

NanoFabNet

international Hub for sustainable
industrial-scale Nanofabrication

Post-pandemic Professional Networks



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Acronyms Listed in Document	
PPP	Public-Private-Partnership
P2P	Public-to-Public Partnership



Executive Summary

The best innovative solutions to pressing large-scale problems are found at the interface of recombined processes and tools that may be proven and established to work in different (more limited) contexts; successful examples range from the photosynthesis-inspired improvement of photovoltaic devices to the virus-inspired editing of genomes, to name but a few.

Both the complexity and the detailed scientific research needed to advance the anticipated nanotechnology-based solutions require a widened international collaboration that goes beyond the boundaries of countries and disciplines. A successful implementation of advanced R&I activities at the relevant disciplinary interfaces, however, first and foremost requires the willingness and opportunity to communicate outside one's own network and circle of expertise; in most (if not all) cases, it may be necessary to support initial attempts of such interdisciplinary communications and collaborations through the harmonisation of language and terminologies. The [NanoFabNet Hub](#) provides both initial solutions and room for further advancements to both of these challenges: an online collaboration platform for scientists, technologists and innovators from both the disciplines of micro- and nanotechnology and sustainability from all over the world, as well as network-activities and representation to provide further advancement, as well as visibility and impact to the resulting sustainable high-tech innovations.

Professional networks will have to continue to run a significant part of their services and activities in the form of virtual meetings and collaborations.

Through its 30-months-development time during the COVID-19 pandemic, the NanoFabNet has created and simultaneously stress-tested a professional network that combines the best elements of the physical and the online worlds.



1. Introduction

If there was one thing that the NanoFabNet wanted to write onto its flag as a new interdisciplinary network, it was the spirit of old-fashioned working collaborations that are born slowly out of face-to-face meetings between experts that may previously not even have appreciated that an expert stranger from a far-away discipline may have anything to offer to their own area of expertise. In fact, the NanoFabNet approach to the establishment of long-lasting networks was supposed to be a celebration of traditional ways, in which individuals from different cultural backgrounds and schools of thought could get to know, appreciate and trust each other, in order to eventually foster collaborations on new ideas at the interface of their respective disciplines.

When conceptualising the two-year development time of the NanoFabNet, it was clear that the establishment of a new expert community in an uncharted territory somewhere between the fields of ‘sustainability’ and ‘nanofabrication’ would throw up numerous challenges of siloed thinking and methodologies, so that any additional barriers to the required direct interaction between expert (such as those barriers inherent to video- and teleconferences) would be detrimental to the network’s core idea.

2. The NanoFabNet Approach

The NanoFabNet was designed and determined to be set up as an international network of experts, who would meet at in-person NanoFabNet Meetings on different topics and organised and hosted by different NanoFabNet Members in different suitable locations all over the world. An underlying ‘digital twin’ of this network would provide a strong singular identity to an otherwise distributed, shared networking exercise; this central digital installation would merely serve as a central memory to the achievements of in-person meetings, as well as an information and members-registration hub. Figure 1 illustrates NanoFabNet’s ambitious plan to create a new community-owned network that would overcome the limitations of its siloed components to form an aligned, collaborative approach towards sustainable high-tech innovation.



Figure 1: Illustration of the NanoFabNet’s ambitious plan to create a new community-owned network that would overcome the limitations of its siloed components to form an aligned, collaborative approach towards sustainable high-tech innovation.

A analyses of the underlying challenges that the NanoFabNet approach aimed to address and solve can be found in ANNEX – A1.

3. Professional Networks in the Times of Pandemics

The original plan of establishing the NanoFabNet as a traditional network focussed predominantly on in-person meetings that would be supported, but not carried or driven, by a central digital hub, was turned on its head when the NanoFabNet development team commenced its planned work in March 2020: the necessary collaborations within the international team of experts who stemmed from different disciplines (ranging from ethics to high-tech nanofabrication), and who were based on three different continents (ranging from countries, such as the USA to EU Member States, to Israel and to Japan) became a testbed for its own approach to setting up and running new international, interdisciplinary networks during a pandemic that afforded unprecedented and unsurmountable limitations to the originally planned reliance on in-person collaborations.

With the ongoing and unpredictable duration, repeated flaring up an ever-changing impact of the COVID-19 pandemic around the world, it became obvious that NanoFabNet's future would lie in its digital presence, while the previously emphasises in-person meetings could be regarded as occasional events that strengthen the regional establishment of the network.

