A STUDY OF INTERDISCIPLINARITY AT NTNU ENERGY

Abstract

Through interviews, literature and analysis, this paper examines the obstacles to, and benefits of, interdisciplinary research at NTNU Energy. Challenges such as that of addressing the top-down incitement of funding organisations' call for interdisciplinarity, the differing approaches to, and expectations of, collaborations as well as requirements of non-academic partners are examined to demonstrate that the problem of transferring the benefits of interdisciplinarity from theory to practice is in itself a "wicked" problem that can require a structural and intentional intervention to break open.

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1.0 Introduction – the meaningfulness of interdisciplinarity

Based on a study conducted during an internship at NTNU Energy, this paper explores the meaningfulness of interdisciplinarity in NTNU's energy research. Based on discussions on the definition of meaningfulness in the context of NTNU and NTNU Energy, the main research question of the study consequently seeks to explore if interdisciplinarity in energy research adds more value to society than traditional monodisciplinary approaches. Meaningful research is, in other words, defined as research which adds value to society. This interpretation is corroborated by NTNU's overall strategy of creating "*knowledge for a better world*" and the general turn in academia towards solution-based research.

To discuss the meaning of interdisciplinarity within the framework of NTNU Energy, we must, however, first take a quick look at the specific goals and values of NTNU Energy. NTNU Energy is one of NTNU's four current strategic research areas. From 2014 – 2023, the research areas Energy, Health, Sustainability and Oceans are to "lift and intensify research, education and innovation through interdisciplinary collaboration". Furthermore, NTNU Energy is, like the other strategic research areas, assigned to: "be well-known participants in the public debate, provide facts and research-based opinions when important subjects within their area is discussed." and "the research areas must be characterised by their innovative power and ability to contribute to knowledge-based solutions".[1]

Reflecting these original ambitions from the board of NTNU, NTNU Energy's ambitions have been comprised and defined by the following five goals:[2]

1. Interdisciplinarity, contribute to collaborations across disciplines.
2. Funding, create a better framework and access for energy research.
3. Utility (samfundsnytte), connect NTNU's energy bubbles with industry, businesses, the public sector, and other research unities.
4. Communication, contribute with knowledge to public players.
5. Innovation, contribute to increasing the utility of ideas and research, especially from the FMEs (Centres for Environment-friendly Energy Research).

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[1] NTNU Energi Treårsrapport, p. 2
[2] NTNU Energi Treårsrapport, p. 17

Finally, but crucially, as NTNU's vision is to "*increase sustainable value creation and find answers to major challenges*" and "*contribute actively towards achieving UN's Sustainable Development Goals*"[3], NTNU Energy is inherently dedicated to research in not just renewable but sustainable energy. In specific, NTNU Energy is focussed on goal seven, Affordable and Clean Energy, and goal 13, Climate Action. As such the sustainability of the output of research conducted as part of NTNU Energy is at the core of the strategic research area.

Based on these specifications of the values and goals of NTNU Energy and the overall research questions this study will firstly investigate if interdisciplinarity furthers sustainable energy technologies in a more efficient manner than monodisciplinary research. This will be explored from a theoretical point of view, meaning that this section will talk of interdisciplinarity in its ideal form without discussing the challenges in achieving this. This will, however, be studied in-depth in the following sections which investigate if interdisciplinarity, in the form that it takes place at NTNU Energy, furthers innovation and knowledge sharing to a greater extent than monodisciplinary research. This will lead to an examination of what hurdles researchers experience in achieving the purported results of interdisciplinarity and subsequently an examination of whether these hurdles also hamper collaborations with external non-academic partners. The final part of the paper will tentatively explore possible approaches to the problems presented.

2.0 Method

This study takes its offset in a philosophical practice and thus, for its theoretical part, leans on texts within the philosophy of science, technology, and sustainability. Texts are chosen on basis of relevance and impact. Through the literature it is primarily investigated whether interdisciplinarity is particularly apt to deal with scientific problems withing sustainability and, if so, what kind of interdisciplinarity the energy transition and NTNU's goals call for.

Furthermore, the literature has been used to inspire the questions posed in 16 interviews conducted with researchers from NTNU Energy's teams from 4 October 2022 – 4 December 2022. Combined with the literature, the interviews seek to establish how researchers approach interdisciplinary work and how and why this approach affects the outcome of collaborations both in regard to research results and in regard to the level of professional satisfaction experienced by the researchers. The interviews have been conducted with two members from each team, when possible, from disparate

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[3] NTNU Strategy 2018-25

disciplines. In all teams, at least one of the interviewees is part of the team's leadership group. For practical reasons, only one member of Team LMIC and Team CCUS are included.

Furthermore, the research interviews will be used to establish whether researchers experience the interdisciplinary approach encouraged at NTNU Energy as value adding in regard to the parameters discussed above. Interviews will be used qualitatively to illustrate general and individual points. On requests from interviewees all quotes and information will be presented anonymously and, if requested, approved by participants before inclusion. Some quotes may have been edited for clarity if doing so has been possible without altering the meaning. To illustrate conflicting approaches to interdisciplinarity between different disciplines, it will, when relevant, be indicated if information or quotes come from a source within the natural sciences or social sciences or technological disciplines. Opinions and quotes from all interviews conducted for this study are represented, but greater attention has been applied to the researchers most experienced in interdisciplinary work. To make sure that the study represents a balanced picture, a maximum of four quotes from the same source is used.

In addition to interviews with researchers, interviews have been conducted with five external partners who have collaborated with researchers or groups within the NTNU Energy teams. To avoid indirect criticism of individual researchers, quotes and points from these interviews will also be presented anonymously. These interviews seek to establish if external partners experience increased benefits form interdisciplinary collaborations, and what kind of interdisciplinarity, if it is defined, the organisations are looking for.

3.0: Does it need to be interdisciplinary to be sustainable (and will it be sustainable if it is interdisciplinary)?
"We know that our work has to be more interdisciplinary and integrated to be able to view solutions in the perspective of sustainability."[4] This viewpoint as expressed by NTNU's rector, Anne Borg, is a widely adopted perspective among university leaders and funding bodies.

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[4] NTNU Treårsrapport, p. 8

Indeed, in the science of sustainability, interdisciplinary (and transdisciplinary) research is widely considered as best practise as current disciplines, many believe, do not in themselves have methodologies for resolving sustainability problems. [5]

"Sustainability problems are often regarded as wicked, crosscutting problems that require those who address them to understand the limitations of, and to some extent overcome, the boundaries of individual disciplines*,"* writes Johannes Persson in *Toward an Alternative Dialogue Between the Social and Natural Sciences.*[6]

In the context of NTNU Energy, however, it should be noted that NTNU Energy is not NTNU Sustainability. The focus on energy and NTNU's history and profile as a technological university means a technological dominance on all energy teams, except Team Society. So, if we are not talking Sustainability Science, but science that advances sustainable energy technologies, is Borg still right that an integrated interdisciplinary approach is needed?

