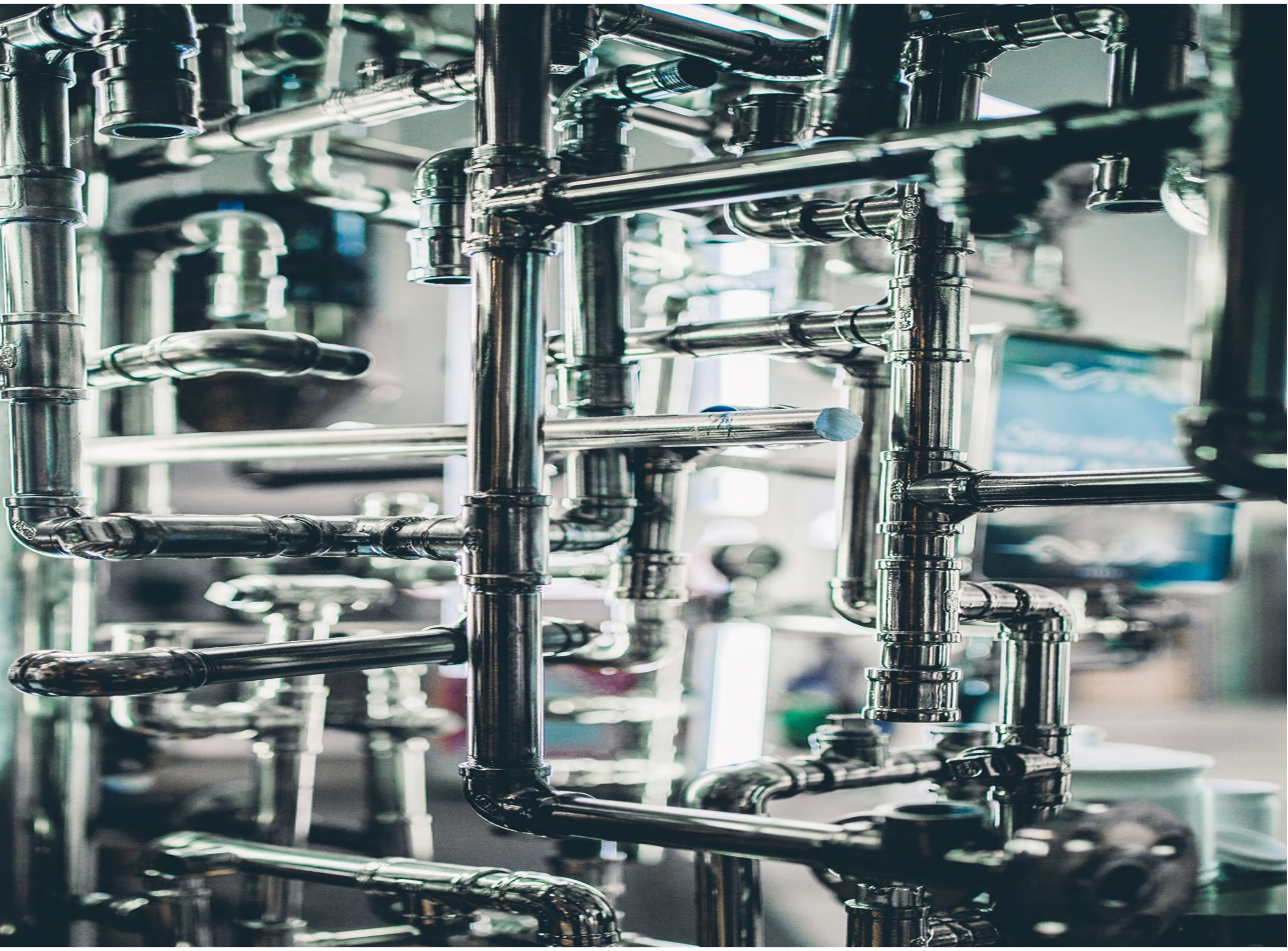

Building a Nordic innovation ecosystem around technology infrastructures and testbeds

A feasibility study of Nordic testbeds collaborations

DANISH TECHNOLOGICAL INSTITUTE

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Prepared in collaboration with
GTS, Denmark - VTT, Finland - SINTEF, Norway - RISE Sweden

Funded by
Nordic Innovation

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Foreword

The Nordic Research and Technology Organisations (RTOs) represented by GTS, Denmark, VTT, Finland, SINTEF, Norway and RISE Sweden have launched a *joint initiative with a long-term aim of offering Nordic companies access to a portfolio of advanced test facilities (testbeds) and expert knowhow across the Nordic countries*.

Feasibility study on Nordic testbed collaboration

One element of this initiative is our report presenting a feasibility study of Nordic testbeds collaborations where we have identified different models for testbeds collaborations and examined the feasibility of the different models. The feasibility study gives an in-depth assessment of the potential for establishing Nordic collaboration between testbeds from a supply-side perspective where the aim of the collaboration is to encourage commercial use of technology. In other words, the key questions are what the RTOs can offer together from the current perspective, while the demand side has only been touched lightly.

Internationally, we have observed that cross-border collaboration between RTOs/testbeds is becoming a key subject of interest to give industry better access to research and technology infrastructures and knowhow. The European Commission has placed the subject on the political agenda as well as at EU-programmes level. We have found several models for offering technological service in the international market and organisational models for cross-border collaboration between RTOs ranging from informal to legal collaboration models.

Position Paper with Recommendations

By interviewing the Nordic RTOs, we have tested the feasibility of different collaborative models. A main outcome was that we simply lack experience with cross-border collaborations in the Nordic countries, and consequently the assessment of the different models has been theoretical to some extent. The overall impression is that the RTOs and other involved actors have not identified the best solution for the growing demand for ambitious and strategic cross-border collaborations. To meet our long-term aim, the preconditions for establishing sustainable cross-border networks of Nordic testbeds need to be strengthened. This calls for thinking beyond the current state of affairs and we have prepared a Position Paper with specific recommendations that can take us in the right direction in the years to come. [1]

We would like to thank Nordic Innovation and especially Elis Benediktsson for their support and all those persons who gave their time and valuable insights through the interviews. We would also like to acknowledge the opportunity to include the outcome of the Activity Plan: DTI as High-Tech Production and Material HUB supported by Danish Agency for Institutions and Educational Grants.

Copenhagen, January 2020

On behalf of the Nordic RTOs

Lars Fremerey, GTS (Project Coordinator)

[1] GTS, SINTEF, RISE, VTT (2020): Position Paper by Nordic Research and Technology Organisations - Paving the way towards sustainable economy - alleviating the "Valley of Death" through Nordic Testbed collaboration

1. Summary

Nordic Research and Technology organisations (RTOs) take an important position in transforming new research and technologies into use in industry and society. By bridging basic research with practical use of technology, RTOs offer access to testbeds and technological knowhow, which is vital for deployment of technologies. However, technology is becoming more complex, and as knowledge becomes global RTOs must be able to offer more specialised technical facilities and at the same time recognise that their domestic, commercial markets in the Nordic countries are most likely becoming too small. Cross-border collaborations, or internationalisation becomes necessary. Even though RTOs have opportunities to move in this direction, several factors act as obstacles to moving forward which may catch the RTOs in a lock-in situation with a negative impact on their opportunities to maintain strong research-as-a-service systems.

1.1. Aim of the feasibility study

The Nordic RTOs represented by GTS, Denmark, VTT, Finland, SINTEF, Norway and RISE, Sweden have launched a joint initiative with a long-term aim of offering Nordic companies access to a portfolio of advanced test facilities (testbeds) and expert knowhow across the Nordic countries, see Annex 2. To meet this long-term aim, the Nordic RTOs will prepare the ground for establishing sustainable cross-border networks of Nordic testbeds.

One element of the initiative is this report presenting a feasibility study of Nordic testbeds collaborations where we have identified different models for testbeds collaboration that the RTOs might be able to implement on their own. Moreover, we have examined the feasibility of the different models.

1.2. Approach

Based on desk research, the feasibility study presents different models for collaboration between RTOs, and we have included six case studies to illustrate the collaborative models, see Annex 1. We have used these models as a point of departure for testing the feasibility for cross-border collaboration between the Nordic RTOs especially related to testbeds within digital economy and bioeconomy:

- *Digital economy* is an economy which focuses on digital technologies, i.e., it is based on digital and computing technologies having an impact on all business, economic, social, and cultural sectors, etc. Industry 4.0 is a vital concept for understanding the digital transformation. Within Industry 4.0, we observe a need for testing new production methods and products.
- *Bioeconomy* encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products, and bioenergy where testbeds contribute by testing new solutions, etc.

Testing the feasibility for cross-border collaboration between the Nordic countries, the feasibility study is based on desk research and interviews with representatives from the strategic managements of GTS, Denmark, VTT, Finland, SINTEF, Norway and RISE Sweden, and managers and experts related to testbeds within the digital economy and bioeconomy, see Annex 3 for a list of interviewees. The interviews were carried out in the autumn of 2019.

1.3. Key observations

The study gives an in-depth assessment of the potential for establishing Nordic collaboration between testbeds from a supply-side perspective where the aim of the collaboration is to encourage commercial use of technology. In other words, the key questions are what the RTOs can offer together, while the demand side has only been touched lightly.

Internationally, we have observed that cross-border collaboration between RTOs/testbeds is becoming a key subject of interest to give the industry better access to research and technology infrastructures and knowhow. The European Commission has placed the subject on the political agenda as well as at EU-programmes level. We have found several models for offering technological service in the international market and organisational models for cross-border collaboration between RTOs ranging from informal to legal collaboration models. However, the overall impression is that the RTOs and other actors involved have not yet identified the best or optimal solution for ambitious and strategic cross-border collaborations.

By interviewing the Nordic RTOs, we have tested the feasibility of different collaborative models. However, a main outcome is that we lack experiences with cross-border collaborations, and consequently the assessment of the different models has been theoretical to some extent.

A general observation is that most of the interviewees are uncertain as to the implications of applying more legal types of collaboration, and they are therefore reluctant to implement such models. The uncertainty relates to how much the models will impact the dominant business models and business cultures. A new legal form will, according to the interviewees, require that the participating RTOs give up some of their sovereignty and accept financial liability and profit sharing. A legal entity will presumably require that all the associated, individual testbeds align with the overall strategy of the collaboration.

More informal or negotiated forms of collaboration are more acceptable such as networks, cluster organisations, etc., as well as ad hoc projects that are typically funded by different research and innovation programmes. However, such activities are mainly 'business as usual' and do not improve the ability to offer Nordic companies access to test facilities (testbeds) and expert knowhow across the Nordic countries.

However, a review of Nordic testbeds and trends in the market for technological service call for rethinking the technology infrastructure. The Nordic RTOs recognise that the technology infrastructure is at a crossroad where more intensive cross-border collaboration between the Nordic RTOs will be a key stone in providing industry with access to advanced testbeds and technological service.

Furthermore, the Nordic RTOs also stress that Nordic RTO-collaboration must focus on technological areas that have the potential to become a Nordic growth area for the industry (positions of industrial and scientific strength), indicating that the technological areas must benefit from the transition needed both in society and the industry, e.g., within green technology, resource optimisation, health care, digitisation/Industry 4.0/electricity market, urban development, and housing. By pointing to rather broad areas of technology, we also stress the relevance of developing cross-border collaboration within the concept of Nordic ecosystems.

Despite many similarities, we also observe dilemmas placing the Nordic RTOs in very different situations or giving them different preconditions for entering Nordic cross-border collaboration:

- Testbeds or the technology infrastructure (innovation infrastructure) are supported financially, but we have observed an overall tendency to reducing public support. Thus, some RTOs could be forced to reduce investments in testbed facilities, and some RTOs may be pushed in the direction of commercial technological service without testbed facilities to boost deep-technology innovation.
- Many testbeds operate in close collaboration with other research organisations (e.g., universities) and some are closely integrated with a local ecosystem. Attention should be paid to the concept of 'Smart Specialisation', especially, with regards to applying the concept in a Nordic setting
- The Nordic RTOs have foreign companies as clients, and some RTOs have established foreign subsidiaries. This is especially the case in Denmark. However, the overall impression is that commercially based internationalisation is not a market activity at present - but it could be a potential market.