The initiation of the development team's work was exhausting; not only was it hampered by the fact that most of the expert individuals had never met in person, but their chances of getting to know each other online was further worsened by the bad quality of data infrastructures and low-level availability (or total absence) of remote working provisions in the collaborating institutions. After more than half a year of the dreaded 'can you hear me'- and 'can you see my slides'-routines, the NanoFabNet development team had found a rhythm to co-operate and communicate in a manner that pre-empted the very nature of the virtual collaboration network, which they aimed to establish: the **NanoFabNet Hub – a international Hub for sustainable High-Tech Innovation** that was developed in a predominantly virtual fashion, and that would thus prove to be an example for the professional network of the future.

4. Post-pandemic Professional Networks

In the second big lesson-of-life learned during the NanoFabNet development, it turned out that the title of this report '*Post-pandemic Professional Networks*', proposed in February 2021, now falls into the category of 'wishful thinking', since we are nowhere near a post-pandemic time just yet. The underlying thought, however, remains true and accurate: it is reasonable to assume that the changes that professional networks needed to make to their internal set-ups and processes, in order to continue functioning during the pandemic, are here to stay. As a silver-lining (if ever there was one) to the disruptions caused by the corona virus the world over, video- and teleconferencing tools have improved significantly and online collaboration software has become available to emulate all sort of previous bean-bag- and post-it-note exercises, so much so that virtual meetings seem to have become a default and in-person meetings a rare adventure.

With the development of the NanoFabNet now fully concluded, and the resulting virtual NanoFabNet Hub (www.NanoFabNet.net) formally launched at in-person events in both the USA¹ and Europe², it is time to look back and draw lessons from the creation and establishment of the first pandemic-proof, truly international Hub for sustainable High-Tech Innovation as an example for future (and hopefully soon 'post-pandemic') professional networks.

An accompanying detailed discussion of the Pros and Vons of all-virtual and hybrid meetings can be found in ANNEX – A2.

¹ NanoFabNet US Launch Event, held during the TechConnect Conference, on the 14th June 2022 (Washington D.C, USA).

² NanoFabNet EU Launch Event, held during the SUSNANOFAB Project Workshop '*SUSTAINABLE NANOFABRICATION: Joint Networking Event*' on the 6th of July 2022 (Braga, Portugal).



4.1 Strengths

A professional network that is predominantly enabled through a central, virtual platform can be **truly international and profoundly regional** at the same time. With the exception of concerns (and in some cases demands) pertaining to privacy regulation and data security, the members of a virtual network notice, or indeed care about the country of registration of a virtual network, as much as they notice or care about the location of the servers they are using during their daily work or social networking. In addition, regional datahubs and services can be established and provided, if regional groups within the network wish to set these up to support specific services or collaborations through them; such regional exercises may include information in local languages and offer meetings conducted in local languages, in order to be fully inclusive to those members who are not used to or otherwise engaged in international collaborations, but who strengthen interdisciplinary collaborations within their own country.

4.2 Weaknesses

Even the best virtual networks need to host in-person meetings to strengthen its corporate identity through physical appearance, and to (re-)confirm the ownership by its members and commitment of its service-providers.

Video- and teleconference-calls are well-suited to follow up on running activities, but they are inappropriate for the planning and commencement of a novel collaboration, let alone the initiation of one that is based on an unprecedented combination of disciplines or processes. (NOTE: Necessary provisions during the pandemic may have demonstrated that such initiation of novel collaborations is possible in an exclusively online format, but the process is unnecessarily lengthy and laborious, and carries a high risk that some aspects have not been considered with the same openness, as they would have been mentioned and discussed during in-person meetings.)

Truly **interdisciplinary events** that aim to foster collaborations between experts that have never met before, **are rarely successful when conducted online only.**

While it seems tempting to combine the best of both worlds through the conduct of hybrid events (i.e. in-person events with a sizable number of both speakers and attendees participating online only), it needs to be noted that these rarely are worth the extra effort they require to set up and run well. Since not only the benefits, but also the drawbacks of in-person and online event-forms (i.e. technical problems, such as sound and visuals) are combined in hybrid events, the feeling of being 'left out' or 'insufficiently informed of what is going on in the room' is enhanced in the online community, while the in-person community tends to become restless and side-tracked.