Firstly, when looking at technological disciplines in general, many will argue that interdisciplinarity is inherently necessary. That, despite the widespread modern illusion "that [....] technological progress is a matter of revealing purified truths of nature, sequestered from the asymmetric structures of world society", technological disciplines comprise a mix of natural and social science."[7]

Furthermore, it seems only logical that since the energy transition poses a wide range of challenges and will have an equally wide range of effects, the solutions need an equally broad basis. In particular, the task of decarbonizing the energy system depends both on technological solutions and societal changes, including consumers' lifestyles, values and attitudes.[8]

But as work within NTNU Energy demonstrates, the challenge goes further yet as many energy technologies depend on formal sciences for their large-scale application in society and both depend on and affect the natural world. As such, it seems a sustainable energy transition, like other wicked sustainability problems, depends on broad interdisciplinary collaborations, including the technological disciplines as well as social, formal, and natural sciences, for their solutions.

Most (14 of the 16) of the researchers interviewed for this study also expressed support for the view that interdisciplinarity (undefined) is valuable to sustainable energy research. Considering that the

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[5] Nagatsu et al., 2020, P. 4

[6] Persson, 2018

[7] Persson et al. 2018, P 9

[8] Cohen, 2021, P 2

interviewed researchers are for the most part actively and voluntarily taking part in interdisciplinary teams, this, of course, should come as no surprise. Perhaps more surprisingly, out of the 14 researchers that replied positively, half added that it was so in theory but went on to mention a number of different hindrances in practice, including time, lack of funding, difficulties crossing disciplinary borders. Furthermore, five went on to specify - in different phrasings - that interdisciplinarity is needed to "land big projects" indicating that the value is not (only) in the interdisciplinarity itself, but in the fact that it leads to more funding opportunities.

However, one advantage of interdisciplinarity in relation to sustainable energy research mentioned by many researchers was the fact that it speeds up processes that might be highly time-consuming if working in traditional "silos". The speed of things was stressed in connection with several things including application processes and communication with media and external partners, but also, by some, as a tool to speed up the research process. This is relevant as another aspect of sustainability science and sustainable energy research is that to be sustainable, it has to take place within a practical problem-solving and strictly time-defined framework. Why? Because knowledge that cannot be applied within a short timeline has no use in the current climate crisis, and spending time and resources on energy research that has no use in solving the crisis is highly unsustainable. This is also often reflected in project calls of a specific problem-solving character and with strict time frames. The necessity of speeding up the research process in the perspective of sustainability is well expressed in the following quote from an interviewed researcher.

"I don't see how to do something of meaning without crossing disciplines. It made sense before when the problem was less complicated and did not need that much of other technologies or we were fine to let someone else solve it afterwards. But now, the timescale has been mixed up in what used to be done very slowly on a higher level and what needs to be done very fast. You need to take into account a bit of everything, and more and more every time."

As we will see, this means that we must work with a specific definition of interdisciplinarity for it to make sense within the context of NTNU Energy. But with the very basic definition of interdisciplinarity as research that connects disciplines instead of "isolating them in silos", it seems evident that this is needed to promote sustainable energy solutions.

4.0: Yes, but what is interdisciplinarity?
With the broad consensus that interdisciplinarity is required to solve sustainability problems, such as

that of providing a sustainable energy transition, it is no wonder that it is becoming one of the most powerful trends in contemporary science. This is also exemplified, in e.g. the wording of Horizon 2020 (EU's research and innovation programme from 2014-2020 succeeded by Horizon Europe). "Horizon 2020 should stimulate a break-down of the silos of different research disciplines and stimulate integration in order to maximise impact."[9]

As such, the talk of interdisciplinarity may, in the words of Finnish Philosopher Uskali maki, who has written extensively on the topic, need further (philosophical) scrutiny.

"Talk about interdisciplinarity is different from interdisciplinarity present in scientific practice. The two may be (and often are) out of phase with one another. On the one hand, there is quite some empty, pretentious or misguided talk about interdisciplinarity; on the other, there is much unrecognized or misunderstood genuine interdisciplinarity in the actual practice of science. One should therefore not uncritically draw straightforward inferences from the talk to the thing in making observations about the structures of interdisciplinarity or about changes in its prevalence, and one should also be earnestly cautious with normative recommendations, both in giving and judging them."

Indeed, with the various different variations of cross-disciplinary[10] work, researchers, universities and funding bodies may actually be looking for and/or getting something other than interdisciplinarity - or something other than their interpretation of interdisciplinarity. In general, terms such as multidisciplinary (flerfaglig), interdisciplinary (tverfaglig), and transdisciplinary (transfaglig) are loosely and interchangeably used to indicate different forms of cross-disciplinary collaborations, and the meaning and differences of the terms are often overlooked.

In the traditional view as presented by Erich Jantsch in 1970, however, multidisciplinary is characterised as problem solving involving several disciplines but without cooperation between disciplines. Tasks are split up and parts solved without integration or understanding. Interdisciplinarity, on the other hand, requires "coordination by a higher-level concept", meaning that the disciplines have to change some concepts and principles to integrate and create a unity continuously shifting but constantly guided by the higher-level concept.[11]

Traditionally, transdisciplinarity was defined as the next level of cross-disciplinarity requiring multilevel coordination. In this traditional view the three forms of cross-disciplinarity are thus considered as part of an evolutionary ladder meaning that interdisciplinarity can only take place as

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[9] Horizon 2020 2014,P 6
[10] Cross-disciplinary is used here to cover all variations of non-monodisciplinary work.
[11] Persson 2013, P 339 - 340

the evolvement of a multidisciplinary collaboration.

Today, however, transdisciplinary is widely understood as collaboration that transcends disciplines bringing in external stakeholders and solving problems with effects that transcend the academic sphere. This, as well as alternative interpretations of interdisciplinarity, will become relevant later as we will see that perhaps interdisciplinarity is not what is needed to achieve all of NTNU Energy's goals or perhaps a more specific definition of interdisciplinarity might create a broader acceptance among researchers.[12]

Numerous philosophers of science have, in the last decade, noted the problem of working with the traditional understanding of interdisciplinarity when working within sustainability problems. "It begins to look like a rather ineffective tool for characterising interdisciplinary collaborations of shorter duration. Sustainability projects aimed at practical problem-solving are frequently of this type. The traditional perspective becomes incapable of discriminating between shorter projects."[13]

While researchers working in interdisciplinary teams do not need to evaluate what kind of cross-disciplinary collaboration they are part of, the interviews with researchers seem to indicate that the root of discontentment among some researchers could partly be differing interpretations and understandings of what to expect from interdisciplinary collaborations.