At national level, we observe that collaboration between testbeds is a general practice and that international activities in RTOs are increasing. However, no straightforward solutions to unfolding cross-border collaboration have been identified. Nevertheless, to move forward, we have identified some elements and ideas in the interviews that can feed into developing an action plan towards cross-border collaboration between Nordic RTOs where the following could be considered:

- Nordic cross-border collaboration must be initiated incrementally, and such a process will presumably take some years.
- Identify areas of technology for initial testing of cross-border collaboration, and preferably technology areas that are relatively new and highly relevant for the Nordic countries (e.g., technology areas that could be a point of departure for mission-oriented research and innovation policies), but at present not subject to commercial business (in a precommercial phase).
- Initiate pilot cases testing different forms of cross-border collaborations.
- Establish a Nordic task force to be the main driver of the process with reference to the top management.

It is unquestionably a challenging process to develop and implement a new organisational structure for cross-border collaboration between the Nordic RTOs. Internally, the Nordic RTOs have highly qualified platforms of testbeds and researchers/experts, which is an excellent point of departure.

2. Market trends for technological services call for new solutions

In the Nordic countries, the technological infrastructure has been a crucial part of the entire innovation system for about 100 years. Investment in technological infrastructure has always been motivated by the need to improve the absorption capacity of the industry to utilise new technologies as deployment of knowledge is vital to increase productivity and thus the competitiveness of the industry.

Technological infrastructure represents technological facilities and knowledge which the industry can use when testing the exploration of new technologies and developing product and manufacturing technologies, see Textbox 2.1. This is different from a traditional research infrastructure which focuses on scientific questions at low Technology Readiness Levels (TRL)[2], whereas technology infrastructure is complementary and work at a higher TRLs aiming at supporting industry to apply new technologies.

Textbox 2.1: Technology infrastructure.

"Technology infrastructures are facilities, equipment, capabilities and support services required to develop, test and upscale technology to advance from validation in a laboratory up to higher TRLs prior to competitive market entry. They can have public, semi-public or private status. Their users are mainly industrial players, including SMEs, which seek support to develop and integrate innovative technologies towards commercialisation of new products, processes and services, whilst ensuring feasibility and regulatory compliance'.

Source: European Commission (2019): Technology infrastructure. Commission staff working documnat

In the last decades, we have observed several trends that have affected the conditions for RTOs to operate technology infrastructure and testbeds, and this has motived this feasibility study.

In general, the technology and the innovation processes have changed in nature: '*Technology is more complex, technology cycles are shorter, knowledge becomes global. Besides, such complexity and the interdisciplinarity of technology makes it even more difficult for industry to fully capture its full value creation potential, which requires an important understanding of non-technological aspects as well*.' [3] A consequence of these main trends is that companies increasingly tend to initiate collaborative innovation processes and make use of technical facilities and competences offered by, e.g., RTOs.

Furthermore, when technologies become more complex, technology infrastructures and competences need to become more specialized. This has consequences:

First, the need to invest in technical facilities, testbeds, pilot and demonstrations plants tends to increase both when it comes to establishing and when it comes to keeping up with the state-of the-art of the existing facilities. Especially for the Nordic RTOs, it can be a challenge to meet the required investments as the domestic market is relatively limited and therefore less profitable.[4]

Second, when the demand becomes more specialised, the RTOs will increasingly be challenged to meet the needs or the demand. Moreover, the number of potential clients tend to decline for the specialised

[2] https://enspire.science/trl-scale-horizon-2020-erc-explained/
[3] EARTO (2018): European Innovation Hubs: An ecosystem approach to accelerate the uptake of innovation in key enabling technologies.
[4] See also Christian Ketels, et al. (2019). Peer review of the Danish R&I System. Ten steps, and leap forward: Taking the Danish innovation to the next level. European Commission, DG Research and Innovation.

technical facilities, and companies will more often find that their needs cannot be fulfilled by the domestic RTO market anymore.

Consequently, we observe a tendency that especially larger companies purchase technical services abroad, while SMEs are facing serious barriers.[5] Furthermore, RTOs are facing challenges related to 'prioritisation of technology infrastructures, their visibility and accessibility as well as their networking'. [6] This leads to the question how we can maximise the output and impact of the technology infrastructure, especially at a time when few national strategies focus on encouraging cross-border use of the technology infrastructure.

In the following, we discuss the use of different instruments to strengthen the supply of technical facilities and encourage the demand[7] and how to organise the supply of technical facilities. In other words, it appears that the discussion about a more efficient and effective technology infrastructure calls for organisational innovation to meet the above-mentioned challenges. For this reason several initiatives, which are mainly funded by EU-programmes, aim at encouraging cross-border collaboration especially for giving access to the technology infrastructure across borders, and different organisational models for offering access to the technology infrastructure across borders have been discussed, tried and initiated. [8]

Overall, the rationale for developing a technology infrastructure giving access to testbeds, etc., across borders is obvious as it can improve access to highly qualified facilities to the benefit of a still more specialised production community. However, it is less clear how the RTOs can organise cross-border delivery of technological service jointly. This calls for re-thinking. This study aims at taking a deeper look at the challenges related to organisational innovation when the Nordic RTOs are going to collaborate a cross borders.

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[5] GTS (2017): Den teknologiske videnbro – nu og I fremtiden

[6] European Commission (2019): Technology infrastructure. Commission staff working document

[7] OECD (2019): Science-industry knowledge exchange: A mapping of policy instruments and their interactions. Policy paper 66.

[8] European Union (2019): Policy challenges in exploiting research and innovation infrastructure. A policy brief from the policy learning platform of research and innovation.
EARTO (2018): European Innovation Hubs: An ecosystem approach to accelerate the uptake of innovation in key enabling technologies

3. A methodological framework

Our first review of international experiences has revealed a considerable number of case stories and examples of how to encourage cross-border access to technological services. A general review of initiatives has revealed different generic approaches to improving access to technological service. Organisational innovation has taken place in many ways to improve access to technological services. Nevertheless, this study only presents some archetypes or typically seen solutions to improve access to cross-border technological services.

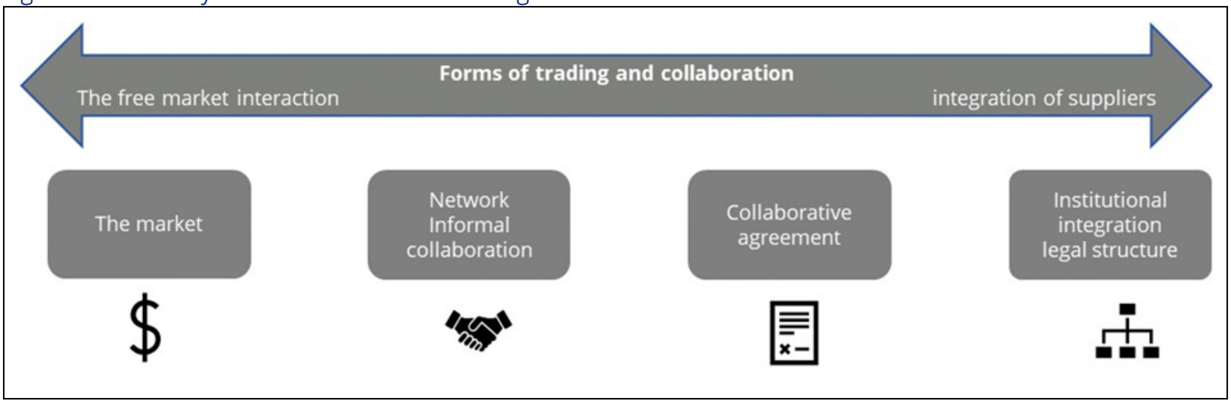
3.1. A model for organisational innovation

To illustrate the diversity of initiatives systematically, we have developed a model for intervening or changing access to technological service. The analytical model illustrates different organisational forms of handling the transaction of technological service. The transaction can take place within a ***continuum*** of different organisational forms:

- A *pure commercial transaction* (the free marketplace), which is characterised by a price-quality relationship and may be challenged by inefficiency as the offered technological service is difficult to reach and/or does not meet the needs (quality and prices) of the client. Sales would largely be the basic motivation for using this initiative.
- *Networks as informal relationships or meeting places* could be an arena where RTOs/service providers and clients meet to become acquainted with each other. This way, the RTOs/service providers will be able to present their (customised) services.
- *Negotiated forms of collaborations* can lead to establishment of platforms for transactions, where the RTOs/service providers join forces, e.g., to offer a broader range of services.
- *Institutionalised forms of collaborations* are based on a common business strategy, and in their most integrated forms they are set up as a legal entity to execute the strategy. In such cases, the integration will be complete in terms of technical specialisation in the service offered, and in economic terms as liability and profit sharing will be part of the 'collaboration'.

The analytical model is only presenting some archetypes. However, organisational innovation – new ways of organising cross-border collaboration – may not be restricted to only one form as shown in Figure 3.1, since the boundaries are blurred and organisational innovation may involve different market players and/or combine different forms of agreements or ways to operate.

Figure 3.1: An analytical model: The arena for organisational innovation



Source: Danish Technological Institute

The models in Figure 3.1 are only illustrations of how RTOs can try to reorganise themselves towards the market to establish a better interface with the market or their clients and thereby respond to market demands. However, the model does not indicate anything about how trading takes places (trading models) in terms of trading by pricelist (fixed prices), invitation to tender, or negotiated trade agreements in which the terms are quoted.

Moreover, political intervention aimed at improving access to technological service (a response to so-called 'market failure') is also common. Such policy instruments can have an impact on how RTOs organise themselves, but not necessarily, as the aim is often to provide better access to technological service or increase demand and hereby give companies a stronger cross-border purchasing power. Such initiatives are seen in R&D-programmes, business development programmes, or regional programmes offering technological support (such as participation in R&D-projects, cross-border projects, voucher schemes or tax incentives).[9] However, it is out of reach of the RTOs to make decisions about such programmes and typically such financial support is temporary and is therefore not taken into consideration in this study.

3.2. How to review new organisational forms for collaboration between RTOs

The point of departure for this study are RTOs and their opportunities to join or enter new organisational structures providing enterprises with easier and/or a more efficient access to testbeds service. International experiences in the form of (cross-border) RTO collaborations presented in our study are primarily based on our cases. In agreement with the parameters listed in Table 3.1, the cases are presented in the Annex and in Section 4 where they are analysed to understand which attributes are common, which ones are shared, and which ones seem to work most effectively, or which ones are likely to be contingent on each other. Finally, the cases can also give some indications of the main challenges and pitfalls.

Table 3.1: Key analytical subjects

Main subject	Subjects to be considered – all questions will not be relevant in every case
Rationale	1. Industry is demanding new knowledge, technical facilities, etc., which may not be accessible locally. 2. RTOs are offering more specialised services based on heavy investments in testbeds, but the local demand is too limited to pay back the debt of the investment. More clients - a large market - are needed. This can be achieved by an increased number of clients or an increased share in cross-border markets. 3. Form a large informal network as a platform for joint Research-Development-Innovation projects (RDI-projects)
Organisation - service provided	4. The organisational structure and form, management structure, and procedures: a. technological facilities (competing or complementary technological areas); b. profit-sharing, risk-sharing, etc. 5. Operational procedures, such as carrying out joint activities, sharing clients, agility, timeframe … (informal vs formal) 6. Legal aspects such as NDAs 7. Crisis management such as handling disagreements, partner failing to operate, etc.
Business model	8. Commercial activity 9. Public funding/granting (direct/indirect)

Source: Danish Technological Institute

[9] OECD (2019): Science-industry knowledge exchange. A mapping of policy instruments and their interactions

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4. Efficient access to foreign technology providers

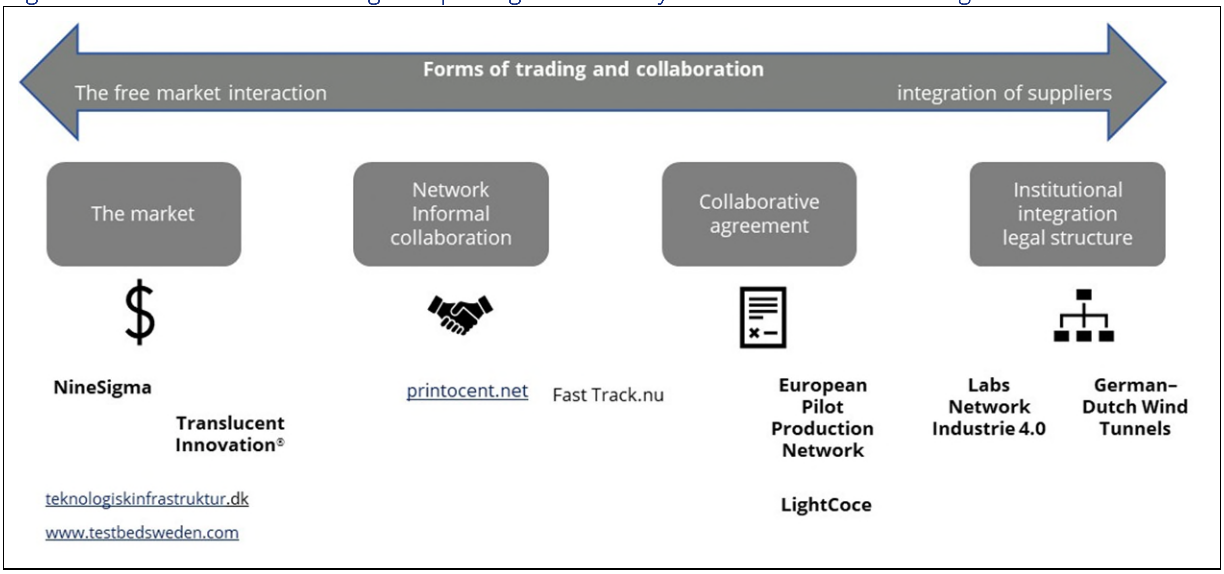
RTOs have been involved in various initiatives that have aimed to improve the efficiency of the market for technological service including giving easier access to test and demonstration facilities. We have screened several of these initiatives and selected six initiatives to illustrate different approaches within the arena for organisational innovation, cf. Figure 3.1. The selected initiatives – or illustrative cases – can be found in the Annex 1.

