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Building with Nature: Mainstreaming the Concept

H.J. de Vriend
EcoShape Foundation, Dordrecht, the Netherlands

ABSTRACT: Building with nature (BwN) is a pro-active approach to meet the demand for hydraulic engineering infrastructures. Instead of assessing and mitigating *a posteriori* the environmental impacts of a set design, it considers nature as an integral part of the design right from the start of the project development process. It utilizes natural processes and provides opportunities for nature as part of the infrastructure development and operation. After a first phase of 'showing that it works' in a number of pilot projects, time has come to introduce the BwN-ideas into the mainstream of hydraulic engineering ('make it happen'). A number of example projects are described and lessons learned are given. The general conclusion is that BwN is increasingly being applied in practice, but that there are many non-technical hurdles and pitfalls.

Keywords: Building with nature, Soft engineering, Green engineering

1 INTRODUCTION

More than half of the world's population lives in urban areas located near rivers, deltas or coastal areas. As the world's population grows and its prosperity level rises, so too will the demand for goods (food, energy, merchandise) and services (transportation, accessibility, safety, recreation).

Accommodating this growth will involve the development of hydraulic infrastructure, such as harbours, access channels, land reclamations and flood defences. Sea level rise and climate change are enhancing the demand for adaptable designs. At the same time, people need space for recreation – beaches, parks and waterfronts – which generates its own special demands on spatial and infrastructure planning. These developments need not only to be realized in often fragile environments that are under constant pressure, but also in complex societal settings, with a variety of stakeholders involved in decision making.

Sustainable development is crucial if we are to maintain river, delta and coastal environments around the world, and the ecosystem services they provide. The latter include (1) provisioning services, related to the supply of food and other products; (2) regulatory services, related to natural processes such as water purification, carbon sequestration and flood control; and (3) cultural services, related to recreational, spiritual and other non-material benefits that people derive from nature. Finally, they offer support services necessary for the delivery of all other ecosystem services, such as nutrient cycling, water storage, regulation and recharging, as well as wildlife habitats, nesting sites and foraging grounds. Balancing the sustainable functioning of ecosystems, on the one hand, with the demand for their development and use, on the other, is one of the greatest challenges for the future of humankind.

It is crucial for us to learn how to design infrastructure that is serving more than one purpose, aligned with natural processes rather than working against them and adaptable to changing conditions such as sea level rise and climate change. Traditional approaches usually focus on a single purpose while attempting to minimize the negative impacts of an envisaged project (building *in* nature) and compensating for any residual negative effects (building *of* nature). Stepping beyond these 'reactive' approaches, building *with* nature aims to be proactive, utilizing natural processes and providing opportunities for nature as part of the infrastructure development and operation process (also see: De Vriend and Van Koningsveld, 2012).

Meeting the interests of nature and other stakeholders through new project designs is an essential element of the building-with-nature approach, which aims at sustainable and socially acceptable solutions to infrastructural needs. In the past, project developers focused almost exclusively on the primary function, such as protection against flooding. The new approach challenges designers to extend project objectives with nature development and/or creating opportunities for other functions, such as recreation or housing.

The use of adaptable solutions allows society to respond gradually to changing circumstances such as sea level rise and climate change. Typical building blocks of such adaptable solutions are salt marshes, sand nourishments, shallow foreshores and ecosystem engineers. A traditional response to sea level rise, for example, is to strengthen coastal defences and to build higher dikes. These kind of projects have a set design lifetime and are constructed all at once, based on an agreed scenario of design conditions. The Building with Nature approach promotes the consideration of more gradually developing solutions. Especially when used in combination with traditional proven technologies, this approach can lead to cheaper and more aesthetically appealing solutions that adjust or can be adjusted to changing circumstances.

After a phase of concept development and pilot projects ('show that it works'; see De Vriend and Van Koningsveld, 2012; Temmerman et al., 2013; De Vriend et al., 2014), Building with Nature is now entering the phase of introducing the ideas in the mainstream of hydraulic engineering works ('make it happen'). The present paper describes of examples where this embedding in practice actually takes place.