4.1: What is interdisciplinarity at NTNU Energy?

Before we continue to look at in what form interdisciplinarity takes place at NTNU, it may be helpful to take a short glance at the structure in which it is expected to take place, the framework which is created to facilitate and promote interdisciplinary collaborations at NTNU Energy.

First, it should be noted that NTNU Energy was created to deal with what we earlier saw named "a wicked" or "complex" societal problem, namely the energy transition to renewable, sustainable energy. As such, when looking at the subcategories of the interdisciplinarity proposed by philosophers of science, NTNU Energy lands within the "problem and purpose oriented interdisciplinarity which focuses on problem framing and agenda setting." [14]

NTNU Energy is one of four strategic research areas focussing on a complex societal problems. But though interdisciplinarity is encouraged in all of the strategic research areas, NTNU Energy is the

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[12] Nagatsu et al., 2020
[13] Thoren, 2013, PP 340-342
[14] Rader, 2011, P 7

only of the four to have created interdisciplinary "teams" consisting of researchers from different departments and faculties. Four of the teams are focussed on renewable energy sources, Hydrogen, Wind, Hydro, and Solar, two of the teams are focussed on integration, team Society and team smartgrid, one team is focussed on the energy transition on low- and middle-income countries team LMIC and the last on carbon sequestration and storage, team CCUS.
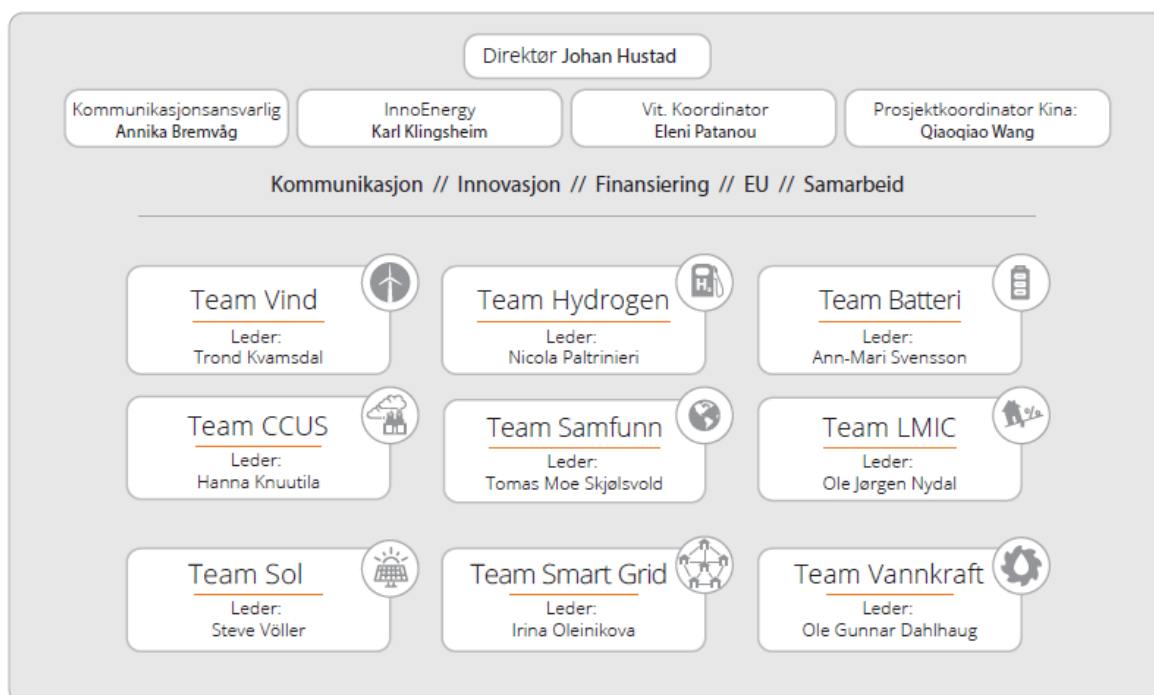
The teams include between 12 and 70 researchers who are either automatically added due to their employment within a specific department, have been invited or have asked to be on a team. Some researchers are members of several teams. Each team is managed by a leadership team of between one and three professors.

The nine teams were not created all at once, but have come into existence during the years since 2017 when director Johan Hustad took over the management of NTNU Energy. The team structure was initially inspired by the EERA joint programmes (18 EU programmes covering the whole range of low carbon energy technologies). When he took over the management, NTNU Energy was represented in 13 of these groups, explains Hustad in an interview. The researchers representing the university in the different fields were, however, very driven by their own research, and as such the idea of creating a group of researchers within each field arose. At the same time, professors from team Wind, who had previously been part of a now concluded FME and were feeling their network slip apart, contacted Hustad about the possibility of all creating a research unit through NTNU Energy. "Then we had two correlating starting points for the teams, EERA and Team Wind," explains

Hustad, but stresses. "It was a bottom-up process with all the teams, but we had a dialogue between us and them and in that we looked at the organisation of EERA, we looked at which people we had who were active in EU projects and then we worked to find the right organisation for each of these. The goal was that the team should be interdisciplinary. The teams should at least be across faculties."

Apart from the team structure, with leaderships groups responsible for EU projects and EERA representation, the definition of interdisciplinarity and which faculties to involve was left to the experts in the teams.

In general through it seems that, internally (expressed and promoted by Hustad and the teams' leadership groups) and externally (expressed on website and in three-year rapport), the interdisciplinarity promoted through NTNU Energy is defined more though end-means terms such as innovation, impact, sustainable value creation, communication, problem-solving, etc. than by a means definition. Interdisciplinarity is, it seems agreed, the means to achieving all of the above. This is not unusual. "It is commonplace to define interdisciplinarity rather richly in end-means terms. Interdisciplinarity in these characterisations manifests the ambition to solve broad or complex problems by combining and integrating two or more disciplines."[15]

However, when researchers were asked what they thought was the purpose of interdisciplinarity at NTNU Energy, incongruent answers revealed that the goal itself was also diversely perceived. The answers included as various end terms as "collaboration across teams to **facilitate a complete sustainable energy transition**", "different disciplines **covering the whole value chain of a specific technology**" and "technical disciplines getting together to **make a specific technology work**." (generalised quotations). Obviously, the understanding of the interdisciplinarity that would facilitate those different goals would also vary significantly, and the lack of a clear and coherent strategy is also noted by a couple of researchers in leadership teams.