The illustrative cases can serve as inspiration for designing cross-border collaborations. In the following, we focus on organisational mechanisms and experiences that might be useful.

4.1. The selected organisational initiative – at glance

The illustrative cases have applied different approaches to improving the efficiency of the market for technological service, see Figure 4.1. The initiatives mainly influence the way the RTOs organise their supply of technological services or their marketing strategy. Some initiatives apply a variety of organisational mechanisms and some initiatives also impact the purchasing behaviour of the clients.

Figure 4.1: Illustrative cases aiming at improving the efficiency of the market for technological service



Source: Danish Technological Institute

In short, the illustrative cases address similar problems (rationale), but they apply different mechanisms to improve the market for technological service:

1. *A digital portal* as a mechanism to be more exposed in the market
   - Improving the accessibility and visibility of testbeds by establishing a new marketplace by setting up a digital portal (a marketplace), e.g., Testbeds Sweden or Teknologiskinfrastruktur.com.
2. A *brokerage mechanism* linking requests for proposals with a network of testbeds and/or experts (service providers):
   - NineSigma, a private, globally operating company, offers a brokerage service where companies are linked to high-profile experts, researchers, etc. (service providers), which

can assist the client with solving their technological problem. NineSigma appears to be benefitting from an extensive global network of experts and a customer base, which also includes multinational companies with significant purchasing power.
  - Translucent Innovation® is a brokerage facility established by an RTO (RISE, Sweden) to call for requests for proposals from international clients. The requests for proposals are solved by RISE experts, but also from partners in the RISE network, and generate a project pipeline for RISE. Translucent Innovation® is free of charge (in case an external service provider solves the project, a small finder's fee is charged to the project) and is considered to be a marketing and project generating instrument.
3. *A network facility* aiming at strengthening the personal interconnection between clients and service providers (e.g., RTOs, universities, etc.)
    - Interconnectivity is the key mechanism to establishing a dialogue about technological challenges or problems, which can then lead to formulation of a project or assignment. Clients may have free access to such networks (meetings), but the meetings may also have a specific technological focus or be organised within a framework of a cluster (technology and business area). Participation in a technological focus network is typically by invitation only (free of charge), and some networks only invite complementary service providers. In terms of social challenges, such networks can bridge the gap between basic research and commercialisation of research, and for the participating RTOs it can be a project generating platform (see fast-track.nu Denmark or printocent.net Finland). However, the Fast-Track case also has access to a funding mechanism to fund R&D/innovation projects, which can accelerate the process of adaptation of new technologies by the clients/in society.
4. *A single-entry-point* to facilitate easy access to technological service
    - In several cases, service providers (RTOs, universities, etc.) are reorganising the access to technological service by establishing a single-entry-point as seen in EU-funded projects such as 'The European Pilot Production Network' and 'LightCoce'. The basic idea is to establish a 'HUB of HUBs' to encourage geographically distributed hubs in Europe to establish a coordinated effort to increase accessibility to their facilities. Typically, the aim is to establish a 'single-entry-point to handle requests for proposals/service and distribute the requests afterwards'. In EU funded projects, the overall ambition is often to establish the single-entry-point as a legal entity. However, in these cases, it still unclear how the single-entry-point will operate and be financially sustainable; how the distribution of requests for proposal will be handled and the type of legal entity the projects will apply.
5. *An association as an entry-point to business support and test facilities*

    Labs Network Industrie 4.0 is an association (legal entity) founded by companies related to the Plattform Industrie 4.0. Labs Network Industrie 4.0 offers companies a membership that gives them access to technical support and aims to assist the companies with bringing new products to the market and hereby gaining access to a multitude of different test facilities. Companies pay at membership fee, and small companies pay less than large companies. The fee gives access to the service of Labs Network Industrie 4.0 but the cost of using the test facilities is not a part of the service.

6. *Test facilities merge into a common company*
   - German-Dutch Wind Tunnels is an example of a complete integration of service providers that have formed a legal entity. By establishing a non-profit foundation, several test facilities have joined forces in a single legal entity with one management enabling German-Dutch Wind Tunnels to supply large-scale technology-advanced test facilities to a market represented by technology leading companies.

Overall, the illustrative cases largely address the same problem, but even though they represent several similarities in the problems addressed, they have applied different solutions to solving the problems, see Table 4.1.

Table 4.1: Overview of the solution that have been applied in the selected cases

The case in short	Rationale (Problem)	Overall solution – service provided	Organisation
Digital portals	Difficult to find and get into contact with test facilities or technological service	A free open portal	An add-on facility to RTOs offering market information about test facilities
Brokerage mechanism			
NineSigma	Clients have a technological problem, but the challenge is to identify a (best qualified) service provider	Qualify requests for proposal and send the request to a network of experts Access to a global network of expert/service providers	Main business activity Independent company Commercial operating
Translucent Innovation®		Qualify requests for proposal and send the request to a network of experts An internal network of expert/service providers. If no match, external expert may be considered	An internal facility operated in collaboration with other organisations
A network facility			
Fast-Track.nu	A personal network is valuable for sharing technological knowledge and a key to matching problems with solutions. However, many clients and service providers lack a professional network.	An offer to join a network within a specific technological and/or business area Network meetings for the industry, universities, and RTOs (presentation on technology trends, research results, company visits and a discussion forum) A possibility for small collaborative projects.	A project organisation established by large companies, universities, and RTOs
printocent.net		Network/cluster meeting	A cluster organisation established by an RTO, a local university and business support organisation
A single-entry-point			
The European Pilot Production Network	Companies have limited knowledge about the service offered by RTOs, locally and internationally. The local/national RTOs are specialised and/or do not cover the entire innovation course	A single-entry-point facilitates a common platform for marketing 175 pilot plans (RTOs) giving clients access to an entire ecosystem of facilities related to nanotechnology and advanced materials. The single-entry-point is also servicing pilot plants.	The single-entry-point is organised as a project funded by the EU
LightCoce		A single-entry-point provides clients with a more efficient access to technical service and test facilities within lightweight multifunctional concrete and ceramics (creates an ecosystem)	The single-entry-point is organised as a project operated and funded by the EU

The case in short	Rationale (Problem)	Overall solution – service provided	Organisation
An association as an entry-point to business support and test facilities			
Labs Network Industrie 4.0	Companies have limited knowledge of the services offered by RTOs, locally and nationally. It can also be a challenge to bring an idea to the market The local/national RTOs are specialised and/or do not cover the entire innovation process	Labs Network Industrie 4.0 offers enterprises innovation service by guiding enterprises through the process of development of, e.g., new products including providing access to test facilities	The network is a non-profit association governed by its own articles. Clients must be members of the association and they pay a membership fee to be part of the network
Test facilities merge into a common company			
German-Dutch Wind Tunnels	Demand for advanced technological service and test. A need for coordination and investment	A common strategy for investment and offered test facilities	One organisation responsible for investment and daily operations

Source: Danish Technological Institute

The cases basically share the same motivation for establishing an organisation for offering technological service. The proliferation of new technologies and/or increasing specialisation have an impact on technological service. In order to meet market demands the service providers will typically have to invest heavily in new facilities and at the same time increased specialisation may mean that the number of local/national clients will be reduced except in cases where the local ecosystem is highly specialised within the area of technology. Consequently, a financially sustainable business can find itself in a lock-in situation, where the local/national market is too small (return on investment cannot be achieved due to a limited local/national demand).[10]

The illustrative cases present different approaches to organisational innovation to meet this challenge, but they mainly do it by developing the way they offer technological service, the ***supply side***, and more rarely by influencing the ability of the clients to purchase technological service, the ***demand side.***

Supply side

The service providers have applied different mechanism to improve the access to technological service. Even though the illustrative cases do not represent cross-border collaboration, all the mechanisms they apply can most likely be applied in a cross-border context. The following main types of mechanisms for developing the supply side have been identified:

- Mechanism for distributing *request for proposal* to a wider circle of testbeds/RTOs.
- Mechanism for *a dialogue between clients and RTOs with the aim of defining/developing request for proposals*, typically to be solved by the involved testbeds/RTOs. Such types of dialogue can take place within the framework of informal network or clusters.
- Mechanism for reorganisation of technological service typically within a specific technological field where RTOs, test facilities, etc., *join forces by presenting themselves as entities* offering, in principle, all types of services and facilities related to digitalisation, nanotechnology, etc. These types of organisations have been called hubs or single-entry-points.

[10] This argument does not take into consideration that public R&I-policy will consider this situation to be a market failure by offering financial support to maintain a national technological infrastructure.

Overall, the mechanisms also signal an overall aim of scope. In particular, the last two mechanisms mentioned above will tend to have a narrower technological focus. In principle, all the mechanisms for developing the supply side can be applied nationally and in the international marketplace by addressing the Nordic countries, all EU Member States, or global profiles. In other word, the scope of the supply side will be followed by the question of scale of the market as a matter of course. Overall, the scale and scope of the technological services on offer are closely interlinked.

Demand side

Regarding the *demand side*, the providers of technological services have relatively few mechanisms they can apply since they cannot impact the business strategies of their clients. However, according to the illustrative cases, the RTOs do have some opportunities to impact the trading performance of their clients, such as:

- inviting clients to become members of networks or clusters; and
- offering clients membership of, e.g., a hub, where paying a membership fee gives access to some advantages.

All in all, the mechanisms that can be used to influence the clients are rather weak as the RTOs are just offering some benefits to their clients but without really having a major impact on the demand in terms of economies of scale and scope; or, in other words, how much the clients are demanding and the type of services in terms of technologies and innovation support that they are requesting.

One of the illustrative cases, in particular, combines a supply and demand side approach within a hub. The Labs Network 4.0 (LNI4.0) promotes specialisation within digitalisation by having a multitude of testbed facilities that members can access if they join the collaboration (as partners). At the same time, by connecting many RTOs to a single-entry-point by compiling a catalogue of services that are available to companies, LNI4.0 exposes the RTOs to new clients. Consequently, the outcome will improve technological services (more specialised/advanced and complex services) and presumably the outcome will be more satisfied clients.

A key argument for collaboration is the need/demand for more specialised/advanced and complex technological services. However, none of illustrative cases (the applied mechanisms) have really taken any action to upgrade or change the technological services they offer. We have not found any explanation for this observation, but it could be that the present technological level is advanced and that the key challenge is to secure financial sustainability.

However, the German-Dutch Wind Tunnels (DNW) case illustrates that it is possible to aim at a very advanced technological level, by keeping clients with a great purchasing power in sight. DNW operates facilities distributed over five locations in the Netherlands and Germany. Each facility has specialised their operations by virtue of sharing resources and technologies. This way DNW can provide better and more cost-effective testbed facilities than they would have been able to if they had not been integrated.

In short, the main aim of increasing RTO-collaboration seems to be more exposure to new clients rather than aiming at enhanced specialisation.

