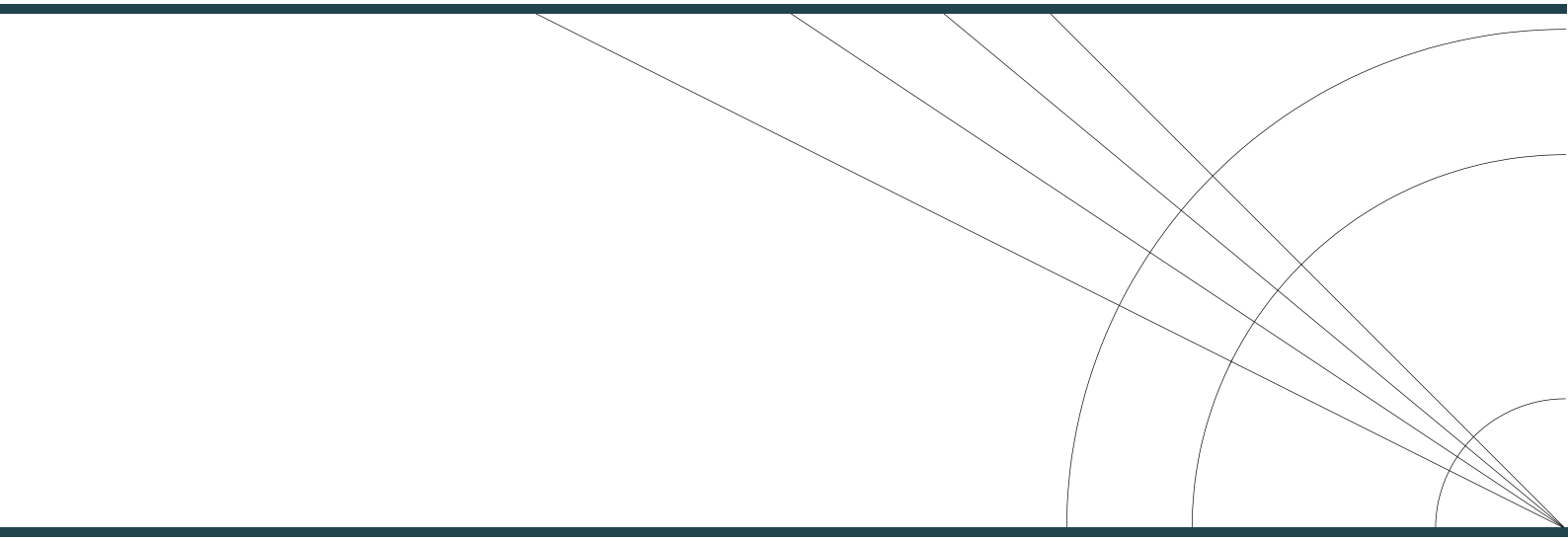
DBI
FIRE AND SECURITY

POWER-TO-X APPROVAL PROCESSES IN DENMARK AND NORWAY

INSIGHTS FROM INTERVIEWS AND RECOMMENDATIONS



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1.1. Background and project scope

The transport sector is one of the largest emission sectors, and a sector that continues to increase its GHG emissions[1,2]. The shift towards electric mobility seems to establish new market opportunities for those able to modernize infrastructure, digitalize technology, and embrace innovation. As a consequence of changes in the manufacturing industry, service and energy companies may also benefit from electrification, as these sectors will experience increased activity. Innovation and development of new environmentally-focused technology in these sectors is predicted to create new employment opportunities[3,4] which may be different from traditional ones[5]. Thus, electric mobility is the main focus of discussions concerning sustainable and energy-efficient means of transportation[6,7].

The European Commission considers public transport a strategy for lowering emissions[4], and therefore part of the solution to the European emissions problem, a position with which the IPCC agrees[8]. In order to address the problem with emissions in the public transport sector, the goal set by the European Commission is emission-free urban passenger transportation by 2050 (i.e., no more conventionally fuelled cars in cities) and emission-free freight transportation in urban areas by 2030. A case study[9] conducted on the Metro Manila, showing that urban sprawl and the associated workplace-home distancing in developing countries leads to greater public transportation use, and consequently more emissions. They point out the several interacting factors leading to increased carbon emissions from the transport sector. One of these is the low fuel efficiency of public transport. However, even with better fuel efficiency, emissions will inevitably rise with growing passenger volume.

In Norway, there are several areas within the transport sector that have responded to policies for decarbonization. For example, electric cars have taken over large parts of the car market. Equally important, but not as well known, is the electrification of Norway's ferries. This is often referred to as the silent revolution, both because of the ferries' now considerably lower noise level, but also because the changes have led to relatively little conflicts and thus also little attention. The transformation has also been revitalizing for the sector itself, now understood as being at the forefront of technology development and implementation. The transformation started with battery-powered ferries, which provided a collaborative platform that can be seen as a step towards realizing the world's first stretch of hydrogen-powered ferry.

It can prove insightful to compare Norway’s move into decarbonization with Denmark’s approach. These two countries are similar in many ways – yet, it seems that they choose to go about the green transition in different ways. With the Danish government’s proclaimed goal of 70% reduction in carbon emissions by 2030 and the Global Climate Action Strategy[10], there is still great potential and many unknowns in the Danish green transition. While increased and widespread electrification is taking

place in Norway, Power-to-X (P2X) production of alternative fuels is in Denmark and many other countries destined to replace emissions-heavy fuels, by converting stored renewable power surplus into "green" hydrogen, ammonia, methanol or other fuels[11,12]. However, the transition to green fuels requires change on every level; from production, storage, and distribution to handling, training, and application. Since the area of P2X is still in its infancy, many questions are still unanswered. The ongoing debates among actors in the P2X value chain on the choice of technologies and fuels, on safety and market-offtake, and on how the infrastructure should be built and expanded, show that both building of new knowledge and expertise with P2X, as well as tranferring past experience from existing fields of energy production, are needed to strengthen the field.

At DBI, we believe that fire safety and well-adjusted risk assessments are basic requirements for successful scale up of P2X infrastructures[13] – not only in Denmark, but on a global scale. The use of new green fuels and emerging P2X technologies and value chains raises questions about new fire risks and safety concerns that must be tackled, since the existing risk models, simulations, and regulations are not well-adjusted or validated for the new application area[14]. Consequently, we may have very incomplete pictures of safety and risks associated with P2X. This may result in disproportionate safety requirements resulting in too high costs, or in fatal accidents due to inaccurate safety requirements. Irrespectively, failure to tailor P2X technologies and infrastructures to the market as well as society will most likely affect the general, public impression and acceptance of P2X negatively, and thus hamper its role in the green transition[15].

Building a green P2X infrastructure – with all that it entails of connecting and aligning technologies, regulations, stakeholders, professions, workplaces, human behavior, and risk assessments – calls for a thorough and comprehensive effort. Indeed, underdeveloped regulations, ill-adjusted guidelines and hesitant collaborations indicate lacking knowledge and inexperience with how to successfully combine all the various factors in one ecosystem. This is perhaps no surprise, since what is being created are entirely new, green infrastructures[16] which enable the storage and expenditure of energy. Such infrastructure is not *only* made up of pipes, cables, turbines, facilities, grids, trucks, ships, and vast numbers of other technical and material devices. From a social science perspective, infrastructures represent *"dense social, material, aesthetic, and political formations that are critical both to differentiated experiences of everyday life and to expectations of the future"*[17]. In short, infrastructures are *"built networks that facilitate the flow of goods, people, or ideas and allow for their exchange over space"*[18]. Consequently, human beings – be they you and me, or service crews, businesspeople, engineers, or policy-makers – and our perspectives, professional experiences, and ambitions for the future play a key role in what constitutes P2X infrastructures.

1.2. Study design

In the Spring and Summer of 2021, DBI carried out a qualitative interview study in collaboration with Gudveig Gjøsund and Jens Røyrvik from NTNU Social Research. Kristine Vedal Størkersen (formerly employed at NTNU Social Research, now employed at SINTEF Ocean) was also part of the Norwegian research team and helped carry out the first round of interviews.

DBI have carried out 13 qualitative semi-structured interviews[19] with Danish national authorities, international class companies, local municipalities, national and local emergency management authorities, and companies involved in onshore energy production and in the maritime sector in relation to P2X approvals (see table 1 below). Note that all interviewed caseworkers employed at the Danish national authorities or Danish local emergency departments have backgrounds in engineering, chemistry, or mechanics, and many of them have 15+ years of experience with assessing and dealing with gasses and risk companies.

NTNU Social Research have carried out 8 interviews among comparable stakeholders (see table 2 below) based on similar interview guides. The structure of the interviews changed slightly according to what the interviewees emphasized as most salient and relevant to discuss due to their job type and professional experience[19,20].

The interviews thus cover different stakeholders and authorities across various stages in approval processes in Danish and Norwegian P2X industries. We seek to cover various layers and actors to include perspectives, perceptions and practices ranging from drafting of regulations and guidelines to local implementation and execution of these guidelines to better understand the approval processes and highlight potential knowledge gaps, misunderstandings, and cultural differences. By doing so, we wish to highlight not only how approval practices are 'imagined' in legal document etc., but also how these approvals are 'done', carried out, and interpreted in real life by both authorities and applicants[21].

Table 1. *Interviewed organizations in Denmark*

Organization	*Denmark*	*Amount*
National authorities	Danish Environmental Protection Agency Danish Working Environment Authority Danish Safety Technology Authority Danish Emergency Management Agency Danish Maritime Authority	1 interview (n=2) 2 interviews (n=2) 1 interview (n=1) 1 interview (n=1) 1 interview (n=1)
Local authorities, maritime class companies etc.	1 maritime class company 1 local emergency dept. 1 local authority (environment & planning)	1 interview (n=1) 2 interviews (n=2) 1 interview (n=3)

Applicants	1 energy company 1 ship owner	2 interviews (n=2) 1 interview (n=2)
Total	**10 organizations**	**13 interviews (n=17)**

Table 2. Interviewed organizations in Norway

Organization	*Norway*	*Amount*
National authorities, regulators etc.	The Norwegian Public Roads Administration The Norwegian Directorate for Civil Protection Norwegian Maritime Authority	1 interview 1 interview 1 interview
Local authorities, class companies etc.	Class company County Municipality	1 interview 1 interview 1 interview
Applicants	Norwegian shipping company	2 interviews
Total	**7 organizations**	**8 interviews (n=8)**

A BRIEF NOTE ON LIMITATIONS OF THIS STUDY

We have not interviewed all stakeholders potentially relevant for covering the topic of approval processes within P2X and related fields. However, the purpose has not been to carry out an exhaustive mapping of all possible challenges and perspectives within P2X approvals. Rather, we seek to compare experiences from the two countries, explore the interrelationship between various actors, and consider gaps and differences in order to help building a better understanding and overview of P2X approval processes.