One researcher said. "It seems to me, the interdisciplinarity [in NTNU Energy] is related to illuminating one technology through different disciplines, typically technical and economic disciplines. I guess if I were to characterise that interdisciplinary, it is geared towards getting that technology to work through the mobilisation of different disciplines and collaboration in that sense. Beyond that I don't know if there is a clear strategy with interdisciplinarity, and what they want it to be besides a generic idea that collaboration is good"

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[15] Maki, 2016, P 331

A researcher from another team shared the understanding that the teamwork in NTNU is about covering different aspects of a technology, but mention none of the terms usually used to define interdisciplinary collaborations: "I think it is to ensure that different aspects of technology are covered and taken care of in research. Also that we collaborate in an efficient manner. That is quite important for how to define resources."

Tellingly, the researchers interviewed also referred to the benefits of the interdisciplinary structure of NTNU Energy as everything from ease of locating relevant researchers to integrating and creating better ideas in research questions.

Likewise, when pressed for their own definition of interdisciplinarity, researchers gave various answers differing widely in terms of everything from the width of collaborations, its purpose and the way to get there.

Different definitions of ID as expressed by members of NTNU Energy teams:

- Aiming at one goal with different backgrounds and different knowledge.
- Looking at this one big elephant from different points of view.
- Linking the different disciplines together and trying to work out new ways of looking forward so sustainable in all ways not just in engineers' minds.

- When the aim is energy transition, when we talk about interdisciplinarity I include everything from history to psychology to technical disciplines, very wide understanding
- Active cooperation between researcher from different disciplines - I'd define disciplines as a rather narrow term, physical chemists are different from organic chemists.
- Professionals, experts in two or more disciplines working together on joint task, problem. That would be working definition. I think it is kind of difficult what these disciplines are.
- It can be on different levels, very technical…or broader with social sciences.

- Questioning assumptions across different discipline
- It is about input and output - you do research that is valuable to others and need output from the others

- I think if people collaborating with different backgrounds there is high possibility to get to interdisciplinarity.
- It takes a least a year to establish, with weekly meetings.

5.0: Does innovation and knowledge-sharing develop from the bottom and up?

As exemplified by the quote from Anna Borg, interdisciplinarity and the integration of disciplines is the most widely promoted and desired variant of cross-disciplinary research. As we saw above, this is partly due to the understanding that sustainable solutions require interdisciplinarity, but in this argument is also inherently the understanding that it is the role of the university to provide

"solutions" not just research and knowledge. That this has increasingly become the case in the last decades is broadly acknowledged and this new dominating turn in academia is often referred to as problem solving research, postacademic science, post disciplinary, or triple helix research and innovation.[16] As the terms indicates, the expectation is that universities provide innovation and share knowledge in a way the benefits society as a whole and that this is done by crossing the normal boundaries of academic research. As we saw earlier, knowledge sharing and innovation were also among the explicit goals of NTNU Energy.

The belief that interdisciplinarity can help provide this is shared at national and international governmental level and is among the reasons for its growth in popularity with research and funding bodies. However, it has, as Maki points out, also created a sometimes inflated language on both sides of the application process.

"Importantly, the growth of talk about interdisciplinarity shows in the declarations and calls for proposals by research funding agencies. This phenomenon ranges from the local to the national to the multinational levels (such as from particular universities to the European Research Council). In responding to these calls, scholars and their groups do their best to advertise their proposed research as interdisciplinary. On both sides, talk about interdisciplinarity may be just a matter of wishful programmatic declaration or of truthful factual description, or something in between." [17]

This is also reflected in the interviews with researchers in this study. Many discuss the structure of interdisciplinarity (broad or narrow, long or short) in terms of what is required by funding bodies and project calls. For some, especially in technological disciplines, the increasing number of project calls looking for broad interdisciplinarity is expressed as the main motivating factor for pursuing this. When asked what s/he believed the purpose of interdisciplinarity at NTNU Energy is, one researcher answered: "For project applications it is more or less necessary to have interdisciplinary as part of the research programme. That has been growing quite a lot, the importance of that. I am not sure what NTNU's strategy is."

When asked whether they find the work in the team satisfactory, the same researcher replies: "Yes and no. Yes, I think we are doing very good work, the team is team interdisciplinary when it comes to project application and when it comes to communication. That works really well. But when comes to the research going on, there is very little common initiative."

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[16] Schmidt, 2008, 55
[17] Maki, 2015, 330

They go on to add that there is also common initiative when it comes to education, but that a common project is missing. The focus on communication, knowledge sharing and ease of reaching researchers within the needed disciplines to fulfil the criteria for specific project calls, is reflected in many interviews. A researcher from a technological discipline said: "It also helps bring information up and out. It helps in figuring out, if a company or journalist calls me to ask about something, usually they are interested in not exactly what I do or partially what I do. The teams help me finding a pathway in the jungle of professor and fields – it accelerates a lot of things, brings out more information than what would otherwise be brought out"

 As a matter of fact, when asked about the interdisciplinary work within the team, several researchers note that the teams are not teams, but more like "informal networks."

 In the interview with Johan Hustad, he also reflects that the teams are to be considered more like a platform, an opportunity, to engage in interdisciplinary work rather than fully fledged interdisciplinary teams. "When you put 40 professors in a team, you will always have many differing opinions of what a team is – some feel a strong connection to the team, others just feel it's interesting to be a part of. We help sum up what subjects they cover, which labs they have so that it is easy to show the activities taking place on NTNU's website. What they do varies a lot, but it is important to see this as a training ground for interdisciplinarity – it will take a long time for it to develop as the DNA at the university."

Interviews with researchers thus suggests that while organic interdisciplinarity may not be extensively flourishing (yet), the team structure, the network and ease of communication it creates, is generally valued because it makes it easier to present projects to external partners, improve media communication and promote research (share knowledge with public players). Mainly, however, it seems valued because it makes it easier to fulfil project applications looking for interdisciplinarity. One researcher with some experience in interdisciplinary collaborations said: "All Horizon Europe projects, you need to take into consideration both environment and social perspectives in order to get any projects. We see that in new Norwegian Research Council projects as well - that if you take this into consideration it strengthens the project. Technology is just one part of the projects. Earlier, we were looking at Interdisciplinarity as having different engineering partners -mechanic, civil and so on - we looked at that as interdisciplinarity, but that is far from interdisciplinarity today; things are changing, and it has changed fast."