4.3 Opportunities

Virtual networks can have a much larger geographical and topical reach. The ease to organise different meetings within a short timeframe, as well as the lack of a requirement for a minimum number of attendees to justify in-person meeting costs, **benefits the network by increasing the diversity of topics** it can address through its activities and services. The (prospective) member, on the other hand, benefits from the much higher non-committal flexibility, with which they explore new topics and get engaged in discussion, even if it turns out to be a one-off occasion.

New ideas can thus be trialled in a much more tentative fashion; if the virtual network portrays and communicates this flexibility well enough to its (prospective) members and encourages them to engage with the wider activity- and service-offering of the network in an exploratory manner, the network can reach a point where tacit knowledge is exchanged more easily than is the case during standard online events. This would ultimately strengthen the initiation of novel ideas and collaborations across disciplinary boundaries and alleviate one of the main draw-back to all-virtual meetings between experts that do not yet know each other.

4.4 Threats

Virtual networks are threatened by the same dangers that befall every one-off online meeting:

- (a) the impression of a **non-committal (physical) distance to the meeting** that results in a high ratio of no-shows (especially for events that do not charge a registration fee), and the sudden disappearance of high-level speakers that had to attend to another urgent matter, and
- (b) the **insufficient allocation of time to prepare for a meeting and follow up on it**. The start- and end-time of an online meeting in one's calendar is too often misinterpreted as the time when one needs to start (and can stop) thinking about or engaging with the subject matter. This leads to an over-booking with different online meetings and too little time to prepare for and follow up on them, or to acclimatise in the meeting one just entered and commit to the discussion topic and to the specific engagement required.

In contrast to one-off online events, however, virtual networks can counteract both threat (a) and (b) above by strengthening the corporate identity of the community and the sense of ownership by its members. This strengthening, in turn, requires a healthy dose of in-person events hosted by the network.

The future of (post-) pandemic professional networks thus lies in a healthy balance between virtual and in-person activities.

5. Conclusions

Professional networks will have to continue to run a significant part of their services and activities in the form of virtual meetings and collaborations.

Through its 30-months-development time during the COVID-19 pandemic, the NanoFabNet has created and simultaneously stress-tested a professional network that combines the best elements of the physical and the online worlds: The [NanoFabNet Hub](#) provides both initial solutions and room for further advancements to both of these challenges: an online collaboration platform for scientists, technologists and innovators from both the disciplines of micro- and nanotechnology and sustainability from all over the world, as well as network-activities and representation to provide further advancement, as well as visibility and impact to the resulting sustainable high-tech innovations.

ANNEX – A1: The Design of the NanoFabNet Hub as a Solution to the prevailing Fragmentation of scientific and technological Disciplines

The NanoFabNet Project will create a **strong international network for sustainable nanofabrication**, whose structure, business model, detailed strategies and action plans are designed, agreed and carried by its international stakeholders during the Project duration, in order to yield a self-sustaining collaboration platform: the **NanoFabNet Hub**, at whose centre the registered **NanoFabNet membership organisation** will provide an accountable, permanent secretariat. It will be responsible for the implementation of a long-term business plan, and the provision of validation services, trainings and consultations, while collaborative and cooperative activities between actors of the wider international nanofabrication community will be fostered within the open architecture of the hub, and may be supported by membership organisation, if necessary.