2. Insights from Danish interviews

This chapter contains insights from the Danish interviews carried out. It is divided into three main subsections reflecting the most salient topics from the interviews and in the analysis.

2.1. Varying safety concerns and risk perceptions

WEIGHING THE IMPORTANCE OF SAFETY VS. MARKET CHALLENGES

From the interviews, it appears that safety concerns, unclear approval processes, or lacking standards are usually not perceived as equally pressing or challenging compared to more dominant challenges with pricing, 'guarantees of origin', tariffs, and market offtake. Price and market dynamics are heavily discussed on a company level, because they are perceived to be more difficult to solve and interrelated with numerous other factors compared to e.g., safety, which is perceived as a more or less purely technical issue that can be solved. One reason why concerns about market dynamics dominate is that the value and success of P2X has to be proved and demonstrated. Thus, the discussion about breaking down P2X-barriers denotes discussions about how to successfully demonstrate the value of P2X and how to establish mandate for companies to work within this industry.

> *"It [P2X, ed.] is one of those areas where we all go like: someone will figure that out. The hardest part is market offtake. That no one has the nerve to invest until you are sure that there is demand".*
>
> (manager, ship owner company)

Ultimately, safety is mostly perceived by both companies and authorities as one obstacle among many, and merely something to be dealt with by engineers. It varies a great deal to which degree safety is a concern. Indeed, safety is unquestionably a major concern for all interviewed stakeholders, as they deal with it on a daily basis. The authorities are more preoccupied with the need for political leadership on the zero-emission agenda compared to the need for regulations on e.g. safety.

In sum, safety is perceived as a technological challenge to be solved by applicants themselves, rather than by the authorities. It varies whether human safety is explicitly highlighted as part of the overall safety challenge. For some, it is not a concern. For others, the 'human factor' is a major concern, particularly in terms of crew safety, handling of new equipment and new digital devices and software.

VARYING RISK PERCEPTIONS AND EXPRESSED NEEDS FOR MORE TRAINING

Risk perceptions and risk assessments among the interviewees go hand in hand with caseworkers' and authorities' professional discretion. This means that great variety and changing perceptions of what is of utmost importance and what is risky changes from person to person. Substantial organizational and ethnographic research supports this finding[22–25]. Indeed, fire safety expertise is not constituted by finite practices, but is an outcome of contested assessments of risk and safety in a given situation [26–29].

> *"We don't agree 100%. Otherwise it [standards, ed.] would be written down. When we go to a meeting we present the Danish opinion, partly from Danish politics and partly from Danish companies. We highlight what matters most to us. Some countries' opinion is not technical but political and economical. For instance, the countries selling oil don't have an interest in changing these things... But when we get into the workgroups and subcommittees, we discuss technical stuff, and not politics – and is much more fun. In these groups there are no major disagreements, but rather questions about how much and when…".*
>
> (Caseworker, national authority)

Not surprisingly, several interviewees highlight the importance of early-on, continuous and extensive dialogue between the involved partners, not least between authorities and applicant. The dialogue among the authorities themselves is either too infrequent or entirely missing. Ethnographic studies of risk communication and companies working with risk assessment show that precisely *dialogue* is a key way to tackle and mediate varying risk perceptions[23,25].

A fair number of the interviewees (across the various stages in the approval process) believe that hydrogen and ammonia are well-known fuels and substances, which some industries have dealt with for decades and therefore know quite well. These professionals find that it is sufficient to apply regular gas rules and regulations to handle hydrogen/ammonia facilities, as these areas are seen as niche areas compared to others.

Note that such perceptions are often typical among interviewees who regulate, plan or engineer the P2X solutions. Such risk perceptions are rather different compared to those who work directly with these fuels. Among local authorities and in local emergency departments, interviewees are very specific in their concerns. When it comes to leakage, hydrogen is perceived as less problematic since it *"just dissolves into the air"* whereas the toxicity of ammonia is highlighted as problematic. When it comes to explosions, hydrogen is highlighted as dangerous, but seen as manageable, as long as it is at a distance from people, not in confined spaces, and one builds strong walls and weak roofs. Indeed, local emergency departments are not 'afraid' of hydrogen and ammonia, or concerned about what it can potentially 'do', because they are used to dealing with gasses and explosives. What they <u>are</u> afraid of is <u>not knowing</u> or having been instructed in how to respond, precisely because they are expected to be first responders.

Such differences in circumstances and risk perceptions can cause difficulties in scoping the need for safety training. However, caseworkers from both local and national authorities highlight the need for updated training and courses on e.g. hydrogen safety; not only for technical staff, but also for the operational crew, and for all other slightly related personnel, crew, or passengers etc. In their opinion, all will need updated knowledge on how to handle cases with hydrogen and ammonia. Indeed, some studies highlight the importance and value of training to mitigate risks[30], while others document that proper safety practices are not only acquired through training but importantly via everyday engagement in professional communities of practice[31–33]. Interestingly, ethnographic studies have documented discrepancies between 'risk perceptions' and 'risk estimation'[33,34]. Such studies show that while authorities may believe that more training is needed, it may not be that the operational crew or other practitioners have a risk perception, which is comparable with the risk estimate among the caseworkers[34]. Such possible discrepancy between what authorities or managers perceive to be risky and what practitioners estimate to be risky is worth keeping in mind and looking into when scoping the safety training in relation to the P2X field.

The problem of 'freedom of method' and questions of expertise

The authorities stress the importance of 'freedom of method' (da: *"metodefrihed")* when the applicants demonstrate safety and carry out risk assessments. However, while they maintain this notion, it does not mean that they think the approach is sufficient per default, or that they practice the same freedom themselves. Once probed a bit more, it appears that there actually *is* a fairly clear opinion about how risk assessments should be carried out and which methods to use, e.g. HAZIDs or HAZOPs. Thus, there appears to be a standardized but not explicitly verbalized way of performing a risk assessment among the authorities. In other words, while they say that there is freedom, they themselves have rigid impressions of what a risk assessment should look like. This makes the notion of 'freedom of method' very problematic. If an applicant or consultant is new to this way of thinking and working, they will be clueless until presented with the more specific demands for it. Whether it will ever be possible to produce such specific list of demands is unclear from the interviews, since risk perceptions and notions of safety hinge on individual discretion, social factors and

> *"Oftentimes you will do a risk assessment, for instance a HAZOP. Here you'll identify various risks and consequences. For instance, you'll often have problems with pipes not being properly connected. Therefore, the risk company must assess all the various risks that they have identified. Usually, you'll apply different methods to make the overall risk assessments. And once the authorities have received this assessment they will all sit down together and discuss how you reached the different conclusions in your assessment. Most often they are going to take a look at reports and scientific publications to decide whether the assessment is 'good enough'."*
>
> (Caseworker, national authority)

professional background[21,22,35]. As mentioned previously, continuous dialogue during such processes becomes a powerful tool to help articulating these differences and overcoming miscommunication. Perhaps not surprisingly, interviewees complain that the 'freedom of methods' presents them with quite a few challenges, because such seeming "freedom" makes risk assessments very different and unlike. It also results in fluctuating and at times poor quality in risk assessments done by the applicants, because the benefits of 'freedom of method' only take effect when both applicant *and* caseworker – are highly educated and experienced.

The caseworkers do not blame the applicants for producing assessments of poor quality. Rather, they blame the applicants' consultants. The caseworkers criticize the professional standards in the risk assessments produced by these consultants – even though they do not consider themselves as experts but only administrators. The authorities think of themselves as *"observers giving input when needed"*, thereby helping the applicant, and making the process run more smoothly. Instead, the authorities see the companies, industries, and applicants as the experts. Therefore, authorities also expect and encourage applicants and industries to step up with the standardization work if they find that it progresses too slowly. Meanwhile, authorities also transgress this role at times and act as experts giving advice.

> *"For Danish ships, the authorities are not a part of the risk assessment group. But they would like to participate as observers. Here, we can discuss and say 'try to take another look at this and so on. There is a process back and forth between authorities and de-sign groups and such. It can take a while. It can easily take several months."*
>
> (Case worker, national authority)

Authorities encourage applicants to initiate local dialogues between applicant and municipality in advance of initiating applications (da: *"forhåndsdialog"*) to help settle as early as possible which categories the applicants fall into and whether e.g. the Seveso-directive applies. The authorities believe that such early-on dialogue and clarifications may enable them to help shape and facilitate risk assessment in a positive direction, help applicants save money, and help reduce time-to-market for facilities and technologies because misalignment and miscommunication is avoided.

2.2. Clashes and gaps between regulations and practices

The threshold of 5 tons of gas marks the difference between 'risk companies' and 'non-risk companies' according to the Seveso directive[36]. Several interviewees highlight an unease with this threshold. They worry about producing, storing, and handling amounts just below the limits, because these facilities may be equally risky, but are not granted the same attention or help. If applicants find themselves above the threshold, they launch a well-structured process taking them by the hand – while also bringing quite a few demands and strict rules to follow.

Most of the risk assessment take place on a national level if the Seveso directive applies. The local authorities and municipalities are usually included as responsible for handling, documenting and administering the approval processes. Furthermore, the local emergency department is also involved. Nevertheless, the local authorities may only have one or few cases a year, making it hard to build local competencies and expertise. It is not at all times perfectly clear when the local or the national authorities are involved. Regardless, it seems that whatever expertise currently accumulated stays within the national authorities.