Another researcher from a technological discipline is more explicit in the dichotomy between the advertised form of interdisciplinarity and his/her perception of interdisciplinarity: "We had a call for

this sustainable project where they required a project that had a component of social science and other completely different disciplines in order to make it interdisciplinary. I strongly disagree with that definition. I think this kind of restraints is not good. It will result in proposals that are put together to fulfil call, but not for the purpose they want to study. The researchers should have much leeway with the concept of interdisciplinarity when defining their own project."

This is interesting because it indicates that in whatever form they exist, many of the interdisciplinary collaborations at NTNU Energy are what Maki terms "managerial top-down interdisciplinarity". Interdisciplinary collaborations motivated by external incentives such as research funding schemes or job structures.[18] This seems to contradict the beforementioned belief expressed in NTNU's three-year-report that interdisciplinarity cannot be forced or created from the top down but must happen bottom up. "Tverrfaglighet kan ikke tvinges fram. Vi jobber utelukkende med initiativ der det er sterk forankring i forskningsmiljøene, og der dedikerte forskere er engasjert. Vi velger derfor å bruke vår strategiske forankring til å støtte "bottom-up" -initiativer." The text goes on to state that one of the ways of doing this is to help secure, the often lacking, funding for interdisciplinary projects. [19]

As we saw earlier, the kind of interdisciplinarity promoted by NTNU Energy is the most common kind of interdisciplinarity associated with technology, problem and purpose oriented interdisciplinarity, which is motivated by societal problems too complex to be solved within one discipline[20]. Evidently, this requires researchers to agree on the shared problem, and it is not unusual that this, as it is noted by researchers at NTNU Energy, becomes a significant hurdle hindering teams to develop from network to actual teams, and collaborations to go from "filling in holes" to actual integrated teamwork. The problem described by a researcher of much interdisciplinary experience. "I think it takes a lot of work and talking if one wants to really do something interdisciplinary. First, trying to find what are the common concepts, what language to talk to each other. Definitions are often different, it can be really small things, but there are also different problems. Different ideas about what relevant problems are, what is worthy and interesting. That is what makes it hard."

In the paper *the Second-order Science of Interdisciplinary Research* the problem is described perfectly: "The perspectival nature of scientific disciplines leads to the problem of problem making. Different disciplines necessarily see different types of immediate problems due to their different methods and instruments of observation, different concepts, categories and theories, and different

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[18] Maki, 2015, 342
[19] NTNU Energi Treårsrapport P 16
[20] Schmidt 2007, PP 65-66

concerns, questions and values. Each research perspective forms its own version of what the problem is, and this is part of what makes the problem "wicked." The paradox that has to be resolved in the face of wicked problems is thus that it takes a concerted effort to establish a shared problem, and it takes a shared problem to establish a concerted effort."[21]

This somehow explains why researchers who are presumedly working "on the same problem", whether that would be the energy transitions a whole or the development of solar still may struggle to find a shared problem to attack interdisciplinarily. The very same sentiment is expressed by a technological researcher with much experience in interdisciplinary collaborations in and outside NTNU. S/he says about the work in one of the well-established teams at NTNU Energy. "We do a lot of work that is problem driven, but the problems are defined within their own disciplines so we seldomly have really interdisciplinary problems. The best is that it is useful to have input from other disciplines. Then we have [the team] where it is easy to find people that could help you. But we are not at the level where we consider truly interdisciplinary problems."

This experience is recognised by a researcher from the social sciences who has partaken in several constellations supposed to be interdisciplinary. "If you sit in a room with ten people and you are the only one trying to bring in a social science perspective, it is extremely difficult because the discourse is formed by majority; the language is different, and that makes it difficult to even get the perspective through"

Another thing that became apparent during interviews and subsequent talks with the management of NTNU Energy on the activity levels of the teams was that the more interdisciplinary activity a researcher had engaged in, the more likely the researcher was to define interdisciplinarity as highly beneficial but extremely difficult and time consuming. Researchers from teams that had, judging by information from NTNU Energy and/or their own information, partaken in few or only very narrow interdisciplinary projects were much more likely to consider interdisciplinary work as straightforward and problem-free.

5.1 Why is this a problem?

One of the problems of interdisciplinary collaborations motivated by the search for funding and not by a "real" shared problem, is that this can lead to exaggerated expectations from other disciplines

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[21] Alrøe, 2014, 69

and little incentive to dispel these.[22] A few researchers who have been extensively involved in interdisciplinary collaborations comment on the exaggerated or simplified expectations from other disciplines. "It is interesting to interact with people from different disciplines in this way because it is easy to underestimate the problem on each side. Technology people would tend to think social side is not a big issue vice versa the social side would tend to think that technological development just comes by itself."

Some, mainly from the social sciences and humanities, also comment on the feeling of being invited into a project mainly to fulfil application guidelines and not for the purpose of solving a shared problem. This, in turn, is often combined with a simplified understanding of how the discipline works and consequently also a tendency to underestimate the complexity of social and environmental problems. One social science researcher said:

"According to my experience, engineers look at social science and humanities as very limited, that we study how to get people to accept a technology - they do not understand how diverse the social sciences and humanities are and how many different questions we can address, about the energy transition as whole."

Another researcher from the social sciences commented on the fact that the social sciences are often expected to solve a very specific problem, one that is not accepted by the discipline, providing a social science alibi for a specific technology: "It's a bit uncomfortable to think of yourself as support personal advocating for different technologies. I guess, most social sciences would take a more agnostic approach."

That some disciplines are included in projects mainly for the sake of getting project proposals accepted is confirmed by several researchers in technological disciplines. Looking at this problem form a different perspective, one says: "My personal experience is that we don't have problems in acknowledging the importance of the different disciplines but on the receiving side, those who evaluate the proposals, I don't always have the same experience. My feeling is that it's not easy to sell technological proposals. If I say I will develop a piece of technology which is will solve the problem, it's actually more difficult to sell than if I say I will study the problem, I will look at the consequences of the problem."

