9:

- There are gaps in knowledge, research, and dissemination that need to be addressed (unanimous).
- Interdisciplinary, interactive clusters of people make a difference in development.
- Standardization and policies are needed.
- International knowledge and networks provide a strong background for supporting development.
- Green roofs present multi-perspective values with their diverse uses in urban development.

Qty	Opportunities
4	*Multi-perspective values with diverse uses*
	Ecology
2	A focus on climate change adaptations from municipalities
	Economy
2	Specific economic advantages in stormwater runoff as a primary reason for implementation
2	Market trends and interest can make urban agriculture on rooftops possible
1	Most Norwegian buildings can carry a semi-intensive green roof
1	Monetizing green roofs in innovative ways helps with financial institutions perceptions
	Society
8	*Gaps in knowledge, research, and its dissemination*
7	*Interdisciplinary, interactive clusters of people make a difference in development*
5	*Standardizations and policies promote widespread construction of green roofs*
5	*International knowledge and networks support local situation*
3	Public demonstrations stimulate increased interest
3	Political interests drive the policy creation
2	There are widespread examples of turf roofs and several examples of sedum roofs in Oslo

Table 9 - Opportunities for green roofs in Oslo from the perspective of key stakeholders. Qty (out of 8) represents the amount of respondents that mentioned the topic in their interview.

Focus group

From the focus group, multi-perspective challenges and opportunities in developing green infrastructure in Norway were identified in Tables 10 to 12. Six main themes were extracted from the focus group. Italicized text reflects similarities to the findings from interviews.

- Norwegian climate and insufficient locally relevant research
- Ecosystem perspective and multi-perspective uses from stakeholder groups
- Significant financial boundaries to development and proliferation
- Stakeholder cooperation in achieving mutual goal
- Lack of examples and regulating tools
- Dissemination of knowledge

Ecology	
Challenges	Opportunities
- *Norwegian climatic variations* - Significant dependence on imported substrate materials such as lava	- *Include ecosystem perspective to increase awareness* - *Combining of local materials, varied plants and substrates in research and application* - *Significant research gap in water retention from different substrates and vegetation* - *Despite well-developed knowledge of how grey infrastructure manages stormwater and flood risk, little is known about complex grey-green hybrid solutions* - *Norwegian Directorate for Civil Protection is participating in an EU project on climate change adaptation and measures in Oslo and Gothenburg currently.*

Table 10 - Ecological challenges and opportunities in green infrastructure development in Norway as was identified in the focus group

Economy	
Challenges	Opportunities
- *Values mostly viewed in economic terms* - *More plans being made for construction than realized and project investment estimates tend to underestimate* - *Economy and knowledge impact construction* - *Initial investment is a stagnating force* - *Developer concerns about property value* - *Carrying capacity of buildings is difficult and expensive to increase* - *Carrying capacities of roofs are not equal throughout roof space* - Market usually delivers homogeneous solutions while retrofits would do best with varied solutions	- *Actor network can be expanded to consultants and landscape gardeners* - *Prices have declined substantially in recent years* - *Study of the economic impact of investment in green vs grey infrastructure for stormwater management* - *Clusters support commercialization of innovative ideas by combining force of companies that individually they would not be able to achieve alone*

Table 11 - Economic challenges and opportunities in green infrastructure development in Norway as was identified in the focus group

Society	
Challenges	Opportunities
- *Values mostly viewed in economic terms* - *Lack of good demonstration pilots* - *Current green roofs are being built with limited purposes* - *Research will likely continue focus on retention and stormwater management, and is less likely to develop for other important social values* - *Too broad of research oversimplifying green infrastructure, urban ecology, and urban ecosystems will not provide necessary concrete results* - *Lack of knowledge among planners, consultants, engineers leads to greater perceived risks than real risks* - Lack of regulatory instruments¨ - Lack of research and testing damping innovation development - The actors that would benefit most from research are fragmented and unable to gather resources needed for long-term - A challenge for a cluster may be in gaining critical mass due to the distances between stakeholders in Norway. - Norway is in the green infrastructure development phase where project failures can dampen interest	- *Dissemination of knowledge and awareness* - *Probably a large and unrealized willingness to conduct necessary research* - *Norwegian standard is being developed for extensive green roofs, which will be followed by at least two other standards for semi-intensive roofs and 'roof gardens'.* - *Coordination of stakeholders for obtaining funding for research and projects from Norwegian Research council* - Video conferences can address the critical mass issue between geographically separated stakeholders - Development will create need for innovations - Timing - Ample focus on green roofs, but city planners should switch focus to larger picture of 'blue-green city' in which green roofs have a role

Table 12 - Societal challenges and opportunities in green infrastructure development in Norway as was identified in the focus group

Additionally, several questions were generated during the focus group. They included:

- What green elements in inhabited areas should be covered by research on green infrastructure?
- Is a Norwegian research strategy needed for green infrastructure, one that covers the whole value of the image of green infrastructure?
- There is a significant potential for innovation in terms of new combinations of substrate, plants, and technical bases for green roofs, but is this the kind of innovation that Innovation Norway or other public sector would sponsor? Can independent, voluntary initiatives create the same force?
- If property developers have concerns about property values with green infrastructure, are the financial institutions accurately valuing the properties?

There was not a critical mass achieved with the meeting to promptly start a cluster but considerations were made for future development. Following the meeting, the cluster initiators and NFGT explored the possibility of applying to host the 2016 World Green Infrastructure Congress, alongside Oslo's hopeful win of the 2016 European Green Capital. Ultimately, neither was successful. There was not enough time to apply by the WGIC October deadline and Oslo did not win to host the European Green Capital.

Survey

Though the public was on the periphery of the discussions with stakeholders, they are the important consumer group to consider for future development. Results from the study indicated that the public would like a wider range of uses based on the ways that they would optimally use green roof space. One comment from the survey summarized the enthusiasm that the public had towards the study, as was supported by participant observations.

> *"I am a grandmother and so happy that the young folks today are interested in growing plants in the city. I have always believed plants make our lives a better place. In Norwegian I could explain better. We are nothing without plants."*

Of the 50 respondents, 40 live in Oslo and were considered in the results. The top reasons for building or using a green roof were polled, reflecting commonly recognized benefits. Environmental benefits, urban agriculture, and relaxation and leisure were the top three results. Other reasons given by participants included dreams of growing plants on roofs, prettier cities, and health reasons (more sunlight for people and plants). Results are show in Fig. 17. The reasons for participating in urban agriculture were also polled to connect any similarities, as well as the availability of garden space for them in the city. Reasons listed in the survey were also commonly recognized values of urban agriculture. The top three results of the reasons for participating in urban agriculture were for growing organic foods, hobby and leisure, and the connection to food and nature, as shown in Fig. 18. Other reasons given by participants include the joy of picking what you eat, importance of self-sufficiency since the future is unforeseen, and avoiding food waste by not buying in bulk from stores.

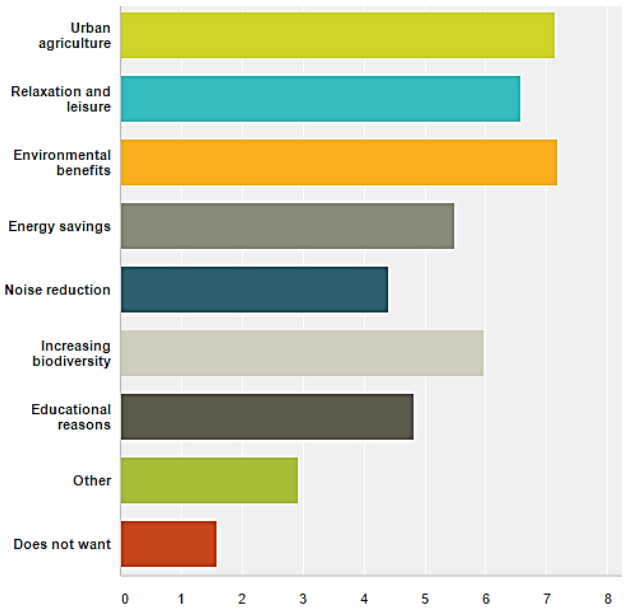

Figure 17 - Reasons for Oslo residents to have or use green roof space

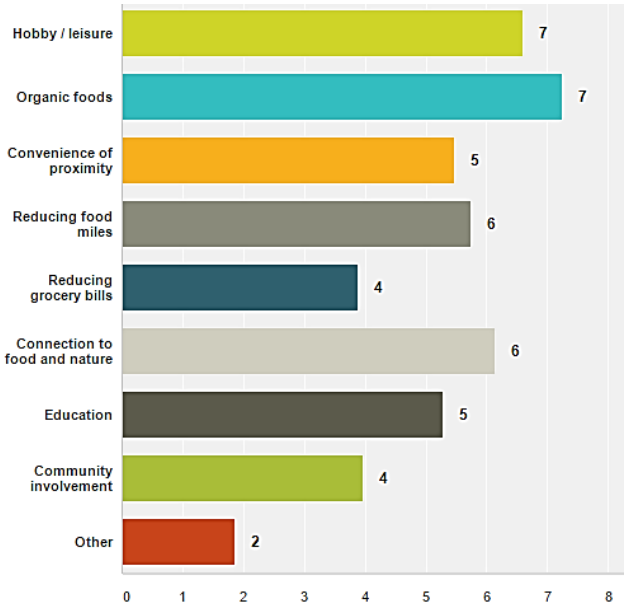

Figure 18 - Reasons for Oslo residents to participate in urban agriculture

- 68% of participants said that they already have a space for urban agriculture in Oslo.
- Of those surveyed, only one person that did not already have a space distinctly said that they would not like to have one.
- 92% of respondents are interested in using a green roof space for urban agriculture.

CHAPTER FOUR: DISCUSSION

What is the current situation of green roof development in Oslo?

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Seven main themes were present consistently throughout the research collection. They include money (section 4.1), research and knowledge (section 4.2), demonstrations and information dissemination (section 4.3), interdisciplinary interactions (section 4.4), climate (section 4.5), regulations (section 4.6), and multi-perspective issues (section 4.7). These themes will be discussed in terms of their impact on the local, internal situation as well as in regards to the external system with which Oslo interacts. On overview of the current system can be seen in Fig. 19, displaying barriers, fragmented actors, knowledge and information generation isolated from the collective whole, and an ideal future situation which incorporates sustainable ecological, economic, and social perspectives that are both beneficial to the internal Oslo system and the greater environment.

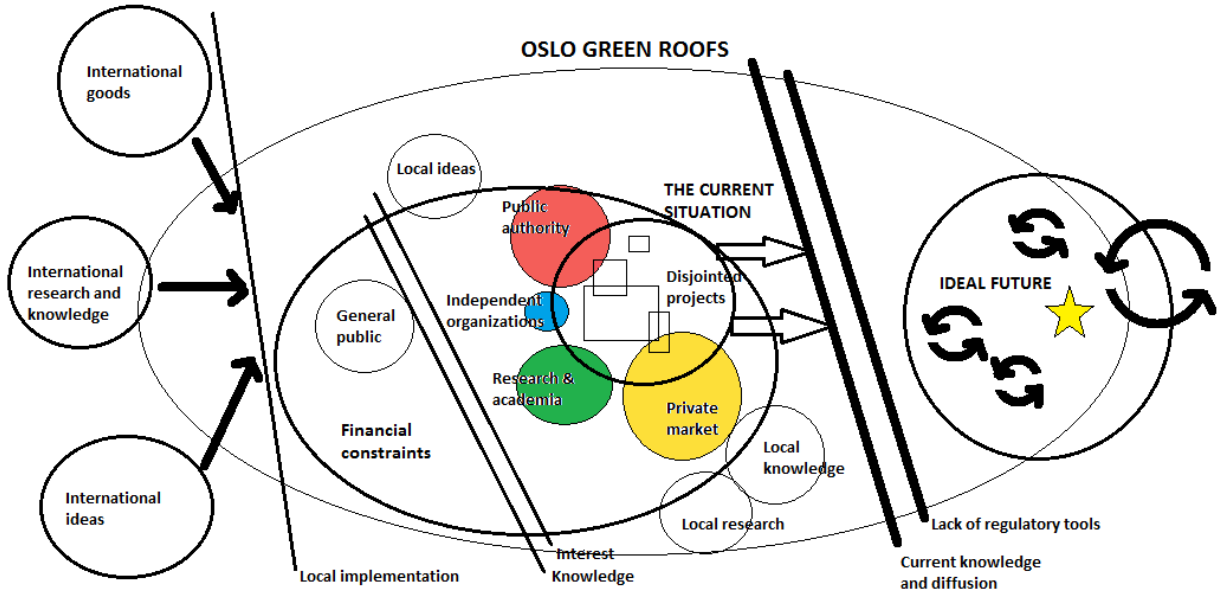

Figure 19 - The current situation of green roof development in Oslo including human and non-human actors. Depicts the biggest barriers to achieving a sustainable future situation.

4.1 Money

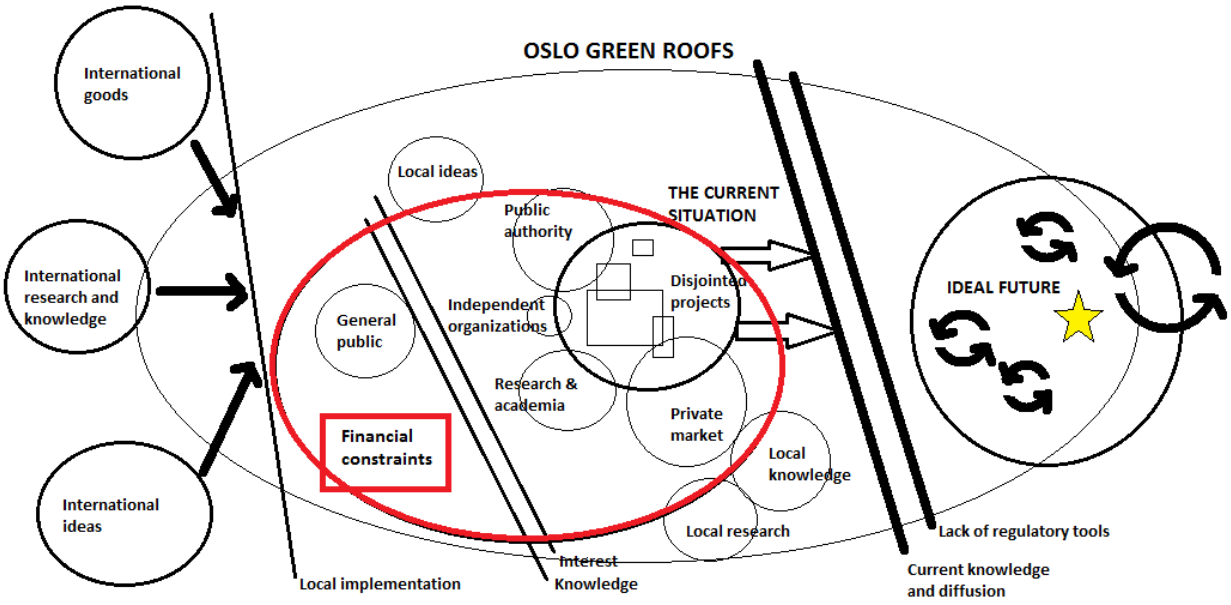

Figure 20 - The effects of money on the Oslo green roof development situation. Red marks key problem areas.

Green roof development in Norway is slow and limited, particularly compared to Scandinavia and the rest of Europe. One of the biggest overarching reasons is due to money, as shown in Fig. 20. Six of the eight stakeholders discussed it as a significant factor in the current system and it was widely discussed in the focus group. Naturally, money drives the private market, the stakeholder group with the most widespread knowledgeability. The Norwegian market focuses on traditional turf roofs, not modern green infrastructure possibilities. Traditional roofs are a well-understood element and not designed to have the same impact as other green roofs with more technical components. Retrofitting existing buildings can be expensive. High initial investment costs of more complex green roof and green infrastructure systems are difficult to overcome, though it is increasingly just a perception (Morten, interview; focus group). The valuation of green roofs is very focused on the economy, not truthfully reflecting societal or ecological value. Property developers are wary of the financial rewards for their buildings due to this valuation system. Financial institutes are at fault, though not solely responsible due to the lack of available information. But obtaining funding to overcome these obstacles is very difficult today (Erik, interview). Money drives the system and the funding opportunities do not necessarily match the research or societal needs.