> *"The Danish Environmental Protection Agency is the responsible authority when it comes to risk companies. It depends on how much gas is stored. So they were very interested in that: 'where are you on that limit?' We are under that limit. But they were interested in knowing that early on, because that triggers other things. All the authorities come together and say: this is a good idea, this can go here, and so on. There is some sense to that. As opposed to our case, where one application goes one way and another goes the other way. With risk companies, something brings them all together. I know they can't do that for all the little projects below the limit, because that would drain all their resources. But I have the feeling that the more complex it is, the more you are guided; the requirements are higher, things are processed in a different way, and they look closer into what you are doing. When it's not a risk company, you have a lot of things going on in parallel and it's not always super clear who does what and knows what."*
>
> (engineer, energy company)

BELOW 5 TONS

If companies are below this threshold, the case is usually taken care of by local authorities and may appear as a very ad-hoc process to the applicant company (see figure 1 below).

The Danish Emergency Management Agency (DEMA) is very often involved here, although it is sometimes unclear to the local emergency authority caseworkers when and why DEMA is involved. At this level, the involved authorities may not coordinate or collaborate, and it is not unusual that the various authorities issue conflicting demands to the applicants. The applicants and their consultants are left alone in understanding these demands and in navigating the system and approval processes.

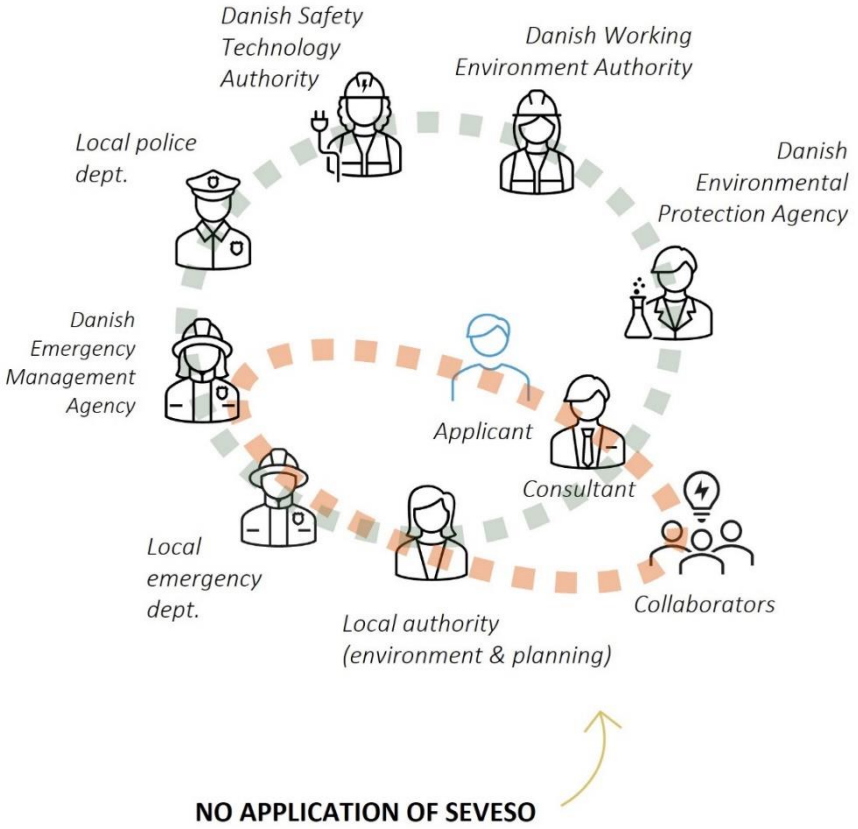


FIGURE 1. THE INTERRELATIONSHIP BETWEEN THE VARIOUS AUTHORITIES IF THE SEVESO DIRECTIVE DOES NOT APPLY. THE FIGURE ILLUSTRATES THE INTERVIEWEES IMPRESSION AND EXPERIENCE OF THE SETUP, AND NOT THE FORMALIZED, PRE-DEFINED WAYS OF WORKING.

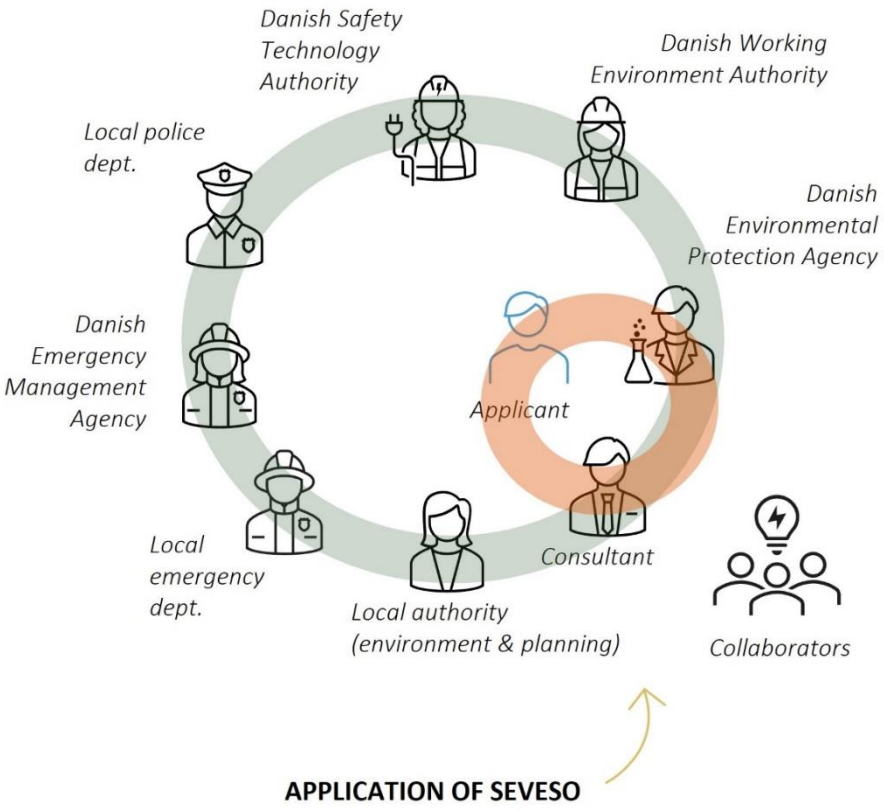
ABOVE 5 TONS

When above the limit of 5 tons, a handful of national Danish authorities get together, coordinate, communicate and takes the applicant through a thorough dialogue and risk assessment process (see figure 2 below).

Currently, these are:

- the Danish Environmental Protection Agency
- the Danish Emergency Management Agency (DEMA)
- the Danish Working Environment Authority
- the local police
- and local authorities, i.e. the municipality and local emergency teams
- the Danish Safety Technology Authority

The Danish Environmental Protection Agency coordinates the collaboration and process, and ultimately grants the final approval of onshore facilities. If offshore, the responsibility and authority sits with the Danish Maritime Authority and looks slightly different (please see figure 4 on p. 30 in chap. 4).



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CHALLENGES WITH NAVIGATING THE SYSTEM

In sum, 'risk companies' benefit from a well-regulated and resourceful approval process, whereas 'non-risk companies' may suffer in a non-coordinated, ad-hoc process. On the one hand, it may be advantageous to stay below the limit to avoid an abundance of strict rules to comply with; conversely, it may be advantageous to get above the limit to ensure the best possible help, attention, and assistance from the authorities.

Despite the seemingly explicit Seveso-threshold, there are challenges with understanding and navigating the system and process – both for companies, but also for local authorities, and among the

national authorities. Unless authorities are collaborating on a specific case due to it being a Seveso-case/risk company, not much inter-authority, authority-applicant communication, or knowledge sharing takes place. Some national authorities do not communicate their assessments, knowledge or procedures to local authorities, leaving them clueless at times and at best as 'paper administrators' (da: *"papirflyttere"*).

Interestingly, some interviewees mentioned that they experienced cases where DEMA got involved even though they need not according to the Seveso directive. However, since DEMA currently has more knowledge and expertise than local authorities they are continuously involved, despite the fact that approx. 60% of the administrative casework on risk companies is carried out by the local authorities. The local emergency departments are split on this issue of the relation between national and local levels. Some caseworkers genuinely appreciate the possibility to involve DEMA as a source of expertise and capacity when needed during approval processes. Meanwhile, others are somewhat annoyed at the lacking knowledge transfer between DEMA and the local emergency departments. Such challenges are crucial to keep in mind and deal with, since research show that silo-effects across organizations challenges the possibilities to learn more, to foresee accidents and future hazards, and to improve and intensify local competence building[37].

> *"Nothing comes out when they [DEMA, ed.] have learned something new. We get the paper with the conditions, but without any background for the requirements. Some of it could be helpful for emergency tactics regarding incidents with hydrogen facilities. If something comes up during process, it has to go back to DEMA every time. Because we don't have enough knowledge to evaluate. So our evaluation is kind of disconnected, and we're out of the loop. There are nothing mentioned about where we can read more on the hazardous characteristics. But it would be great with some info on what to look out for with these kinds of facility. Basically, I don't think that we are equipped to handle the applications; they are just shipped through and then we wait for the national authorities to do their part."*
>
> (Caseworker, local emergency dept.)

The negative effects of these silos are not only local problems, but potentially global challenges. For instance, one interviewee working in an international maritime context stressed that a consequence of such slightly opaque and fragmented intra- and inter-stakeholder setup among the authorities is that it can be difficult for applicant and external collaborators such as consultants or class companies to find out where/who to refer to with inquiries, questions etc. at the authorities.

2.3. Missing standards and Implications of risk assessments

Regulatory framework depends on context and design

As of now, virtually all offshore designs related to P2X falls into the category of 'alternative design', which triggers a need for risk assessments. Onshore design most often may be fitted into existing regulatory frameworks on gas installations, gas facilities etc. Working with alternative solutions such as hydrogen and ammonia is seen as more cumbersome by *all* interviewees. Meanwhile, the caseworkers at the authorities *also* deem it a very doable process; the only problem is that it takes *"a bit more time"* due to the need to perform risk assessments, have extensive dialogues between the various authorities etc. The caseworkers see this added time as a precondition for doing a good job and being thorough. Some of their managers, however, acknowledge that these caseworkers – being experts and specialists themselves – have a tendency to get caught up in details that may not be of relevance for the overall approval. Thus, some of the authorities are currently working to streamline their processes and speed up the case work in targeted areas.