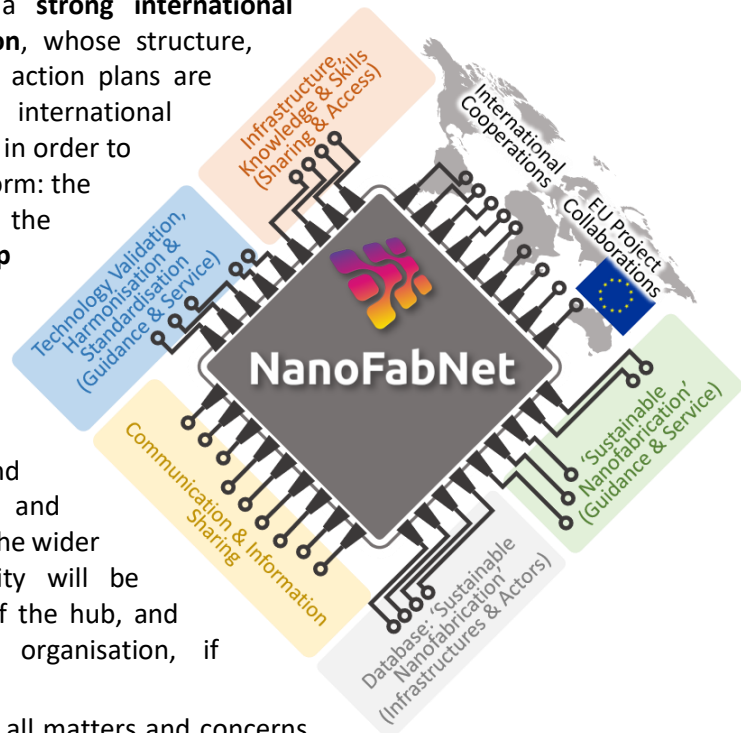


Figure 2: Illustration of the elements and structure of the NanoFabNet hub.

The hub aims to be a **one-stop-shop** for all matters and concerns pertaining to sustainable nanofabrication and its successful incorporation into the complex, large-scale high-value industries by bringing together governmental and academic laboratories with large industries and SMEs, and thereby offering a coordination space for past, current and future collaborative nanofabrication projects (incl. both EU-funded projects and initiatives, as well as public-to-public partnerships (P2Ps) and public-private-partnerships (PPPs)) (Figure 2).

The necessary consolidation of the existing innovation infrastructures with the diverse and widespread nanofabrication stakeholders is currently hampered by the manifold barriers of technologies, discipline, language, regulation and geography between the individual domains and the fragmentation within them. The **NanoFabNet Project specifically addresses and aims to overcome** these hurdles by taking the proposed NanoFabNet Hub beyond **the current state-of-the-art**:

Networks and partnership differ in the funding- and business models of their members: Governmental and academic laboratories tend to have little interaction with large-scale and small-scale industries, other than the consultancy services they are offering the latter.

- ⇒ The engagement and consultation of the **wide variety of identified stakeholders at the first hour of the NanoFabNet's creation** specifically counteracts the tendency that members of existing networks and partnership tend to gather according to the likeness of their funding sources, geopolitical mandates and underlying business forms and models.
- ⇒ An 'organisational or business model innovation' will be incorporated into the simultaneous creation of the **NanoFabNet membership organisation** and the wider **NanoFabNet Hub**: the NanoFabNet stakeholder community will exchange its opinions and views (during and between the NanoFabNet Development Workshops (NanoFabNet DW), in order to commit those elements of the community that require legally binding securities to the NanoFabNet business plan (e.g. NanoFabNet validation services), while those elements that tend to be hampered by premature



binding agreements under a specific jurisdiction will be left to be established and flourish within the more loosely defined NanoFabNet Hub.

(Sub-)disciplines differ in origin, the challenges they address, the media in which they work, the skills they require, and the value-chains in which they operate: Traditional '(nano)fabrication' laboratories tend to be inspired by the engineering discipline of micro-electronics; they focus on 'top-down' fabrication processes and incorporate only those nanoscale building blocks that can be fabricated on site (and often in-situ). By contrast, 'bottom-up' process of synthesising nanoscale building blocks (e.g. in chemical/physical vapour deposition or solution-chemistry approaches) have largely sprung out of the disciplines of inorganic chemistry, chemical engineering, and materials science, where products and intermediaries tend to be produced in bulk quantities for 'ex-situ' integration further down the value chain.

⇒ The fragmentation of the field through discipline origins and schools-of-thought will be overcome through the choice of representative stakeholders from different disciplines. Within this context, the NanoFabNet Project will address one specifically ambitious and ground-breaking objective, namely that of developing a bespoke **NanoFabNet concept of 'sustainable nanofabrication'** by inclusion of world-leading technology sustainability experts.

Geopolitical clustering prevails: Nanofabrication laboratories tend to cluster on the national or federal level, due to factors connected to their immediate economic, political and geographic infrastructures and those of their client industries; the individual stakeholders and their communities know of each other and tend to meet at international conferences, but aside from investigator-to-investigator collaborations, hardly any formal partnerships exist between the nanofabrication communities around the globe.

⇒ The fragmentation into geopolitical clusters will be overcome through (a) the inclusion of two US Partners in the Project Consortium, with each of them inputting into different core areas of **NanoFabNet** activities, and (b) the selection of strategic EAB members, who are representing various stakeholder groups (incl. academia, large industries and SMEs in different sectors) and regions (incl. Israel, Japan, Switzerland, Netherlands, Portugal USA).