That one discipline, usually the one that initiates the project, takes the lead is, according to the paper *The Jobs of Others – Speculative Interdisciplinarity as a pitfall for impact analysis*[23] a natural

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[22] Rader 2011, p 4
[23] *Rader 2011*

consequence of collaborations without a shared conceptual framework, and can be part of the reason for exaggerated expectations to results from other disciplines. "A major problem in interdisciplinary research in fields where it has not previously been established is the lack of a common conceptual framework. In such cases, it is not unusual for one of the disciplines involved to take the lead, usually the discipline which provided the impulse for the interdisciplinary endeavour. It then usually has a rough conceptual framework combined with expectations of the results of the other participating disciplines."[24]

In short, the fact that collaborations mainly happen in project applications and often take place within short timeframes without a shared conceptual framework and with too little attention to the organisational aspect means that the barriers of interdisciplinary collaboration, language, terminology, and conceptual framework, are often not overcome.[25] The time limits on projects and distance between the technological majority and the social sciences and humanities may lead to what is termed "problem-feeding" interdisciplinarity. A form of interdisciplinarity typical, some state, of sustainability problems of shorter duration and characterised by the transfer of problems from one discipline to another, especially in projects involving disparate disciplines. In the traditional view, this kind of problem-feeding collaboration remains at the multidisciplinary level, and with the bias towards the technological disciplines at NTNU Energy it is no surprise that minority researchers express the discontented experience of being unilaterally fed problems.[26] Genuine interdisciplinary innovation may thus, it seems, be limited by the lack of time and resources to establish shared problems.

One researcher says: "It is a bit of a sort of a slightly naïve approach on how to achieve interdisciplinarity work. Anyone that's tried it knows it is extremely difficult, it takes a lot of time. Of course, it depends on the types of disciplines working together. But there is something to be said about what is required to succeed, and it is typically slightly more than just putting people together and having them address a certain topic."

Indeed, both the literature studied for this paper and interviews with the researchers of the most interdisciplinary experience, seem to confirm that overcoming the barriers of interdisciplinarity to establish a shared problem does not happen by coincidence in the break room. "Having a coffee together now and again is not enough," one researcher says. It requires significant time and resources. Indirectly, a member of the management team in a team with little activity confirms this

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[24] Rader, 2011, P. 13
[25] Rader, 2011, P. 10
[26] Persson, 2013, 338-343

by saying. "We hardly meet physically; we are from all over the campus [...] It is more of an informal network across NTNU." Meanwhile a member of the management team of a team with a few more years and successful long-term projects on its back says: "The challenge is that we are speaking different languages. Use different words with different meaning, it is all about getting to know each other, making sure we understand each other, spend some time on this so we are 100 percent sure that we actually communicate what we want to communicate. It is all about people meeting people. To me the key has been that we have met each other so many times, that it opens up not being afraid of making a fool of each other. Being confident in the meeting, confident enough to open mouth, and speak freely. That takes time. That's the tool, meeting regularly on regular basic and discussing different topics, that's the key, and in, in my opinion the tool."

However talk about "how big a share of the work package" individual disciplines get -which is expressed by many researchers wo have participated in long-term projects such also the FMEs - also indicates an non-integrated cross-disciplinary approach even in the projects where time would allow for interdisciplinarity to develop and thus indicates that collaborations remain at multidisciplinary level when not initiated by shared problems but, as it seems most often the case, by project calls and funding.

If defined more narrowly as, says, different technological disciplines working together or different social sciences and humanities working together, the picture may be different. The organically created Team Society, which includes researchers from the social sciences and humanities, but none from the Faculty of Engineering, reflects this. Likewise, as we saw earlier, researchers within the technological disciplines also comment on the often forced requirement to include disciplines outside the technological field, and many express a preferred understanding of interdisciplinarity as different technological disciplines working together.

Looking at the wording of the ambitions of both NTNU Energy and NTNU as a whole, it is clear, however, that in theory at least, broader interdisciplinary collaborations including traditional sciences and technological disciplines are believed to be needed to solve the energy transition. Johan Hustad says: "NTNU was founded in 1996, before that it was two organisations, and a part of the mandate was interdisciplinarity – the Social Sciences and technology and natural sciences were to collaborate more. In fact, that was the beginning, but then not a whole lot of interdisciplinarity happened by itself."

The need for broad interdisciplinary research is also expressed by funding bodies and the non-academic partners interviewed for this study. Thus weeing as this form of interdisciplinarity still is

not happening widely organically at NTNU Energy, despite NTNU Energy facilitating better communication and easing the application process for interdisciplinary projects, the next chapter will take a look at what may be the obstacles, why researchers are not pursuing broad interdisciplinary collaborations of their own accord.

5.2 A summary of the problems

Evident from the 16 interviews conducted for this study is the fact that, in general, both researchers from the technological disciplines and from the social sciences find it challenging and, in some instances, meaningless, to pursue broad interdisciplinary collaborations on the energy transition. Thus while many agree on the necessity of interdisciplinarity in theory, when it comes to the actual demands from funding organisations and/or the expectations from collaborating disciplines, the tone is less positive. Lack of time; calls for forced interdisciplinarity; lack of shared terminology; lack of understanding of a discipline's methods and complexity from collaborating disciplines; the physical location of researchers; and NTNU's perceived lack of understanding of the complexity of interdisciplinarity; and a lack of understanding of the strategy of NTNU Energy and the purpose of interdisciplinarity are among the issues cited as reasons for lacking interdisciplinary research in the teams. Furthermore, the obvious dominance of technological disciplines is mentioned.

Additionally, in teams where interviews have been conducted with more than one member of the team's leadership group, it has become evident that leadership groups do not necessarily share the same definition of interdisciplinarity or perceive the same obstacles. It thus appears this has not been examined. This could indicate that the issue of what interdisciplinarity is or how to promote is somewhat neglected at all three levels of NTNU Energy (management, team leadership, and, some individual researchers).

Another significant obstacle mentioned by many and broadly acknowledged in the literature on interdisciplinarity is that of getting academic credit for the results of collaborations. One researcher of some interdisciplinary experience (outside NTNU Energy) says of their participation in one of the newer teams: "I am quite optimistic and enthusiastic, but I also know obstacles. One that is extremely important is how we can, when we start to write papers, choose the journals to upload the articles to." They go on to add that some people who contribute to a paper may not get credit because the journal is not recognised in their fields and says: "This is one of the most serious obstacles for interdisciplinary collaboration."
It seems highly likely that this obstacle is exacerbated by the decreasing number of permanent

positions in academia and the consequent need to continuously bolster academic credits with publications and citations.

Interview answers also seem to suggest that the researchers who have in-depth experience and insight in interdisciplinary work has had so before their involvement in NTNU Energy, indicating that the structure of NTNU Energy, while beneficial to those experienced in interdisciplinarity, does not generate interdisciplinarity in itself. The researchers' involvement in interdisciplinary projects seems instead to be spurred partly by concrete shared problems, realising that they were stuck on their own, or by participation in long-term interdisciplinary projects due to past employment structures or participation in EU programmes.