> *"There are procedures and processes to lean on. There are guidelines, a few. But they are always specific. There is nothing holistic. Some authorities might write: 'you may also need approvals from other authorities' – and then they don't mention which?! Then you become afraid of missing something, right? It is up to us to navigate the different few guidelines that already exist."*
>
> (project manager, energy company)

Culture clashes in risk assessments

Authorities and class companies highlight that risk assessments are not always the best or most easy choice for a project/application. Indeed, authorities and companies alike highlight the challenges and frustrations of *"not knowing when enough is enough"* during risk assessments and what is *"best practice"* during an approval process. This is due to the fact that this kind of tacit knowledge – knowing when enough is enough and what is best to do – hinges on professional experience shared among colleagues on past cases and projects[38,39]. Such experience is still relatively non-existent within the P2X ecosystems.

> *"When you do a project like this, you think: 'Are we doing this? Fine, we'll do it!'. But here with Power-to-X it is always like: "We will have to look into that." But, when is enough enough? That is the frustrating thing about this: you never quite know when enough is enough. The only way to evaluate that is through experience from earlier projects. And maybe that is why it is so hard for them to create this guide, because it is all so new. But we can hope that it will become more specific, I think that is something everyone needs"*
>
> (project manager, ship owner)

Meanwhile, abundances of tacit knowledge and experience do already exist in the well-established, pre-existing industries coming together to shape the new P2X infrastructures, e.g. the wind industry, oil and gas, the maritime, and the authorities. The challenges and barriers experienced during approval processes oftentimes link to encounters between various organizational and professional cultures and ways of working within a given industry. Each industry has different working cultures, risk perceptions, traditions etc., such as the wind industry and the oil- and gas industry. As different professional cultures are coming together to work side-by-side in building the new P2X infrastructure, there will be cultural clashes on how risk is perceived and assessed along the way, as pointed out above in section 2.1.

> *"Sometimes you get grey hairs from all the paperwork! But I must admit that a lot of it make sense. I mean, things are the way they are for a reason. It could be more flexible. But when we haven't done it before, everything is a bit tricky on the first go around. It is still a process … and the culture! Agreeing when enough is enough is a bit of a challenge. The hydrogen is fairly new. The people making hydrogen technologies don't have 50 years in oil and gas. Maybe they have, but not necessarily. They don't always have the same kind of tradition. And wind energy has a third one, right? So somehow, they all have to meet. That's a bit of a challenge."*
>
> (engineer, energy company)

Some long-term implications of these assessments

Risk assessments might bring an applicant through the process right now, but simultaneously it is a hassle to deal with in the following years. In the maritime/offshore sector, there is such a big focus on the role of the class companies that some applicants and consultants forget the administration that follows in the slipstream of the risk assessment. Within this sector, the interviewees caution us to think about the practical and operational implications of a risk assessment 5, 10, 20 years after the risk assessment has been done, and how it will fit in into changing settings which are perhaps not so comparable to the original setting in which the risk assessment was performed.

Risk assessments are often fragmented, compartmentalized, and only take into consideration specific parts, technologies, or devices. Down the road, such fragmentation is difficult to handle and administer *both* for companies and authorities. According to authorities, combining risk assessments with an application of the machine-directive for *each* part of a system is what we are currently doing. But in their opinion, it is not the best way to make long-term solutions. To avoid regulations and practices clashing, to reduce miscommunication, and to improve overall quality, several authorities look positively to holistic risk assessment taking the entirety into account. This is not always possible, but it is a path that many authorities hope we may take within P2X. They argue that it is the industries who must push for this change in order for it to happen and make the approval process more standardized and streamlined.

LACKING STANDARDS AND GUIDELINES – AND DIFFERENT LOGICS

Companies argue that there is a need for standards in the field in order to properly work and know what to do and not to do. Authorities agree that there are no standards in place, but see it as an issue that the industry can blame themselves for. The industrial actors do not join most standardization committees - only a few selected. Thus, if the industry wants something to be a standard, *"they can just sit down and agree on it"* as a caseworker put it. It may be worthwhile to consider joining standardization committees more extensively, as authorities consider standards to be expressions of 'best practice'.

> *"The push for standardized methods for approval processes has to come from the applicants. We could have a shared website that has all relevant information on risk companies, which they could refer to and use every time. We could also make a guide on how risk companies should prepare for approval processes. We don't have that now, no one does […] But at the same time, we do have freedom of methods and we don't adhere to a single method. Therefore, we sometime see applicants' consultants who could have done much better. The case work becomes very lengthy then, because it is hard to make heads or tails of what they say and do."*
>
> (Caseworker, national authority)

When it comes to discussing the lacking standards within P2X, it is worth noting that it may be very profitable for companies to produce certificates of origin of e.g. green hydrogen, as it will be of great market value to show that products comply with certain guidelines or standards. This means that when industries both in Denmark and globally are calling for action to devise standards but simultaneously cannot agree on these standards, the issue is not solely one of varying and diverging risk perceptions and safety standards. The inability to agree on standards also have to do with economic interests, market shares, profit etc. Put differently, the missing standards may be seen as expressions of lacking cultural and social agreements on settled market structures, modes of energy exchanges, and economic terms for P2X technologies and infrastructures. Indeed, social science research have documented that the way people organize institutions, define collaborations, and classify and regulate our worlds have crucial impact on how governments, business, and economies function[37]. Thus, market challenges, industrial silos, and lacking agreements on standards within P2X are as much about financial problems as they are about social tensions and clashes between different ways of doing things.

Standards aside, the authorities interestingly do not feel they miss a regulatory framework. The existing acts and regulations are most of the time enough for them. For instance, DEMA and the Danish Safety Technology Authority perceives hydrogen and area of P2X as a 'niche' which can be handled under regular gas regulations. So far, authorities feel that the regulations and approval processes may evolve and develop alongside the technology, and that they are learning companions with the applicants. This 'we-invent-the-wheel-as-we-go'-approach is very frustrating for applicants. Many of the steps in the approval process are built on continuous dialogue between the various stakeholders,

which means that at times the work feels speculative since no-one have the right or full answers to all of the questions yet.

Such dialogue is perceived as very positive from the authorities' point of view. It grants them the possibility to curiously, slowly and thoroughly explore possibilities, constraints, and risks within P2X-infrastructures and technologies. The caseworkers see this as ultimately benefitting future applicants, because it helps improve the overall approval processes along the way. Still, they also genuinely do not wish to block the process. However, a large group also feel that they need more guidelines on how to apply and fit existing regulations into the new contexts and settings. For instance, different kinds of legislations may clash when combined in the attempt to handle the safety of ammonia or hydrogen and characterizing is as flammable or not. The caseworkers do acknowledge that there may be a challenge for companies to understand the Danish as well as European regulatory framework, to navigate these, and to understand the pace of an approval process, especially if the applicant is not a typical risk company and not used to or trained in this way of working or thinking. Indeed, the applicants often feel that the authorities delay the process beyond reason.

In case of knowledge gaps within a national authority, they turn to colleagues in their own organization, class companies or sister authorities in Norway, Sweden, and Finland. American guidelines coming from National Fire Protection Association (NFPA) are by some judged as relevant but as highly irrelevant by others, since the emergency response and insurance setup is very different in American society. NFPA aside, it is well-agreed among the interviewees that Northern European ways of working, standardizing, regulating, and assessing cases are applicable and transferrable to Danish contexts. Thus, there is an interesting paradox between the request for more international standards and regulations, as well as harmonized processes across countries and sectors – while at the same time, the same people caution against applying standards 1:1 and argue that they are particular and shaped by local contexts. Thus, while there is a cultural appropriation of standards taking place, standards are simultaneously verbalized as universal and the best solution to local and highly complex problems.

> *"Safety doesn't receive much attention. It's sad, but we haven't had a big accident with hydrogen in any nearby country. The thing is, there has to be a big accident before people wake up and do something. There is great pressure from the industry, and we can sound the alarm for safety. But we are too small a player. We have to wait for that big incident close to Denmark, and then it will get attention. Even cases from the US do not have an effect in Denmark. Examples have to be from nearby EU-countries to be relatable."*
>
> (Fire safety engineer, local authority)

Interestingly, but perhaps not surprisingly, caseworkers at the authorities underline the importance and impact that political decision-making have on the advancement and ease of P2X processes. The placement of P2X facilities in Denmark may be heavily influenced by local political concerns and agendas. Likewise, international political concerns and agendas on economy and market shares shape how intensively various governments advocate for green transition and which kind of transition they advocate.

> *"We are aware that these cases receive a lot of political attention, so we prioritize them – but it has to be done objectively and thoroughly. It is important that we do not have any slips that might ruin projects. We have to go through the entire procedure and follow the protocols each time."*
>
> (Caseworker, national authority)

3. Insights from Norwegian Interviews

This chapter contains insights from the Norwegian interviews carried out. The interviews focused on presenting an actual case of implementing a hydrogen ferry. Thus, we will first provide a bit of case background presenting a previous study on a battery driven ferry before delving into the insights from the interviews that deals with the introduction of the hydrogen ferry.

3.1. Case background: Experiences with battery driven ferries

The tender process and e-ferries

A ferry route that was out early with batteries and which has been important for developing good processes in the tender phase is the Flakk-Røyrvik connection just outside the city of Trondheim. There was a stated political goal that the ferry should be battery-powered, and the tender that was developed should meet that goal while also being technology-neutral. Equally important was that the tender and the process should distribute risk between the actors in a good way, and further ensure competence development and dissemination among them.

The process for a new public tender for the Flakk-Rørvik connection started in 2015. Assisted by the Norwegian Innovative Procurement programme, the county arranged dialogue meetings which involved suppliers and vendors. As the owner of the tender, the county decided to opt for a ferry contract tender with eligibility requirements. This means that in order to be eligible to compete in the tender, the proposed solution cannot exceed a fixed emissions amount. Setting this eligibility requirement enabled the county, through AtB[1], their transportation administration company, to make a standard price/quality tender weighted at 70% price/30% quality, without any need for environmental requirements nor demands for specific technology.

