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How to innovate useful technology – and put it to use!

In these pages, we have previously written about the Danish Regions and their involvement in development of environmental technology. A question remains: What has come out of all the inventiveness, and what are the tricks to put something useful into actual use? In this article, we will give some insights.

The five Danish Regions are major public problem owners, being responsible for mapping, investigating and remediating orphan contaminated sites. The number of sites and the number of recognized pollutants are growing, which places regional budgets under stress. And the task is expected to last several decades, if not more than a hundred years (read more in Prognose for regionernes indsats på jordforureningsområdet). The big question is, can we protect our groundwater-based drinking water supply and surface waters in time, and protect indoor air in houses and schools? The answer lies in informed prioritization and development of cost-effective solutions.

Here we will dig into the second part of the answer by looking how we in the Capital Region of Denmark (CRD) involve ourselves in developing new promising solutions, that can be compared to the existing market standards.

Developing useful technology

Invent stuff that users demand, and then let them use it. It sounds simple and obvious. But reality is rarely that straightforward, and we have seen too many projects flounder or left forgotten on a shelf. We have seen a need to increase our focus on inventing solutions that meet real needs and on paving the way for implementing useful solutions in our operations. To operationalize this, we (the CRD Technology Development Team) are currently fine-tuning our innovation processes with inspiration from an innovation management standard (*European Committee for Standardization (2014): Innovation Management Standard CS/TEN 16555. This standard is currently being updated and released as the ISO 56000-family of standards*).

The CRD Technology Development Team at a strategy day in 2019. Photo: CRD.

Here we will highlight three of the central aspects of our process: Identification of user needs; evaluation of cost-effectiveness and continuous ‘pressure testing’. And give examples of how we work with these concepts.

Identification of user needs

Before we begin an innovation project, we examine what the potential users need and how this need can be fulfilled by new or alternative solutions. Our users are our colleagues and ourselves who carry out investigations and remediations. Sometimes the need is obvious (e.g. “we need to remove PFAS from water”), and sometimes it is vaguer (e.g. “we want to increase digitization”). In the latter cases, we can investigate the apparent wish or demand with the users to determine the underlying need. The ‘design thinking’ methodology provides several easy-to-use tools for this (read more about design thinking here).

One of the central tools is going through and talking through the users' journey when doing their tasks the traditional way. What are the obstacles and annoyances along the way? This helps us dig down and understand what the users need, not only what they want. Reaching a consensus with users on what we want to solve is also the first step in putting the new solution to use at the project's final stage. We want to create a "pull" for useful solutions among users, instead of "pushing" new solutions, that the users did not know they wanted.

In 2019 we ran a digitization project, which started out with the vague aim of improving preventive maintenance in our pump-and-treat (P&T) operations through better data integration. Data from P&T plants were collected and kept in several different data sources and formats, and we had the idea to improve decision support by developing a digital platform that integrated all those data and presented an overview and trends.

We held workshops with the users to map the key operating decisions, the necessary data support and investigate the journey toward making the decisions. Next, we discussed possible solutions and their advantages and drawbacks. Through this process we discovered that yes, a digital platform would be nice, but the foremost need was a user-friendly way to digitize several close-to-analog registrations. So, the project was re-framed to focus on creating a 'digital logbook' that could handle these registrations. Handle them in a way that would both ease the user's routines and support integration with other P&T data at a later point. The logbook is currently implemented on 20 P&T plants in CRD, and the remaining 70 plants are expected to follow in January 2021.

Evaluation of cost-effectiveness

How do you define and measure if a new solution is cost-effective? In the Capital Region, we define a cost-effective solution as being cheaper, having less environmental impact and being at least as practically applicable as a comparable traditional solution.

We measure the cost-effectiveness by calculating the economic and environmental cost and the general trouble of performing a real-life "job to be done". Defining a comparable "job to be done" concretely can be challenging, but it is very helpful when you get to the point of evaluating the performance of a new solution. Examples of such "jobs" are: Cleaning a volume of soil or water; containing a certain risk or gathering a number of quality data points.

We are currently evaluating the cost-effectiveness of the most promising new solutions we have tested for remediating chlorinated solvents in clay till. The purpose is to help answer the question of "which method to use where and why", to overcome the temptation of just sticking with the traditional "safe" option. The new solutions are scrutinized and compared with each other – and traditional methods – with different specific "jobs to be done" as the framework.

The following new solutions have all been developed to a proof-of-concept stage with full or pilot scale applications:

- high-pressure ("jet") injection of sand and iron products using geoprobes for in situ chemical reduction,
- electrokinetically aided in situ biological degradation,
- soil mixing where iron products are added for in situ chemical reduction and a binder is added for stabilization. The technology has been developed in part through a Swedish-Danish project funded by the EU Interreg programme.

The new solutions are compared with the more traditional options of excavation and thermal remediation. The "jobs to be done" have been defined as four different realistic contamination source zones, each of which must be removed to a certain concentration threshold.

Each solution is evaluated on seven parameters representing the cost, environmental impact, timeframe, certainty of effect and general practicality. The different solutions can be compared either by looking at radar-diagrams showing all parameters or through a single "final score" where the parameters are weighted based on context.