However, those researchers also all mention the obvious differences in methods, goals and terminology between the social sciences, technological disciplines and natural sciences as hurdles that take time and resources to overcome. Furthermore, it is clear that the level of integration perceived as "necessary" varies broadly from researcher to researcher. This may of course very well reflect the different types of problems researchers work with, some may require interdisciplinary solutions other multidisciplinary or transdisciplinary collaborations. Some will require broad and loose collaborations with disciplines from disparate fields working to solve ach their part of a problem, others narrow and wholly integrated collaborations between e.g. different technological disciplines. The issue, it seems, is the lack of awareness of the different types of collaborations, their pitfalls, and the effort required to make them work optimally. Where this knowledge and awareness seems to exist it does not seem to be shared.

Possible solutions as suggested by literature, and the researchers and external collaborators interviewed for this study will be discussed in the conclusion after the following investigation of the relationship between interdisciplinarity and external partners.

6.0 How do the problems affect external collaborations?

The issue of academic credit is one that is also mentioned by industrial partners as obstructing constructive interdisciplinary, or transdisciplinary[27] collaborations. A partner at a partly state-owned company which collaborated with energy researchers from NTNU Energy teams said too many academics focus too much on presenting rather than creating: "The university needs to think out how its professors and employees should get points for contributing to making products and ideas,

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[27] In the literature on cross-disciplinarity, collaborations including non-academic partners would as most often be defined as transdisciplinary

that is invent with the companies they collaborate with, and not just for presentations."

Still, all but two or three of the researchers interviewed for this study straightforwardly agreed that interdisciplinary collaborations were required by, and of benefit to, non-academic private and public partners. One pointed out that the chance of "getting answers faster with interdisciplinary collaborations" made municipalities and industries keen on interdisciplinary collaborations. Another said: "Industry typically asks for holistic solutions. Now, they have NTNU Energy which is more coordinated – it is a great benefit that we have such teams." The fact that "industries are generally busy and really appreciate being able to gather perspectives form different disciplines," was noted by a third researcher.

These quotes, however, obviously do not reflect the nature of interdisciplinary work in specific, but of any cross-disciplinary collaboration. As a matter of fact, the talk of speed may (when added with the fact that this refers to groups of researchers put together for the specific project and thus not with an existing conceptual framework) indicate, that the collaborations are more of the "conquer and divide kind of multidisciplinarity" than actual integrated interdisciplinary work. This theory is supported by other statements such as: "Yes, I would say so, because industry is also dealing with various sort of problems not just technical, but physical and material […] We can collaborate better if we have different team members covering different aspects of these areas."

The support for interdisciplinarity and the broad interpretation of this term is also confirmed by the five interviews conducted with external partners of projects. Including a municipality, a state-owned company and three private or semi-private companies, all but one of the interviewees confirmed the benefit of interdisciplinary (in their definition of this) collaborations with NTNU and their contentment with past or current projects. However, all also pointed out that the requirement for interdisciplinarity, and the width of the collaboration, depended on the specific problem at hand. A partner from a municipality said: "Some projects will always require more hardcore competencies in one field than other. But for us and our current task […]interdisciplinarity is key to succeed." Some technological researchers also stressed that the type of collaboration required depended on the problem the partner wants solved. One researcher pointed out that "industries don't want disciplines they don't understand.

However, asked why interdisciplinarity is attractive to their company, a partner from a private company said: "It benefits us because we get to understand the whole picture. We need to know our customers, how they feel, and the regulations in hydropower - business regulations for rivers, how they can operate, regarding water levels, fish conditions and all aspect, also get insights on how we

should regulate machines according to the net frequency stability and everything, we have a quite specialised product and [..] we need to see the broader picture in this, and also get information on how this will develop over the next years."

In general, the three commercial organisations highlighted the need to understand "the customer" as one of the reasons for pursuing broad interdisciplinary collaborations including social sciences and psychology. Asked whether the company benefitted the most from collaborations with interdisciplinary groups or individual researchers, one said: "Both, dependent on what we need - innovation or technology. Sometimes you need cutting edge knowledge [...] It depends on the technology. Mostly we need a team. Because you have to see innovation and technology in context that is bigger than technology. Especially true with energy technologies."

This seems to support the view advocated by many governmental and funding bodies that broad interdisciplinarity creates stronger innovation while also reinforcing the technological researchers who state that when it comes to developing a specific technology, narrow collaborations make more sense.

Another point that is perhaps worth noticing is that only two of the partners interviewed were aware of NTNU Energy, and several researcher also noted that they did not think of the teams as partners in collaborations, but as, sometimes, starting points for them. Furthermore, the benefits of a specific focus on interdisciplinarity may, it seems, in some instances be difficult to convey to industrial partners. When asked if interdisciplinarity in general is an advantage to industrial collaborators, a partner at a state-owned company that just entered an interdisciplinary collaboration on wind energy said. "I guess so. But I think it might be difficult to communicate the benefit, often you focus on one specific problem and maybe you don't see that problem can be looked at from different angles. It may be difficult for the company to understand the benefits - they may be narrowly focused on solving one problem, but maybe more holistic approach could be better."

When being approached by external partners looking for interdisciplinary collaborations, having already established teams (and hierarchies) may be crucial to the success of projects. One external partner from a private company, says he had "a shocking experience" when a trusted collaborator at the university tried to set up an interdisciplinary meeting within his energy field (before the establishment of a team): "The problem was that they were, in the collaboration, they were interested in doing what they have always done. It's a problem with universities across the world –

they're too independent of industry. They do not care about outcome, more about internal politics., who is getting more money and who is not." He goes on to say: "If we still have divide and conquer attitude from so many different parts of NTNU [...] It is a very dangerous and unproductive approach."

Consequently, it appears that though it is widely agreed among both researchers and private and public non-academic partners that interdisciplinarity benefits those partners, just like all other cross-disciplinary work, the task of defining the width and level of integration of the collaboration is essential to the solution. Furthermore, the obstacles to interdisciplinarity, that of getting researchers to pursue real life impact rather than academic credits and the fight for funding for individual projects rather than collaboration, remain.