The dialogue meetings beforehand suggested that it was possible to electrify the ferry connection substantially. The county therefore applied for infrastructure funding from Enova, a state-owned support agency, for an eventual dock-side charging infrastructure. The county thus guaranteed that they would provide to charging infrastructure to any bidder proposing a solution involving a degree of electrification.

Central actors in this tender process

The process that led to the tender for Flakk-Røyrvik has been formative for how technology development – and how to emphasize the environmental aspect - is implemented, also for other connections and technologies such as for the Hydrogen case. Depending on existing alliances and stakeholders there will be other actors involved elsewhere in the country. However, the type of actors

and not least the focus on dialogue to bring about a successful process is similar. For Fakk-Røyrvik, the most important actors and their roles in the process are as follows:

The administrative company, AtB, administers public transport in Trøndelag county, and is tasked with planning, purchasing, and marketing the public transport service. AtB's responsibilities include buses, trams, boat/high-speed boats and ferries, and the school buses, etc. The company is registered as a limited company and is fully owned by Trøndelag County[40].

The ferry operator, Fosen Namsos Sjø AS won the tender for the operations on Flakk-Rørvik from January 1, 2019, with their two new hybrid ferries and a biodiesel-run back-up ferry. Both new ferries were purchased from the local shipping company Myklebust Verft and made at one of their shipyards in Western Norway. The shipping company received financial support from the private sector funding scheme called the NO_x fund, administrated and self-funded by the private sector. Norway has for some time been exploring the possibility of establishing a CO_2 fund based on the NO_x fund model. The ferry operator also buys electricity from the local energy provider. According to the project managers, the electricity is cheaper than the biodiesel for generators, so there is a strong incentive to optimize the rate of electrification.

Enova SF is owned by the Norwegian Ministry of Climate and Environment. It is one of the Norwegian government's main economic instruments for reducing GHG emissions, and for supporting the development of climate and energy technologies, as well as for strengthening the security of the energy supply. The county may apply for funding from Enova related to the dock-side infrastructure. However, there are some limits to the funding, in terms of which project can be funded, the extent to how much it may receive, and whether or not it results in innovative or otherwise unattainable results[41].

The National Programme for Supplier Development was set up to accelerate innovations and the development of new solutions through the strategic use of public procurement, while at the same time contributing to new market opportunities for these innovations[42]. The innovative procurement program—as the program is often referred to—is a collaboration among several important public and private sector entities, each with their own unique strengths, networks and focus areas.

The Agency for Public Management and eGovernment (Difi) provides pertinent support in developing relevant tools and guidance on public procurement in general as well as on innovative public procurement in particular which is of tremendous support "on the ground."

The Norwegian Association of Local and Regional Authorities (KS) naturally provides the link to both local and regional authorities and stimulate actors in the direction towards innovative public procurements.

The Confederation of Norwegian Enterprise (NHO) provides the link to the private sector actors. The Programme secretariat is hosted by NHO, which gives direct access to relevant suppliers within specific sectors.

Innovation Norway (IN) is the Norwegian Government's instrument for innovation and development of enterprise and industry. They support companies in developing their competitive advantage and to enhance innovation.

The Research Council of Norway (FR) serves as the chief advisory body for the government authorities on research policy issues and distributes approximately nine (short-scale) billion NOK annually to research and innovation activities. In the case of the Flakk-Rørvik project, the programme was initiated in advance, connecting and engaging actors across the spectrum and facilitating dialogue with the county and AtB in the early stages of the procurement process.

There were other actors involved as well. On the hard dock-side infrastructure, there are several business actors and stakeholders present. The county, in this case, chose to outsource the hard infrastructure management to the Norwegian Public Roads Administration. Practically, this means they are tasked with tenders and contracts with sub-contractors relating to the dock-infrastructure and, in this project, the electro-installers. The Norwegian Public Roads Administration awarded the contract to build and upgrade the dock-side infrastructure to a regional entrepreneurial firm. For the technical infrastructure track, the county itself placed tenders for the dock-side land-battery system and the automatic mooring machines. As previously mentioned, the Flakk-Rørvik project is the first of its kind to have high-voltage power with a land-based battery buffer dock-side to provide sufficient charging effect for the docked ferries. This was the only feasible way to achieve the required charging speeds without disrupting the local grid. Siemens also provided the two ferries' battery system for the operator Fosen Namsos Sjø.

The Flakk-Rørvik e-ferry is a case of policymakers successfully achieving their intended results, i.e., the implementation of new technology and environmental policy, within the confines of the tender system. The principles were passed on to Hydrogencaset, with the difference that the tender was not technology neutral, but as we will discuss in the coming, there are some challenges and opportunities that are hydrogen-specific.

3.2. The hydrogen ferry case

The world's first hydrogen-powered ferry "MF Hydra" began operating in the summer of 2021. Initially, it was powered entirely by batteries, but during the spring of 2022 it will switch to hydrogen, when the hydrogen facilities on board are completed. The ferry operator is Norled, and the ferry sails the Hjelmeland connection in Ryfylke in the west of Norway. The liquid hydrogen is for now taken from Linde's large-scale hydrogen plant in Leuna, Germany.

PREREQUISITES AND STRUCTURAL FRAMEWORK CONDITIONS

When asked about why hydrogen has been looked at as an alternative energy carrier the last few years, many of the interviewees mention international trends towards renewable energy. Internationally a lot is happening with decarbonization and fuel cell technology, and new energy carriers are therefore forcing their way forward.

This has led to cooperation between national policy makers and the industry. Due to previous experience with, among other things, battery driven ferries, the relationship between the industry and the national policy makers is characterized by trust. On the other hand, the authorities are completely dependent on the industry being an active part in this development since the industry is at the forefront of technological development needed to realize a transition to renewable energy sources.

> *"When politicians, industry, and administration want the same thing, we achieve a lot. Zero emissions from 2030 came not only from the political side, but also from us who said that this was possible. Then the politicians could believe in it enough to insert it in the tender."*
>
> (Norwegian Public Road Administration)

Even though the relationship between national authorities and the industry is described as trusting, they do not always agree on who takes most of the risks. In Norway there are allocated a lot of national incentives to push this kind of technology forward. Even so, the shipping companies feel they have to bear too much of the risk. Although it may involve some risk for industry actors to be in front of technology development, there is often more to lose from not being a front-runner. Since the residual value of boats with old technology will be very small, it is better to use modern technology that makes it possible to sell the ferry for a reasonable price after some years.

Another frame condition which has been important for hydrogen ferries to become a reality in Norway is the tender principle they used, called *competitive dialogue.* The Norwegian Public Roads Administration (PRA) invited shipping companies in Norway, and three out of four decided they would attend. Then an eight-month dialogue between PRA and the shipping companies, which also consisted of knowledge sharing to enable all the providers, took place before they went into a normal tender situation. Not only the chosen shipping company, but all the tenderers received compensation that covered much of the tender work. The *competitive dialogue tender process* was then also a technological development process that brought them closer to the realization of hydrogen ferries.

> *"It meant that we had a dialogue with the Norwegian Public Roads Administration for about 8 months before we went into a normal tender situation."*
>
> *(Shipping company)*

CHALLENGES

Even though the structural framework conditions for developing and implementing hydrogen ferries in Norway are conducive, there have been a number of challenges and obstacles for all parties.

One of them is the collaboration and coordination between the involved parties; technology developers and producers, investors, shipping companies, authorities (legislation + incentive actors), and local authorities including infrastructures providers (production, bunkering, transport). In order to move this technology forward and to implement it, a lot of actors must have the same goals at the same time and take coordinated action. One of the challenges is that the maturity can differ between the actors, e.g. that the technology is ready for implementation, but not the regulations that have to be in place in order to certify it.

To be in the lead of technology development always has an element of uncertainty. It can be expensive and demanding. Even if there are national incentives to support this process, it is difficult to estimate how big the risk is. And since this process is dependent on so many different actors with their own risks, the uncertainty gets even greater because it is difficult to know how others act upon the risks.

> *"When it comes to hydrogen, no one really has a standard or historical understanding of safety to build on. We need to put experience in place before we have regulations in place."*
>
> (Norwegian Maritime Authority)

The fact that there is a different pace of maturity among the different actors can also lead to safety challenges. When it comes to hydrogen, no one has pre-existing understandings of safety to build on. Even the authorities say they must gain experience before the regulations can be in place. For the moment they use the same rules as for LNG (liquified natural gas) since there are no special provisions for hydrogen. Even if the authorities may be worried about the industry having the lead on the development, they think it is important not to set requirements that put a stop to the development. The industry is not comfortable with the lack of guidelines and restrictions, and is trying to be stricter than required from the authorities to be on the safe side.

Another safety challenge comes when the new technology meets the local community: the small municipality where the ferry is going to be located. When it comes to hydrogen as an energy carrier, there are immature national regulations, and the local authorities who are going to "host" the new ferry are of course not prepared to take the necessary precautions. A representative from this municipality is worried about whether they have good enough routines when it comes to bunkering of hydrogen. As a small municipality with a part-time fire service they are not in the position nor do they have the resources to find out what precautions to take. They have tried to start a dialogue with authorities, but have received very little feedback.

> *"It is not so easy for us as a small municipality to do this around bunkering properly. We have a part-time fire service that will handle this, and we do not receive support for it from society at large. We have sent a ROS analysis and asked the Norwegian Public Roads Administration for more dialogue, but they are not interested in that."*
>
> *(Municipality)*

When industry and authorities are asked about their perception of safety with hydrogen ferries, they say that the immature technology, different risk assessments and the difficulties with coordinating all the involved actors is challenging, but they also say that a hydrogen ferry in itself does not have to be a bigger safety risk. The requirements for this ferry will be as strict in terms of safety as for all other ferries. Even though the safety challenges are greater here, a substance such as hydrogen has many more safety-ensuring measures than less dangerous substances.