4.2. Business model

Independently of the chosen collaboration model, collaboration involves elements of sharing responsibilities collectively and financial dependence. While the specific business models may be complex, the archetypical extremes of the business model spectrum are clearer. On the one hand, there is no institutional integration, and, on the other hand, the service providers are highly integrated. The illustrative cases represent different business models, see Table 4.2.

Table 4.2: Overview of applied business models among the illustrative cases.

The case in short	Business model	Main challenges
Digital portals	An investment in marketing. The economic value is uncertain due to lack of information as to whether the portals generate new commercial projects or collaborative publicly funded projects	Economic impacts uncertain (new projects) as well as the impact on business in general
Brokerage mechanism		
NineSigma	Commercial operations where clients pay for the services	Enough clients with substantial purchasing power. Access to a large network of highly specialised experts and researchers, which can also meet the demand from research intensive companies
Translucent Innovation®	An investment in a marketing facility aimed at generating new commercial projects (by application, can also be funding by business support or R&D-programmes). New project will directly or indirectly finance Translucent Innovation® but uncertain whether the business model can be financially sustainable.	By targeting a national market, the number of potential clients can be too limited Services mainly delivered by in-house expert – might not meet the needs of the clients. Return on investment uncertain
A network facility		
Fast-Track.nu	Based on public funding allocated to organising the network activities as well as funding for small R&D projects. No plan to establish a business model making the network financially sustainable.	Personal relationships will not generate enough new projects attracting additional funding for commercial projects or publicly funded projects. Alternatively, have participants pay to join the network (membership fee)
printocent.net	Cluster activities operated by an RTO	N/A
A single-entry-point		
The European Pilot Production Network	Based on public funding primarily from the EU (H2020), but the ambition is to establish a legal entity to operate on market condition.	Lack of business model or future funding of the network. If a legal entity, uncertainty as to how the funding RTOs should join regarding investment, risk sharing, and how to share business activities
LightCoce		
An association as an entry-point to business support and test facilities		
Labs Network Industrie 4.0	The non-profit organisation where the business model is based on members paying a membership fee	General acceptance that the funding model prioritises small enterprises

The case in short	Business model	Main challenges
Test facilities merge into a common company		
German-Dutch Wind Tunnels	Aim at operating large-scale, specialised/advanced test facilities to target a technologically demanding commercial market and do front-edge research A non-profit organisation with an income from commercial testbed services and from publicly funded R&D projects	NA

Source: Danish Technological Institute, see Annex

Within this range of business models (cf. Section 3.1), we have found the following characteristics:

- Brokerage service offers on a commercial base.
- The RTOs provide the investment and pay the current costs of brokerage services or facilitating networks/cluster matching clients and RTOs/service providers. The return on investment will come from new commercial projects or projects funded by public R&I programmes. There does not seem to be evidence that indicates that this business model is economically sustainable.
- A hub or single-entry-point established as a legal entity is an ambition in several cases. However, it is rarely seen that independent RTOs establish a joint legal entity, which has an impact or consequences in terms of defining common business opportunities (and hereby could have an impact on the strategic decision of the individual RTOs) or requiring financial liability. Some H2020- projects try to target an ambition of establishing a legal entity, and so far, some projects have investigated the feasibility of different legal models.[11]
- A hub or single-entry-point established as an independent association as an entry-point to business support and test facilities, e.g., focusing on a narrow specialised technological field. The operation of the association will be defined in its statutes and controlled by the founding members. Furthermore, the current costs could partly or completely be covered by membership fees. Overall, this business model does not appear to intervene with the business model of the founding members or that of other RTOs. However, trust and transparency may be crucial for making it a success even though the founding members can control the current business, especially a fair distribution of new projects among the participating RTOs.
- A complete integration of individual test facilities or a merger of several RTOs into a joint legal entity. German-Dutch Wind Tunnels is an example, whereas German-Dutch Wind Tunnels is a technologically very focused facility. This presumably makes such a financial integration more feasible than a merger between large RTOs dealing with many different technological fields.

Above we have presented some of the opportunities, but these opportunities should only be the first step in deciding whether to proceed toward establishing a new way of offering technological services. However, a key question to keep in mind is the question of how to handle economies of scale and scope, where scale refers to the question of internationalisation of the testbeds service (size of the client base) and economics of scope to the level of specialisation.

[11] marinerg-i (2017): Final review and SWOT. Analysis of Potential legal Environment. http://www.marinerg-i.eu/wp-content/uploads/2017/04/GA739550_MARINERGI_D5.2.pdf

5. A starting point for Nordic cross-border testbed collaboration

A precondition for the feasibility study is to pay attention to testbeds within the digital economy and bioeconomy, as these areas have been identified as having a high potential for growth and innovation.

The Nordic RTOs have set up several testbeds within these technology areas and for the study we chose to collect information and experiences related to cross-border RTO-collaboration based on some selected testbeds. It should be noted that these testbeds have not primarily been selected as potential cases for testing the feasibility of establishing any forms (collaborative models) of Nordic collaboration, but rather to investigate the feasibility of Nordic collaboration as such. Within the framework of this feasibility study, it is not the intention to perform any kind of a 'due diligence', such as revealing matches/mismatches regarding the applied technology, business models and any other characteristics as conditions for establishing any form for Nordic collaboration.

Consequently, the aim of this section is first to present related testbeds, second to discuss the precondition for establishing cross-border Nordic collaboration, and third to make an initial assessment of the feasibility for cross-border collaboration.

Testbeds within printed electronics and biorefinery will be used as illustrative cases within digital economy and bioeconomy, but managers representing other testbeds within digital economy and bioeconomy have also been interviewed and the information is also used in relevant sections. See Annex 3 for a list of interview persons.

We have chosen printed electronics as it offers new technological opportunities to produce embedded electronics to be integrated typically in flexible materials. Furthermore, printed electronics can be used in products which will typically be an integral feature of Internet of Things or Industry 4.0. Biorefinery represents a processing technology where the testbeds explore new processes and extracting (new) components from any biomass in principle where the components can be use in other products.

Within these two areas of technology, printed electronics mainly represent mainly laboratory test facilities, while testbeds within biorefinery operate small laboratory units as well as large demo-plans. Overall, these two areas take somewhat different approaches to technological development and testing.

5.1. Testbeds related to printed electronic

The six illustrative cases have different ways of accessing testing within printed electronics. Nevertheless, some of the testbeds may also overlap.

DTI's laboratory for printed electronics mainly works with basic printing technology, which also seems to be the case at the RISE-testbed. However, the RISE-testbed also has small-scale production facilities for developing new products. At VTT, the testbeds offer facilities that take printed electronics closer to manufacturing. At SINTEF, the Manufacturing Technology Norwegian Catapult Centre does not have a dedicated focus on printed electronics, but printed electronics will presumably be a technology to be applied in new digitalised manufacturing methods, see Figure 5.1.

Figure 5.1: Testbeds within digital economy – printed electronics

Manufacturing Technology Norwegian Catapult Centre (SINTEF)
Based on Industry 4.0 standards, the Manufacturing Technology Norwegian Catapult Centre (MTNC) is a test centre for developing and testing new manufacturing methods. The centre provides testing facilities such as small-scale manufacturing facilities, digitalisation/internet of things, and artificial intelligence.

Laboratory for printed electronics (DTI)
The laboratory produces cost effective functionalised silver and copper nanoparticles designed for printed electronics applications. The laboratory can provide nanoparticles with controlled size ranging from 50-500 nanometres. The tailored capping materials are compatible with several solvents to optimise dispersion properties. Through controlled filtration, dispersions in a number of solvents can be produced, meeting the needs of conductive ink manufacturers and at concentrations larger than 50 wt%.

Printed Electronics Arena at RISE
Printed Electronics Arena-Manufacturing is a test environment for the development and small-scale production of printed electronics aimed at developing new products or processes. The arena offers access to automated sheet-based screen printers, slot die coaters – Photovoltaics, Eardrop Inkjet, Aerosol Jet, Won Flash, Best Datacom Flip Chip Bonder (Pick and place) and Dry Phase Patterning, metal foils, antennas.

VTT Print Cent
VTT Print Cent offers a roll-to-roll (R2R) pilot manufacturing environment and R&D services for the development of printed intelligence products and processes. The pilot manufacturing environment consists of production lines using production methods such as reverse and forward gravure printing, flexographic printing, rotary screen printing, slot die coating, rotary die cutting, lamination, hot embossing, evaporation, etc.

Sources: https://mtnc.no/om-ntmc/
https://www.testbedsweden.se/en/test-demo/pea-manufacturing
https://www.vttresearch.com/services/smart-industry/printed-and-hybrid-manufacturing-services/pilot-manufacturing-services-and-infrastructure
https://www.dti.dk/specialists/nanomaterial-powders-and-dispersions-for-printed-electronics/38438?cms.query=printed+electronics

An observation among the interviewed Nordic testbeds is that they have a somewhat different approach to be a testbed. In general, all testbeds aim at bringing new technology into use to the benefit of society, but some testbeds believe that this is mainly a research issue (applied research), while other testbeds have a very practical approach to specific technological development. In the case of printed electronics, the testbeds seem to be more oriented toward a practical approach rather than applied research. Furthermore, the four illustrative testbeds are organised slightly differently. Typically, the testbeds are an organisational integrated part of an RTO, but in some cases, they have close ties to the local ecosystem:

- VTT PrintoCent was founded by VTT, University of Oulu and Business Oulu.[12]
- Printed Electronics Arena at RISE collaborates closely with Linköping University and the Laboratory of Organic Electronics and is hereby part of a local research environment. The testbed also has access to test facilities hosted by their cooperation partners.[13]
- The testbeds at SINTEF are anchored in a partnership representing NCE Raufoss[14], NTNU (Norwegian University of Science and Technology) and others.

Even though, the organisational setting is different to some extent, all the testbeds within printed electronics collaborate across borders with other RTOs and research institutions, typically based on personal relations and ad hoc (research) projects.

[12] https://www.printocent.net/about-us/
[13] https://www.printedelectronicsarena.com/about/
[14] An industrial cluster with the role as the national competence centre for lightweight materials and automated production in Norway; http://www.nceraufoss.no/en/

5.1.1. Cross-border collaboration

Cross-border collaboration exists in several forms among the testbeds. The basic form of collaboration consists of informal networks between individual researchers/experts aiming at knowledge sharing. The informal networks are based on knowing each other personally (to know and be known) where academic or technological competences as well as ability to work efficiently and mutual confidence are key criteria for being accepted into the networks. The networks seem to be vital and a point of departure for other types of collaboration including more formal types of collaborations.

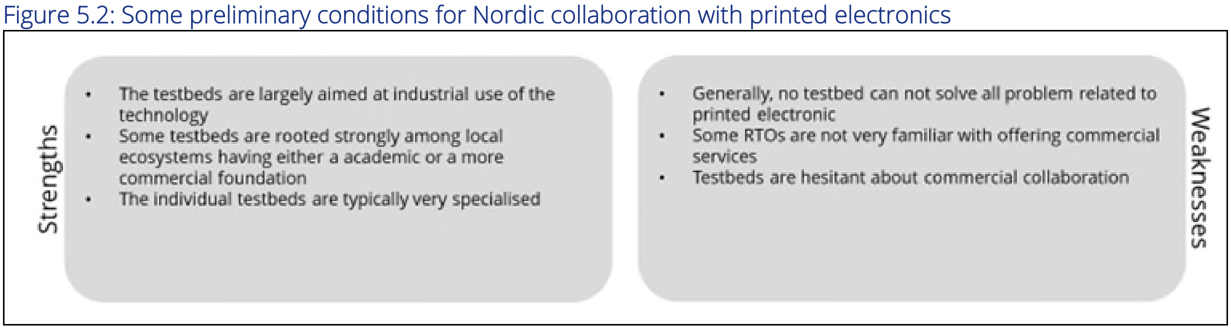
It is very common to participate in international R&D-projects that are typically funded by international R&D-programmes (mainly EU projects). R&D collaborations are typically project-based, and such international collaborations appear to be rather uncomplicated as project agreements (a contract) regulate the collaboration regarding division of tasks, financing, liability, IPR, etc. However, some testbed managers stress that they do not or hesitate to collaborate with testbeds that are technologically of strategic interest to themselves as they want to protect their own unique competences. Thus, technological complementarity appears to be a key precondition for collaboration. This observation can also be explained by the fact that these testbeds are rather close to the market.