7.0 Conclusion – tackling a wicked problem

One of the conclusions of this study has to be the fact that the problem of establishing a shared problem also exists when it comes to interdisciplinarity itself. With the broad consensus that interdisciplinary adds value to energy research, the problem seems simple - how to further it. However, in analysing the views of researchers in purportedly interdisciplinary collaborations, it becomes painstakingly clear that this is not one problem. Some, predominantly from the technological disciplines will perceive the problem as the requirement for forced broad interdisciplinarity and the exaggerated focus on analysis rather than solutions. From the perspective of the social sciences and humanities, the problem is that of a simplified understanding of interdisciplinarity and exaggerated demands for solutions rather than understanding. From the viewpoint of external stakeholders, the main problem in sight seems that of academia's race for publication credits and citations rather than innovation. Finally, from the viewpoint of the funding bodies, speculative interdisciplinarity and exaggerated expectations in the chase for funding may be the main concerns.

If we look for an interdisciplinary solution, the first step would thus be to establish a shared problem as this is necessary to establish the concerted effort that finding a workable approach to interdisciplinarity would take. In other words, interdisciplinarity is in itself a "wicked question" that requires an interdisciplinary or transdisciplinary solution this leaves us with the beforementioned challenge: "Each research perspective forms its own version of what the problem is, and this is part of what makes the problem "wicked." The paradox that has to be resolved in the face of wicked

problems is thus that it takes a concerted effort to establish a shared problem, and it takes a shared problem to establish a concerted effort."[28]

More than half of researchers interviewed for this study mentioned more meetings between the teams as one of the tools that could improve interdisciplinary research. As part of this study, one such meeting was observed, and it was noted that while ongoing projects and results were presented, few problems were addressed and the issues of the team structure, and the lack of interdisciplinary research and other issues mentioned in this study were not discussed. This makes sense in an environment where the presumption is that the collaborations taking place are interdisciplinary (and interdisciplinary projects are more likely to get funding). The issues described above may, however, suggest that a meeting to move closer to a shared problem in regard to the pursuit of interdisciplinary work (and thus a shared solution) could prove beneficial. An example of one such shared problem could be that the different approaches to interdisciplinarity leads to less contentment with, and thus less effort to establish, interdisciplinary collaborations.

Ideally, such a meeting would include representatives from funding bodies and external industrial collaborators as well. Establishing the problem would work to increase the chances of a "concerted" effort. But as Alrøe implies, the first effort may have to be rather forcefully incentivised. Presumedly, the different variations of cross-disciplinary research and their individual challenges, applications and benefits would naturally become a topic of such a meeting. In turn, being more specific about goals - the energy transition, the development of the whole value chain, or a sustainable technology - and the appropriate form of cross-disciplinary collaboration to meet these goals, may lead to greater satisfaction among researchers and external partners.

In the context of NTNU Energy, it seems at least a handful (of the interviewed researchers) have an in-depth understanding of, and experience with, interdisciplinarity. These researches are also the ones, who are, naturally most interested in the problems of interdisciplinarity. Having several established researchers with this experience and real-life examples of how to address the problems, sharing these tools and experiences would seem the next step. In other words addressing the problem, would have to be the first step to solving it. This following statement from a team leader from a technological discipline supports the thesis that the best way to do this would be for fellow researchers to provide real life examples: "There are lot of workshops and seminars where you do not work on anything, just blabla and theory, but if it really could be a workshop on how to do things

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[28] Alrøe, 2014, P69

with examples, then it could improve. I am now team leader, but nobody told me how to lead the team."

In the same way, shared problems to address in interdisciplinary teams could be developed through interdisciplinary dialogue, suggests one researcher of interdisciplinary experience. "We have never seen teams streamlined in a way that address common research questions. When we meet then it's more about strategic issues and communication and then we go back to our research projects again. It would be really cool to sit together to define what are the ten more pressing issues, say in hydropower. That would get the discussion going across disciplines. These could maybe be distilled by NTNU Energy to basic questions that NTNU Energy as a whole would like to address."

In a meeting on shared experiences, challenges and tools to attack these, the issue of time and academic credit would be likely to be addressed as it is many times in the interviews for this study with one researcher stating: "There is a lack of knowledge between different disciplines… So it is important to have initial meetings, to tell what we are doing without having a strict agenda. One needs to spend time to learn about each other. Read someone else's paper without understanding everything. That is important." They add that it takes at least a year with weekly meetings and the view that overcoming the initial hurdles to establish interdisciplinary research takes time is widely supported in this study. Thus without time or resources allocated, researchers are unlikely to agree on shared problems and conceptual frameworks. Applications for project calls are thus more likely to result in multidisciplinarity which is which is broadly deemed less efficient in the goals of NTNU Energy than interdisciplinarity.[29]

The hurdle of time, becomes more pressing due to the fact that team leaders are often well-established professors with multiple projects, PhD students, teaching obligations, prestige projects etc. One way of addressing this issue would be to have someone less established as perhaps not team leader but team coordinator. This however would face the issue of academic credit as a less established researcher may be more concerned with lacking disciplinary credits. Seeking a solution in structural changes thus seems rather utopian - longer contracts, and more time and funding for novel research – few people employed in academia would disagree that this would help the problem, most problems in fact, but fewer still would probably think it realistic.

Thus with the many external factors making interdisciplinary work challenging, time consuming and, for some, academically risky, in the end, it has to be the individual researcher's understanding of its benefits that drives collaboration efforts. Obviously getting funding is a significant benefit. But as it is

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[29] Nagatsu, 2020, P4

confirmed by several researchers, it is not one that comes from interdisciplinary research but from interdisciplinary research applications.

The researchers (by estimate five or six from various disciplines) who have worked extensively and have an in-depth understanding of broad interdisciplinary research all stresses the value of those collaborations as well as the difficulty in building them. One researcher says: "Before I adopted this second discipline, it was fairly easy to publish. I could get lot of papers out. But now I learned a bit more of a second approach I learned what I was doing - it was almost meaningless or could be summarised into one or two papers not 20... Now I realise, looking back, that it was a good choice of getting out of my comfort zone, I suffered a bit in the beginning, but now I can see that I was living in cave before. It is much easier to understand and attack a problem, the more viewpoints you have on it."

Perhaps a structural acknowledgement of this initial struggle and of the fact that the existing academic structure does present challenges for interdisciplinary collaborations would help decrease frustration and increase contentment. As one researcher points out, part of their interest in interdisciplinary work stems from the challenge of it. If acknowledged like this, it may lead to more and not less contentment. The result of projecting and promoting an idea of interdisciplinarity as organically sprouting and thriving in a normal academic environment may on the other hand lead to frustration. In the same way, recognising that many interdisciplinary projects are motivated top-down by project calls and the need for funding and that most collaborations are consequently problem oriented, short-term problem-feeding interdisciplinarity may also help mitigate dissatisfaction by motivating dissatisfied researchers to work within these parameters to become the problem feeder as well as the problem fed.

<div align="center">END</div>

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