2 THE DELFLAND SAND ENGINE

The Holland coast, a 120 km long sandy coast protecting the economic heart of the Netherlands from the sea, is maintained by nourishments. This approach enables the coast to keep up with sea level rise and is more environmentally friendly than hard defence structures. Yet, the present practice, with relatively small-scale nourishments (typically one to a few mio m^3 of sand) whenever the coastline retreats between a given setback-line, has a number of drawbacks. By repeatedly nourishing only the upper part of the coastal profile, this profile tends to over-steepen, for instance, and hence cross-shore transport tends to increase and nourishments tend to become gradually less effective (Stive et al., 1991). Also, small-scale nourishments have to be repeated typically every five years, which is about the recovery time of the disturbed coastal ecosystem. Thus this ecosystem remains in a more or less permanent state of disturbance.

The Delfland Sand Engine is a full-scale experimental mega-nourishment, initiated by the Province of South-Holland and the Netherlands Ministry of Infrastructure and the Environment (see http://www.dezandmotor.nl). It reflects the idea that one big disturbance every 20-30 years will be preferable to smaller ones every 3-5 years. In the first half of 2011 a 21.5 mio m^3 nourishment was made on the coast of South-Holland near Terheijde, a village between the hard points of Scheveningen Harbour and the entrance of the Nieuwe Waterweg (the access channel to Rotterdam) near Hook of Holland. This amount of sand was predicted to suffice for at least 20 years for maintaining this 18 km coastal strectch.

Figure 1. Evolution of the Sand Engine. Left: situation July 2011; right: situation December 2013.

The initial form of the nourishment was a sandy hook (Fig. 1, left panel), but soon this evolved into the more natural coastline shape of a bell which is gradually spreading alongshore (Fig. 1, right panel). In the first two years of its existence, about 2 mio m^3 (10%) of the nourished sand had moved, on the Sand Engine (0.6 mio m^3), to its immediate vicinity (0.9 mio m3) or into the dunes (thus feeding the dune area) or offshore (thus feeding the lower shoreface and reducing the over-steepening problem).

Although the primary objective was coastal protection, there were important side objectives, such as expanding and enriching the dune area, the formation of juvenile dunes and pilot vegetation on top of the nourishment, the provision of habitat, nursery and resting places for fish, sea mammals and birds, the creation of new opportunities for recreation, etc. Two years after completion, the Sand Engine was covered with juvenile dunes and pilot vegetation (Lennartz, 2013), it had become an attractor for beach recreation and a kitesurfer's paradise, its bay functioned as a nursery for fish such as plaice, and as a resting place for seals and a variety of birds. Moreover, it has developed into an icon project of Dutch coastal engineering, visited by colleagues from all over the world.

A variety of aspects, physical as well as biological and societal, of the Sand Engine evolution is monitored in a comprehensive program jointly funded by the Netherlands Government and the European Commission (European Fund for Regional Development). Data are analyzed, interpreted and translated into generic knowledge and information for practical application in a joint research program with 12 PhD-students and 3 postdocs, funded jointly by the STW Technology Foundation and partners of the EcoShape consortium (see http://www.naturecoast.nl/home).

3 PRINS HENDRIK DIKE, TEXEL

An example of dike strengthening on an active tidal inlet is the dike of the Prins Hendrikpolder, Texel, the Netherlands. The 2006 assessment showed that this 3.2 km long dike bordering the Wadden Sea near the Marsdiep inlet (Fig. 2 left) needs strengthening because it falls short on various failure mechanisms, such as foreshore erosion, instability of the inner slope and piping. The deep and very active Texelstroom tidal channel lies 400 m or more offshore, but tends to slowly migrate shoreward. Therefore, the underwater bank (transition between dark and light shade, Fig. 2 right) has been stabilized and is kept in place by Rijkswaterstaat. Further inshore there is a 200 ha shallow area at about MSL - 1 m (light shade, Fig. 2 right).

Figure 2. Prins Hendrik Dike, Texel; left: present situation; right: dike strengthening scheme.

If one would cope with this problem in the traditional way, one would place a wide berm on the inside of the dike, at the expense of the valuable nature area inside the polder. In order to avoid this, one has decided to strengthen this dike by putting a sand dune in front of it (grey shade in front of the dike, Fig. 2 right). Volume and shape of this dune are enough to withstand a design storm with a probability of exceedance of $2.5\ 10^{-4}$ per year. In front of the dune, there is room for saltmarsh to develop behind two sheltering shoals (light areas in Fig. 2 right). Clearly, this 'soft engineering' solution will require a certain amount of maintenance, but this is thought to be compensated by avoiding the berm at the inside and by additional benefits to the natural system, especially the marsh in front of the dune. The project is expected to be executed between 2015 and 2019.