In some cases, the testbeds join informal networks for technological experts. Besides sharing knowledge, these networks in some cases operate a platform for 'request for proposals' where clients try to find someone to solve a problem for them often via an expert. The testbeds emphasise that the network should not be involved in any commercial activities, but problems must be solved using a bilateral agreement between the client and the expert solving the problem. The argument is that it is too complicated to integrate different RTOs, or in other words to integrate independent legal entities, even when they have different business models.

5.1.2. A point of departure for Nordic cross-border collaboration

Based on the interviews, we have made a very preliminary assessment of the technological profile of the testbeds as a precondition for establishing Nordic cross-border collaboration. With some reservations, we could argue that there could be, from a technological and even a market perspective, a rationale for Nordic cross-border collaboration between testbeds within printed electronics, see Figure 5.2.

Figure 5.2: Some preliminary conditions for Nordic collaboration with printed electronics



Sources: Danish Technological Institute

The argument could be that these testbeds represent technologies and test facilities that are somewhat complementary aiming at developing and testing new technological solutions with a potential to be applied in manufacturing. The testbed market for technological solutions with embedded printed electronics solutions will probably increase in the next 10 years as the market for printed electronics has potential for a significant growth.[15] All these testbeds should be able to capture the expanding market for printed electronics by offering a broad range of complementary test facilities supporting product development rather than by acting on their own. However, some of the testbeds hesitate to join commercial collaborations. Moreover, several of the testbeds are organisationally integrated in the local ecosystem. Consequently, the testbeds can find themselves in a lock-in situation which might be an obstacle to tighter cross-border collaborations, especially when the aim is to address the short-term commercial market for test facilities.

5.2. Testbeds within bio-refinery

The illustrative cases all work within bio-refinery and, in principle, with all kinds of biomasses. In the study we have not been able to identify detailed technical differences and technical specialisation among the testbeds regarding the applied process technologies and/or highlight core competences related to specific types of biomasses. However, the capacity of the processing facilities seems to differ, where DTI seems to have a small-scale facility compared to the facilities in the three other Nordic countries. Moreover, VTT, SINTEF and RISE seem to be more research-oriented than DTI, see Figure 5.3. Consequently, the test beds at VTT, SINTEF and RISE are more oriented towards national and international collaboration with other research institutes and large research-oriented companies.

Figure 5.3: Testbeds within bioeconomy – biorefinery

Thermo-chemical biomass conversion (SINTEF)
The laboratories perform experimental research on thermochemical biomass conversion using laboratory units in the range from bench- to semi-pilot scale such as reaction and kinetic studies, benchmarking, screening and process development of catalysts and processes, product analysis and characterisation. Furthermore, the laboratories offer experimental and theoretical expertise along the value chain from conversion of raw materials to upgrading to final products, e.g., biogas upgrading, catalytic synthesis to fuels and chemicals, pyrolysis, catalytic stabilisation and upgrading of bio-oils

Generic pilot plant for bio-refining (DTI)
Pilot plant for bio-refining is generic and was established for upscaling. It was built to be flexible in terms of handling various biomass types, both 'green', 'yellow', 'blue', etc. The pilot plant has expertise in refining biomass and setting up business cases based on the achieved results. Furthermore the pilot plant works for companies participates in research and development projects.

Biorefinery Demo Plant at RISE
The Biorefinery Demo Plant was established for the development of green chem, fuels and future materials based on renewables. In condition similar to the manufacturing condition in the industry, the Biorefinery Demo Plant is able to test and carry out demonstrations of new products such as chemicals, paint, fuels feeds, etc., based on bio raw materials, The plant is very flexible and can be used for many types of raw materials as well as process configuration

VTT Bioruukki - Process modelling
This plant develops and utilises process and phenomena simulation and modelling to improve process efficiency. The efficiency measure may be energy, costs, or selected environmental indicator, etc. The mass and energy balance data obtained through the models are a prerequisite for all these assessments. Models are also developed for continuous development at mill sites, and the evaluation of novel production concepts integrated into existing systems. One example of this is the evaluation of the impacts of integrating biorefinery processes on the cost efficiency of pulp production. The plant's focus is on modelling different pulping and biorefinery processes

Sources: https://www.dti.dk/specialists/generic-pilot-plant-for-bio-refining/38707?cms.query=+bioraffinering
https://www.testbedsweden.se/test-demo/bdp
https://www.vttresearch.com/services/bioeconomy/industrial-process-efficiency-and-management/process-optimization-and-support/process-modelling
https://www.sintef.no/en/all-laboratories/thermochemical-biomass-conversion-laboratories/

[15] The market for printed electronics is estimated to increase from USD 41.2 billion in 2020 to USD 74 billion in 2030. Source: IDTechEx: Flexible, Printed and Organic Electronics 2020-2030: Forecasts, Players and Opportunities

Furthermore, the organisational set-ups also differ among the testbeds where special attention should be paid to the Biorefinery Demo Plant at RISE. This testbed is part of a local hub for biorefinery where the test facility is university-owned. Regarding organisation the test facilities are placed at the company SEKEB while RISE is the operational partner operating the demo plant. The hub is an outcome of a national strategic initiative involving collaboration with research institutes, universities, authorities, vehicle manufacturers and other companies in the forest and chemical industry.[16]

5.2.1. Cross-border collaboration

Several of the interviewed testbed managers have experiences from collaborating with other testbeds both nationally and internationally. Reviewing their attitude and experiences, we can sum up some main characteristics:

Internationally, the RTOs within bioeconomy are mainly focused at R&D collaboration as a platform for competence development and knowledge sharing. The RTOs consider the outcome of R&D collaboration as an important input to their ongoing development of knowledge and research-based testbed facilities. In this instance, international R&D collaboration is seen as an observation post for new technological/research trends to ensure that the RTOs are at the technological forefront to attract partners for applied research in collaboration with domestic universities and typically large companies.

The above characteristics largely dominate the VTT, SINTEF and RISE testbeds since they are more research oriented than DTI. Commercial activities are rarely an element in cross-border collaboration but in a few cases some RTOs do engage in commercial projects with large foreign companies.

Informal collaboration is very common and typically takes place in informal networks where non-confidential, precommercial information and knowledge can be shared. Collaboration mainly takes place in collaborative projects based a joint agreement/contract that is typically funded by public R&D programmes regulating work conditions, cost, IPR, etc.

The R&D-collaborations are typically deeply rooted in personal networks where the researchers/experts know each other and use the networks to select partners for collaborative projects. Such networks are informal since the code of conduct involves knowing each other personally, being a recognised and trusted researcher, and being productive in collaborative projects (high-quality input at the agreed time) otherwise the researcher will be 'excluded' from the network.

5.2.2. A point of departure for Nordic cross-border collaboration

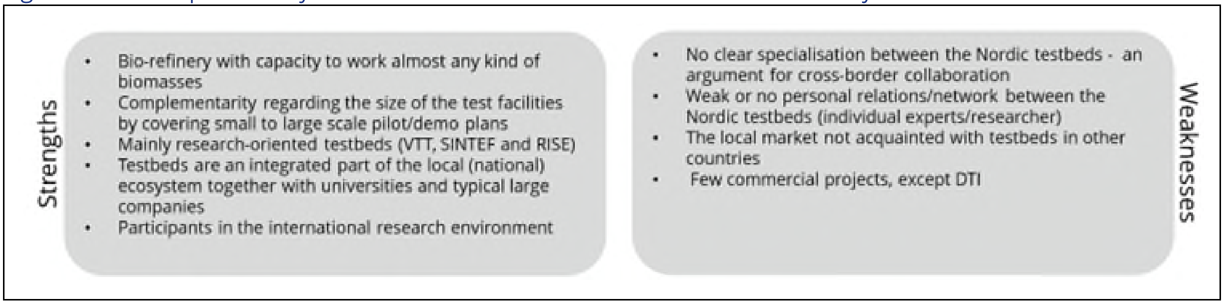
The interviewed testbed managers have described their testbeds and based on this information we have made a very preliminary assessment of the technological profile of the testbeds as a precondition for establishing Nordic cross-border collaboration. With some reservations, we could argue that there could be a rationale for Nordic cross-border collaboration between testbeds within bio-refinery, see Figure 5.4.

Broadly speaking, bio-refinery is based on process technologies, and based on information from the interviews it is our impression that a strategy for developing new biomass-based products could benefit

[16] https://www.sekab.com/en/about-us/about-the-company/our-collaborations/

from small-scale test facilities for the initial testing while the final testing could benefit from large or full-scale testing. The testbeds of the study represent test facilities ranging from small-scale to large-scale and demonstrations plants. Moreover, there may also be an opportunity for further specialisation between the testbeds by being specialised within different biomasses. Additionally, the testbed at RISE is apparently at the technological forefront in Europe as a large-scale test/demo plant.

Figure 5.4: Some preliminary conditions for Nordic collaboration with bio-refinery



Sources: Danish Technological Institute

All in all, we assume that Nordic companies could benefit from having access to a more coordinated offer of biorefinery facilities, but would this be attractive from the various RTOs' point of view currently, unless there was a real market demand driven by Nordic industry?

5.3. The rationale and aim of Nordic testbeds collaboration

Above we pointed out some structural challenges for cross-border collaboration. We also noted that some trends in the market for technological services call for new solutions in the way testbeds and RTOs can serve the industry, cf. Section 2.

The interviewees from the Nordic RTOs have also reflected on what a Nordic market for testbed facilities could be. Two main argument have been put forward.

First, several of the interviewees found that the Nordic countries have a common cultural platform and a common understanding of how to collaborate and to do business and this makes it easier to collaborate.

Second, Nordic RTO-collaboration must focus on technological areas that represent a common Nordic challenge and/or have potential for becoming a growth area for the industry (positions of industrial and scientific strength), indicating that the technological areas must benefit the transition needed both in society and industry. A preliminary assessment of the interviews points to areas such as green technology, resource optimisation, health care, digitisation/Industry 4.0/electricity market, urban development, and housing. These areas are highlighted in the European Green Deal as well.[17] However, some of the interviewees recommended initiating a roadmap on technology trends and to include the expectations of the industry as an indication for new testbeds in particular, whereas others thought that researchers have a better insight into technology trends. By pointing to rather broad areas of technology, the interviewees also stress that there should be room for several complementary testbeds.

[17] https://www.euractiv.com/section/energy-environment/news/eu-commission-unveils-european-green-deal-the-key-points/

All in all, the study cannot give an in-depth assessment of the technological and market potential by establishing Nordic collaboration between testbeds, but there are indications that there is some potential for further collaboration - and prioritisation of the Nordic technology infrastructures - with a market perspective.

6. An assessment of the feasibility of different models for cross-border collaboration

In the Nordic countries, we find a considerable number of testbeds within different technological areas[18] as well as testbeds offering technologically overlapping test facilities. In the Nordic countries, RTOs and testbeds bridge the gap between basic research and deployment/commercialisation of new knowledge. However, there are national differences in the way the RTOs take up this role as illustrated Section 5. Furthermore, innovation policies in all the Nordic countries support the testbeds infrastructure – but in different ways.[19]

Within this overall framework for Nordic testbeds, we have interviewed managers of testbeds in the Nordic countries as well as representatives from GTS, VTT, SINTEF and RISE with a strategic outlook on the market for testbeds and technological services. In the interviews, we have discussed the opportunities for Nordic testbed collaboration as well as different organisational models for establishing cross-border Nordic collaboration, cf. Section 4.

Based on the interviews, ***this section assesses the feasibility of different models for cross-border collaboration in a Nordic context where the aim of collaboration is to encourage commercial technology use.*** Even though many RTOs carry out research and participate in international research projects, we do not include research in this assessment as research is typically funded by public programmes or large companies within the framework of specific projects. Nonetheless, the boundaries between the market for testbeds and technological service on the one hand and research on the other are blurred, but we try to stick to this distinction.