> *"Money first, quality second." (Erik)*

> *"There is no funding through the Kommune." (Einar)*

> *"Money rules." (Morten)*

But there can be significant economic benefits. While it is possible to try and isolate this one systemic factor, it is challenging to do so in reality. This is illustrated by two examples:

- H&M property owner Aspelin Ramm loves the green roof at their distribution center. It saved them 350,000 NOK by not requiring an underground overflow system.
- Aspelin Ramm sees noticeable energy savings at their Alna Senter green roof. (Morten)

Not requiring an underground overflow system insinuates better water management practices through the use of green infrastructure, impacting the health of urban water ecology. Energy savings equate to a lower use of electricity, which equates to lower fossil fuel use in locations where energy does not come from renewable resources. Part of the problem with the economic valuation system is that it does not make this sort of information widely available to potential users. This provides a significant barrier to the entire green roof development system.

4.2 Research and knowledge

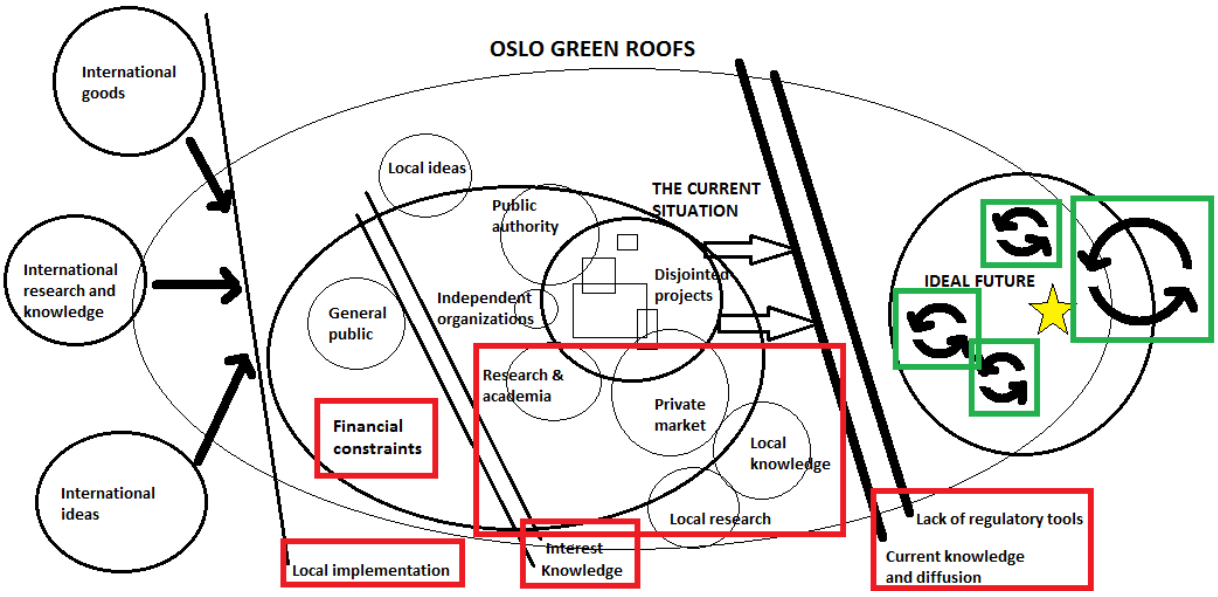

Figure 21 - The effects of research and knowledge on the Oslo green roof situation. Red marks key problem areas. Green marks major positive effects.

Research and knowledge is extremely important to the success of green roof development in Oslo, as shown in Fig. 21, and as recognized in agroecology's application as a science. This was unanimously agreed upon by stakeholders. There are significant gaps in knowledge and research, particularly in relation to the local adaptation of international information but highlighted by the limited amount of locally produced reports. Bjørvika's Barcode district exhibited this due to unexpected wind conditions and the unrealized consequences of soil saturation and water retention. Still, in the case of the Barcode District, the property developer was very excited about using green roofs even with an incomplete understanding of them based on the eco-friendly values (Morten, interview). Even among the stakeholders interviewed, several acknowledged that despite their interest in the topic of green roofs in the city, citing different reasons like urban agriculture and landscape design, they did not have much knowledge or input to give. But even if they were limited in their contributions, they were enthusiastic towards contributing to this study's research on the issue.

As acknowledged, one of the greatest barriers to research and knowledge is the availability of funding for projects. The theme most focused on by the public authority is the effects of green roofs on stormwater attenuation and control, which is the bulk of the local projects to today. It is hard for other stakeholder groups to gather funds to create their own projects, though not impossible. For example, Bioforsk restructured its departments in the fall of 2014 to include an 'urban greening' sector, reflecting trends in funding opportunities, though currently there is not an extensive focus on green roof research in private institutes (Erik, interview). Nittedal Torvindustri contributes to local research projects (Busklein, 2010).

The focus on stormwater control, though justified by Oslo's problems with flooding, creates very narrow boundaries for development.

"Stormwater collection is just a small piece of the future." (David B.)

If a focus continues on this specific ecological value, a wide range of easily identifiable applications of green roofs may be largely ignored and discussed more thoroughly in Section 4.7.

"It is important to have better knowledge about plant biology." (Siv)

"Education and knowledge is lacking in quality for urban agriculture on rooftops."
"There are many opportunities for green roofs when you open your perspectives." (Joner)

- Red and black-listed species research (Einar, interview)
- Pollution control for Oslo's smoggy winter (Ingrid, interview)

There are several different approaches to encourage stronger research and knowledge development, which will be discussed in Section 4.4. But one simple way is to enlist the help of students, requiring a minimal amount of financial resources and potentially giving fresh and innovative insights (Ingrid, interview).

One significant point to illustrate from Fig. 21 is that the majority of the knowledge lies in the technocracy. The private industry suppliers and the researchers have the majority of the knowledge, making it more complex for the bureaucrats and general public to access both in terms of physical availability and linguistically. Their influence on the development of green roofs is strong, as was evident in the stakeholder analysis. These are important points to address in green roofs' sustainable urban development.

Though like the effects of money on the system, knowledge impacts every portion as well. But, the largest impacts that knowledge will have on the overall outcome of the system is the movement of relatively separate subsystems into the successful conglomeration that unites ecological, economic, and social integrity within the local system and contributes positively to the greater system environment.

4.3 Demonstrations and information dissemination

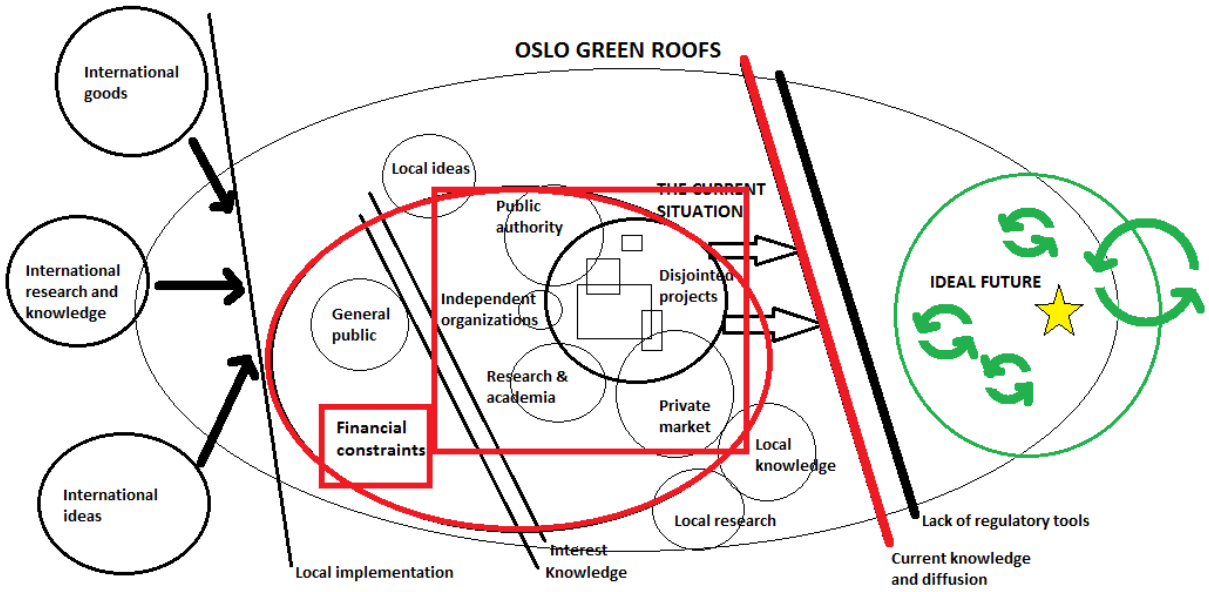

Figure 22 - The effect of demonstrations and information dissemination on the situation of Oslo green roof development. Red marks key problem areas. Green marks major positive effects.

Adequate demonstrations and examples can have an equally strong role in the progress of green roof development as research, as is illustrated in Fig. 22. Demonstrations reflect the second agroecological cornerstone of practice. They build upon the understanding of green roofs in the Oslo environment, thereby reducing the negative effects of using international goods and research. There are several examples of demonstrations in Oslo, as noted in the projects descriptions, but they all experienced some sort of mishap in their application. Green roof plans were reduced or removed at Strømsveien 102, Alna Senter, Oslo City hall, and Sagene; weather-related problems at Bjørvika; and there are further concerns from public authorities on sedum survivability in the Oslo climate (Einar, Bent interview). Oslo is in a phase where problems or failures with projects dampen the interest of developers and this is part of why there are more plans being made than realized. This loops back to the interaction of demonstrations with research and funding, because funding issues make it hard to install research or demonstration examples but conversely the lack of green roof prevalence in the city results in this limited interest in funding projects.

Demonstrations present the opportunity to address the syntax of research reports by spreading information in way that is more receptive to non-technocrats. To facilitate widespread development, the entire urban population needs to be considered in a plan. Reaching the part of the social system that does not benefit from technical or industrial information requires a plan of vertical information distribution among the different hierarchies in an audience – from scientists and industry to the public authority and general public (Rogers, 2008). Since the subsystem of this study focuses on the four main stakeholder groups, horizontal or peer-to-peer information diffusion is adequate for the moment, but will require expansion as the field develops. This spread of information via demonstrations is an appropriate way to address the multi-perspective values of green roofs on a city.

While there is a recognized lack of demonstration examples among stakeholders from the study, the ones that exist generate ample interest. There have been more than ten front page news articles about green roofs since the City of Oslo released their will of creating a green roof strategy in 2013. The employee formerly in charge of writing the Oslo green roof strategy was optimistic about the prospects of green roof development in Oslo based off of the media attention generated by Strømsveien 102 as a the first City of Oslo demonstration site. Tours were led three to four times per week and included a diverse group of people like students, national groups, and other agencies and many phone call inquiries were received (Einar, interview). The public authority is interested in both the sharing and generation of knowledge as much as possible.

"Strømsveien 102 should provide a big step forward." (Einar)

Whereas there is not a large amount of green roofs in Oslo, the ones that do exist are fulfilling Gladwell's second DOI step. Still, the limitations of both research and demonstration harm the ability to progress through each step.

1) Influential early adopters or champions are necessary,
2) It needs to have a quality that people find compelling,
3) It needs to fit into the broader physical and social environment.

While knowledge diffusion is essential for innovation uptake, there were conflicting views about information sharing in Oslo:

"Spreading info is the key to success, but people harbor too much individually." (Morten, private market)

"People are fairly generous with information." (David B., independent organization)

This has deeper seeded roots in the actor network, as will be discussed in the following section, but it is interesting to see the disparities between the views on information sharing from the private market in comparison to an independent stakeholder. There have been a variety of projects that involved interdisciplinary interaction (Busklein, 2010; MAJOBO, 2014; Noreng et al., 2012), but is there may still be reservations.

4.4 Interdisciplinary interactions

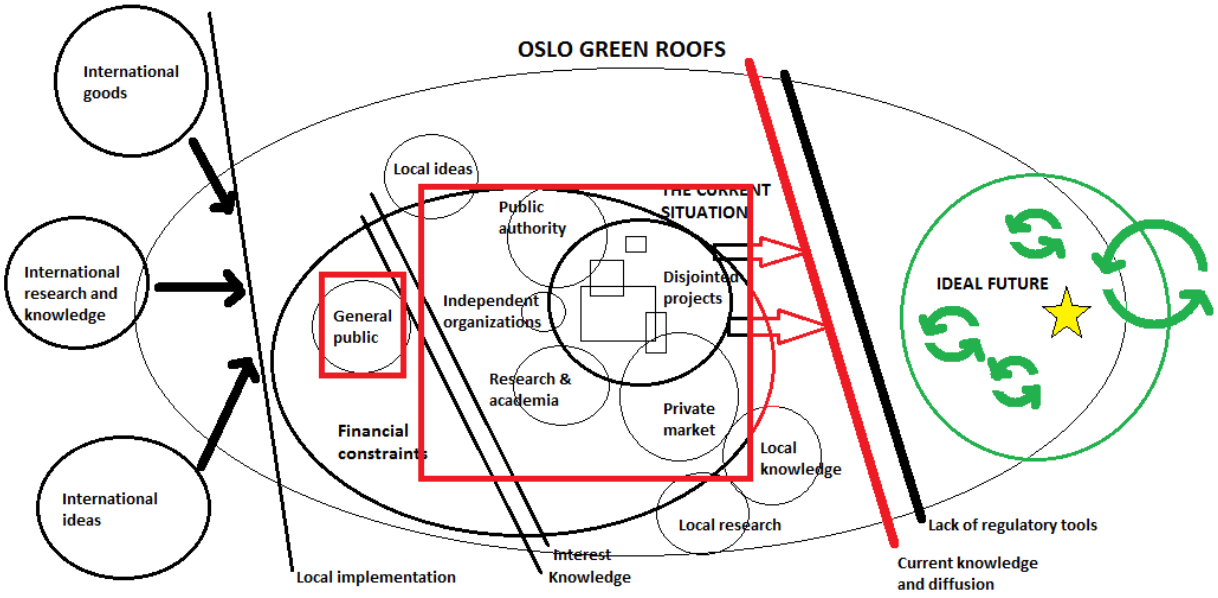

Figure 23 - The effect of stakeholders on the situation of Oslo green roof development. Red marks key problem areas. Green marks major positive effects.

Four major groups comprised the stakeholders – public authority, private market, independent organizations, and research and academia. Each have different goals in developing the green roof situation of Oslo. Combining their efforts is needed to achieve the ideal future situation of multi-purpose, multi-perspective implementation in sustainable urban development, as shown in Fig. 23. The groups holding the most influence – including power and interest – were identified in the stakeholder analysis. The 'players' were Bymiljøetaten, NVE, Nittedal Torvindustri, Vital Vekst, Bioforsk, SINTEF, and NMBU. Three different stakeholder groups were present here, which was reinforced by their collaboration on projects and studies.

A noteworthy point to make in this analysis is that the public authorities and research institutes are large organizations that have wide-ranging objectives. This makes them both powerful and ideal to contribute to improving the green roof situation due to their ability to supply resources as well as weak in their diverse array of focuses. But, in accordance with DOI, champion stakeholders are necessary to elevate an innovation's uptake. In spite of their wide interests, there is at least one champion stakeholder present that is willing to work for the cause of increasing Oslo's green roof development. In the case of NMBU, the influence lies in the hands of students. The private industry contributes most by providing their professional expertise to the policymakers through standardizations and project support. Public authorities ultimately are widely recognized as being a common driving force for the uptake of green roof technologies (L. J. Whittinghill & D. B. Rowe, 2012). This 'player' stakeholder category will be most responsible for organizing action in change.