4 OEVERDIJK, LAKE MARKEN

The west side of Lake Marken, the southwest part of the former Zuiderzee, is bordered by steep dikes with houses built right behind it or even in it (Fig. 3, left). These dikes no longer meet the present safety standards, falling short primarily on height, inner slope stability and piping. Strengthening them the traditional way would be quite intrusive to the people living near the dike. Strengthening at the inside would mean costly removal of many houses, and even if the dike would be strengthened at the outside, working from the inside would mean a major disturbance (heavy traffic, noise, dirt, etc.). Moreover, the subsoil consists of a thick layer of peat of unknown strength. Building a heavier dike on top of it might lead to liquefaction of the peat and subsidence of the dike.

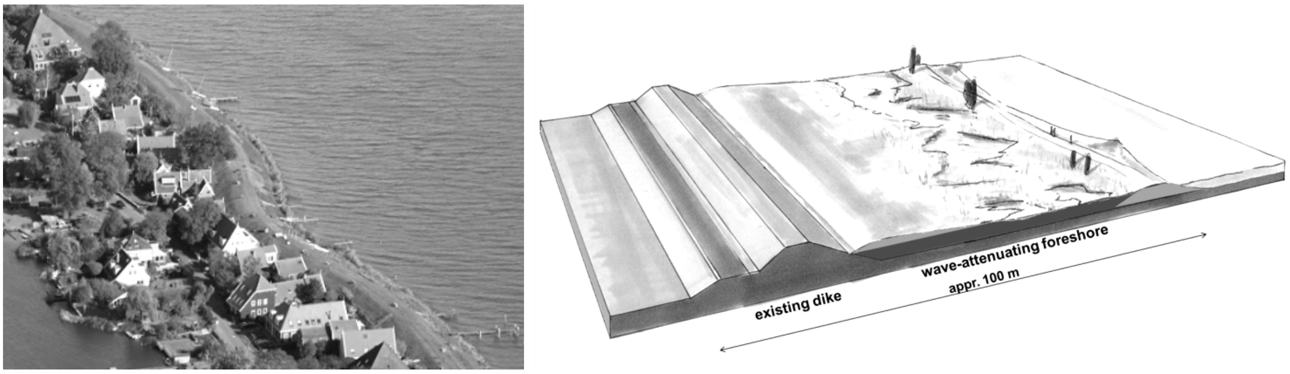

Figure 3. West bank of Lake Marken near the village of Uitdam;left: present situation; right: artist impression Oeverdijk (adapted from Bureau Stroming).

An alternative would be to work from the outside, creating a shallow foreshore which includes an impermeable clay layer in order to extend the seepage length, thus prevent piping and reducing the groundwater pressure at the inside of the dike (Fig. 3, right). This would also solve, or at least reduce, the stability problem at the inside of the dike. Further strengthening of the outside can be done from the foreshore, such that people living on the inside of the dike don't have to be disturbed. Especially at places with many houses at the inside, this solution is expected to be cheaper than traditional engineering ones (e.g. Fiselier et al, 2011; Wichman et al, 2012).

The foreshore itself can be made into a wetland nature reserve and a recreation area, thus constituting a multifunctional solution to the dike strengthening problem. As the lake contains large amounts of suspended sediment, sediment-trapping vegetation will enable the foreshore to keep up with a gradual rise of the lake level. In order to be ready to function whenever necessary, the foreshore and especially the protective sand ridge at the lake side will require regular inspection, an appropriate assessment protocol and maintenance if and when necessary.

5 MARCONI PROJECT, DELFZIJL

The Marconi project is a multi-purpose project meant to upgrade the local flood defence system and at the same time reconnect the city of Delfzijl, the Netherlands, to the Ems Estuary and increase the spatial and environmental quality of the area. It consists of several parts (Fig. 4, right panel), among which the construction of a recreational beach near the city centre and an artificial marsh along the harbour dam. Part of the plan is also to remove a mound of highly alkaline (pH 9-12) calcium carbonate (offshore shaded area), a by-product of soda (sodium carbonate) production which has been deposited in the estuary.