6.1. Trends and dilemmas

All the Nordic RTOs are non-profit institutions characterised by operating test and demonstration facilities aimed at deployment of technologies, also called the innovation infrastructure to dissociate themselves from the scientific research infrastructure. Despite many similarities, we also observe trends and dilemmas placing the Nordic RTOs in very different situations or giving them different preconditions for entering Nordic cross-border collaboration:

- Testbeds or the technology infrastructure (innovation infrastructure) are supported financially, but we have observed an overall tendency to reduce public support. This tendency is significant in Sweden and Finland but also in Denmark where the support is already low compared to other countries.[20] This tendency can force RTOs to reduce investment in testbed facilities, or increase fees for use radically allowing mainly R&D heavy companies with decent budgets to utilise testbeds. This might push the RTOs in the direction of commercial technological service, without testbed facilities to boost deep-technology innovation. The RTOs could aim to attract private co-funding of testbeds or demonstration facilities which in turn could give priority to the co-funding

[18] See, e.g., https://www.teknologiskinfrastruktur.dk/, https://swedishtestbeds.com/en/about-swedish-testbeds/, https://www.sintef.no/ and https://www.vttresearch.com/services

[19] Leif H. Jakobsen et.al. (2018): Nordic test and demonstration facilities. A mapping of test and demonstration facilities in the Nordic region. Nordic Council of Ministers.

[20] See also Christian Ketels, et al. (2019). Peer review of the Danish R&I System. Ten steps, and leap forward: Taking the Danish innovation to the next level. European Commission, DG Research and Innovation.

companies[21], which would typically be large R&D driven companies. This could impact the accessibility to testbeds for SMEs negatively.

- Many testbeds, especially in Finland, Norway, and Sweden, find that their key mission is to transform new research into a form where industry and society will be able to use the new technologies. Their mission is typically applied research aimed at deployment of technologies, i.e., not to establish testbeds to offer technological services that just meet the industrial needs for technological service without a certain level of technological novelty. Among these RTOs we also observe a tendency where they prefer to collaborate with companies capable of absorbing new technologies while companies without such a capacity are not considered relevant for bringing new technologies into use. On the other hand, we find testbeds where the main mission is to offer better technological services that can meet the needs of the industry. In this case, vital issues are commercialisation as well as mature technologies as the industry should be able to use the technology immediately.
- RISE, which was established by mergers of applied research institutes, testbeds, etc., in the last decade, is very concerned about strengthening collaboration internally as well as across technologies as many technological challenges are considered to be complex demanding holistic solutions. The key ambition of this strategy is 'clustering testbeds'. However, we must also emphasise that the other Nordic RTOs are large organisations and their individual testbeds cannot enter institutionalised collaborative agreements with other testbeds on their own.
- Many testbeds operate in close collaboration with other research organisations (e.g., universities) and some are closely integrated with a local ecosystem (cf. Section 5). All in all, testbeds collaborate and domestically they may be engaged in collaboration with several stakeholders, which is a condition that should be considered before entering new or other types of cross-border collaborations. Attention should be paid to the concept of Smart Specialisation[22], particularly in the context of applying the concept in a Nordic setting
- The Nordic RTOs do have foreign companies as clients, and some RTOs have established foreign subsidiaries. This is especially the case in Denmark. However, the overall impression is that commercially based internationalisation is not a particular market activity, but it could become a trend in the future.

At national level, we observe that collaboration between testbeds is a general practice and that international activities in RTOs are increasing. However, the RTO governance structure itself could pose some obstacles or at least challenges when aspiring to increased cross-border collaboration.

6.2. An overall assessment of Nordic cross-border collaboration

Based on their experiences, we asked the interviewees how they think the different collaboration models will work in a Nordic context, cf. Section 4. However, since nobody really had any experience with legal forms of collaboration, we could only review collaboration based on legal forms based on the assumptions of the interviewees.

[21] Astrazero (http://www.astazero.com/) and LORC (https://www.lorc.dk/about) are some examples companies being an integrated part of the established of the testbeds

[22] 'Smart Specialisation Strategies include a focus on identifying niche areas of competitive strength, solving major societal challenges, bringing in a demand-driven dimension, fostering innovation partnerships emphasising greater coordination between different societal stakeholders and aligning resources and strategies between private and public actors of different governance levels.' https://ec.europa.eu/jrc/en/research-topic/smart-specialisation

We have identified some advantages and disadvantages in case of strengthening the collaboration between the Nordic RTOs:

Advantages

- Possibilities to share test facilities/testbeds and competences by carrying out tasks for each other.
- Common marketing of Nordic testbed facilities to become more visible.
- The Nordic market – a relatively large home market – could also attract RDI investment from outside the Nordic region. Our strengthening Nordic collaboration, co-creation and a clear end-user perspective, which should be used to positioning a "Nordic First Opportunity" within applied research and innovation, among other by using Nordic testbeds.

Disadvantages

- Administrative burdens, high transaction cost.
- Sharing testbeds, i.e. having direct access to and use of testbeds at each other's premises, is problematic due to technical and confidentiality risks.
- Giving up (some) autonomy could be a problem.

Finally, the overall advantage will be increased attractiveness of the Nordic counties as an innovative region with strong capacity and competences within testbeds. However, the question remains whether the Nordic RTOs can overcome the organisational disadvantages, and there are therefore many unanswered questions or challenges in connection with establishing Nordic cross-border collaboration:

1. Investment strategy: If a joint investment, who will decide, and which criteria will be used to decide what technologies to invest in and in which testbeds?
2. Roles and responsibilities: Which mechanisms – governance structure - will be used to distribute new task and sales inquiries among the testbeds? Knowledge management will be an even more important challenge.
3. Priorities of the technology level:[23] Which types of testbeds are applicable for forming cross-border collaboration focusing on industrial use of technologies? Among the Nordic RTOs, we find different definitions of how testbeds should work regarding the orientation toward applied research and commercial activities. However, some testbeds even dissociate themselves from any activities with the short-term aim of maximining profits.

Even though the majority of the interviewees agreed on the objective for cross-border collaboration to be improved visibility, accessibility as well as networking and eventually giving companies and society access to new technologies, they point out that there are several critical operational questions that need to be dealt with and that these questions, if they remain unanswered, can become an argument for abstaining from establishing cross-border collaboration.

[23] Referring to the Technology Readiness Level, see https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

6.2.1. Cross-border collaboration based on legal forms

The overall opinion of the interviewees is that legal forms of collaboration will not be feasible as it will be in opposition to the dominant governance and business models and organisational and business cultures. A new legal form will require that the participating RTOs will have to give up some of their autonomy and accept financial liability and profit sharing. A legal entity will obviously require that all the associated, individual testbeds align with the overall strategy of the collaboration.

In many aspects the legal governance model could be different from the management models of the individual testbeds that are mainly dominated by a bottom-up approach where each testbed can set their own strategic direction. Personal networks, trust, and openness are the basic driving forces of the testbeds. Therefore, several of the interviewees feared that more formal organisational forms with sub-optimisation and possible high transaction costs could have negative consequences regarding quality and customer service.

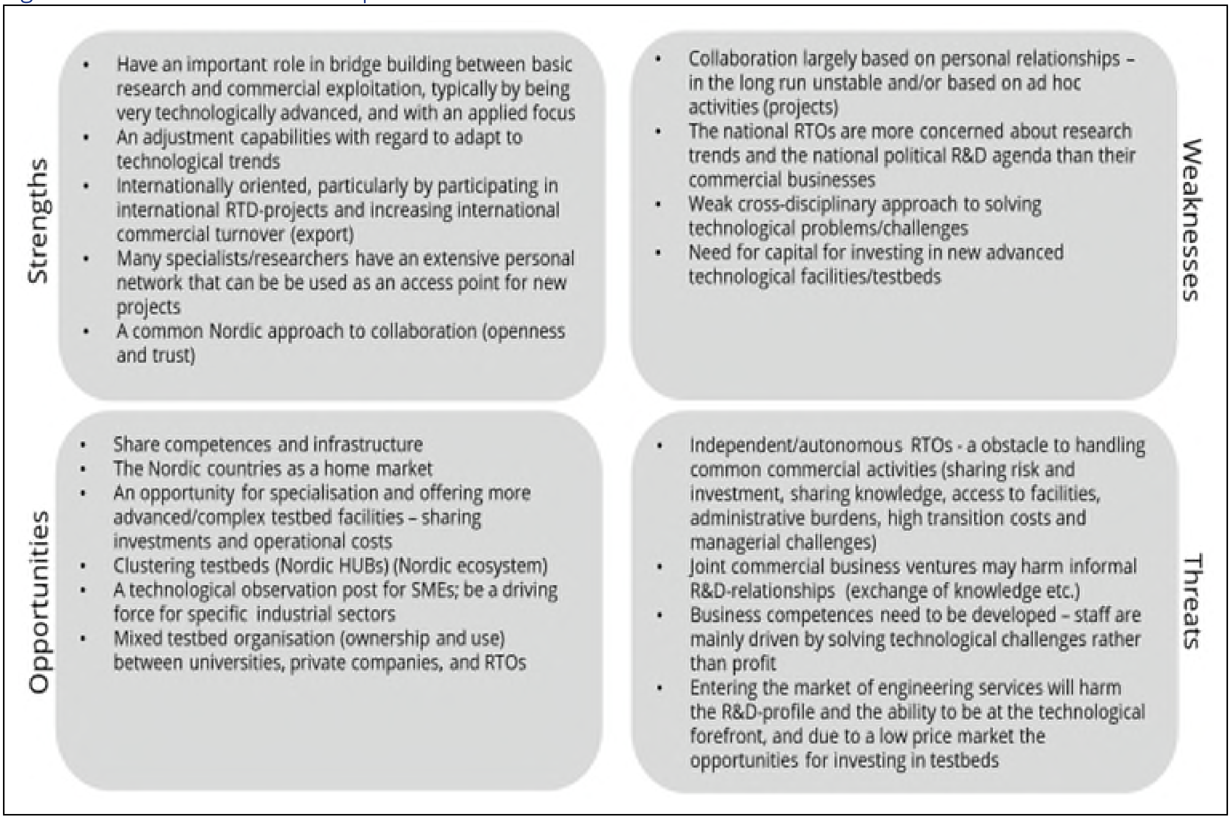
6.2.2. Cross-border collaboration based a looser form

The Nordic RTOs and testbeds commonly appreciate the idea of looser forms of collaborations such as informal networks as well as collaborative projects based on a joint contract. Such informal collaborations feed into the idea of collaboration based on trust and personal relationships, which are often the point of departure for doing collaborative and even cross-border projects. The projects will typically be funded by research and innovation programmes or by private companies. As these projects are temporary, they do not challenge the governance structure or strategy of the individual RTOs. Thus, the projects are 'safe' and at the same time fulfilling any long-term strategy ambition can only be based on mutual trust and openness. Furthermore, such projects can contribute to research and competence building but we have not seen that such projects could have been the basis for design of investment plans for new facilities or new ways of offering technological service in a Nordic perspective.

6.3. Nordic testbeds collaboration – a SWOT analysis

It has been very difficult for many of the interviewees to evaluate or assess the implication of applying different organisational models for cross-border collaborations, cf. Section 3. However, several of the interviewees had ideas about circumstances that could influence cross-border collaborations positively or negatively. Based on this information, we have made a SWOT-analysis where we highlight internal and external factors that could encourage or impede the feasibility of establishing cross-border collaboration, see Figure 6.1.

Figure 6.1: SWOT to illustrate the position for RTOs to enter Nordic cross-border collaboration



Source: Danish Technological Institute

All in all, the Nordic innovation infrastructure appears to be outstanding in its way of bringing (new) technologies into (commercial) use as the testbeds are largely technologically advanced and able to identify and adopt research and new technologies.[24] However, renewal of the technology innovation infrastructure and competitiveness are challenged by several factors or trends. The driving force for technological renewal seems primarily to depend on very competent and skilled employees, new technology trends, and industry demand. However, technological renewal is not purely a bottom-up process, it must take place within the systemic framework of the governance and business models and the roles of the RTOs in the national innovations systems.

When technologies become more complex and intertwined and when knowledge becomes global, RTOs must be able to offer more specialised technical facilities. At the same time, they need to recognise that the domestic, commercial market most likely will become too small (the issue of economies of scale and scope). Cross-border collaboration or internationalisation becomes necessary. Even though RTOs have opportunities to move in this direction, several factors become obstacles to moving forward which may catch the RTOs in a lock-in situation with a negative impact on their opportunities to maintain strong research-as-a-service systems.