One of the best groups to target for increasing development is the context setters, or those with high power but low interest. In the study, the context setters were VAV, the politicians, the City of Bærum, Standard Norway, and MAJOBO. VAV is in charge of supplying Oslo with safe drinking water and waste

management, with a natural connection to the water cycle impacts of green roofs. Though the City of Bærum is not Oslo, it is connected in many ways, one being because of their participation in the Framtidens Byer green roof project that funded Strømsveien 102 and another being the prominence of a champion green roof stakeholder in their municipal authority. Inter-municipal networking is valuable to generating better and more applicable research and demonstrations. Standard Norway is in charge of developing guidelines for green roofs, an important factor in development as will be discussed in Section 4.6. It was interesting to see MAJOBO placed in this location since they are an independent, mainly volunteer-driven network, but they bring the important ecological and social dimension to the situation. As well, three of the stakeholders interviewed participate on the board of MAJOBO, highlighting the depth of interdisciplinary interactions and interest.

The last context setter group is the politicians. Politicians were routinely remarked upon for their powerful but superficial interest in green roofs. They are not a part of the technocracy and do not seem to be aware and/or care about technical details like research.

> *"Politicians are in charge of making the rules and creating incentives to get green roofs established. Politicians are not asking industry for advice." (Morten)*

> *"One of most important factors is for high level politicians to have an interest in green roofs. If they think that it is fun and cool, that is when there is more focus on the issue."*
> *"Research should come before policy, but it is kind of a hen and egg situation."(David B.)*

> *"We need one more year for research [for making a good strategy]" (Bent)*

> *"Politicians really want a policy, but they are not so into details like getting enough research beforehand."*
> *"The Kommune is already struggling in developing a policy because there is not enough research for the policymaking."*
> *"Politicians really want green roofs on all roofs but laws and regulations need to be placed first." (Einar)*

This is a threatening force, one that risks compromising the benefits of green roofs due to personal political agendas.

The next ideal target group are the subjects with high interest but low power. Subjects include VegTech, ZinCo, Bergknapp, the business and research cluster, Hallingtorv, Naturtorv, and COWI. This group is comprised almost entirely of private industry (COWI is private and independent), and the remaining organization has the intentions of uniting fragmented actors to support the Norwegian green infrastructure market. The most effective way to target this group is by doing precisely what the cluster attempted to do – address their interests so they are motivated to collaboratively create positive change. This was referenced during a several interviews as in ideal step to pursue, though difficult. One upside to this possibility is that there is an extensive network of cooperation between stakeholders and many know each other well personally due to the limited amount of stakeholders and minor networks in Norway like NFGT, as well as much larger existing networks to provide support and information internationally.

> *"Clusters of people make a difference." (Morten)*

"Putting together all stakeholders in the same project won't happen by itself." (Erik)

"There is an insufficient model of cooperation now […] that is close to pathetic." (David B.)

As discussed in the focus group, those that would benefit most from research are the fragmented actors that have not been able to create projects. This applies to suppliers, municipalities, research and educational institutes, insurance companies, etc. As mentioned, there may be deeper issues to Erik's comment than just a lack of effort. This circles back to the power of money in the development of green roofs. Within industry, people are territorial (Morten, interview), which affects their involvement in improving the situation collectively as well as in sharing information freely. This reinforces the idea that industry may be the limiting factor for development. Ultimately, even the focus group, despite the enthusiasm surrounding it, was unable to achieve a critical mass from industry to officially begin, perhaps reflective of this point as well.

A multi-perspective, interdisciplinary cluster would benefit development by uniting fragmented actors to address common challenges and collectively improve the overall situation. But, it requires time to set up such a network. Both the City of Oslo and this cluster missed an opportunity to host large events that would attract widespread attention in 2016, something that could have significantly propelled the development of green roofs in the city. For now, multi-perspective contributions in a cluster or in open discussions about green roof development are important. More importantly, knowledge spread between both vertical (bottom-up or top-down) and horizontal (peer-to-peer) hierarchies will facilitate green roof development uptake. This will be especially true for the general public, which currently has a limited role in the development of green roofs in Oslo, despite being the main consumer. Their interests need to be taken into consideration as well. Cumulatively, efforts in improving research, demonstrations, and interdisciplinary relationships will expand the amount of Oslo stakeholders present and transition from being Oslo as having innovators to having early adopters, as seen in Fig. 24 (Rogers, 2008).

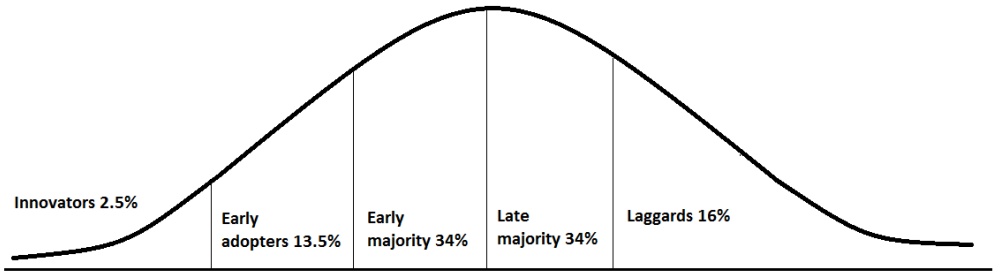

Figure 24 – Adapted model of innovation diffusion (Rogers, 2008)

Some of the biggest successes and advancements for green roofs in Oslo were from personal initiatives. A 2013 conference on green roofs was led by the motivations of David B., working for the City of Oslo and with the Green Party. It attracted international experts and was considered a success, though minimal follow-up has happened since, besides the announcement of preparing for a city policy (David B., interview). Another stakeholder, Bent, took the initiative to conduct research on his personal green roof at home to be proactive about solution finding (Braskerud, 2014). Bent also, while sponsored by the state,

made a web page with different solutions of for the Cities of the Future objectives (Einar, interview). Representing the private industry, Nittedal Torvindustri has funded research projects independently (Busklein, 2010) as well. It is important to not underestimate the power of the individual in such a complex problem

4.5 Climate

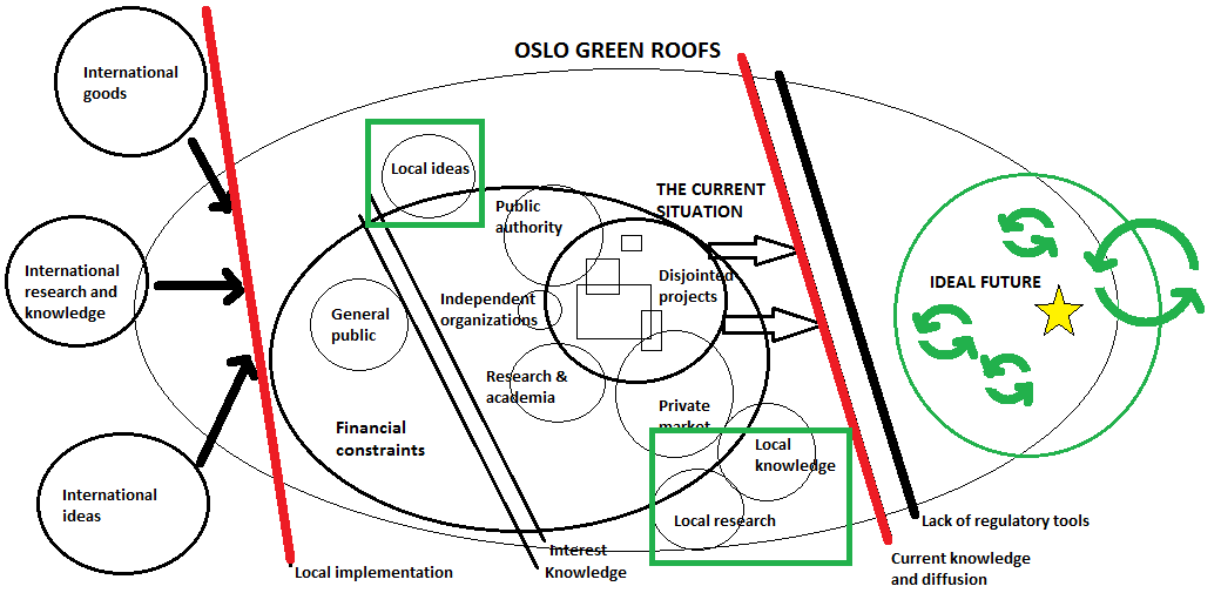

Figure 25 - The effect of climate on the situation of Oslo green roof development. Red marks key problem areas. Green marks major positive effects.

Norway has a challenging climate and its relationship with green roofs is not well understood, as discussed. It is a problem both at the receiving end of international information as well as creating adequate local research, as shown in Fig. 25. Whereas the major challenges of climate have been previously discussed, commentary of opportunities for research will be addressed here. Oslo has highly variable weather conditions, from extremely heavy rain, prolonged droughts, high wind gusts, and freeze-thaw cycles. This presents numerous opportunities for Oslo, but is currently limited due to the narrow scope of the current homogeneous roof designs. Stormwater runoff control is the focus of the City of Oslo, which is appropriate and timely given the current struggles with flooding and predicted worsening of rainfall event intensity. In this regard, green roofs are most beneficial to areas that contain streams that are now covered, which are likely to flood.

Norway has a strong history of climate research, which is something that green roofs can contribute to. Creative solutions are needed to address not just Oslo's increasing urbanization and urban densification, but for the rest of the world as well. Local research not only improves the ecological integrity of the immediate area, but can impact global systems as well. Green roofs can sequester carbon to mitigate climate change, though not in substantial amounts presently. Green roofs also provide a space for urban agriculture, lessening the dependence on external food inputs and reducing transport fossil fuel use.

4.6 Regulations

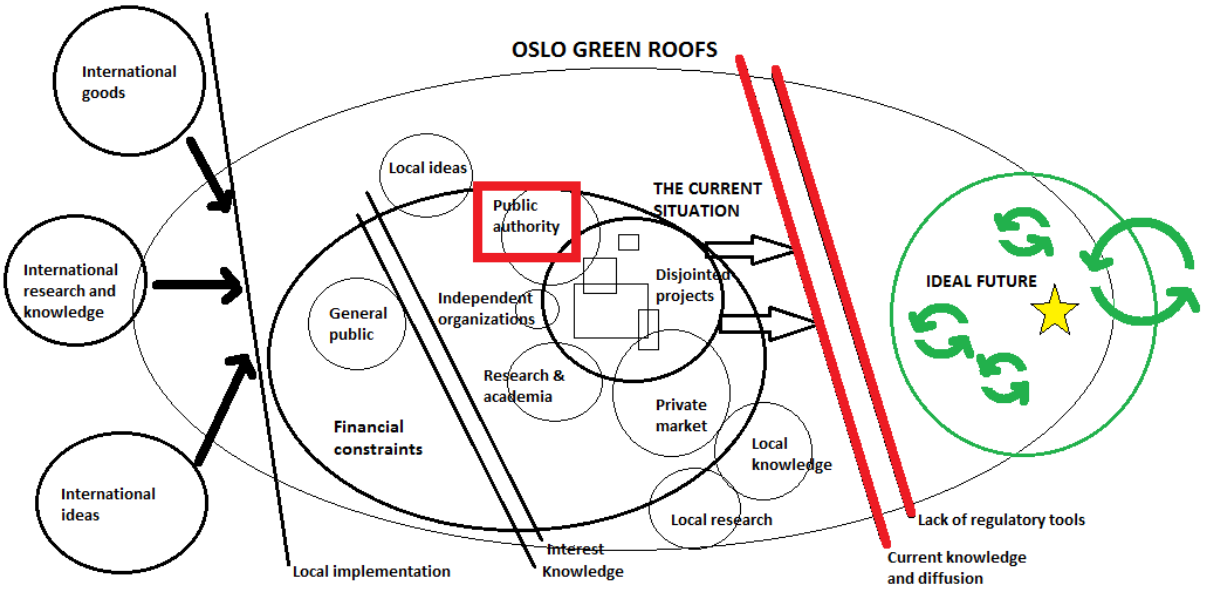

Figure 26 - The effect of regulations on the situation of Oslo green roof development. Red marks key problem areas. Green marks major positive effects.

"Requirements for new buildings would be a good step forward." (Erik)

Another large challenge is the lack of regulations about green roofs, coming in the form of policies, strategies, protocols, or guidelines, as shown in Fig. 26. Policy or strategy is often a driving force for development and research, per examples from North America (Leigh J Whittinghill & D Bradley Rowe, 2012). Protocols and guidelines are necessary for technical components (Bent, interview). Green roofs struggle not only because of the Norwegian climate, but also because they frequently use materials that come from international sources, are not well adapted, and do not follow any uniform guides for construction. This is the critical junction between appropriate knowledge and application, and was listed as significant barrier in achieving the ideal future situation by stakeholders. Currently, Standard Norway is addressing this by creating technical protocols for extensive green roofs with plans for developing standards for semi-intensive green roofs and roof gardens in the future (David B., interview), but the public authority has the main responsibility for this theme. Both standardizations and policies are need for green roof development in Oslo, and it is recommended to have a committee of the public authority specifically governing the application and control of such regulatory tools.

Stakeholders gave ideas about possible opportunities. The blue-green factor, a tool developed in Germany, gives a scoring system to a landscape based on the amount of blue-green infrastructure on the property. This scoring system can be used for taxes on storm and/or household wastewater effluent (Bent, interview). The idea of using Copenhagen as a model was referenced as well. Two stakeholders cited Copenhagen as typically being about five years ahead of Oslo, and it began its policy in 2010 (David B., Einar, interviews). This places Oslo on track for starting a policy in the next year. In Einar's interview, he said that whereas Copenhagen has a city-wide policy requiring a green roof on any new building's roof if

its slope is less than 30 degrees, Oslo will likely have targeted areas that are more problematic, such as Grunnerløka.

4.7 Multi-perspective issues

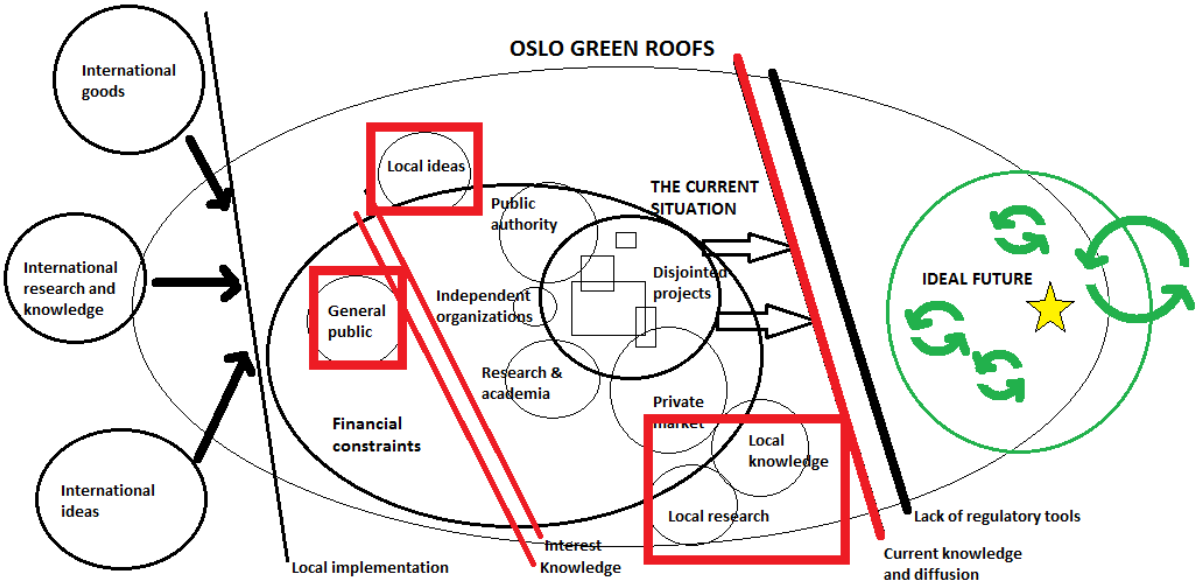

Figure 27 - The effect of multi-perspective issues on the situation of Oslo green roof development. Red marks key problem areas. Green marks major positive effects.