It is anticipated that all of the barriers described above will be further lowered, as more stakeholders join the community and engage in defining the NanoFabNet according to their needs and views. By far the most impactful measure to lastingly eliminate the barriers, however, will be the establishment of the **NanoFabNet Database**: the database aims to act as a '**digital twin**' of the **NanoFabNet stakeholder community**, cataloguing information about the infrastructures and actors that have been initially identified by the mapping exercise, as well as the collaborations and corrections between their expertise and capacities; through this digitalisation step, the fragmented communities will be re-mapped according to the **NanoFabNet Database terminologies and ontologies**, and thus become independent from their previous fragmentation.

ANNEX – A2: Discussion of the Pros & Cons of all-virtual and hybrid Meetings

The virtual conference format holds both advantages and disadvantages over that of face-to-face meetings, not least considering the increased inclusivity and sustainability of the former’s travel-free nature. Table 1 below discusses some of the most pronounced PROs and CONs of all-virtual meetings.

Table 1: Listing of the most pronounced PROs and CONs of (all) virtual conferences

PROs of (all-)virtual conferences	CONs of (all-)virtual conferences
<p>Younger researchers and those at early stages of their careers feel that they can meet and interact with high-level experts more easily than this would be possible at face-to-face meetings.</p>	<p>The lack of in-person, serendipitous networking opportunities (e.g. in the famous queue for the coffee, or in the lady’s powder room) prevents bilateral exchange of tacit knowledge, which formed a demonstrable part in scientific breakthroughs, and enables career-changing moves at multiple occasions.</p>
<p>High-level speakers and those with busy timetables tend to be more often available to attend virtual conferences, than they would be, if they had to travel to every event they are invited to speak at.</p>	<p>When they are not speaking or part of the discussion (or otherwise appearing on camera), high-level speakers may get side-tracked during the event by their many competing duties at home.</p>
<p>Short conference appearances are easier to arrange and can be delivered at a higher frequency, allowing for wider, more inclusive sharing of knowledge of and interaction with experts.</p>	<p>Time-zone differences often lead to the inclusion of experts outside their local office hours; since they otherwise continue to maintain their normal, local workload, experts can be tired and unwilling to spend nightshifts giving presentations. The conference organisers’ response to scheduling the experts’ presentations at more amenable times, in turn, can challenge the logical planning of conference sessions.</p>

It is probably fair to assume that virtual participation options will continue to be implemented in almost all face-to-face meetings, even after the pandemic may no longer limit in-person travel, because virtual participation enables both a higher inclusivity, as well as a better sustainability of international meetings.

The famous interactions in the coffee queue that is frequently used by those conference delegates, who prefer a one-to-one interaction with a speaker of a previous session (let that be for reasons of confidentiality or shyness), is difficult to replace. Younger researchers suffer more from this than more established experts, because virtual conferences cannot reproduce the networking opportunities of in-person conferences, no matter how immersive and reality-like the online-meeting software is (although some are better to simulate the random coffee-brake conversations better than others).

The COVID-19 pandemic and its prevention measures have significantly advanced the technical capability and functionality of virtual meeting assistants, and a vast range of versatile programmes are now available. In addition, both the organisers, invited and presenting experts and audiences have amassed in-depth experiences about the best practices of virtual meetings.

The format of a **‘hybrid events’** that combines face-to-face participation in a conference room and virtual participation of individuals is the most difficult conference arrangement, since it (a) requires the technical organisation of two full events, and (b) suffers from emphasising the disadvantages of



each event format (e.g. clashes in the alignment of logical conference programming with the availability of the relevant experts across different time-zones; the difficulties to network *via* virtual means exacerbated by the natural networking during conference breaks within the face-to-face community; enhanced perception of disruptions cause by possible technical problems (i.e. virtual presentations) for those that are attending the face-to-face meeting). One possibility of overcoming some of the disadvantages of hybrid events could be the scheduling of separate (serial) exclusive face-to-face and all-virtual sessions (of different days) of the same meeting; these should be designed and arranged to be complementary to (not competing with) each other (e.g. international sessions of a meeting could be held as all-virtual sessions, while technical discussions within small groups of experts could be arranged to be conducted as face-to-face meetings; detailed mutual reports of the relevant sessions in the respective other session would assure the inclusion of all discussions into the whole of the overall meeting).



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