[24] See also the international review/evaluation of the Danish innovation system: Christian Ketels, et al. (2019). Peer review of the Danish R&I System. Ten steps, and leap forward: Taking the Danish innovation to the next level. European Commission, DG Research and Innovation

6.4. Elements to an action plan

The SWOT-analysis outlining the present situation of the Nordic RTOs was recognised by several of the interviewees, and the identified models for cross-border RTO-collaboration do not appear to be straightforward solutions to unfolding cross-border collaboration. However, with the interviews we have identified some elements and ideas that can feed into developing an action plan towards cross-border collaboration between Nordic RTOs. Below we sum up some of the key steppingstones that should be considered:

- Nordic cross-border collaboration must be initiated incrementally, and such a process will presumably take some years.
- Identify areas of technology for initial testing of cross-border collaboration and preferable areas of technology that are relatively new and highly relevant for the Nordic countries (e.g., technology areas that could be a point of departure for mission-oriented research and innovation policies) but at present not subject to commercial business (in a precommercial phase).
- A first step could be pilot cases testing different forms of cross-border collaboration:
    - A common booking system for using cross-border testbeds could be interesting, but practical experience with such a model is required. A step could be testing and learning from some pilot cases.
    - Designing a service concept that can meet any challenge along the entire innovation process. Some of illustrative examples on how to distribute assignments/projects among partners are presented in Section 4, but there are other cases to learn from.[25]
- Establish a Nordic task force to be the main driver of the process with reference to the top management:
    - The task force must not turn their role into a 'salesman' running cross border pilot cases. Several interviewees stressed that it is important to be very clear about the different roles, especially the role of a 'salesman'. Some consider this role to be important as the 'salesmen' would coordinate the incoming projects and the distribution among the testbeds while other found that such a role could only be handled by researchers or experts. Consequently, such a discussion can basically ruin the idea of establishing a common commercial entity.

It is unquestionably a challenging process to develop and implement a new organisational structure for cross-border collaboration between the Nordic RTOs. Internally, the Nordic RTOs have highly qualified platforms of testbeds and researchers/experts, which is an excellent point of departure.

[25] Knowledge and Innovation Communities carry out activities that cover the entire innovation chain: training and education programmes, reinforcing the journey from research to the market, innovation projects, as well as business incubators and accelerators. https://eit.europa.eu/our-communities/eit-innovation-communities;

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Annex 1: Illustrative cases representing different form of collaboration

NineSigma

Established in 2000, NineSigma is a private company operating worldwide. With access to more than 2 million service providers, NineSigma offers to connect companies with a problem to service providers that might have a solution to their problem. Thus, NineSigma is addressing a market gap. Companies often lack information about potential service providers and the type of services they can offer. Moreover, NineSigma can create a viable business from their services by charging the client for managing the matching process. By 2015, NineSigma apparently had had more than 3,500 Requests for Proposals

Rationale

NineSigma works as a broker by matching companies with a technological problem (presumably any problem related to business development) with technological service providers. In other words, they operate in 'Intermediate markets' where an upstream provider licenses its knowhow to downstream developers and producers.

When companies (the clients) want to find and connect with a service provider offering the most promising solutions to a technical problem, the service providers have the opportunity to respond to real, tangible projects with their ideas and technologies.[26] Thus, NineSigma utilises their knowledge and insights into the technology market to offer a service that bridges the gap between picking the right service providers within the plethora of technologies being offered on the market and organisations that can provide these solutions.[27]

Services

NineSigma helps their clients define the problem so that Requests for Proposals (RfP) contain the information required by the solution providers while not producing too much information to protect the client's intellectual property rights. RfP are then posted to their community of solution providers. NineSigma acts as the intermediary managing the process, and in about 4 weeks they receive, summarise, and present the results to the client. This process helps the clients to locate and communicate with solution providers that they most likely would not have found on their own.

Additionally, NineSigma's may also help to identify a solution provider that is specialised in exactly the area where the client needs assistance. NineSigma has established an extensive database of over 2 million service providers worldwide representing experts within industry, universities, RTOs, etc.[28] NineSigma encourages service providers ('solution providers') to respond to the requests NineSigma issues on behalf of their clients, ('solution seekers'), so that they may create 'win-win' relationships. The connections that are formed aim at creating real value for both parties in the form of contracts, supply agreements, co-development or licensing arrangements, research contracts and consulting agreements across a broad range of industries.

Established in 2000, NineSigma is a global company working on a commercial basis with offices in Europe, North America, and the Asia Pacific (Japan and South Korea). In 2009, NineSigma stated that they

[26] https://www.ninesigma.com/about-us/solution-providers/
[27] https://www.ninesigma.com/about-us/
[28] https://www.tii.org/public/plugins/news/documents/news/gestnewsdocuments/19-may-d2-1130-ninesigma-1.pdf?t=1560513365

had had 25,000+ RfP and more than 1,700 open innovation projects had been completed.[29] By 2015, this number had apparently increased to 3,500+ representing a total of 32 industrial sectors and more than 700 clients.[30]

Business model

The client compensates NineSigma based on a shared risk model which rewards NineSigma for helping the client make connections that result in transactions that solve the client's problems. Solution providers benefit because the process is fast, reduces the prospecting time, and in case of a successful match, they can enter into a commercial agreement with the client while not being liable for any costs pertaining to RfP.[31]

Handling IPR

NineSigma recognises that intellectual property rights are significant when developing new technologies and processes. To avoid contamination of IPR, requests between clients and providers contain no confidential or competitive information. This ensures that only when a contract is signed can there be any exchange of important ideas based on the knowledge that each party possesses. Additionally, clients may remain anonymous should they wish to do so. This is a further guarantee that competitors cannot interfere with the relationship while the client is seeking out a provider. When entering into an agreement, NineSigma insists that a confidentiality agreement which outlines the IP and business terms for the collaboration be signed, ensuring that both parties are aware of the impact of the collaboration.[32]

[29] https://www.tii.org/public/plugins/news/documents/news/gestnewsdocuments/19-may-d2-1130-ninesigma-1.pdf?t=1560513365
[30] https://www.tii.org/public/plugins/news/documents/news/gestnewsdocuments/19-may-d2-1130-ninesigma-1.pdf?t=1560513365
[31] https://freethinkr.wordpress.com/2007/05/04/going-from-tradeshow-to-solutionshow-via-open-business-model/
[32] https://www.tii.org/public/plugins/news/documents/news/gestnewsdocuments/19-may-d2-1130-ninesigma-1.pdf?t=1560513365

Translucent Innovation®

Translucent Innovation® is an Open Innovation Platform established by RISE, Sweden. Translucent Innovation® operates on Request for Proposals proposed by companies. Companies can use Translucent Innovation free of charge to search for service providers to solve their problems. Translucent Innovation mainly provides access to service providers with RISE and associated national partners. In the case of no match or if the company chooses to use a service provider within RISE and associated national partners, Translucent Innovation® is free of charge. Otherwise, the company must pay a fee.

Rationale

Translucent Innovation® is an Open Innovation Platform based on Request for Proposals that companies are invited to use when facing challenging problems, and when they need external assistance to solve the problems and need to identify qualified service providers. By using Translucent Innovation®, companies gain access to a broad network of service providers (experts) among which they can select a preferred service provider (a proposed solution). Via the platform and an app, companies can access potential service providers more easily because they need only to approach one platform/organisation (i.e., Translucent Innovation®) which will then undertake the work of identifying, locating, and determining relevant service providers vis-à-vis the needs of the companies.

Translucent Innovation® is a platform for request based on Open Innovation developed and owned by RISE – Research Institute of Sweden, and operated in collaboration between RISE, SISP – Swedish Incubators and Science Parks, and Business Sweden – The Swedish Trade & Invest Council.

For RISE, Translucent Innovation® is also a platform to present their competences and research activities since half of their revenue originates from industrially financed (research) projects, and they constantly need to get new (research) projects from industry.[33]

Services

Translucent Innovation® connects companies with service providers via a platform and an app. The process consists of the following steps:[34]

1. Request for Proposal (RfP) – a two-page specification of the problem
2. The company and a team of experts from RISE translate the RfP into a µRfP of maximum 140 characters.
3. The µRfP is launched on an app distributed internally among expert at RISE and their partners. RISE expect the experts to respond to the µRfP and use the app to interact with colleagues.
4. The internal experts must also consider if any external experts (university, some foreign RTOs, etc) could be of relevant for the solution to the problem.
5. RISE searches for solution proposals and valuable competences within RISE and externally.
6. After 20 business days, RISE will present the identified solutions (a report) to the companies.

As a point of departure, RISE will search internally for experts to respond to the RfP, as RISE has more than 2000 scientists. However, they also take advantage of their external networks among university groups, SMEs, entrepreneurs, EU projects, and global companies.

[33] https://translucentinnovation.org/about-translucent-innovation/
[34] https://translucentinnovation.org/about-translucent-innovation/

Business model

For the companies, the use of Translucent Innovation® is free of charge giving both companies and RISE the opportunity to reach a broader audience without committing any money up front. However, Translucent Innovation is an opportunity for RISE to enter new projects with companies and generate an income. Up front, RISE pays the costs and investments for Translucent Innovation®, and, eventually, it must generate an income from new projects which can cover this investment.

However, if the company chooses to use an offer from an external contact, RISE will charge the company a small finder's fee when a formal agreement has been signed.

Handling IPR

Translucent Innovation® treats the RfP with the utmost confidentiality as they are very aware of the risks of compromising intellectual property rights while collaborating with partners. Once Translucent Innovation® has understood the RfP, Translucent Innovation® and the company explore how detailed they can disclose the RfP into a µRfP, and they respect if the company prefers complete confidentiality.

On the one hand, the company may also supply Translucent Innovation® with lists of companies or industries that are not to be contacted, such as competitors or suppliers, but, on the other hand, they may also supply lists of companies or industries that the company believes it would be beneficial to contact. Overall, only experts selected by Translucent Innovation® will be able to read the RfP – not competitors.[35]

[35] https://translucentinnovation.org/about-translucent-innovation/

European Pilot Production Network

The European Pilot Production Network is a 'HUB of HUBs' aimed at encouraging regional hubs in Europe to coordinate efforts to increase accessibility to pilot facilities. In effect, this provides a sort of 'meta hub' that works as an interactive marketplace for associated pilot plans.

Rationale

The rationale behind the European Pilot Production Network (EPPN) aims at being an expansion and improvement of services offered by regional hubs in the areas of nanotechnology and advanced material technologies as low availability of pilot plat hampers the rate of technology take-up. Moreover, SME technology uptake is restricted due to lack of knowledge about the opportunities offered by the pilot plants.[36] Thus, by increasing the supply and marketability of testbed facilities, the basic idea is to establish a structure encouraging regional hubs to promote their services and activities to the clients (the enterprises) by giving access to a broader supply of pilot plants. As a network of innovation hubs across the Member States and/or regions, EPPN offers coordination and support action services to the network of European pilot facilities.

Services

Through coordinated action, EPPN will boost European competitiveness through the exploitation of existing European pilot line production facilities (across Europe). The intention is to create a network of fully connected and collaborating pilot lines and boost the effectiveness and the efficiency of existing (and future) pilot line facilities and by creating a digital ecosystem acting as an interactive marketplace for professional members.[37]

EPPN aims at leveraging technological research into product demonstration and contribute to an enhanced innovation ecosystem and attractive business environments by:

- creating a sustainable ecosystem involving all the stakeholders capable of promoting collaboration along the value chain;
- developing supporting tools for pilot plants and potential users; and
- promoting the creation of Innovation hubs, catalysing, and fostering the sustainable business development of EPPN.[38]

To promote the collaboration between regional hubs, EPPN has taken actions such as creating a single-entry-point, mapping testbed facilities, creating a helpdesk, organising workshops, etc. Hence, the structure of the network is like a 'meta' innovation hub consisting of national and regional hubs.
In the autumn of 2019, 175 pilot plants were registered by EPPN[39] giving them access to showcase their services and look for solutions in terms of technology and expertise, exchange information, build collaborations, and increase business opportunities.[40]

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[36] https://www.euronanoforum2019.eu/wp-content/uploads/2019/07/03_ENF2019_Bucharest_PaulaGalvao_W1.1.pdf
[37] https://www.euronanoforum2019.eu/wp-content/uploads/2019/07/03_ENF2019_Bucharest_PaulaGalvao_W1.1.pdf
[38] https://www.eppnetwork.com/about
[39] https://www.eppnetwork.com/user/41623
[40] https://cordis.europa.eu/project/rcn/211459/reporting/en

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Business model as a challenge

Financially, the EPPN relies solely on H2020 funds. It has received approximately EUR 1 million in funding over a three-year period (2017-2020) to establish and run the EPPN facilities.[41]
The H2020 funding will soon expire.