The concentration on the economical aspect of green roofs in the present green roof situation undermines the opportunities in ecology and society, as shown in Fig. 27. Another challenge in embracing the multi-dimensionality of green roofs is that most of the green roofs discussed in this study and present in Oslo use a standard, homogenous, sedum-based green roof model. The remaining green roofs are typically in the traditional turf roof style. Though both styles of green roof are useful in many ways, they do not necessarily optimize multi-perspective values. Including multi-perspective values and diversifying the roofs' purposes were regularly cited as important paths to pursue for future development. But in today's slow development in Oslo, these opportunities are not the reality.

> *"Turf roofs are what Norway is used to." (Morten, interview)*

> *"There is a minimal amount of work being done in the city, it is close to pathetic." (David B., interview)*

> *"Norwegians have a romanticism of turf roofs." (Morten)*

This romanticism was mentioned multiple times during interviews and the general public's resistance to change created a barrier that stakeholders felt was a significant. Part of this can be attributed to the knowledgeability of the public, but part also due to the Norwegian concept of Jante Law, where it is taboo to stand out (David B., interview).

> *"People that are negative towards green roofs tend to have uninformed opinions." (Morten)*

"The idea that a green roof can be modern is very new." (David B.)

Clearly, there is some disconnect present. One opportunity to close the gap is to involve the community. Currently, much of the information and knowledge is held by technocrats and the public authority is responsible for creating ideas about local change. Getting the general public involved in these aspects could benefit from a stronger focus on the socio-ecological aspects of green roofs. There is a growing interest in green roofs in the local media (Kjersti F Eriksen, 2013; Kjersti Flugstad Eriksen, 2013) and from foreign influence (Copenhagen, 2010). Referencing the survey, respondents were most likely to use a green roof for environmental benefits, urban agriculture, and relaxation and leisure. To contrast this, one stakeholder polled the property owners that participated in a green roof research project that she took part in to uncover their reasons for installing their green roof. Some of her project participants cited stormwater reasons, but some gave no reasons whatsoever (Ingrid, interview). This last piece raises an interesting question – why do people choose to install a green roof if that have no particular reason for doing so?

Connecting the community and general public by urban agriculture is a debatable solution. Urban agriculture is feasible on roof tops in Oslo. Crop choices would be limited due to climate, but Oslo is located in the region with the most agricultural productivity (Flaten & Hisano, 2001) due to sufficient rainfall, favorable light conditions, and cool temperatures that moderate plant pests and diseases (Knutsen, 2007). Urban agriculture is growing in popularity in Oslo, and there are long waiting lists to get space in an urban garden. For example, at Herligheten in Bjørvika, 3,790 people applied for 100 plots last year (Hovind, 2013). Despite the limits of ground space, urban agriculture is not yet common on local roofs and there are very few examples in the city. These limited examples come with a caveat:

"Urban agriculture – are people aware of the work it takes?" (Erik)

"Most people that are interested in urban agriculture on roofs are social scientists, not biologists, and have a limited knowledge of agriculture." (Siv)

There are a few examples of local studies supporting green roofs and urban agriculture, including student theses, municipal, and independent studies (Bymiljøetaten, 2014; Dæhlen & Ortiz, 2013; Falck-Pedersen, 2012; Van der Horst, 2013). The results of the survey were in favor of urban agriculture combined with green roofs. There is a bias from within the study group, since they are people already interested in urban agriculture through MAJOBO. Still, there are long waiting lists for community garden spaces in Oslo that imply that more space is needed, such as roof tops. Oslo residents, according to the survey, have similar valuations for green roof use and urban agriculture use with a heavy emphasis on recreation. Results also reflected conscientiousness in ecological awareness and food choices. Creating enjoyable spaces for the public on rooftops is an optimal approach to encourage their participation.

The overall results on the topic of urban agriculture in the study are mixed. While stakeholders generally expressed some sort of guarded enthusiasm for it and media focus has generated interest from the general public, one stakeholder had a different story to tell regarding interest. He is involved in the URBACT sustainable food systems project and gave a presentation about urban agriculture on green roofs at a meeting called 'Business leaders for climate solutions.' Around 30 people were present, only half of which seemed very interested, 20% with seemingly no interest that were on their phones during the presentation, and older people 'with their mouths wide open.' (David D., interview).

It is unlikely that Oslo is adequately prepared to support widespread rooftop urban agriculture due to the deficit of research and experience, but it should not be removed from planning. Residents and stakeholders both see more diverse possibilities to using green roofs besides stormwater runoff. These sorts of alternate uses make green roofs more appealing and encourages the scaling-out, not up, of development. Scaling-out development with diverse uses encourages ways to find solutions to current challenges rather than simply increasing the amount of current, limited green roofs and increasing the magnitude of their existing problems. Numerous other ways of building the multi-perspective, multi-functionality of green roofs were given, besides urban agriculture, to achieve an ideal future:

- Soil projects for increasing sustainability
- Red-list species awareness
- Educational promotion of sustainability objectives, localism
- Combining with hybrid solutions for urban water management such as flooding roads, swales, rain gardens
- Local composting initiatives
- Experiments with substrate and plant combinations
- Food production
- Green walls
- Unforeseen opportunities
- Urban aesthetics and air quality
- Wastewater treatment
- Biochar
- Sundecks
- Rainwater harvest
- Pollution control
- Biodiversity
- Art exhibits

4.8 How can this knowledge help to facilitate green roof development?

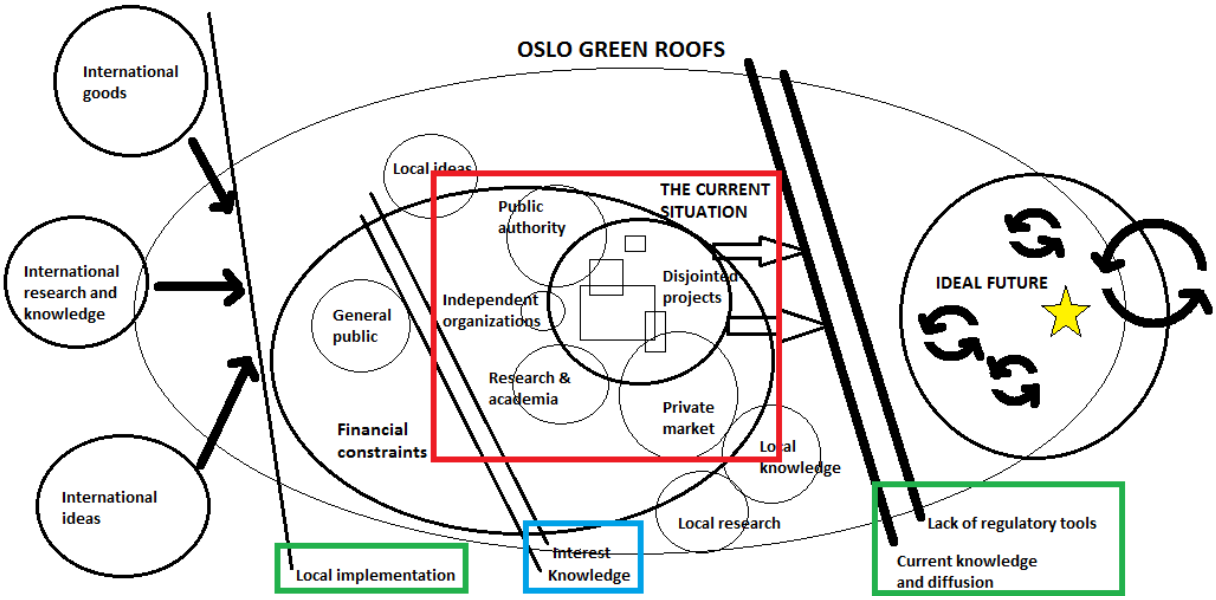

Figure 28 - The current situation of green roof development in Oslo. Red indicates DOI step 1, blue indicates DOI step 2, green indicates DOI step 3.

The preceding information about current challenges and opportunities can be useful for the creation of a green roof strategy as well as the development of green roofs in Oslo as a whole. One way to use the far ranging information from the study is in the context of DOI theory. As shown in Fig. 28,

1) Influential early adopters or champions are necessary and can be identified as key stakeholders within the public authority, independent organizations, research and academia, and the private market.
2) It needs to have a quality that people find compelling, which can be achieved by breaking down the barrier separating funding opportunities and the general public from impacting the current situation. This is done through knowledge dissemination and increasing interest.
3) It needs to fit into the broader physical and social environment, which is achieved through policy measures, technical standards, and further research and experimentation.

Applying this information to the following considerations for strategy development will create an optimal plan for the future.

Considerations for a green roof policy

Policies can be designed for the national, municipal, and community levels and can be realized in the following ways (T. Carter & Fowler, 2008):

- Regulations
- Financial incentives
    - Direct financial incentives, such as subsidies for new installations
    - Indirect incentives, such as density bonuses

- Funding of demonstration or research projects
- Technology standards, such as building code requirements
- Performance standards, such as on-site stormwater retention
- Build demonstration projects and institutionalize a commitment greening roofs on publicly-owned buildings to best educate others and gain necessary experience

Policy type	Pros	Cons
Direct financial incentives	Provide building owners compensation for initial costs	Subsidy programs exist for limited years
Indirect financial incentives and performance standards	Voluntary and favors those who can install green roofs in a cost-effective manner	Difficult to guarantee at the installation
Mandates	Best to ensure roof greening	Likely to be unpopular
Technology standard	Ensures better quality	Can stifles innovation with rigid criteria

Table 13 – Advantages and disadvantages of policies (T. Carter & Fowler, 2008)

There will be advantages and disadvantages to all styles of policies, but specific criteria should be addressed, regardless of the policy. At least one environmental concern should be identified to ensure political uptake, like stormwater runoff control or climate change adaptations. There should be well-defined standards for qualifying green roofs. Many countries use Germany's FLL guidelines (Bent, interview). Targeted areas should be identified, like urban drainage areas that have high amounts of rooftop area and/or where flooding is a concern. The public authority should enlist the help of advocacy groups or local individuals to promote the issue. It is vital to not underestimate the power of an individual. And lastly, and institutional authority should be created to oversee green roof program implementation (T. Carter & Fowler, 2008).

Strategies from other cities

Several cities around the world have green roof policies or strategies in place. While the public authority has a prominent role in many of these, as shown in Table 14, it is also possible for other stakeholders to lead the way, such as universities. Many cities have more than one policy or incentive, encouraging scaled-out uptake and development, and several of these cities are prominent examples in the world. Germany leads the way, with around 14% of its total roofs being greened (Kohler & Keeley, 2005), demonstrating the impact of economic incentives. Recently, the Green Party proposed that Oslo should follow Copenhagen in requiring a green roof when there is less than a 30 degree slope. The City of Oslo intends on using Copenhagen as its model, given climatic and demographic similarities (Einar, interview). But unlike Copenhagen, Oslo plans to have specific target areas, not a generalized rule.

Many of these existing strategies are related to new construction, but strategies should also address the costs of retrofits for existing buildings. In Oslo, this can play a large role since building roofs are usually only designed to carry a certain amount of snow weight, and were not intended to have soil and plants as well (Morten, interview).

Location	Year	Policy
Copenhagen	2010	Required on new buildings with a slope of < 30^0
Malmo	2001	Guidelines with minimum standards of Biotope Area Factor (BAF)
Germany		Approx. 50% of German cities offer some form of direct subsidy to building owners. BAF is a common tool.
Berlin	1983 - 1997	Residents reimbursed 50% of green roof construction costs
London	1998	Included in BREEAM rating tool
Linz, Austria	1984	Required on new rooftops >100m2 and <20^0 and on the roof space of all underground structures. 30% of construction costs were covered in 1989, and decreased with time as developers accepted green roofs as a necessity.
Basel, Swizterland	2002	Required on all new buildings with flat roofs >500m2, with additional requirements for substrate composition and depth
Netherlands	2008	Subsidies of 25 to 30 €/m2, with FLL guidelines to be respected
Toronto	2006	When feasible and practical, 50-75% of building roof space should be green for all new city-owned buildings and for existing city-owned buildings as roofs are replaced, $10CDN/m2 rebate for eligible roofs
Washington, D.C.	2013 - 2014	Subsidy of $7/ft2, or up to $10/ft2 in targeted areas
Lansing, Michigan	2000	Ford Motor Company and Michigan State University installed one of the world's largest green roofs, launching various research projects
Portland	2000, 2008	All new city-owned facilities required to include a green roof with 70% coverage unless it is impractical; 'Grey to green' program with direct financial incentives
Chicago	2006	Use of green roofs exempts building owners from reflectance and emittance requirements, $100,000 grant for 20 projects
Minneapolis	2005	100% credit for green roofs that replace impervious surface
PA, NJ, and NC – USA		Green roofs specified as a stormwater best management practice that can be used to meet standards
Seattle	2007	Green area factor to preserve visual qualities

Table 14 - Cities and their green roof policies

Adding to existing policies to encourage development

Green roofs can contribute to Norway and Oslo's wide array of existing plans that support sustainable urban development. Copenhagen used this technique and added green roofs into the city's Wastewater Plan, Climate Plan, Climate Adaptation Plan, and Strategy for Biodiversity (Copenhagen, 2012). The Oslo Bymiljøetaten is currently mapping the city (Kjersti F Eriksen, 2013), which will provide valuable insight to creating or adding to policies.

It is common for cities to not put regulations directly in place, but to create opportunities for development without mandates. This can come in the form of eco-friendly building certifications, like LEED and BREEAM, through schemes like the Green Area Factor, or incentives. Incentives are often attributed to the fastest growth (Whittinghill, 2012). Incentive programs usually run for a certain spans of time, but they ideally help to create a mentality where green roofs are necessary for urban development thereby solidifying their use indefinitely, as was the case in Linz, Austria (Table 14).

Special considerations for the existing private market

Since a green roof market already exists in Oslo, though with a focus on turf roofs, it is important to consider how a strategy or developments will effect the suppliers. Germany experienced a 10% to 15% growth each year in the green roof industry during past ten years (T. Carter & Fowler, 2008). Will Norway be able to handle such a sharp increase? Specifically, will there be sufficient supply, particularly of local and appropriate materials, to meet their needs? Will there be enough labor to meet the demand? Will pending laws and regulations negatively impact the industry? Does the industry have enough education and knowledge about the topic to ensure successful green roof construction if a demand is created? These sorts of questions should be addressed prior to strategy implementation. Possible ways to support the existing market as it transitions include (Bai & Sarkis, 2010):

- Education about environmental health and green roof technology capabilities
- Training for suppliers about consumer and stakeholder expectations
- Provide advice and awareness for the subject
- Give product development advice to suppliers (i.e. processes and project management)
- Develop assessment programs and give feedback
- Joint and team problem solving on issues, like in a cluster
- Open and ongoing communication between private market, public authorities, independent organizations, and research and academia
- Education for financial institutions to accurately value green roofs

CHAPTER FIVE: CONCLUSIONS

As the City of Oslo has identified, the time is right for instituting a green roof policy. A systemic look into the stakeholders, challenges and opportunities identified seven major themes:

1) Money drives the system
2) Research and knowledge is limited and needing local adaptations
3) Demonstrations and information dissemination is limited and needs a plan for expansion
4) Interdisciplinary interaction is extensive, though not optimally effective in achieving an elevated level of green roof development
5) The Norwegian climate introduces both challenges and opportunities for research
6) Regulatory tools will be an effective driving force
7) Last but not least, the multi-perspective values of ecology, economy, and society need to all be considered in development and research projects, despite the focus on ecology

Based on the findings of the study, a requirement of a green roof for both new construction and existing structures in problem areas should be considered. Problem areas should of course include areas prone to flooding, but it should expand to consider other ecological impacts as well like pollution control, biodiversity and migration routes, and green-deficient spaces in the dense urban center. Outside of these areas, opportunities to facilitate innovative projects with multi-perspective dimensions should be created, such as through financial incentives. Standards and enforcing committees should be developed to moderate the quality of green roof construction for all styles of green roofs – extensive, semi-intensive, and intensive. When a policy is administered, a plan for dissemination of information both horizontally and vertically should be in place as well. Networks like NFGT or the cluster would be appropriate to assist with this. A strategy to tackle to current financial paradigm should also be created to give multi-perspective valuations that will be more widely appealing to the public.