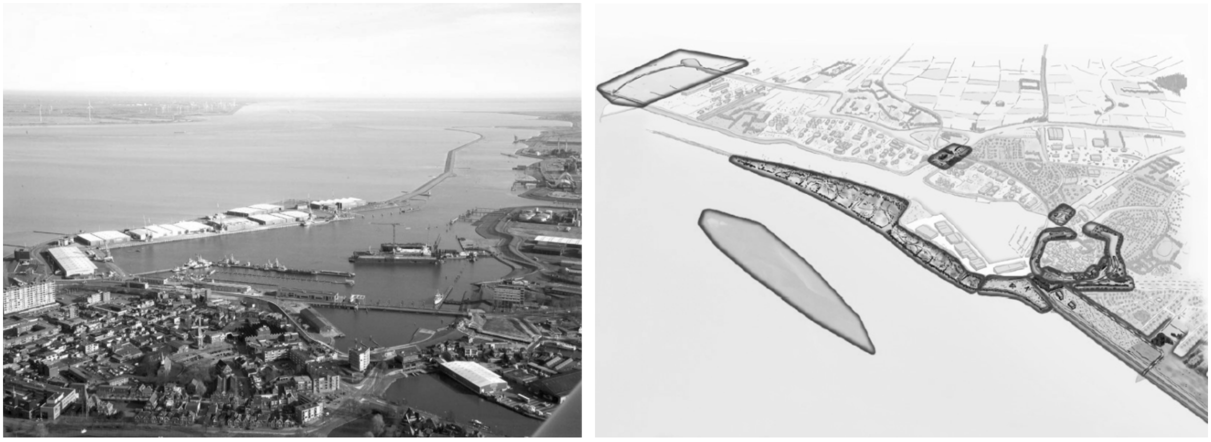

Figure 4. Marconi project, Delfzijl; left: present situation, look southeast; right: project areas.

The harbour of Delfzijl is protected from the sea by a long shore-parallel dam (Fig.4, left), but the primary flood defence is at the land side behind the dam. Raising this dike would be a rather intrusive operation, because of the many buildings right behind it. Therefore, an alternative is sought in reducing wave attack on this dike by increasing the wave damping effect of the harbour dam. The letter is planned to be achieved with an artificial marsh in front of the dam. Creating conditions for vital marsh development is by no means a trivial task, as experience in Japan with river-bordering wetlands has shown (Nakamura et al., 2006). The Netherlands do have hundreds of years of experience with marsh creation in the Wadden Sea (e.g. Dijkema, 1987), but the technique used there is based on slow natural build-up of the marsh by stimulated mud deposition. In the Delfzijl case, the land for the marsh will be man-made and the question is to what extent it is possible to create the right physiotope for the desired ecosystem (vital, wave-attenuating, sediment-trapping, attractive, etc.) and to what extent the marsh will be self-sustaining. If it is, it will be able to trap sediment and keep up with a certain rate of sea level rise.

Clearly, the recreational beach is not natural in this mud-dominated environment and will probably require maintenance. This element, however, was crucial for the citizens of Delfzijl to accept the plan as a whole. This illustrates, once more, that this kind of projects is not just a matter of finding technical solutions, but that convincing stakeholders and the public at large is an equally important element.

6 COASTAL RESTORATION, JAVA

The coast of Java, Indonesia, is facing severe erosion problems, mainly due to groundwater extraction, causing land subsidence, and the removal of natural mangrove forests to build extensive fishponds. Especially when the latter have been abandoned and are no longer maintained, for instance because they have become too polluted with nutrients, antibiotics and aquaculture chemicals, such coasts are susceptible to severe erosion. Fig. 5 shows an example from the Demak district, Mid-Java, where both mechanisms are working and coastal erosion over the last decade extends over large areas (Fig. 5, left, hatched area).