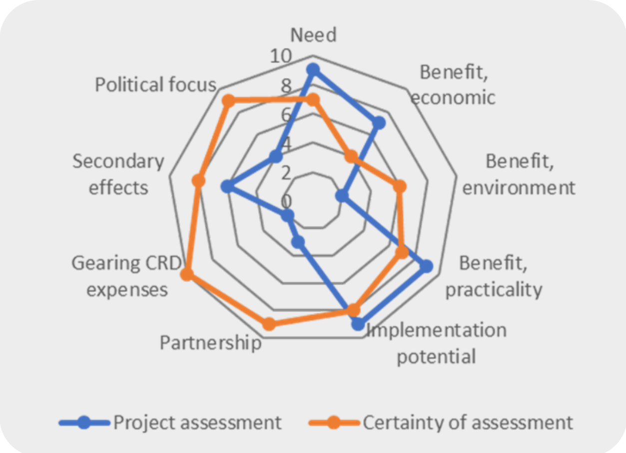
The results are not yet published, but the exercise shows that one of the new solutions appears to perform very convincingly compared to traditional methods. We had a "good feeling" about that solution to begin with, and its advantages and disadvantages have now been made apparent. Hopefully this informed overview will make it easier to consider newer and less familiar methods when deciding on remediation methods in future projects.

An important lesson from this exercise is that if you only evaluate price and certainty of effect, the new solutions will not appear competitive. In part because possible beginner's problems are unknown and in part because the new solutions have not yet been price-optimized on the market. So, if we want to be serious about sustainable remediation, we must be willing to choose the more uncertain and perhaps more expensive option sometimes, if we assess that it may have an advantage in the long run.

Continuous pressure testing

Before we turn a good idea into a real project, we examine the critical assumptions about the project idea. We do this by going through a one-page checklist in which we define the need, the expected project outcome (or "product"), how we expect it to improve cost-effectiveness, and we evaluate the project risks, the strength of the partnership and the potential for implementation with ourselves and with commercial partners.

A radar diagram shows how strongly (or weakly) the idea or project is expected to perform on key parameters and how certain we are of these assessments. We use this overview to identify critical assumptions and uncertainties that need to be examined, ideally before project start or as soon as possible during the project phase. This is called "Fail fast", meaning that we want to come to a possible negative conclusion as fast as possible (e.g. "this solution cannot remove PFAS more cost-efficiently than activated carbon" or "we don't have a significant number of sites needing this remediation"). If a project passes the initial 'pressure test', the following project plan can be designed with go/no go gates based on further examination of the critical assumptions. Throughout this process, the checklist is updated as new information is gathered. In this way we can keep ourselves updated without drowning in paperwork.



Overview diagram for a development project. The diagram shows the strength of nine key parameters (blue, 10 is best) and how well the parameters are assessed (orange, 10 is most certain). In the example, we expect a high economic benefit (i.e. our operations will be cheaper), but the assessment is based only on quick estimates, giving a low certainty to that parameter.

An example of the "Fail fast"-approach was a project proposal about using different specific tracer compounds to investigate how volatile compounds spread from soil to indoor air by different pathways. Initial examination of the proposal showed a critical uncertainty related to the toxicity of the proposed tracers. We did a literature study which revealed that several of the tracers would be potentially toxic in the design concentrations. This was an unsolvable showstopper for the project, and it was terminated only a few steps from the starting line.

Quality testing grounds are still important

We have introduced three valuable concepts in our framework for driving innovation processes toward useful and used solutions. We have left out how we form innovation partnerships and how the actual projects and testing is carried out, since this is very different from project to project. But we will highlight one powerful tool for carrying out well-documented projects without too many surprises, and that is access to quality testing facilities.

In these pages we have previously written about the Danish network of contaminated test sites. These sites are owned or administered by the Regions and offer freedom to test and display new solutions on real-world contaminations in controlled environments (**National network of test sites**). The big advantage is not having to take site owner concerns in relation to the space and time used, the uncertainty of effect and the freedom to build up supporting infrastructure like technical installations and meeting facilities. And not worrying about having to make another hole in a wall or in the ground as seen in the picture.

Drilling holes in the Innovation Garage test site for vapor transport experiments. The trailer on the left belongs to a private consortium, who tested a new groundwater remediation method at the site. Photo: N.D. Overheu, Capital Region of Denmark.

The advantage of test sites can be illustrated by an ongoing development project, that would not work without access to such a site. At the Innovation Garage site in Greater Copenhagen, we are conducting a project on how to understand and control chlorinated solvent vapors under a building. We do this in order to develop more cost-effective solutions for mitigating vapor transport to indoor air. Several ventilation screens have been installed under the floor through holes in the foundation, and numerous measuring points have been installed in the concrete floor and walls. Throughout three years, this setup is used to gather data on system response to different ventilation scenarios as well as rebound effects. With the experience gained, we are better prepared to design optimal ventilation solutions at the many other sites requiring vapor remediation – without spending three years there.

*This was quick peek into some of the things that are currently top-of-mind in the CRD Development Team. Do not hesitate to **contact us** if you want to know more – or if you want to come visit us when the coronavirus has released its hold.*

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