Whereas ecology and food security can both have prominent roles in green roof development, a focus on green roofs and urban agriculture for food security in Oslo would be misplaced. There is an insufficient amount of information and examples to promote widespread use and there is not sufficient evidence to support strong interest. Additionally, Oslo does not suffer from a threat to food security, so any interest in urban agriculture should be to promote a more sustainable food system or recreation. This should not deter champions from pioneering the case, as MAJOBO has done, but the role that green roofs have in sustainable urban development that is most significant is in urban ecology and stormwater management. Still, local food production has far-reaching systemic effects if enacted widely and sustainably. It also encourages the scaling-out of development that promotes multi-perspective, multi-scalar, and interdisciplinary benefits.

In future advances in green roof and green infrastructure both in Oslo and abroad, building a strong network to support the local system is critical to ensuring success. Fragmented actors cannot mobilize change and development alone, and it is important to shift the information and power out of the hands of the technocrats and into the wider community.

Still, the dualistic view of modern research for either urban ecology or urban agriculture is limiting. Today's cities have plans that encompass multi-perspective values and multi-level actors (regardless of their actual effectivity) and the strong focus on these two values restricts development. But it is difficult to create a future ideal solution for green roof development, because I think there will be many more creative opportunities for their use in upcoming years. Creating a feasible solution is what can be done for today.

It is important to remember that there is a much, much larger system that green roofs are a small piece of. While the urban environment is an important aspect of today's society, urbanization has global effects that are more alarming than what green roofs can address. In the case of Oslo, its heavy reliance upon imports – from food to electronics to carbon credits – highlights the underlying, fundamental problem in today's globalized, consumer society. Global sustainability depends on addressing these issues. In all the steps that contribute to a more secure world, green roofs count.

Further research

There were several opportunities previously mentioned in this report that warrant research and further exploration. Additionally to those points, the following significant questions were raised during the study:

- How do rural research institutes connect with urban projects?
- What green elements in inhabited areas should be covered by research on green infrastructure?
- Is a Norwegian research strategy needed for green infrastructure, one that covers the whole value of the image of green infrastructure?
- There is a significant potential for innovation in terms of new combinations of substrate, plants, and technical bases for green roofs, but is this the kind of innovation that Innovation Norway or other public sector would sponsor? Can independent, voluntary initiatives create the same force?
- If property developers have concerns about property values with green infrastructure, are the financial institutions accurately valuing the properties?

REFERENCES

Agriculture, M. o. (1999). *White paper on Norwegian agriculture and food production*. Oslo.

Bai, C., & Sarkis, J. (2010). Green supplier development: analytical evaluation using rough set theory. *Journal of Cleaner Production, 18*(12), 1200-1210.

Banting, D., Doshi, H., Li, J., Missios, P., Au, A., Currie, B. A., & Verrati, M. (2005). *Report on the environmental benefits and costs of green roof technology for the city of Toronto*: Ryerson Univ., Department of Architectural Science.

Benedict, M. A., & McMahon, E. T. (2002). Green infrastructure: smart conservation for the 21st century. *Renewable Resources Journal, 20*(3), 12-17.

Bioforsk. (2014). Bioforsk. Retrieved Dec 9, 2014, from http://www.bioforsk.no/ikbViewer/page/bioforsk?p_dimension_id=15006

Bland, W. L., & Bell, M. M. (2007). A holon approach to agroecology. *International Journal of agricultural sustainability, 5*(4), 280-294.

Bloomberg, M. R., & Holloway, C. (2010). *NYC Green Infrastructure Plan - A sustainable strategy for clean waterways*. New York City: Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf.

Braskerud, B. C. (2014). Grønne tak og styrtregn: Effekten av ekstensive tak med sedumvegetasjon for redusert avrenning etter nedbør og snøsmelting i Oslo. In N. v.-o. energidirektorat (Ed.).

Bryson, J. M. (2004). What to do when stakeholders matter: stakeholder identification and analysis techniques. *Public management review, 6*(1), 21-53.

Bugliarello, G. (2006). Urban sustainability: Dilemmas, challenges and paradigms. *Technology in Society, 28*(1), 19-26.

Bureau, U. S. C. (2008). Total midyear population for the world: 1950-2050. Retrieved 28 Sept, 2014, from http://wwww.census.gov/ipc/www/idb/worldpop.html

Busklein, J. O. (2010). *Urbanization - Green roofs in urban areas and field experiments runoff water*. SINTEF.

byer, N. b. (2014). Nettverket blågrønne byer. Retrieved Dec 9, 2014, from http://blagronnebyer.ning.com/

Byggallianse, G. (2014). Mer om Grønn Byggallianse. Retrieved Dec 9, 2014, from http://www.byggalliansen.no/om_gba.html

Bymiljøetaten. (2014). *Landbruk i Oslo: Utkast til byrådssak*.

Carter, J. G. (2011). Climate change adaptation in European cities. *Current opinion in environmental sustainability, 3*(3), 193-198.

Carter, T., & Fowler, L. (2008). Establishing green roof infrastructure through environmental policy instruments. *Environmental management, 42*(1), 151-164.

Carter, T., & Jackson, C. R. (2007). Vegetated roofs for stormwater management at multiple spatial scales. *Landscape and Urban Planning, 80*(1), 84-94.

Cicero. (2009). Fact sheet 7: Consequences of climate change in Norway. Retrieved Sept 8, 2014, from http://www.cicero.uio.no/webnews/index_e.aspx?id=11161

Copenhagen, C. o. (2010). Green roof ambitions in Copenhagen. In Kommunikationssekretariatet (Ed.).

Copenhagen, C. o. (2012). Green Roofs Copenhagen. In D. Rømø (Ed.): The Technical and Environmental Administration.

COWI. (2014). Our 360 degree brand. Retrieved Dec 9, 2014, from http://www.cowi.com/topmenu/aboutcowi/ourbrand/Pages/default.aspx

Curwell, S. R., Deakin, M., & Symes, M. (2007). *Sustainable Urban Development: The Environmental Assessment Methods* (Vol. 2): Taylor & Francis.

Doron, G. (2005). Urban agriculture: Small, medium, large. *Architectural Design, 75*(3), 52-59.
Dæhlen, M., & Ortiz, R. (2013). Den høye hage: Om urban dyrking på tak *Byøk-Rapport 04/13*: Senter for Byøkologi.
Eriksen, K. F. (2013). Grønne tak skal beskytte mot flom. Retrieved Mar 1, 2014, from http://www.osloby.no
Eriksen, K. F. (2013). Slik skal Oslo stoppe flommen. Retrieved Sept 8, 2014, from http://www.osloby.no/nyheter/Slik-skal-Oslo-stoppe-flommen-7279522.html
Falck-Pedersen, E. M. (2012). *Grønne tak: strategi for implementering, muligheter og begrensninger.* (Master), Universitetet for Miljø- og Biovitenskap.
FAOSTAT. (2008). Statistics Division Resource STAT. Retrieved 28 Sept, 2014, from http://faostat3.fao.org/faostat-gateway/go/to/home/E
Ferguson, B. K. (1998). *Introduction to stormwater: concept, purpose, design*: John Wiley & Sons.
Flaten, O., & Hisano, S. (2001). Food security policy in a food importing country: the case of norway. *Agriculture and Economy, 73*(8), 129.136.
Francis, C., Lieblein, G., Gliessman, S., Breland, T., Creamer, N., Harwood, R., . . . Salvador, R. (2003). Agroecology: the ecology of food systems. *Journal of sustainable agriculture, 22*(3), 99-118.
Getter, K. L., & Rowe, D. B. (2006). The role of extensive green roofs in sustainable development. *HortScience, 41*(5), 1276-1285.
Gladwell, M. (2000). *The tipping point: How little things can make a big difference*: Hachette Digital, Inc.
Gomez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics, 86*, 235-245. doi: Doi 10.1016/J.Ecolecon.2012.08.019
Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field methods, 18*(1), 59-82.
Hovind, A. B. (2013). Herligheten - info in English. Retrieved from http://loallmenningen.blogspot.no/p/info-in-english.html
HUI, D. (2006). Benefits and potential applications of green roof systems in Hong Kong. *Evaluation, 11*, 12.
Hui, S. C. (2011). *Green roof urban farming for buildings in high-density urban cities.* Paper presented at the Hainan China World Green Roof Conference, Hainan China World Green Roof, Hainan, China.
Ingram, J., Ericksen, P., & Liverman, D. (2010). *Food security and global environmental change*: Routledge.
Ison, R. (2008). Systems thinking and practice for action research.
Knutsen, H. (2007). Norwegian Agriculture: Status and trends 2007. *Norwegian Agricultural Economics Research Institute*.
Kohler, M., & Keeley, M. (2005). Berlin: Green roof technology and development. *EarthPledge. Green roofs: Ecological design and construction. Schiffer Books, Atglen, Pa*, 108-112.
Kraft, B. (2012). Bærekraftig Investering AS. Retrieved Dec 12, 2014, from http://www.bkraft.no/en/index.php
Krogland, A. P. (2012, 8 Sept 2012). Bønder i byen - storbyjungelen som matfat. *Aftenposten*. Retrieved from http://www.aftenposteninnsikt.no
Kumar, R. (1999). Research Methodology-A Step-by-Step Guide for Beginners London, Thousand Oaks, New Delhi: Sage Publications.
Latour, B. (1996). On actor-network theory: a few clarifications. *Soziale welt*, 369-381.
Law, J. (1986). On power and its tactics: a view from the sociology of science. *The Sociological Review, 34*(1), 1-38.
MAJOBO. (2014). MAJOBO - English. Retrieved Dec 5, 2014, from http://majobo.no/english/

Modernization, M. o. G. a. (2013). Organization. Retrieved Dec 9, 2014, from http://www.regjeringen.no/en/dep/kmd/min/organisation.html?id=528
Modernization, M. o. G. a. (2014). Framtidens Byer. Retrieved Sept 9, 2014, from http://www.regjeringen.no/nb/sub/framtidensbyer/forside.html?id=551422
Nagase, A., & Dunnett, N. (2010). Drought tolerance in different vegetation types for extensive green roofs: effects of watering and diversity. *Landscape and Urban Planning, 97*(4), 318-327.
NAML. (2014). Informasjon. Retrieved Dec 9, 2014, from http://www.naml.no/informasjon.aspx
NFGT. (2014). Norsk Forening for Grønne Tak. Retrieved Dec 9, 2014, from http://nfgt.no/
Noreng, K., Kvalvik, M., Buskelein, J. O., Ødegård, I. M., Clewing, C. S., & French, H. K. (2012). Grønne tak: Resultater fra et kunnskapsinnhentingsprosjekt (Vol. Prosjektrapport nr. 104): SINTEF Byggforsk.
Norge, S. (2003). About us. Retrieved 28 April, 2014, from http://www.standard.no
Norway, I. (2014). About Innovation Norway. Retrieved Dec 9, 2014, from http://www.innovasjonnorge.no/no/english/#.VIdXOzFzQlo
Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., . . . Rowe, B. (2007). Green roofs as urban ecosystems: Ecological structures, functions, and services. *Bioscience, 57*(10), 823-833. doi: Doi 10.1641/B571005
Oldenburg, B., & Glanz, K. (2008). Diffusion of innovations. *Health Behavior and Health Education Theory, Research and Practice*, 313-333.
Oslo, C. o. (2013a). About Oslo. Retrieved 17 Sept, 2014, from http://www.oslo.kommune.no/english/about_oslo/
Oslo, C. o. (2013b). *Application to Become European Green Capital 2016*. Oslo: Retrieved from http://www.miljo.oslo.kommune.no/.
Oslo, C. o. (2013c, 12 May 2013). Blue-green urban areas. Retrieved 29 Aug, 2014, from http://www.oslo.kommune.no/
Oslo, C. o. (2013d). Reopening rivers and streams in Oslo. Retrieved Sept 8, 2014, from http://www.oslo.kommune.no/english/environment/bluegreen_urban_areas/effective_measures/article257938-65112.html
Oslo, C. o. (2014a). Oslo Kommune Bymiljøetaten. Retrieved Sept 8, 2014, from http://www.bymiljoetaten.oslo.kommune.no/
Oslo, C. o. (2014b). Oslo Kommune Vann- og avløpsetaten. Retrieved 5 Sept, 2014, from http://www.vann-og-avlopsetaten.oslo.kommune.no/
Oslo, C. o. (2014c). Politics. Retrieved Dec 9, 2014, from http://www.oslo.kommune.no/english/politics/
Oslo, C. o. (2014d). *The Urban Development of Oslo*. Retrieved from www.pbe.oslo.kommune.no.
Oslocontributor. (2012). Oslo / Food and Sustainability. Retrieved from http://www.sustainable-everyday-project.net/urbact-sustainable-food/2012/10/08/oslo-food-and-sustainability/
Padmavathy, K., & Poyyamoli, G. (2011). Alternative farming techniques for sustainable food production *Genetics, Biofuels and Local Farming Systems* (pp. 367-424): Springer.
Peters, C. J., Bills, N. L., Lembo, A. J., Wilkins, J. L., & Fick, G. W. (2009). Mapping potential foodsheds in New York State: A spatial model for evaluating the capacity to localize food production. *Renewable Agriculture and Food Systems, 24*(01), 72-84.
Rogers, E. (2008). M,(2003), Diffusion of innovations: New York: Free Press.
Rosenzweig, C., Gaffin, S. R., & Parshall, L. (2006). *Green roofs in the New York metropolitan region: Research Report*: Columbia University Center for Climate Systems Research.
Rowe, D. B., & Getter, K. L. (2010). Green roofs and garden roofs. *Urban Ecosystem Ecology*(urbanecosysteme), 391-412.