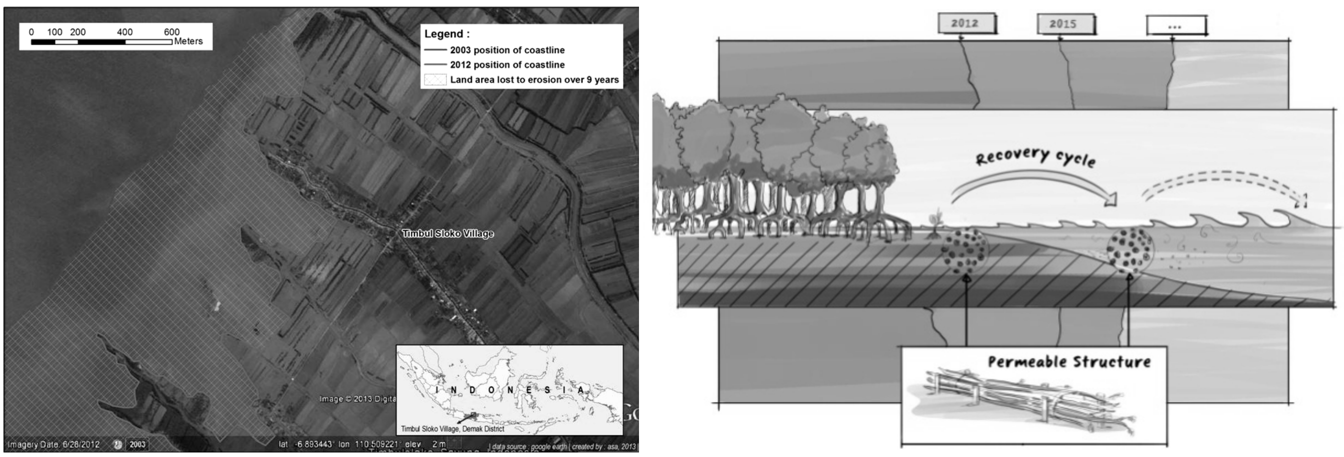

Figure 5. Coastal restoration Demak; left: erosion between 2003 and 2012; right: restoration principle.

In order to restore the coast and provide the local population with safe housing and a decent livelyhood, there are plans to restore the original mangrove coast and to re-establish fishponds in a more sustainable way. The technical design of the project, which is meant as a pilot for much wider application on this coast and elsewhere, is to first restore a natural coastal profile with dredged material and sufficient accommodation space for tidal water behind it, thus creating a physiotope (muddy bed, in- and outgoing tide) that is suitable for mangrove. Wave action is damped by permeable brushwood dams (as applied for centuries for land reclamation in the Wadden Sea), such that conditions are favourable for fine sediments to settle. Once these conditions have been created, mangrove is likely to colonize the area spontaneously, and if necessary initial conditions will be enhanced by mangrove planting.

Apart from coastal stabilization and the capacity to follow sea level rise if sufficient sediment is available, mangrove forest provide important ecosystem services, such as fisheries, room for aquaculture, carbon sequestration in biomass and sediments, provision of timber and non-timber products, opportunities for recreation, etc. Moreover, they shelter the area behind them from the see, thus enabling safe housing and agriculture and aquaculture under controlled conditions. In order to achieve maximum involvement of the local population and optimize the chances for the degraded local economy to come back on its feet, this plan is being developed in close consultation with the local stakeholders. It will start as soon as the necessary funding arrangements have been completed.

7 CLIMATE ADAPTATION STRATEGY ROTTERDAM

Building with nature projects in rural areas often have ample space. This is usually not the case in urban areas, so there other types of solutions have to be found, which renders multi-functionality even more important. Nature in the urban setting usually takes the form of a park with a recreational purpose.

Figure 6. Rotterdam Climate Adaptation Strategy; left: present situation; right: climate adaptation plans (also see: www.rotterdamclimateinitiative.nl).

The city of Rotterdam is rich of water, but also has little freeboard (Fig. 6, left), whence it is susceptible to flooding if sea level rises. Therefore, the city is protected against storm surges by the Maeslant Barrier, a moveable barrier near the mouth of the Nieuwe Waterweg access channel. At the landward side, however, there is no protection from river floods if they occur when the barrier is closed (otherwise, the backwater effect of the river mouth will draw down high river flood levels). Especially away from the river banks, the city is low-lying and flood prone. Moreover, climate change may bring other problems, such as rainwater-induced flooding, and heat-island effects. On top of this, Rotterdam is seeking to make the city greener and more attractive.