NATIONAL INITIATIVES AND LOCAL COMMUNITY

In the local community, the residents did not have a positive attitude towards the new hydrogen ferry. One reason for this was that they were not included in any decisions concerning the new ferry. It was just decided "from above" that they should get a new ferry without any information or discussions about the consequences, neither positive nor negative, which might have led the local public opinion to gain ownership for this. In addition, the transport service in the municipality would become worse with the hydrogen ferry with fewer departments than it had been with the old one. Not even the local politicians wanted to promote new technology at the expense of the transport services in the municipality. People actually wanted a bridge between the shores rather than a hydrogen ferry. As we see, there was a severe lack of grounding in the local community.

Even if the shipping company had arranged information meetings to inform and raise the pride for having the first hydrogen ferry in operation in the world, there is still a lot of bitterness in the local community over the way they have been overrun by national authorities. In addition, as mentioned in the previous section, the municipality feel they are left on their own to develop and build necessary safety systems needed to use hydrogen; something they do not have necessary resources or competence for doing.

"We were not positive. Not because it was hydrogen, but because it made it difficult for us to get a hydrogen ferry "from above". They could have tried to talk to us about the positive aspects of the environment and such, but no one did. (...) My trust in the system has simply suffered a serious setback. It was a clear overpass. And there was no excuse given. This is what the government had decided and nothing more to discuss."

(Municipality)

4. Recommended "pathways" for navigating P2X approval processes

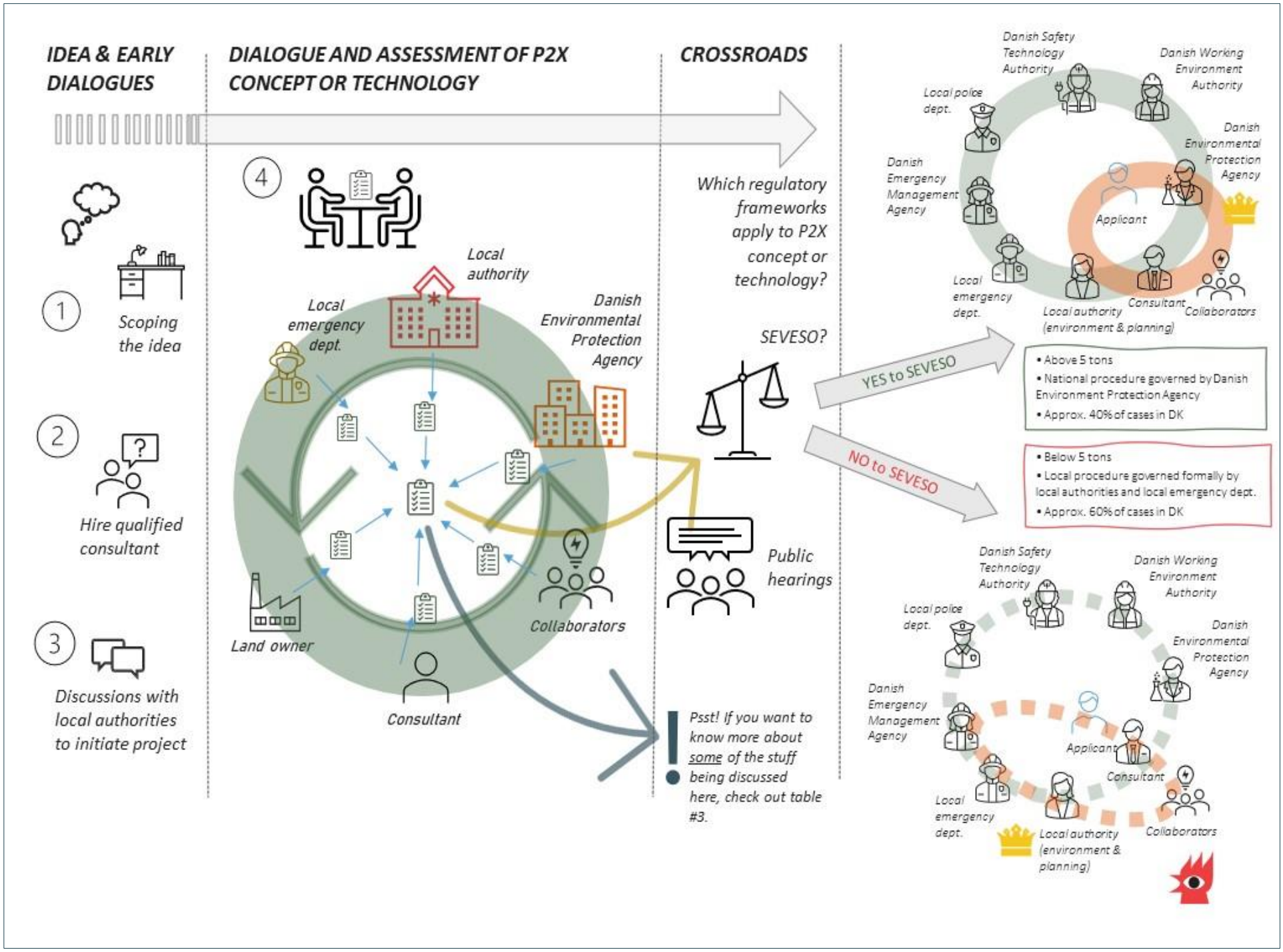
In this chapter, we present different recommendations – or "pathways" – based on the Danish and Norwegian interviews. The pathways consist of models, tables, and recommendations, and are based on a mix of the interviewees' experiences with approval processes, as well as their recommendations on how to best navigate such processes based on their past learnings. These suggested pathways illustrate the work-in-progress that the entire field and industry of P2X is currently undergoing. We consider these 'pathways' as starting points to help industry actors, authorities and stakeholders reflect on their work with approval processes and how they would like them to be now and in the future.

PATHWAY I: EXPERIENCED PROCESS FOR ONSHORE APPROVALS

The first "pathway" in Figure 3 (see below) presents onshore approval processes. In the first left hand column, the figure suggests that applicants start by scoping their idea and initiate early dialogues with the local authorities about the project/concept and idea. The important thing is that applicants start the conversations with the authorities and the involved partners early on.

These early dialogues will evolve into the more technical and serious discussions on what it is applicants want to build, invent, or implement. During these discussions, applicants will be talking to various local and national authorities, who will ask a range of questions according to different regulations, guidelines, and best practices which they pay attention to (please refer to table 3 on page 31 for a broad overview of some of these regulations). Particularly, applicants should be talking with the local municipality and authorities, and later engage in dialogues with the national authorities as well.

At some point, the applicant must decide on which regulatory frameworks applies to the technology or project. Here, the SEVESO directive will come into play. When SEVESO applies, applicants and authorities will get into a well-organized procedure particularly governed by the Danish Environment Protection Agency. If applicants choose not to go for the SEVESO framework, they are much more on their own in an ad-hoc process.



DBI FIRE AND SECURITY

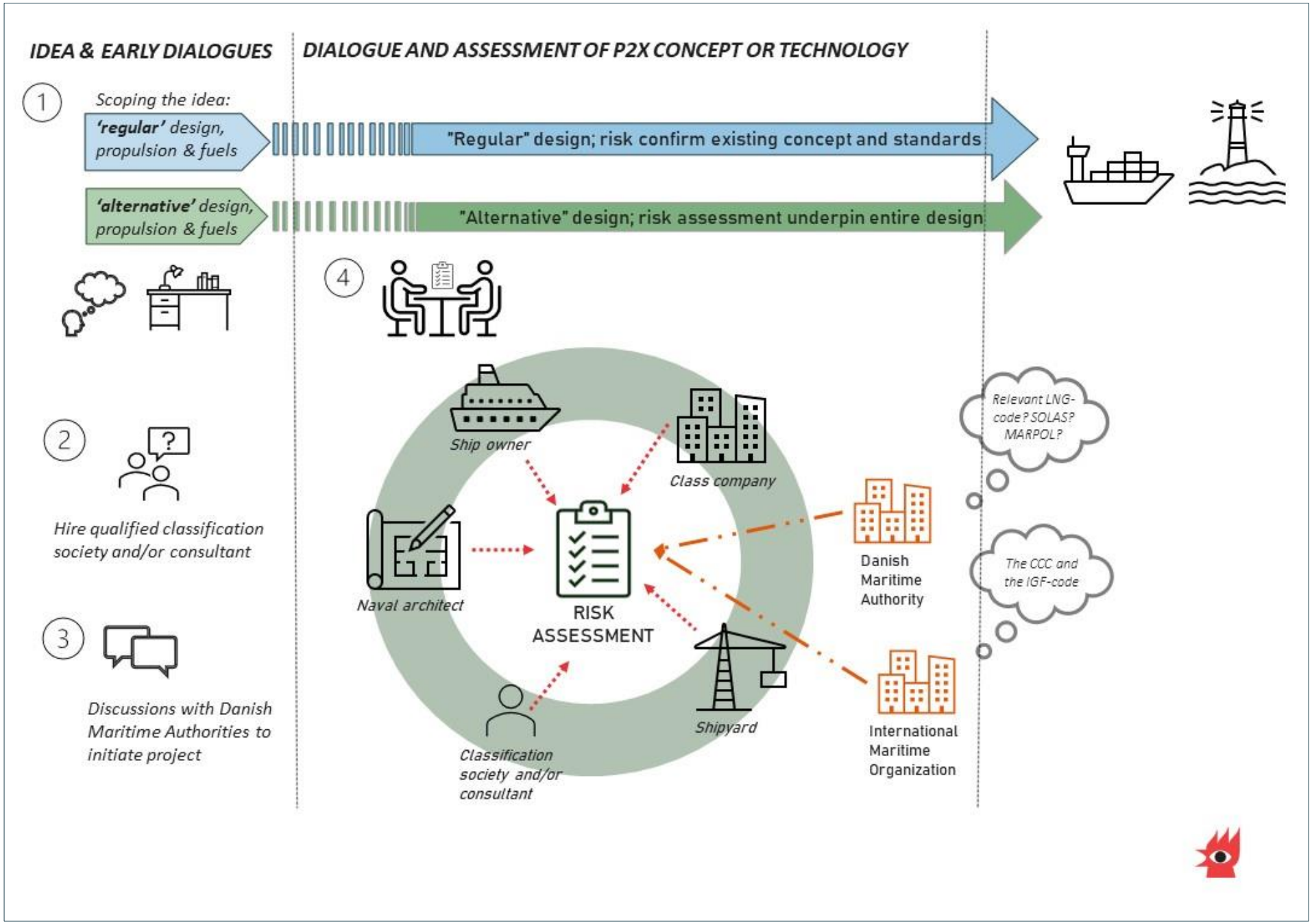
PATHWAY II: EXPERIENCED PROCESS FOR OFFSHORE APPROVALS

The second “pathway” in Figure 4 (see below) presents offshore approval processes. Parts of the approval setup looks somewhat similar to the onshore process, but with some differences to take note of.