Rømø, D. (2012). Green roofs worldwide. Retrieved 1 July, 2014, from http://www.scp-knowledge.eu/sites/default/files/R%C3%B8m%C3%B8%202012%20Green%20roofs%20worldwide_0.pdf
Sanderud, P. (2009). About NVE. Retrieved Dec 8, 2014, from http://www.nve.no/en/About-NVE/
Savage, M. (2014). Oslo's rapid growth redefines Nordic identity. Retrieved 7 March, 2014, from http://www.bbc.com
Shore, W. B. (2006). Land-use, transportation and sustainability. *Technology in Society, 28*(1), 27-43.
SINTEF. (2014). About us. Retrieved Dec 9, 2014, from http://www.sintef.no/home/about-us/#/
Smith, G. W. (1990). Political activist as ethnographer. *Social Problems*, 629-648.
SSB. (2013). Statistics Norway. Retrieved Sept 29, 2014, from http://www.ssb.no/en/forside;jsessionid=3145AF81ADE2A6B7C310462B849C2A82.kpld-as-prod03
SSB. (2014). *This is Norway 2014*. Retrieved from http://www.ssb.no.
Stovin, V., Dunnett, N., & Hallam, A. (2007). *Green Roofs–getting sustainable drainage off the ground.* Paper presented at the 6th International Conference of Sustainable Techniques and Strategies in Urban Water Mangement (Novatech 2007), Lyon, France.
Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental Pollution, 159*(8-9), 2119-2126. doi: Doi 10.1016/J.Envpol.2011.03.007
Turner, B., Henryks, J., & Pearson, D. (2011). Community gardens: sustainability, health and inclusion in the city. *Local Environment, 16*(6), 489-492.
UN. (2012). Africa and Asia to lead urban population growth in next 40 years - UN report. Retrieved Dec 4, 2014, from http://www.un.org/apps/news/story.asp?NewsID=41722#.VICy9TFzQlo
UN. (2014). World's population increasingly urban with more than half living in urban areas. Retrieved Dec 2, 2014, from http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html
UNFAO. (2008). Climate Change and Food Security: A framework document. Rome.
Van der Horst, L., Townsend, L., Jacobs, A. (2013). *Merging man with nature: Restoring the environmental functions and processes of Sørhellinga and the regional biotope diversity by creating a green roof*. Term paper. INA Department. Norwegian University of Life Sciences.
Vekst, V. (2014). Våre prosjekter. Retrieved Dec 9, 2014, from http://www.vitalvekst.no/
Vestreng, T. H. (2013). Urban bonder går i hoyden. 9 Sept 2013. Retrieved 1 March, 2014, from http://www.dagsavisen.no
Walsh, E., Babakina, O., Pennock, A., Shi, H., Chi, Y., Wang, T., & Graedel, T. (2006). Quantitative guidelines for urban sustainability. *Technology in Society, 28*(1), 45-61.
WCED. (1987). *Our common future*. Oxford; New York: Oxford University Press.
Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2011). Agroecology as a science, a movement and a practice *Sustainable Agriculture Volume 2* (pp. 27-43): Springer.
Whittinghill, L. J. (2012). *Vegetable production using green roof technology and the potential impacts on the benefits provided by conventional green roofs*. PhD Dissertation. Horticulture. Michigan State University.
Whittinghill, L. J., & Rowe, D. B. (2012). The role of green roof technology in urban agriculture. *Renewable Agriculture and Food Systems, 27*(04), 314-322.
Whittinghill, L. J., & Rowe, D. B. (2012). The role of green roof technology in urban agriculture. *Renewable Agriculture and Food Systems, 27*(4), 314-322. doi: Doi 10.1017/S174217051100038x
Whittinghill, L. J., Rowe, D. B., & Cregg, B. M. (2013). Evaluation of Vegetable Production on Extensive Green Roofs. *Agroecology and Sustainable Food Systems, 37*(4), 465-484. doi: Doi 10.1080/21683565.2012.756847

Wong, N. H., Chen, Y., Ong, C. L., & Sia, A. (2003). Investigation of thermal benefits of rooftop garden in the tropical environment. *Building and environment, 38*(2), 261-270.

Yin, R. K. (1989). Case Study Research: Design And Methods (Applied Social Research Methods) Author: Robert K. Yin, Publisher: Sage Publicat: Sage Publications, Inc.

Ødegård, O. (2008). Pris til grønt tak av GASA. Retrieved Dec 8, 2014, from http://www.arkitektnytt.no/pris-til-gront-tak-av-gasa

APPENDICES

Appendix I: Reflections on the research process

I have been working with green roofs periodically over several years. I think that they are a very cool, useful concept. This is why I chose to the topic to complete my MSc degree, being particularly interested in the possibilities of combining green roofs with urban agriculture and agroecology. The research methodology proved to be rather challenging for me since I come from a hard science background and my classification as a 'blue' person. But I was interested in exploring a new skill and a new side of research. Learning how to conduct the research appropriately was an exhaustive task, one that I still am not particularly confident with. The same notion applies to the writing. Though I appreciate the clear paths that research in hard sciences have, I think that this style of social science is much more applicable to the real world and I would like to continue improving on the case study research style. This report is not perfect, I acknowledge that, but sincerely I hope that it is more useful to people than as just a decoration on their bookcase.

Appendix II: An overview of green roofs and urban agriculture

What roles do green roofs have in sustainable urban development?

Sustainable urban development improves the quality of life for growing urban populations. It uses plans, programs, and projects to improve infrastructure, transport, safety, security, health, and the well-being of urbanites. It emphasizes ecological integrity and equity (Curwell, Deakin, & Symes, 2007). Green roofs contribute to the improvement of infrastructure, food security, environmental health, and human health and wellness in various ecological, economic, and social ways. They have a unique opportunity to address problems in the food and urban environmental systems. Natural biological processes are reintroduced when using green infrastructure. Adding additional purposes, like urban agriculture, can reduce dependence on imported foods and strengthen urban food security. Healthy urban systems directly relate to healthy rural and global systems. All of this can be accomplished by using existing, underused urban roof space.

What is their impact on the city environment?

As cities expand, previously vegetated lands like forests and agricultural fields are replaced with surfaces that repel water and nutrients, resulting in an environment with less biodiversity, resilience, and ultimately, sustainability (Getter & Rowe, 2006). The differences between a natural and urban environment can be surprisingly great. For example, a US study found that impervious surfaces comprised between 71 to 95% of the area in industrial areas and shopping centers (Ferguson, 1998). Considering that a meager 25% of rainfall is absorbed by urban soils compared to the 95% absorbed by forests (Getter & Rowe, 2006), large amounts of precipitation leave a city before it has the chance to infiltrate and be of benefit.

Green roofs are commonly used in cities to control stormwater runoff and reduce flooding by allowing rainwater to infiltrate into green roof soils and systems. As the climate changes, many cities have an increasing flood risk. Heavier rainfall events are expected and in combination with typically underground, outdated, and insufficient sewage systems, overflows are possible (J. G. Carter, 2011). Green roofs act as a supplementary stormwater infrastructure by retaining more water than standard roofs and delaying its runoff (T. Carter & Fowler, 2008). Banting et al. (2005) showed that green roofs in Toronto decreased the combined sewer overflow by 18%. In Norway and Northern Europe, where precipitation is expected to increase by 5 to 20% in coming years with more intense rainfall events (Cicero, 2009), green roofs can provide a viable option for dealing with this specific ecological concern in urban development. In addition to dealing with the effects of climate change, green roofs can potentially lessen the intensity of it too. A study by Rowe and Getter (2010), it was suggested that 3.64 million kg of CO2 emissions could be sequestered each year by greening 1.1 km2 of roofs (the area of their university rooftops). Adding carbon sinks like biochar to the soils can increase CO2 capture, one example of a creative solution for the multi-perspective use of green roofs.

Urban densification, or the compact growth of a city, is a common strategy used by planners to promote sustainable development. Still, it is associated with a number of negative aspects that can be addressed with the use of vegetation and other natural features, like green roofs. They moderate the banes of urban life like noise and particulate pollution, extreme temperatures, and human stress. They also provide

habitat for urban wildlife and plant communities, particularly beneficial for endangered or migrating species (Gomez-Baggethun & Barton, 2013; Oberndorfer et al., 2007; Van der Horst, 2013). Their value can be analyzed by evaluating their ecosystem services.

These ecological aspects also have direct links to a city's economy. For example, underground technical ('gray') sewer system infrastructure may not need to have extensive upgrades done to manage increasing precipitation when combined with green infrastructure, a component of many cities' budgets. Green roofs increase the lifespan of roof membranes and improve building energy efficiency (J. G. Carter, 2011; Stovin et al., 2007), reducing energy consumption between 2 to 39% in certain areas (Whittinghill, 2012) and offsetting high installation costs (Getter & Rowe, 2006). For many dense, expensive inner city properties, the value to a developer of using roof space as an outdoor amenity space rather than building an equally-sized space at ground level can be great. Understandably, these economic impacts do not equally affect different groups of people. Private markets, city authorities, and the public see different advantages and disadvantages in green roof construction.

As a part of their ecosystem services, green roofs can also be of benefit to society. Social values have an important role in urban development. In cities full of high-rises, cars, and concrete, they are an oasis (Gomez-Baggethun & Barton, 2013; Rosenzweig, Gaffin, & Parshall, 2006). Besides leisure and green therapy, they provide a place for employment, education, community involvement, food production, and social cohesion. Green roof's environmental benefits, like pollutant reduction, improve people's health and happiness as well (Gomez-Baggethun & Barton, 2013; Van der Horst, 2013). As green roofs are more frequently used for their economic and ecological roles, they intrinsically extend benefits to society.

What are their issues?

Despite the wide benefits, green roofs face a large obstacle for construction due to their high initial investment costs. Installation alone can be two to six times more expensive for a green roof (Wong, Chen, Ong, & Sia, 2003). An intensive green roof is likely to be even more expensive due to building structural reinforcement requirements (Getter & Rowe, 2006). Costs can increase depending on the ease of access, irrigation and drainage systems, and substrate choice (Rowe & Getter, 2010). These are major limitations to green roof development, regardless of their long-term benefits.

Though research generally supports the use of green roofs as a tool for improving sustainability, there is still a wide gap in knowledge. Much of the existing research has focused on extensive, *Sedum spp.*-based green roofs, creating distinct limits to the technical information available for more diverse projects, like in urban agriculture (Whittinghill, 2012). There are significant gaps in understanding issues like invasive species and best management practices (fertilizer and irrigation requirements, pest control) (Whittinghill et al., 2013), which leads to the potential of green roofs causing more harm than good. Nutrient-laden water runoff can hurt the environmental and green roof failures from insufficient knowledge results in decreased enthusiasm for use (Nagase & Dunnett, 2010). Still, their broad roles in multi-perspective issues encourages further research, experimentation, and use.

What role can green roofs play in food security?

Urban agriculture on the ground

The global population is projected to be 9.5 billion by the year 2050, and innovations in agriculture will be needed in order to feed everyone (Bureau, 2008; Walsh et al., 2006). Modern industrial agriculture disrupts ecologically sensitive regions with large, monoculture production. Currently, 38% of Earth's land surface is occupied by agriculture and it is expected to reach 60% in the next 100 years (FAOSTAT, 2008). It also uses vast amounts of petroleum resources in production, packaging, and shipping, making it one of the biggest contributors to global climate change. Improving global health and food security requires significant changes in the food system, from field to fork. Four dimensions need to be considered – food availability, accessibility, utilization, and food system stability (UNFAO, 2008) – all of which can be positively impacted by urban agriculture. Urban agriculture is one way to decrease food miles and agricultural sprawl, increase local food production, ensure food security (Peters, Bills, Lembo, Wilkins, & Fick, 2009), as well as contribute to overall urban and global sustainability.

Food security is a complex subject, with diverse influences including climate change, technology, human capacity, policies, prices, trade, and infrastructural context (Padmavathy & Poyyamoli, 2011). It is not just an adequate supply of food, but the adequate access to sufficient and healthy food during crises both at home and abroad (Flaten & Hisano, 2001). Self-sufficiency and adaptability are important aspects that are addressed by urban agriculture. Though it still has challenges, urban agriculture's benefits to food security are undeniable.

Urban agriculture occurs in private gardens, community gardens, and urban commercial farms. It can be a temporary or permanent fixture and can be either public or private. Cities have zoning restrictions, sometimes substantially limiting opportunities. For example, Oslo has large amounts of park space but city approval for food production in them is challenging due to policies on public access. While urban agriculture contributes to food security, it is more than just food production. It impacts the economic, social, and ecological sustainability of a city by (Padmavathy & Poyyamoli, 2011):

- Creating jobs and economic security
- Reducing food miles
- Opportunities in therapy and rehabilitation
- Connecting urban dwellers to community, land, nature, and food
- Reducing food deserts
- Spreading awareness
- Improving physical and mental health
- Providing a sense of purpose
- Growing organic and/or healthy foods
- Providing education and a social action platform
- Producing local foods
- Creating green spaces

Urban agriculture has been a critical factor for survival in various points of history. WWI and II are commonly cited eras when food scarcities resulted in urban agriculture growth. In 1943, the US 'Victory Gardens' initiative produced 40% of the nation's fresh vegetables (Krogland, 2012). England did similarly during WWII, increasing its allotments from 450,000 to 1.5 million (Doron, 2005). In Cuba, after the Soviet Union collapsed and its aid withdrew, locally grown food became a necessity for food

security. Large areas of cities were converted into organic public access gardens that helped to feed millions (Doron, 2005; Turner, Henryks, & Pearson, 2011).

While economic hardship was historically a driving reason for increasing urban agriculture, it contributes to the food security and urban sustainability of both developed and developing cities today. In China, 85% of vegetables eaten in cities are grown within city limits. 10 to 30% of fruit and vegetables eaten in Asian and Latin American cities are locally grown. Even in developed countries with more secure food systems, the local contribution can be huge. It is estimated that one-third of the US's agricultural output comes from urban or peri-urban areas (Doron, 2005).

The biggest constraint for urban agriculture is land availability. Space is not just physically limited, but further competition arises from a lack of land use rights agreements, zoning and use conflicts, soil contamination, and constraints of inputs or labor (Whittinghill, 2012). This is where green roofs can have a niche role. Combining green roofs with urban agriculture can be costly and complicated in today's market, but it provides a unique opportunity to address the challenges found in urban agriculture at ground level. Removing land availability barriers can greatly expand local food production and improvements in the food security of a city.

Bringing urban agriculture to a rooftop

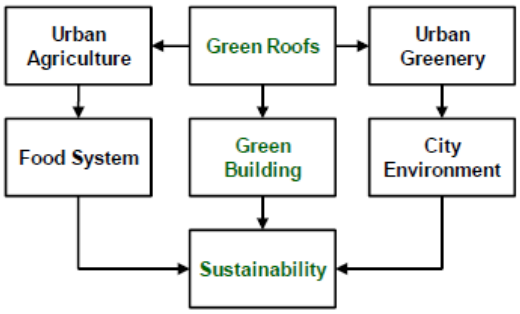

Figure 29 – Green roofs and urban sustainability (Hui, 2011)

When a building is made, the roof space often becomes 'out of sight, out of mind.' On average, around 32% of horizontal space in an urban, high-density region is comprised of roofs (Oberndorfer et al., 2007), up to 85% of which are adequately flat for installing green roofs (T. Carter & Jackson, 2007). Underutilized roof areas present the opportunity for innovative activities and bring environmental, economic, and social value creation. Fig. 30 demonstrates possible benefits of rooftop urban agriculture, which are in many ways similar to the benefits of urban agriculture on the ground.

As mentioned, one of the most exciting aspects of rooftop urban agriculture is the opportunity to address ground-level agricultural challenges. Green roofs 'create' productive land in urban areas where there are shortages or zoning restrictions. Clean, composted, or specially formulated soil mixtures can be used on the roofs, removing the threat of contamination found at ground level. In addition to the benefits found in Fig. 6, they also enable the creation of agreements between building owners and roof users (Whittinghill, 2012), creating action towards sustainable transitions. Additionally, the diversity of green roofs projects allows for activities ranging from leisure space to personal food production to commercial farming (Doron, 2005).

Figure 30 - Benefits of urban green roof farming (S. C. Hui, 2011)

Though there are few studies about food production on rooftops, there are numerous existing projects, as seen in Table 15. In one study by Whittinghill et al. (2013), all food plants – tomatoes, green beans, cucumber, peppers, basil, and chives – survived and produced biomass though with mixed results in quality compared to those from the ground. Food production is feasible, as demonstrated by the research and the existing models, but more research is needed to better understand crops and climates.

Considering the large amount of food production that is possible through urban agriculture, green roofs open up new opportunities for improving not only food security but ecological, economic, and social benefits in cities. As cities continue to expand rapidly, these will become increasingly valuable opportunities.

Name	**Location**	**Description**
Eagle Street Rooftop Farm	NYC	600 m2 organic garden on warehouse
Brooklyn Grange Farm	NYC	4000 m2 (one acre) organic farm
Gotham Greens	NYC	Commercial greenhouse operation for vegetables and herbs
Bell, Book, & Candle	NYC	Restaurant with 60 vertical gardens provided 60% of herb, vegetable, and fruit needs
The Vinegar Factory	NYC	3000 m2 of rooftop greenhouses producing tomatoes all year
Santropol Roulant	Montreal	Rooftop farm for meals-on-wheels and community outreach
Uncommon Ground	Chicago	First certified organic rooftop in USA
'Food from the sky'	London	Produce sold in supermarket below
Omotesando Farm	Tokyo	Rooftop garden rental space
Roppongi Hills	Tokyo	Demonstration rice paddy and vegetable plot, serves as dead weight for earthquakes
Changi General Hospital	Singapore	Demonstration green roof with produce consumed by patients
District Office	Bangkok	Production for building, decrease global warming, composting

Table 15 – Rooftop farms around the world (S. C. Hui, 2011; Krogland, 2012)

Appendix III: Interview questions

Version I: 6.03.2014 to 12.03.2014

Demographic information: name, occupation
What is your work with green roofs?
- When and how did you start?
- Is your professional work related to green roofs? How so?
- What is the most interesting part for you?