[41] https://cordis.europa.eu/project/rcn/211459/factsheet/en

LightCoce – an Open Innovation Test Bed

LightCoce – an Open Innovation Test Bed – has established a common platform to promote information and give companies more efficient access to service providers within technologies concerning lightweight multifunctional concrete and ceramics. The ambition is to establish a single-entry-point funded as a non-profit organisation. However, it remains to be seen how the legal entity will be designed as it can be a major challenge to have autonomous organisations as founding members.

Rationale

LightCoce aims at developing and exploring technologies within lightweight multifunctional concrete and ceramic materials and structures by covering the gap in access to upscaling and testing facilities. To encourage technological development and exports of these technologies, LightCoce will strengthen the European ecosystem by establishing an Open Innovation Test Bed (OITB) encouraging cooperation between stakeholders across Europe (technology providers, service providers, and the industry) as well as building business models based on open access cooperative Innovation.[42] The ambition is to establish a single-entry-point as a service platform, which they intend to organise as legal entity (a non-profit organisation) dealing with the day-to day business.

The main motivation (rationale) for the participating testbed facilities to join LightCoce is presumably an opportunity and ambition to be part of developing this technological field as well as the opportunity to be exposed to potential new customers (while also receiving EU funding temporarily).

Services

As a single-entry-point, LightCoce offers enterprises information and access to physical facilities, capabilities and services required for developing, testing and upscaling. The single-entry-point serves as the recipient of customers' requests for technology solutions. The requests are evaluated and priced based on specific workflows to be determined after collecting input from the involved manager of facilities, etc., and in accordance with the customers' requirements.[43]

The intention of the single-entry-point is to create a legal entity funded by the service providers. The legal entity will act independently and have the power to sign contracts on behalf of LightCoce-members. Even though, LightCoce aims to establish a non-profit organisation, the organisational structure and business procedure (share of assignment, risk sharing, etc.) currently do not seem to be very well-developed.[44]

Business model as a challenge

By establishing an open innovation testbed structure funded by Horizon 2020, the European Commission expects LightCoce to develop a financially sustainable structure by the end of Horizon 2020. For this purpose, The European Commission has developed guidelines for establishing a single-entry-point as a legal unity.[45] For example, the guidelines encourage the single-entry-point to consider.:

[42] https://www.lightcoce-oitb.eu/en/normal/home
[43] https://www.lightcoce-oitb.eu/en/static/iotb
[44] https://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-im-ac-innotestbeds-18-20_en.pdf - page 1
[45] https://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-supp-info-innotestbeds-18-20_en.pdf - page 3

- the general procedures for the single-entry-point in terms of governance structure (organisation, responsibilities, economic liability, etc.), handling IPR and internal transparency among the founding members; and
- general terms and conditions for commercial assignments/contracts between the members and, e.g., SMEs applying for technological service.

LightCoce does not provide any details on how it plans to achieve economic sustainability and how LightCoce will meet the ambition of becoming a legal entity as expressed by the European Commission. However, establishing a legal entity funded by several financially autonomous entities, sometimes even competing service providers/testbeds, and/or even operating under different legal conditions, will presumably encounter several challenges and even legal restrictions.

Labs Network Industrie 4.0

*The Labs Network Industrie 4.0 is an association governed by its own a*rticles of association, *offering enterprises access to* test labs. For the companies, access to the network *is conditional on membership and payment of a membership fee. The membership fee is regulated progressively meaning that large enterprises pay more than small enterprises.*

Rationale

The Lab Network Industrie 4.0 is a German network consisting of more than 30 test labs (test facilities, innovation lab hub, etc.) aimed at encouraging/accelerating the transition of the digital economy and, in particular, supporting the German middle-sized sector by taking a leading role in global digitalisation. The test labs have been selected to ensure a regional distribution, local contacts, technical variance, and international cooperation.[46]

Services

Labs Network Industrie 4.0 offers enterprises to test new technologies, innovations, and business models in an Industrie 4.0 test environment and review their financial feasibility prior to market launch.[47] Additionally, the enterprises can also receive consulting at the most suitable test centre according to their specific requirements.[48] All in all, enterprises are offered a process of strategy and conception, testing and standardisation. Hence, the structure seems to emulate that of a single-entry-point network. The single-entry-point, a coordinating entity, guides the members to the most relevant testbed facilities. Additionally, the network also offers a web-based search tool that members can use on their own to find relevant competence centres that SMEs can use for advice concerning their needs and providing links to the information available on what is on offer.[49] Thus, enterprises only need to approach Lab Network Industrie 4.0 to gain access to a multitude of different test facilities.

The results from test scenarios with Labs Network Industrie 4.0 will encourage the companies to move forward with the Industrie 4.0 standardisation roadmap. This is achieved through close collaboration with the Standardisation Council I4.0 (SCI40.de) to overcome the boundaries that still exist between the electrical engineering, mechanical engineering, and IT sectors in the future. [50]

Business model

The Lab Network Industrie 4.0 is a pre-competitive, non-profit association. The founding members are a number of large German companies *related to the Plattform Industrie 4.0 in cooperation with the the federations Bitkom, VDMA, and ZVEI*. [51] The network has its own board consisting of members, and its articles of association regulates its business. [52]

To gain access to the networks and its facilities, the enterprises must be members of the network (the association). The enterprises must apply for membership. All members pay an annual membership fee

[46] http://files.messe.de/abstracts/77174_CeBIT_20_03_1540_Labs_Network_Industrie_.pdf - slide 4
[47] https://lni40.de/the-association/about/?lang=en
[48] https://lni40.de/membership/benefits/?lang=en
[49] https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/shaping-i40.pdf?__blob=publicationFile&v=3 page 15
[50] https://lni40.de/the-association/angebot/?lang=en
[51] https://www.vdma.org/en/v2viewer/-/v2article/render/30681645
[52] Statute of the Association 'Labs Network Industrie 4.0 e.V.' https://lni40.de/lni40-content/uploads/2018/08/18p2096_01_LNI4.0Satzung-e.V_engl.pdf

that according to the size of the enterprise, which ensures that members with high revenues pay a proportionally higher membership fee.[53] Consequently, the members do not pay for the services of Labs Network Industrie 4.0, instead, they pay an annual sum, whose size depends on the size of the enterprise to access all network facilities.

Thus, in addition to promoting access and specialisation, the collaboration may also affect the demand for testbed facilities because of its progressive membership fees. If SMEs are better able to afford the services, they will increase the rate at which testbeds are being utilised other things being equal.[54] This is a huge advantage for SMEs which usually have a hard time being able to afford to access testbed facilities.

In conclusion, the members pay to use the network which may ensure that the collaboration becomes commercially sustainable. However, if the price structure is balanced, SMEs will benefit relatively more than large enterprises because the fees are based on ability to pay, not the level of usage. One challenge with this arrangement may be that the network will eventually run out of large enterprises that are willing to foot the bill for the relatively more frequent use of the facilities by the SMEs.

[53] Membership Fee Regulations for the Association 'Labs Network Industrie 4.0' e.V. for Promoting Research and Implementation of Industry 4.0 Technologies https://lni40.de/lni40-content/uploads/2018/08/18p2096_05_LNI4.0_Beitragsordnung_engl.pdf

[54] https://lni40.de/lni40-content/uploads/2017/03/LNI40_Beitragsordnung_160228_beschlossen.pdf

German-Dutch Wind Tunnels

German-Dutch Wind Tunnels was established as a merger of several test facilities to become a large-scale, global leading, advanced test facility. German-Dutch Wind Tunnels is a non-profit organisation carrying out research projects and industrial development projects. German-Dutch Wind Tunnels has created a mutually beneficial cooperative organisation being able to handle cross-border collaboration challenges (such as protection of IPR, a comprehensive governing body, etc.) and at the same being financially sustainable.

Rationale

*German-Dutch Wind Tunnels (*DNW) supports the industries and research communities that rely on advanced testing facilities related to wind technologies addressing the market for aircraft, helicopters, UAV, spacecraft, and related equipment. As the German Aerospace Center DLR and the Dutch Aerospace Centre NLR joined forces in 1976, DNW has been able to offer tests facilities supporting experimental simulation requirements of aerodynamic research and development projects. DNW is an example of the benefits that can be reaped by pooling some of the organisations' individual resources to achieve a globally recognised test facility. Today, DNW operates as a non-profit foundation with eleven wind tunnels test facilities.

Services

The main objective of DNW is to provide its customers with a wide spectrum of wind tunnel test and simulation techniques, operated by one organisation, providing the benefits of resource sharing, technology transfer, and coordinated implementation of research and development results[55].
DNW provides solutions for the experimental simulation requirements of aerodynamic research and development projects. These projects may originate in the research community (universities, research establishments or research consortia) or in the course of industrial development of new products.[56] To provide these customers with the best facilities, collaborating with one another on broadening their services makes sense. It increases the likelihood of offering the right testing facilities and creates an opportunity to make the testing facilities more specialised.

To encourage efficient and flexible operations, DNW operates in a decentralised structure with facilities distributed over five locations in the Netherlands and Germany[57] - but under a unified management and supervision. The management is in Marknesse in the Netherlands at the location of its largest wind tunnel. DNW's board, the supervisory body of the Foundation, consists of representatives of the parent institutes NLR and DLR and is complemented with representatives from the relevant ministries from Germany and the Netherlands.[58]

High-tech facilities combined with specialist knowledge have made DNW a global player based on the use of advanced technologies, advanced test facilities, and marketing its skills worldwide.

[55] https://nag.aero/members/german-dutch-windtunnels-dnw/
[56] https://www.dnw.aero/about-dnw/about-dnw/
[57] https://www.mts.com/cs/groups/public/documents/library/mts_009860.pdf
[58] https://www.epicos.com/company/159826/german-dutch-wind-tunnels-dnw

Business model

DNW was established in 1976 with the support of the German and the Netherlands governments. DNW is a non-profit foundation. The business model is based on a combination of a high degree of specialisation which enables DNW to carry out research projects as well as industrial development projects. A high degree of specialisation is also a precondition for being attractive to the high end-market with high technological demands and at the same time the ability purchase advance technological services.

Annex 2: The Nordic RTO project team

The feasibility study has been executed by Danish Technological Institute and commissioned by GTS, VTT, RISE and SINTEF. Members from all four RTOs took part in the RTO project team.

The members of the project team:
Lars Fremerey, GTS-net (Project Coordinator)
Ragnar Heldt Nielsen, GTS-net
Anne Maria Hansen, Danish Technological Institute
Peter Hofmann Holsøe, FORCE
Leena Sarvaranta, VTT
Julie Clavijo, VTT
Jon Haag, RISE
Olof Sandberg, RISE
Anders Byhni, SINTEF
Ernst H. Kristiansen, SINTEF

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Annex 3: Interviewed experts

Organisation	Testbed	Interviewees
Digital economy		
GTS- DTI	LEE-BED; Testbed on printed electronics	Zachary J. Davis, Team manager Leif Højslet Christensen, Director
SINTEF	Smart Grid Laboratory	Salvatore D'Arco, Chief Scientist
RISE	Printed Electronics Arena	Björn Norberg, Business Developer
VTT	VTT Micronova	Heini Saloniemi, Manager, Process Engineering, Micronova Manufacturing Service
GTS-Force	SenseLab; World class audio testing facilities	Søren Vase Legarth, Team manager
SINTEF	Manufacturing technology cata-pult centre	Odd Myklebust, Research Manager SINTEF Manufacturing
VTT	VTT PrintoCent	Ilkka Kaisto, Director of PrintoCent
Bio economy		
GTS- DTI	PVD coatings	Lars Pleth Nielsen, Director
SINTEF	Fermentation laboratory at SIN-TEF	Håvard Sletta, Research Manager
RISE	FEX - Pilot for papermaking	Christian Andersson, Manager
VTT	VTT Bioruukki; Nanocellulose film	Mika Härkönen, Manager Pi-lot Plant Development
GTS- DTI	Pilot Scala facility for biorefining	Anne Christine Steenkjær Hastrup Team manager
RISE	Biorefinery Demo Plant	Marie-Louise Wallberg Senior research advisor
VTT	VTT Bioruukki, Process modelling	Mika Härkönen, Manager Pilot Plant Development
Strategic management		
GTS- DTI		Anne-Lise Høg Lejre, Vice President Production
GTS-Force		Peter Hofmann Holsøe Innovation Project Manager
VTT		Mika Härkönen, Manager Pi-lot Plant Development
SINTEF		Anders Bryhni, Senior Business Developer
RISE		Jon Haag, Director, Business and Innovation

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