As applicants initially scope their idea, they will very early on in the process find that regulations and approvals differ dramatically depending on whether they go with regular designs or with more alternative and green design solutions. It may be that some parts of a vessel falde under alternative solutions while others are regulated according to regular design conditions.

Like the onshore process, applicants may also benefit from deciding early on which classification societies and consultants will be helping them. Furthermore, applicants will also engage in early dialogues with the Danish Maritime Authority to further discuss the scope.

Regardless of regular or alternative propulsion solutions, applicants will be presented with the demand to carry out risk assessments. During this process, the authorities will act as observers providing input when needed.


IDEA & EARLY DIALOGUES
DIALOGUE AND ASSESSMENT OF P2X CONCEPT OR TECHNOLOGY
1
Scoping the idea:
'regular' design, propulsion & fuels
'alternative' design, propulsion & fuels
"Regular" design; risk confirm existing concept and standards
"Alternative" design; risk assessment underpin entire design
2
Hire qualified classification society and/or consultant
3
Discussions with Danish Maritime Authorities to initiate project
4
Ship owner
Class company
Naval architect
RISK ASSESSMENT
Shipyard
Classification society and/or consultant
Danish Maritime Authority
International Maritime Organization
Relevant LNG-code? SOLAS? MARPOL?
The CCC and the IGF-code

PATHWAY III: OVERVIEW OF RELEVANT REGULATIONS AMONG DANISH AUTHORITIES

Please note that the overview below is not exhaustive. There may be more regulatory areas and specific regulations to include concerning specific questions.

TABLE 3. Regulatory focus among **Danish** authorities concerning P2X			AREA
Danish Environmental Protection Agency	The coordinating authority in SEVESO-cases.	○ Environmental conditions, incl. 'Environmental Protection Act' ○ Environmental plan and placement ○ 'European directive on industrial emissions' ○ Political focus ○ Zones, Environmental Impact Assessment (da: VVM) etc.	SEVESO (& REGULAR)
The local municipality (environ. & planning)	Taking care of the approvals. Coordinates when SEVESO does not apply.	○ Placement, zones, & local district plan etc. ○ Local approvals ○ Risk assessment in collab. w. local emergency dept. ○ Commissioning permit	REGULAR & SEVESO
Local emergency dept.	Taking care of the local safety response	○ Technical regulations ○ The Danish Emergency Preparedness Act, §34-2 ○ Focusing on "Column 2"-companies and "Column 3"-companies	REGULAR & SEVESO
Danish Emergency Management Agency	Providing technical input, knowledge and support for the local emergency dept.	○ Concerned with safety zones, safety distances, and explosions ○ Particularly focused on gas storage	SEVESO
Danish Safety Technology Authority	Focuses on gas-related aspects relating to fire, explosions, and accidents.	○ The Danish Gas Safety Act ○ The Machine directive	SEVESO
Danish Working Environment Authority	Ensuring safe ways of working "inside the fences", i.e. at P2X facilities.	○ Technical safety ○ Placement of facility ○ 'Human factors' Dangers of explosions ○ Working environment	SEVESO
Local police dept.	Ensuring safe passage and evacuation "outside the fences", i.e. in the surrounding area of the P2X facility		SEVESO
Danish Maritime Authority	Responsible for enforcing regulations offshore on "things which float".	○ SOLAS convention ○ IGF-code ○ Interim guidelines ○ MARPOL ○ IMO-regulations ○ EU-regulations ○ Various circulars	MARITIME
Consultant	Producing sufficient and adequate risk assessments and helps clients to navigate the process.		ALL

PATHWAY IV: UNDERSTANDING THE CHALLENGES AND WHAT YOU CAN DO TODAY

So far, this report has focused on the challenges in P2X approval processes as highlighted by the interviewees. In this fourth pathway, we have reshuffled and reframed these challenges a bit to focus more on what actions applicants and authorities can take to tackle the challenges. We highlight four challenges, but there may be several more.

- First, the industry face issues of lacking expertise, competencies, and tacit knowledge, both among applicants and their consultants, but also at times among the caseworkers employed at the authorities.
- Second, applicant and authorities alike are struggling with issues of bad timing and coordination between the involved parties and partners, which results in slow, impenetrable, and cumbersome processes.
- Third, the applicants face issues with lacking process plans, understanding, and insufficient explanations provided in advance to applicants.
- Fourth, there is lacking communication and knowledge sharing between authorities, and between authorities and stakeholders.

So, what can we do about that? Below we bring a few suggestions for P2X applicants, applicants' consultants, and authorities.

Applicants and consultants

- Hire a skilled consultant. It will save you money and time at the end of the day.
- Do your "homework" and scope your idea, before approaching the local authorities.
- Rather go for "worst case scenarios" than playing it safe: It will ultimately keep things safer, and it's easier to downsize than having to scale up later on.
- Be honest, even about things you don´t know yet, or things you leave out. Include those aspects in your description.
- Make contact with both national and local authorities as early as possible and start the dialogue.
- Get a comprehensive overview of your suppliers and collaborators, and engage in dialogue with them as well.
- Keep in mind that the authorities are also new in P2X: help them as fast and best you can; then you're helping each other succeed and excel faster and better.
- Remember: you're making history right now!

Local authorities

National authorities

- Be explicit as early as possible about your requirements for the applications, the applicant, and the consultant and collaborators.
- Make an illustrative overview or roadmap of the P2X approval process and your organization's part in it. Put in on your webpage alongside where applicants must submit applications and submit forms.
- Share more of what you know if you work at a national authority. Your colleagues at the local authorities can make much use of you and your colleagues' knowledge.
- The responsibility for authorities gaining knowledge should not be the applicants'. Stat sharing more knowledge and experience in a more well-organized way across authorities.
- Remember: you're making history right now!

PATHWAY V: NORWEGIAN PREDICTIONS ABOUT FUTURE DEVELOPMENT

Most respondents interviewed in the Norwegian case think that hydrogen in some form or another (pure or as ammonia) will be used as fuel in the future. It is an answer to the need for renewable energy and also a needed supplement to the battery driven ferries since hydrogen ferries have a much longer range. The price level is seen as competitive as hydrogen avoids the CO2-fees.

However, there are some prerequisites that must be met.

- There must be a development and upscaling of production, transportation and storage options. Different choices on one of them means different solutions for the others.
- Some decisions have to be taken on who will be responsible and operate the infrastructure.
- In order to get the necessary technology innovations in this field the technology design and legislation must be developed in parallel.
- The regulatory authorities and the industry have to continue the cooperation towards solid regulations that ensure the highest degree of safety at all levels.
- There must be better cooperation between national authorities and local communities, in order to ensure anchoring and safe local infrastructure.

The Norwegian actors also have some views on what it will take for Denmark to switch to hydrogen.

- They mention that something must be done with the approval processes which today are long and complicated due to the lack of regulations.
- There also needs to be a very high degree of anchoring and involvement amongst local authorities since the ferry connections are even more municipal controlled than in Norway.
- That said, the short distances and its benefits for the infrastructure are an advantage for Denmark since it only will take a few hours to reach customers.

5. Conclusions and comparisons

The current report presents insights and findings from qualitative interviews among stakeholders and authorities in the emerging Danish and Norwegian Power-to-X (P2X) industries and infrastructures. Overall, the interviews focus on the interplays between humans, technologies, organizations, local community and national authorities, and political push- and pull-factors, thereby highlighting perceptions, taken-for-granted assumptions, and different approval practices in relation to P2X in the two neighbouring Nordic countries.

The purpose of the interviews has been to qualitatively explore and investigate approval processes within P2X infrastructures in the energy and transport industries in Denmark and Norway, with a focus on practices and perceptions among regulators *and* regulatees. The Danish interviews focus on overarching tendencies, frame conditions, and on understanding the gaps between the various stakeholders. In short, the perspective here is more horizontal. In comparison, the Norwegian input is more vertical. Here, the interviews focused on mapping and understanding the process with getting the world's first hydrogen-powered ferry in operation. Thus, the findings and conclusions have different scopes but supplement each other in a fine way.

What stands out in the Danish interviews is that technical concerns, regulatory dimensions, and market dynamics are ranked as top challenges that Danish P2X actors grapple with in the transitions. During the interviews, safety was not perceived by participants as *equally challenging compared e.g. economic barriers.* Interestingly, what the interviews *also* depict is a heavily fragmented emerging industry battling with impaired inter- and intra-organizational communication, lacking established procedures, inefficient coupling of sectors, and not least full-blown cultural clashes between industrial ways of working and perceiving risks and safety. Neither industry nor authorities have the perfect answer to such challenges, which ultimately may have devastating consequences for levels of safety and handling of risks. And thus, these “soft” yet seemingly insurmountable and cumbersome challenges are rarely verbalized, but indeed practiced. Borrowing from anthropologist and chair of the editorial board of *Financial Times*, Gillian Tett, we might say that such social silence matters[43]. The P2X industry is outspoken about lacking standards, technical challenges, or market issue – but few articulate the human and social dimensions of this transition. However, these aspects – these social silences that we often take for granted – are worth highlighting and looking into. They matter, because they hold key insights into why things look like they do or why given challenges seemingly reoccur[43].