Who do you work with about green roofs?
- How much? How so?
- Any benefits come from your interaction?

What do you know about green roof projects in Oslo?
- Challenges and opportunities?
- What is its value to the city and the people?
- Do you have participation with any projects in the city?
- What multi-perspective value do they have for you?

What do you think about urban agriculture on green roofs in Oslo?
- Its value? Challenges and opportunities? Any projects?
- How can this be realized?

How do you see green roofs in the future? Challenges and opportunities?
- In Oslo and the world?
- On what values will the focus be placed?
- Who will be the driver of development?

Version II: 13.03.2014 to 26.05.2014

Demographic information: name, occupation
Who do you work with about green roofs?
- How? Why? To what extent?
- How do you share your information?
- What value does this have to you?
- What are your impressions of networking in the situation?

What do you know about green roofs in Oslo?
- Projects, mindset, status of projects?
- Who uses them and why? Level of interest?
- What are their value to the city and its people? With diverse uses?
- What are you most interested in?

What are your opinions about the development in Oslo?
- Turf vs. sedum vs. other?
- Challenges and opportunities?
- Policies to model off of?
- The status of stakeholder groups on the issue?

Green roofs and networking
- What is the impact within Oslo?
- What is the impact of international networks?
- How much time is needed for widespread development?
- What factors influence growth?

More…..
- Why do you support green infrastructure?
- What is the projection of your role or organization in the topic?
- Is there competition or collaboration between organizations or people?
- Do you have any relevant literature to share?
- What will your role be in development?
- What are possible innovations?

Appendix IV: Mind maps

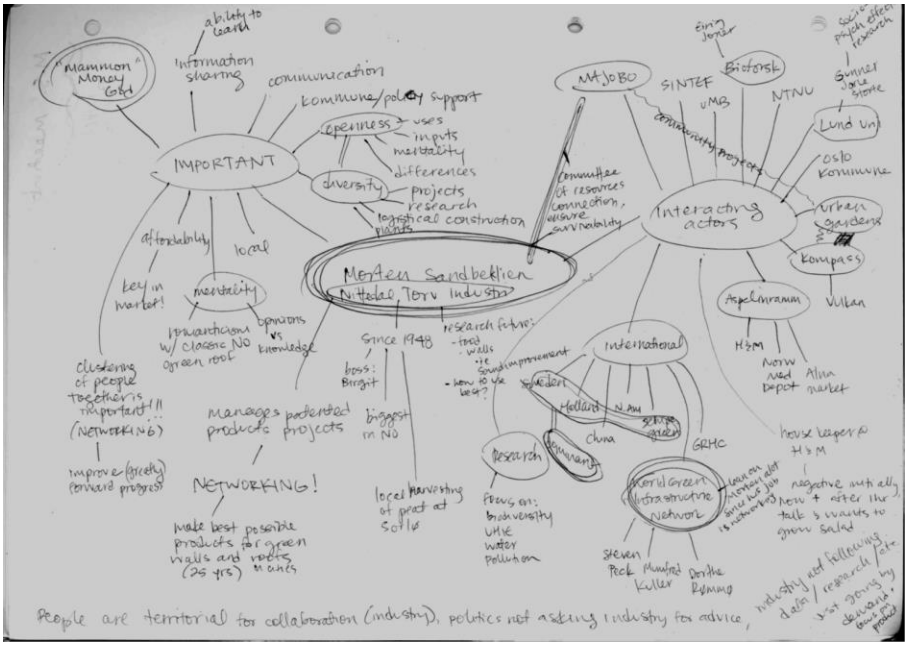

Figure 31 - Morten interview

Figure 32 - Ingrid interview

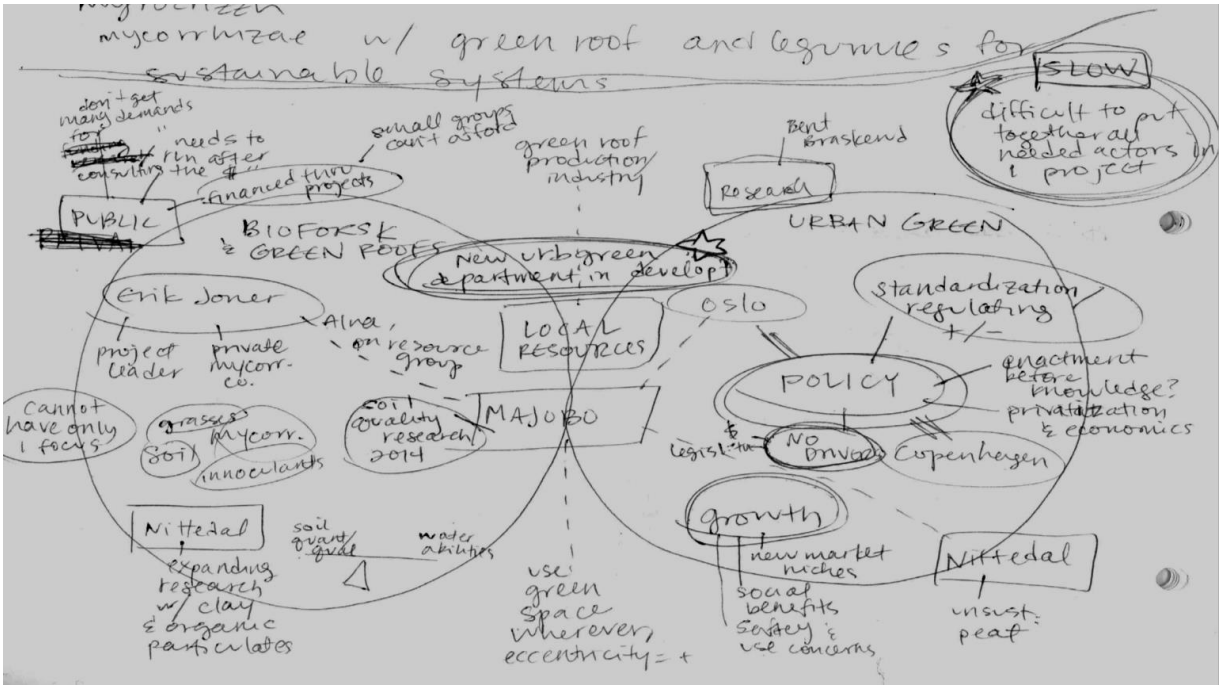

Figure 33 - Erik interview

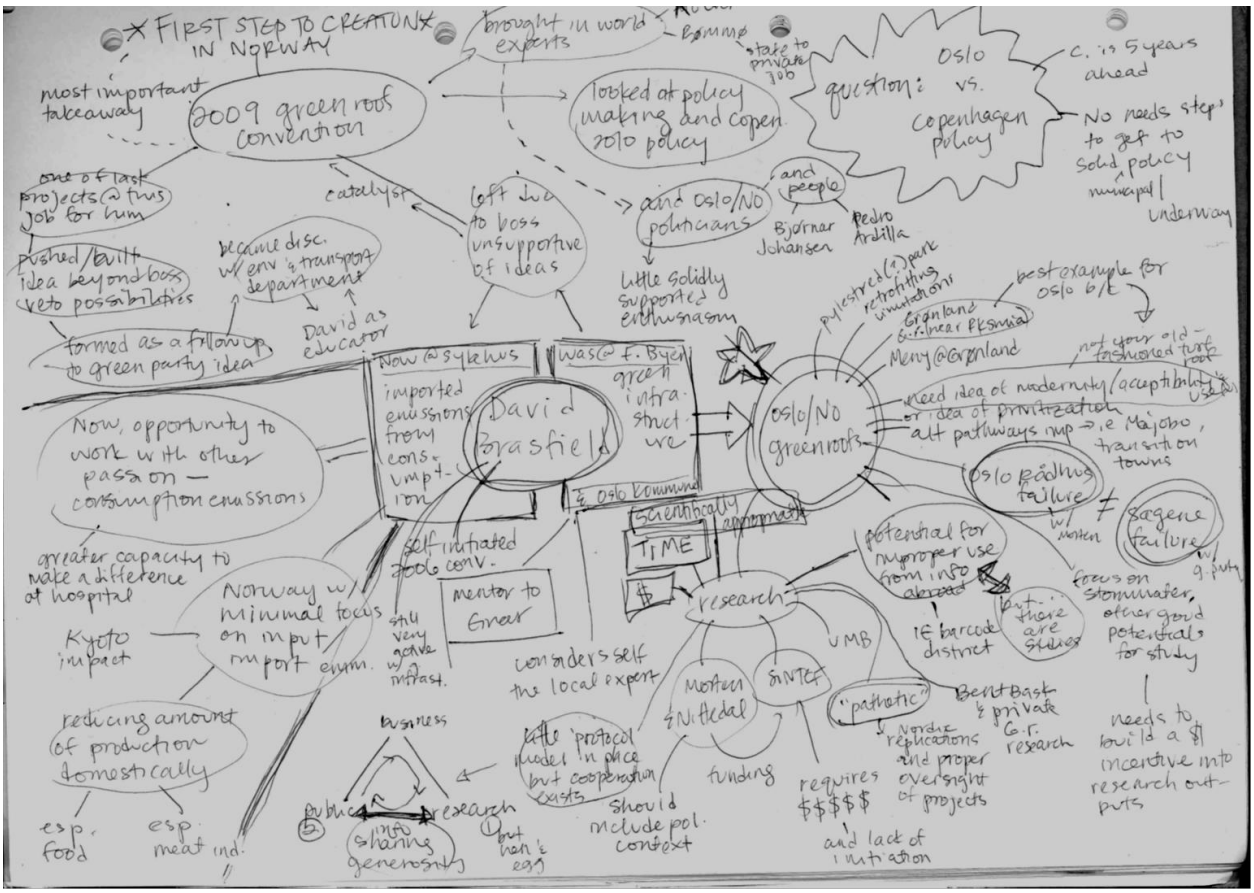

Figure 34 - David B. interview

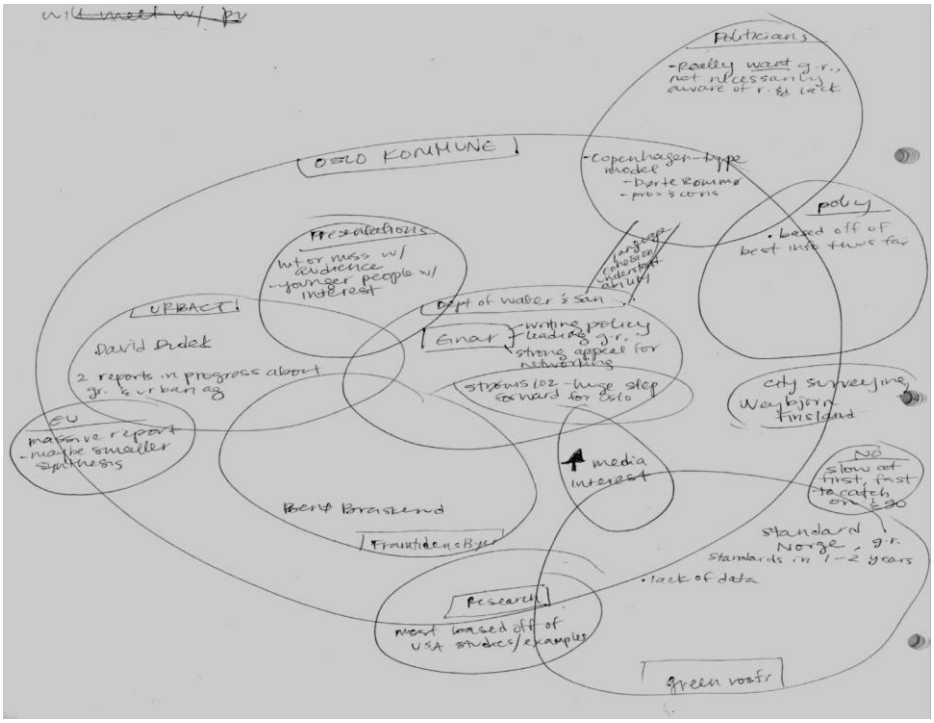

Figure 35 - Einar and David D. interview

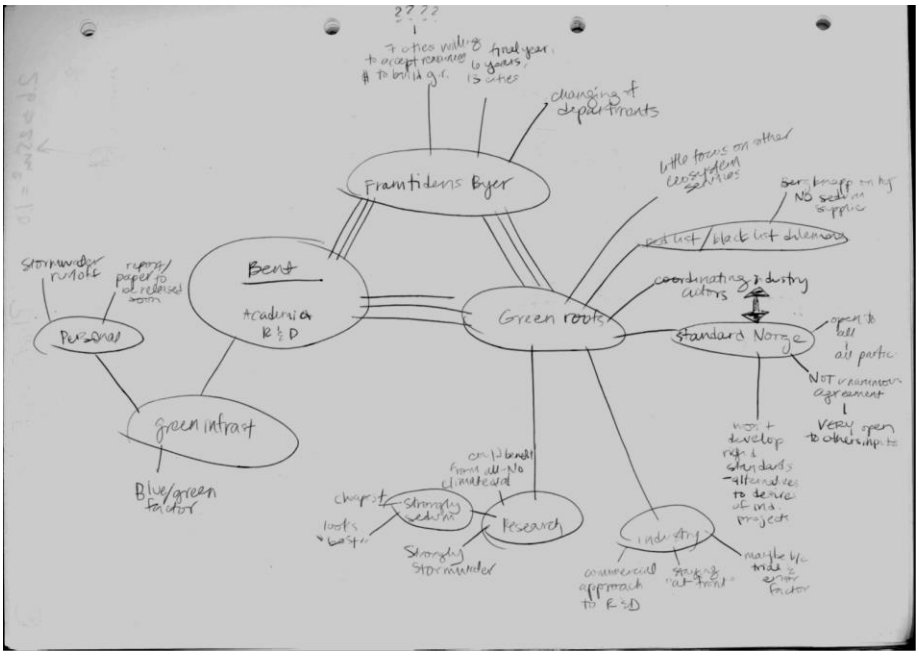

Figure 36 - Bent interview

Appendix V: Notes from Strømsveien 102 planning meeting

- Relevant information
    - Fornebu green roof is collecting and using local ground species
    - Sedum use on roofs is quite new in Norway
        - People need to be convinced that it's a good idea
        - Oslo Kommune rying to improve success rate of green roofs with more projects
        - Bergen IKEA had complete green roof death after first year, due to clogged drainage
        - There is a cluster for green roofs via Norwegian green roof association

- The project:
    - It will be more of an exhibition than scientific research, very important to Oslo now
    - Expectation of differences in results due to different systems used per plot
    - Allow for interaction between people and grasses on roof

- Questions for project:
    - What are the 'right' combinations of substrates and plants?
    - How to tackle red list vs black list issue?
    - How is rainfall runoff affected?

Appendix VI: Notes and minutes from focus group

Invitation

Nærings- og forskningsklynge for grønn infrastruktur i Norge
Kafé Saba, Gamlebyen Oslo (se kart nedenfor)
8. mai 2014, kl. 12:30 til 16:00
David Brasfield & Kristin Pedersen

Grønn infrastruktur vil bli et viktig verktøy i Norsk byutvikling for håndtering av forventede klimaendringer og spesielt økninger i nedbørsintensitet. Innovasjon i håndtering av regnvann vil redusere risikoen for flom og avlaste dagens avhengighet av gamle, underdimensjonerte rørsystemer og forrige århundrets teknologi. Grønne tak og vegger, regnbeds, åpne overvannsløsninger og andre tiltak utgjør kostnadseffektive måter å løse utfordringene på, ved å supplere kapasiteten i eksisterende teknisk infrastruktur til overvannshåndtering.