The Rotterdam Climate Adaptation Strategy (RCI, 2013) sets out the lines along which Rotterdam will tackle these problems. It aims at a climate-proof city for present and future generations, a city that is economically vital and attractive to live and work in. The plans (Fig. 6, right) include a variety of solutions, many of which use the concept of building with nature. One example is the ‘tidal park’, a green zone along the (tidal) river which includes a safe dike as well as a wave-attenuating nature park suitable for recreation. Another project, ‘Green Gateway’, which is already in a later stage of the planning process, concerns greening the separation dam between the Nieuwe Waterweg and the access to the present harbour area by creating a nature and recreation park there. Also, the old abandoned harbours within the city will get a multi-functional upgrade.

8 NEW MEADOWLANDS, NEW YORK

After the wake-up call of Hurricane Sandy, New York and New Jersey put flood safety high on their agenda. One of the areas of concern, from the point of view of flood safety as well as spatial quality, social vulnerability, vital network vulnerability and pollution risk, is the so-called Meadowlands basin west of the Hudson River (Fig. 7, left). In the framework of the Rebuild by Design competition (see http://www.rebuildbydesign.org/) a consortium of urban planners and Deltares won the first prize with a proposal called New Meadowlands, meaning that the plan is to be executed (initial budget of 150 M$).

Figure 7. The New Meadowlands plan; left: location; right: overview (source: MIT_CAU+ZUS+URBANISTEN).

The plan (Fig. 7, right; also see http://www.urbanisten.nl/wp/?portfolio=the-new-meadowlands) is based on an integrated design which includes an elongated green berm as a defence against flooding from the Atlantic Ocean, large freshwater basins to eliminate rainwater flooding, restoration for marshland to yield a regional wildlife refuge (Meadowpark) and an amenity zone (Meadowband) connecting the urban area with the basin. Thus the project serves a number of societal, ecological, economic and infrastructural purposes, at a range of spatial scales.

The building with nature dimension of this plan lies in the green flood protection berm, which combines the functions of flood defence, nature park and recreation area, and in the marshlands with the freshwater basins, which combine the functions of stormwater storage, recreation area and nature park with a range of ecosystem services.

9 LESSONS LEARNED

In these projects various lessons have been learned about mainstreaming the building with nature concept, such as:

- Introduce the ideas of BwN as early as possible in the project development process, preferably as early as the initiation phase. Once a project has been defined and a solution direction has been chosen, it will be difficult to change.
- Therefore, it is important to address the problem owners, rather than the project leader. The latter is usually too strongly bound to budget and time constraints to be able to include new concepts.
- Infrastructural projects like these are nearly always intrusive and affect a range of stakeholders. Getting these stakeholders involved as early as possible is a critical success factor for this type of projects. A BwN-approach may help convincing them of the use of the project.
- In order to have the support of the public at large, express the objectives and the approach of the project in terms that are understandable to lay people and connect with their daily concerns (a probability of 10^{-5} per year does not really appeal to many).
- Make sure the BwN-alternative is defendable in terms of costs and benefits from a lifecycle perspective and if all functions are taken into account.
- When working in terms of net present value, make sure the discounting rate is realistic, especially for the nature components in the project. Note in this respect that nature takes time to develop and cannot be bought ready-to-use whenever it is needed.
- Use realistic estimates of the risk associated with uncertainties in the functioning of the nature components. Project developers sometimes tend to estimate these risks much higher than those of traditional solutions (‘proven technology’), thus rendering BwN-projects economically unfeasible.
- Pay attention not only to the design and realization of a project, but also to its time-evolution, operation, assessment and maintenance. Note that a BwN-project is not completed at the moment it has been built, because the nature component will further evolve with time.
- Mind the legal aspects of a project. Sometimes the existing situation is protected (e.g. under Natura2000) and cannot be altered, even though the envisaged situation would be ecologically much more

valuable. Also the property of newly developed nature areas and the responsibility for its maintenance are sometimes subject to legal disputes.

10 CONCLUSION

The many projects in which BwN-ideas are being implemented show the potential of the concept in mainstream hydraulic engineering and spatial development, not only in rural areas with ample space for 'soft engineering' and 'green' solutions, but also in densely populated urban areas. Common denominators of all of these projects are (1) the inclusion of the natural environment, as a 'stakeholder' as well as a potential contributor to the realization and operation, right from the start of the project development process, (2) an integrated multifunctional approach, and (3) active stakeholder involvement throughout the process. Yet, there are always hurdles to be taken and pitfalls to be avoided, if not technical or ecological, then contractual, societal, or legal, or associated with unnecessary conservatism among professionals.

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