What stands out in the Norwegian interviews is to some extent many of the same dimensions as in the Danish interviews, but the focus is more on the structural framework conditions that has enabled this process. From the Norwegian case, it is exemplified how state-run, national incentive structures, incentives, and partaking in the financial risk reduction creates a fertile setup for engaging with energy transitions, e.g. such as P2X transitions. In comparison, no similar national tenders or state-led initiatives exist in Denmark, let alone sharing the financial risks. Here, more risk and action rests with

applicants, private companies, and the emerging P2X industry. Thus, the frame conditions seem to be different despite harmonized EU legislation, creating different environments for investments.

Collaboration between the Norwegian involved actors and uncertainty due to immature technology and unfinished regulations are described as important challenges when it comes to safety in this initial phase. Indeed, in both Norway and Denmark, involved actors, authorities, and stakeholders battle with uncertainty due to immature technology, collaboration challenges, lacking knowledge about implications of hydrogen in terms of safety, and thus unfinished regulations and guidelines. These challenges influence safety concerns, which are heavily discussed among the Norwegian interviewees. This is slightly different from the Danish interviewees, where the discussions seem to focus more on market challenges. Either way, these uncertainties create a setting where investments are insecure and comes at a slow pace.

In the interviews, the collaboration between national authorities and initiators and local communities is also highlighted as a crucial factor when such innovations are to be implemented locally. In both countries, the "looser" of the 'game' seems to be the local communities and local authorities. The local municipalities are very interested in more dialogue, gaining more knowledge, and in knowledge building to be more knowledgeable about the implications of implementing hydrogen facilities and how they must handle the safety aspects of it. But in the Norwegian case and among the Danish interviewees cases, the local communities and local authorities are left to deal with these issues themselves, once it has been decided upon that the implementation with happen. Once done with the assessments and implementations, the national authorities leave, and the local community is left with all the administration and challenges. Thus, they feel side-tracked and are left with major issues and questions of who will operate and control the infrastructure, and who will make sure it's safe.

Based on the interviews, DBI and NTNU Social Research have developed recommendations and suggestion for Danish and Norwegian applicants and authorities on how to navigate P2X approval processes. Among other things, we urge applicants to initiate dialogue with authorities and to start scoping their ideas as early as possible. Indeed, both Norwegian and Danish interviewees highlight the importance of continuous dialogue to help foster smooth processes and successful outcomes. We also urge authorities do draft more explanatory and instructive guidelines and process plans to help applicants prepare the knowledge and assessments at the time when authorities need this information.

Bibliography

1. European Environment Agency. EEA greenhouse gases - data viewer. *Data viewer on greenhouse gas emissions and removals, sent by countries to UNFCCC and the EU Greenhouse Gas Monitoring Mechanism (EU Member States)* (2021). Available at: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer. (Accessed: 14th December 2021)
2. Taefi, T. T., Kreutzfeldt, J., Held, T. & Fink, A. Supporting the adoption of electric vehicles in urban road freight transport - A multi-criteria analysis of policy measures in Germany. *Transp. Res. Part A Policy Pract.* **91**, 61–79 (2016).
3. Haddadian, G., Khodayar, M. & Shahidehpour, M. Accelerating the Global Adoption of Electric Vehicles: Barriers and Drivers. *Electr. J.* **28**, 53–68 (2015).
4. European Commission. A European Strategy for low-emission mobility. *Transport emissions* (2016). Available at: https://ec.europa.eu/clima/eu-action/transport-emissions_en#ecl-inpage-555. (Accessed: 14th December 2021)
5. Røyrvik, J. O. D., Haavik, T., Kongsvik, T., Almklov, P. G. & Bye, R. J. Professional competence, air and seamanship and safety. in *Proceedings of 8th International Conference on Working on Safety* (2015).
6. Peters, A., Agosti, R., Popp, M. & Ryf, B. Electrict mobility - a survey of different consumer groups in Germany with regard to adoption. in *eceee Summer Study on energy efficiency. Energy efficiency first: The foundation of a low-carbon society* 983–994 (2011).
7. Faria, M. V, Baptista, P. C. & Farias, T. L. Electric vehicle parking in European and American context: Economic, energy and environmental analysis. *Transp. Res. Part A Policy Pract.* **64**, 110–121 (2014).
8. Intergovernmental Panel on Climate Change. Transport. in *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the IPCC Fifth Assessment Report* (ed. Intergovernmental Panel on Climate Change) 599–670 (Cambridge University Press, 2015). doi:DOI: 10.1017/CBO9781107415416.014
9. Andong, R. F. & Sajor, E. Urban sprawl, public transport, and increasing CO2 emissions: the case of Metro Manila, Philippines. *Environ. Dev. Sustain.* **19**, 99–123 (2017).
10. The Danish Government. *A Green and Sustainable World. The Danish Government's tong-term strategy for global climate action*. (2020).
11. The Danish Government. *Climate Programme 2020*. (Danish Ministry of Climate, Energy and Utilities, 2020).
12. Ørsted. Decarbonising society with Power-to-X. A path to scaling production and uptake of renewable hydrogen and sustainable e-fuels. (2020). Available at: https://orsted.com/en/about-us/whitepapers/decarbonising-society-with-power-to-x. (Accessed: 5th October 2021)
13. DBI. DBI Strategisk Forskning: Energi og Transport. (2021). Available at:

https://brandogsikring.dk/forskning-og-udvikling/energi-og-transport/. (Accessed: 5th October 2021)

14. DBI. *Brand og sikkerhed ved Poxer-to-X*. (2021).
15. Martin, V. & Ashworth, P. Exploring the Australian Public's Response to Hydrogen. in *Proceedings of 9th International Conference on Hydrogen Safety (ICHS2021)* (eds. Carcassi, M. N., McKay, S. & Hawksworth, S.) 298–308 (International Association for Hydrogen Safety, 2021).
16. Dansk Energi. *Recommendations for a Danish Power-to-X strategy*. (2020).
17. Anand, N., Gupta, A. & Appel, H. Introduction: Temporality, Politics, and the Promise of Infrastructure. in *The Promise of Infrastructure* (eds. Anand, N., Gupta, A. & Appel, H.) 1–38 (Duke University Press, 2018).
18. Larkin, B. The Politics and Poetics of Infrastructure. *Annu. Rev. Anthropol.* **42**, 327–347 (2013).
19. Spradley, J. P. *The ethnographic interview*. (Wadsworth Group - Thomson Learning, 1979).
20. Mikkelsen, B. *Methods for development work and research, a new guide for practitioners*. (Sage Publications, 2005).
21. Hollnagel, E. *Safety-I and Safety-II. The Past and Future of Safety Management*. (Ashgate, 2014).
22. Boholm, Å. *Anthropology and risk*. (Routledge, 2015).
23. Karsten, M. M. V. Dislocated Dialogue. An Anthropological Investigation of Digitization among Professionals in Fire Safety. *Organization* 1–23 (2020). doi:10.1177/1350508420961527
24. Lipsky, M. *Street-Level Bureaucracy, 30th Ann. Ed. - Dilemmas of the Individual in Public Service*. (NEW YORK: Russell Sage Foundation, 2010). doi:10.7758/9781610446631
25. Boholm, Å. Risk Communication as Government Agency Organizational Practice. *Risk Anal.* **39**, 1695–1707 (2019).
26. Kaprow, M. L. The last, best work: Firefighters in the fire department of New York. *Anthropol. Work Rev.* **19**, 5–26 (1999).
27. Boholm, Å. On the organizational practice of expert-based risk management: A case of railway planning. *Risk Manag.* **12**, 235–255 (2010).
28. Almklov, P. G., Antonsen, S., Bye, R. & Øren, A. Organizational culture and societal safety: Collaborating across boundaries. *Saf. Sci.* **110**, 89–99 (2018).
29. Karsten, M. M. V. Dislocating Promises: How Digitization Organizes and How Organizations Digitize in Fire Safety. (Aarhus University, School of Education, 2021). doi:https://doi.org/10.7146/aul.404
30. Lawani, K., Hare, B. & Cameron, I. Integrating early refresher practice in height safety and rescue training. *Saf. Sci.* **110**, 411–417 (2018).
31. Antonsen, S. The relationship between culture and safety on offshore supply vessels. *Saf. Sci.* **47**, 1118–1128 (2009).
32. Gherardi, S. & Nicolini, D. The organizational learning of safety in communities of practice. *J.*

Manag. Inq. **9**, 7–18 (2000).

33. Grytnes, R. A Sense of Security: Carpentry Apprentices Handling Uncertain and Dangerous Work Tasks. *Ethnos* **83**, 353–370 (2018).
34. Bye, R. & Lamvik, G. M. Professional culture and risk perception: Coping with danger on board small fishing boats and offshore service vessels. *Reliab. Eng. Syst. Saf.* **92**, 1756–1763 (2007).
35. Karsten, M. M. V., Ruge, A. T. & Hulin, T. Closing the gap: Merging engineering and anthropology in holistic fire safety assessments in the maritime and offshore industries. *Saf. Sci.* **122**, (2020).
36. European Parliament & Council of the European Union. DIRECTIVE 2012/18/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC. *Off. J. Eur. Union* **55**, 1–37 (2012).
37. Tett, G. *The Silo Effect. The Peril of Expertise and the Promise of Breaking Down Barriers*. (Simon & Schuster Paperbacks, 2015).
38. Lingard, H., Pink, S., Harley, J. & Edirisinghe, R. Looking and learning: using participatory video to improve health and safety in the construction industry. *Constr. Manag. Econ.* **33**, 740–751 (2015).
39. Squires, S. & Van De Vanter, M. L. Communities of Practice. in *A companion to organizational anthropology* (eds. Caulkins, D. D. & Jordan, A. T.) 289–310 (Blackwell Publishing Ltd., 2013). doi:10.1002/9780470756591.ch21
40. AtB. About us. (2018). Available at: https://www.atb.no/en/about-us/. (Accessed: 14th December 2021)
41. Enova. About Enova. (2018). Available at: https://www.enova.no/about-enova/. (Accessed: 14th December 2021)
42. Innovative anskaffelser. About Innovative Procurements. (2021). Available at: http://innovativeanskaffelser.no/about/. (Accessed: 14th December 2021)
43. Tett, G. *Anthro-Vision: A New Way to See in Business and Life*. (Avid Reader Press, 2021).