For å støtte en effektiv og samfunnsansvarlig markedsutvikling i Norge blir det avgjørende å etablere samarbeid mellom et bredt spekter av disipliner som utdannings- og forskningsmiljøene, design- og ingeniørfagene, eiendomsutviklere, offentlige etater, samt leverandører og installatører av grønn infrastruktur teknologi. Utviklingen av faglig kunnskap, veiledninger, offentlig politikk og kompetanse/kapasitet blant leverandørene er viktige premisser for innovasjon i bransjen og en positiv markedsutvikling som oppfyller samfunnets behov.

I det norske markedet har utviklingen innenfor grønn infrastruktur vært treg. Selv om det i senere år har vært betydelig prosentvis vekst, er det fortsatt vesentlig urealisert markedspotensial og tapte muligheter i prosjektene realisert innenfor gårsdagens tankesett. Verdikjeden er preget av fragmenterte forhold mellom bransjeaktører og manglende evne til å samle og fokusere ressurser til nødvendig forskningsbasert kunnskapsutvikling og offentlig policyutvikling. Med en ny push for grønn infrastruktur og økosystemtjenestene det medfører, ser vi for oss muligheten til å skape et felles nettverk som løser felles utfordringer og legger til rette for bedre markedsforhold for innovativ grønn infrastruktur.

Vi inviterer alle som er involvert i grønn infrastruktur aktiviteter i Norge til en felles dialog for å diskutere mulighetene for å etablere en nærings- og forskningsklynge for grønn infrastruktur. Det legges opp til et lukket møte, og vi ber om dine forslag til andre aktuelle deltakere.

Møtet vil kombinere korte presentasjoner og diskusjon om:

- Hva er grønn infrastruktur? Bent Braskerud, NVE
- Hva er en nærings- og forskningsklynge? Og hvordan bør en klynge utvikles for å fremme grønne infrastruktur?
- Hva er barrierene for markedsutvikling i Norge? Hvorfor ligger Sverige og Danmark foran Norge i opptak av grønn infrastruktur?
- Hvordan kan utviklingen av kommunal og nasjonal politikk og faglig kunnskap framskyndes i Norge?
- Kan bransjeaktørene samarbeide og skape en vinn-vinn markedsutvikling?

Focus group participants
Sunaas (David B.)

NMBU student
Nittedal Torvindustri AS
Naturtorv
Hallintorv
SINTEF Byggforsk
Oslo Kommune BYM /
VegTech
COWI
Bergknapp AS
ZinCo Norge
Vital Vekst AS
NVE
Bioforsk
Bærekraftig Investering AS

Minutes

'Seminar about establishing a business and research cluster for green infrastructure'

Presentation of seminar participants

The seminar had 14 participants from research, green roofs and infrastructure providers, public management and consultancy. The head of the climate change adaptation in Oslo and invited by the municipality's Water and Sewerage Authority was absent from the meeting. It was commented that there was a predominance of participants from green roofs businesses in the seminar (despite representation from the Network for blue-green cities, NVE, SINTEF and the Norwegian Institute. Participants are sent as a separate attachment to the minutes.

What is green infrastructure?

David Brasfield gave a presentation about 40 minutes on definitions, examples, and social values created by green infrastructure. The presentation will be posted on DropBox to seminar attendees and invitees.

Beyond the content of the presentation was the noted work done in the future of cities, and the existence of two organizations in their own way is a driving force for green infrastructure: Norwegian Association for Green Roofs (NFGT) and the Blue-Green Network.

Based on the definitions of green infrastructure in the presentation was the discussion of other actors (other than those asked at the seminar) that could be relevant participants in an industry organization for green infrastructure. Consultants and landscape gardeners were mentioned.

- Pause -

Barrier analysis - why is the market trend in Norway behind Sweden and Denmark?

Many more buildings are drawn in green roofs than the number being realized. The architects have understood. Economy and knowledge deficits for construction. It was said that the market is mostly

limited to Oslo and Stavanger, with some activity in Bergen where reference projects will be built now and later. It was asked if finances were a real barrier or a perceived barrier. Prices for construction of green roofs have declined substantially in recent years with greater volume, more competition and more players in the market. There is a lack of knowledge in some markets (planners, consultants, engineers), which leads to uncertainty in relation to the risk of damage to the membrane, retention effect, etc. It is probably a greater perceived risk than real risk.

We are still in a phase of market development where the failure of some projects can dampen the interest of potential developers.

The initial investment in the construction of green roofs is clearly something big, and it has a stagnating effect. It has so far been difficult for the market to realize the overarching values of green roofs. Projects with strained finances often cut green roofs to stay within the investment framework. There is a lack of good accounting for both the "bottom line" values for the builder / owner and community values (which do not affect the client's accounting). It creates doubt about whether the construction of green roofs brings higher square foot price when they built in regards to the resale of property developers / speculators. For example, the outside areas of the roof are probably undervalued compared to the cost of realization on the ground because land prices are included in the cost.

There are specific barriers to the construction of green roofs on existing buildings. The carrying capacity is difficult to be increased, and ceiling areas with excess capacity is limited to only parts of the ceiling area. In addition, the project investment often underestimates the reality in the operational phase. We lack good pilots that show potential for the creation of green roofs on existing buildings. The market usually delivers homogeneous solutions, while retrofit projects will best be realized with varied solutions that leverage both smaller and larger profits in the carrying capacity.

Financial institutions have varying degrees though that green buildings can have a greater market value, and there is still a need for increased awareness on the part of the market.

There is currently a significant dependence on imported substrate materials, including lava. One question is whether it would be cheaper to produce such materials in Norway. Here was reminded of opportunities for innovation, such as the introduction of biochar in substrates.

It's probably a great time for expansion of combinations of growth medium and plants, such as the use of sedum on semi-intensive or intensive roofs. Lack of research and testing dampen innovation development. Cities of the Future is now working on the development of "testbeds" for green roofs in seven cities in Norway. There is something to be thankful for, but the program ends in 2014 and it is not established plans for monitoring and measuring the demonstration roofs after 2014.

There are large climatic variations in Norway. In Tromsø, constrains on growth are great when it is very cold in winter but often very hot and dry summer.

There is a clear need for dissemination of knowledge and awareness. The green roofs that are being built are used to a limited extent.

The actors who benefit from the measurement, monitoring and research being done has hitherto have been involved in fragmented collaborations and have not been able to gather the resources needed to establish

long-term research programs. This picture applies to manufacturers, municipalities, research and educational institutions, insurance companies and more. There is probably a large and unrealized willingness to implement the necessary research.

It is especially a lack of knowledge about retention from different realizations of substrate and vegetation.

While there is well-developed knowledge of how the technical infrastructure manages stormwater and flood risk, there is little knowledge of how a complex hybrid solution will work, where various forms of green infrastructure, temporary flooding roads and conventional technical infrastructure complement each other. We need new strategies for such combinations.

There is a lot of focus on green roofs, but it is important to shift the focus by city planners and municipal authorities to "blue-green city", where green roofs are a natural part. It focuses on the different social values such as green roofs and other forms of green infrastructure provides.

A Norwegian standard is being prepared for extensive green roofs, which shall subsequently be followed by at least two other standards for semi-intensive roofs and "roof gardens".

Directorate for Civil Protection and Emergency is participating in an EU project on climate change adaptation and measures in Oslo and Gothenburg. The time is ripe for the towns adopt innovative stormwater management techniques.

It seems that the lack of demonstration projects is one of the biggest barriers, plus the lack of regulatory instruments (legislation).

There is a need to put green roofs and infrastructure within an ecosystem perspective to increase awareness of some of the values in green infrastructure.

It asked whether Norway need a research strategy for green infrastructure, which covers the whole value of the image of green infrastructure. It is likely that research on attenuation and stormwater management will start sooner or later, but it is less likely that other important social values explored in a satisfactory degree.

It is important to study the economic impact of investment in green infrastructure, which by definition is laid on surfaces, versus investment in dredge and dimensioning of underground technical facilities for stormwater management.

There are means to retrieve from the Research Council for research on green infrastructure and climate change, but it requires the coordination of stakeholders and capacity. Industry, insurance industry and municipalities have a chance to gather their resources and apply for funding and to initiate research projects.

It is important to find good distinctions between green infrastructure and major academic areas, such as urban ecology, urban ecosystems, "circuit city" etc. Research that gapes too large will risk not providing the necessary concrete results and knowledge we need. However, it is important not to forget urban ecology perspectives, giving reason and need for the inclusion of local stakeholders in the research.

One question is what green elements in inhabited areas should not be covered by the research on green infrastructure. The answer may lie in an approach based on the effects of applied green infrastructure elements.

- Pause -

Industrial clusters

David Brasfield held a presentation on industrial clusters. The presentation will be posted on DropBox to seminar attendees and invitees. The intention of the presentation is to provide a framework for a discussion on the establishment of a cluster that promote market growth in the use of green infrastructure.

It was reminded that the clusters of the type of innovation support Norway has a commercial nature, and purpose to commercialize innovative ideas. Another requirement is that the cluster is required to achieve commercialization as companies individually would not be able to achieve.

There was also reminded that most clusters in Norway established among participants within a limited geographical region, and not nationwide. A challenge is if there is a demand from Innovation Norway for regional appraisal is that the (green roof) industry is so small that it will not be a "critical mass" within a single region in Norway. The digital world where technologies such as video conferencing breaks down the need for physical presence, gives reason to believe that a cluster at the national, or even international level if it were desirable, will succeed. The geographical conditional model will still be desirable from a local political and economic perspective as a driving force for local growth in competition between regions.

It was mentioned "Clean Monday" meetings held under the auspices of OREEC as an example of the kind of activity going on at the regional level. (afterthought - Clean Tuesday could be offered as both physical meeting place and "webinar")

It was reminded that the distance can still be a critical success factor for a cluster value creation. The Innovation Norway and the European Cluster Observatory in Stockholm could provide insights and experiences.

At the next meeting on the establishment of a cluster of green infrastructure in Norway, a representative of Innovation Norway is invited. It provides a good opportunity for further discussion on issues of geographic coverage, assessment of innovation aspect etc.

There is significant potential for innovation in terms of new combinations of substrate, plants and technical basis for green roofs, but ask whether it is the kind of innovation that Innovation Norway or other public sector actors will sponsor.

Network Teal cities, which was started approximately 2 years ago was mentioned as an example of the type and level of interest that green infrastructure can trigger. The network consists of landscape architects, landscape gardeners, water and wastewater engineers and others. After rapid growth (about 300 members) and intensive activity in the period after the network was established, the activity has recently faded. It is due to that it is driven voluntary and lacks the resources necessary to move from ideas to action. It asked who would take responsibility for it in any cluster of green infrastructure. Network Teal

cities is a dormant network, which could possibly be brought to life again. It is asked whether there could be an organizational base for the development of an industrial and research cluster for green infrastructure. One question is whether the network holds the commercial aspect needed to attract support from Innovation Norway.

It takes resources and means to nurture a network for the Blue-Green Network.

Norwegian Association for Green Roof is also an organization that could be relevant as organizational base for a cluster. Here there are a small number of members and it is more dominated by commercial players. The conclusion to the meeting initiators (David and Kristin) is there are existing organizations that could serve as a base for initiating research and business cooperation, but it still seems too early to choose organizational base or model.

If a business and research cluster successfully gets started, it will have to get dedicated technical and financial resources that far exceed the level that is now contained in the Blue-Green Network and NFGT. The most important thing is to find a concept and practice that serves the purpose, and build a common will to achieve it. When a vision and common goals are established, the choice of organizational form and any existing organizational base will be a simple matter.

It seems that the intention is presented in the meeting, and the intention of the Blue-Green Network is similar in many ways. It is clear that the Blue-Green Network needs "new impetus" to be vital again.

It seems that at the meeting time, there is not a "critical mass" that would be needed to establish a viable research and industrial cluster. It reminded once again that there is a difference between an organization that will drive economic development, which is the target audience for Innovation Norway, and an organization that conducts research. In Blue-Green Network there are many commercial operators and the activity which has resulted in improvement of skills. It proposed a dialogue with the board of the Blue-Green Network to examine whether the organization could be attracted to the more action-oriented activities.

A first task is to read carefully the Statute of the Blue-Green Network.

An invitation to attend the May 9 annual NFGT meeting was extended to the meeting initiators, where further discussion on rooting the work of a cluster for green infrastructure is appropriate.

The meeting ended at. 3:30 p.m.

Appendix VII: Laws, tools, and protocols for Oslo's green roof opportunities

Document name	Content	Adopted
Action Plan on the Environment and Climate 2013-2016 (ref. 5)	Based on the UEP. Prioritizes approved measures, in terms of implementation date and annual budget allocations.	2012
Resolution on «Green Municipality» (ref. 6)	Environmental certification of municipal units, according to ISO 14001, EMAS or Eco Lighthouse.	2003
Cities of the Future Programme 2011-2014 (ref. 52)	Reduce greenhouse gas emissions and develop strategies to meet the impact of climate change.	2011
Procurement Strategy, 2013-2016 (ref. 7)	Green procurement, implementing UN's Global Compact.	2013
The Waste Management Plan, 2006-2009 (ref. 20)	A cycle-based waste system.	2006
FutureBuilt, 2010-2020 (ref. 53)	Create prototype projects serving as models for climate-friendly architecture and urban areas.	2010
The Air Quality Action Plan, 2010-2015 (ref. 17 and 18)	Complying with the EU Air Quality Directive.	2010
The Noise Action Plan, 2008-2013 (ref. 19)	Complying with the EU Environmental Noise Directive	2007 (Revision in progress)
Plan for Multiple-use of the City of Oslo's Forests, 2007-2015 for (ref. 27)	Eco-sustainable forestry, where biodiversity and outdoor recreation takes priority over economic returns.	2005
Green Structure Plan (ref. 13)	Maintain and strengthen the blue-green characteristics of Oslo, in line with ecology principles, and provide the habitants with recreational areas within the city.	1993 (Revision in progress)
Resolution on the Preservation of Biodiversity (ref. 16)	States that valuable habitat types are to be considered in the development of new municipal master plans and zoning plans, and integrated in all processes in municipal agencies.	2002
The Urban Greenway Plan (ref. 15)	The system of greenways and trails in the city.	1949
The Grorud Valley Project, 2007-2016 (ref. 54)	Environmental upgrade and urban densification in Groruddalen – 130,000 inhabitants	2007
Oslo Package 3, 2008-2026 (ref. 59)	Further development of transport infrastructure in Oslo and the neighbouring county of Akershus: reducing congestion and improving conditions for public transport, pedestrians and cyclists.	2008
Cycle strategy, 2005-2015 (ref. 11)	Ensures that bicycling is a safe and attractive mode of transport.	2006
Ruter's Strategic Plan for Public Transport (ref. 33)	How Ruder plans to achieve more satisfied customers, increase the public transport modal share, and phase in zero-emission solutions.	2011

Figure 37 - Key strategies and action plans (Oslo, 2013a)

Name	Description
Biotope Area Factor (BAF)	Quantifies the ecologically effective surface area of a piece of land
BREEAM-NOR	Norway's method for classifying sustainable buildings
Plan- og bygningsloven av 2008	Promotes sustainable development that is best for the individual, society and future generations
TEK 10 building code	Regulation that surface water shall be infiltrated or otherwise handled locally to ensure water balance and prevent sewer system overload
Municipal water supply and sewage systems law 2012	Fee for water and sewage charge that can be divided into three parts – water and sewer fees, a connection fee and an annual fee
Water Resources Act of 2000	Ensures proper management of waterways and ground water and imposes degrees of infiltration in planning and zoning in urban areas
Biodiversity Act of 2009	Sustainable use for and protection of biological, geologic, and ecological processes in the landscape so nature can continue to provide a basis for human activity, culture, health, and well-being
Densification of quality	A guide to the effects of densification on environmental quality that stresses the need to plan ahead to minimize negative impact
Lokal overvanndisponering (LOD)	Guide for stormwater management developers

Table 16 - Laws and tools for green roof development (Falck-Pedersen, 2012)