IAQ QUALITY SUSTAINABILITY AWARD 2020

APPLICATION FORM

The complete application includes this application form, a summary (One-page summary) for publication (Attachment 1) and an optional technical improvement report (Attachment 2). Refer to "Applying for the IAQ Quality Sustainability Award (QSA)" for more details. The maximum length of this application form is 4 pages.

For 2021, for applicants in China and India, please send application to your national Quality Sustainability Award partner as per their instructions. (see "List of Partners" for your local contact). For applicants from all other countries than China and India, please submit your complete application to iaqaward@sandholm.se

The official name of the organisation NorDan AB		
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Names and roles of all team-members and organisational belonging Name of project representatives removed in this example		
Project Completion Date 2020-06-05		
Project connection to UN Sustainability Development Goal(s). Please delete goals **not** applicable for your application. A project applying for the IAQ Sustainability Award can focus on one or several of the UN Sustainability Development Goals. For more information about the goals see; https://sustainabledevelopment.un.org/). GOAL 9: Industry, Innovation and Infrastructure GOAL 12: Responsible Consumption and Production GOAL 17: Partnerships to achieve the Goal		
The name of the quality sustainability project (max. 100 characters) Commercial sales of 3D printed windows in biomaterial, applying PDCA methodology and quality tools		
PROJECT DESCRIPTION; *General description of the improvement and development work carried out in the project. Explain the essence of the project, the problem statement, the analysis performed, steps taken, and methodology used. When was it started and when was it completed? Describe also the resources that have been used, human or financial. Finally, describe how the project has contributed to sustainable development in the sense of economic- environmental- and / or social sustainability and what results achieved. Formulations here can preferably build on material from your One-page summary, Appendix 1. Max. 3000 characters)* In 2018 and 2019 NorDan AB conducted a very successful project showing the potential of applying Quality Management philosophy, methodology and tools to achieve notable results within Sustainability. The project delivered the production technique, material solution and marketing concept for commercial sales of 3D printed windows starting end of 2019 and developing into 2020. NorDan has gained international attention and recognition for its innovations in 3D printing and it serves as a very visible and concrete example on how NorDan works with sustainability and digitalization both within the company and towards its suppliers, customers and the market. Throughout the project the PDCA cycle was applied in many iterations, taking one step at a time in a planned way to make progress towards the ultimate and overall goal, i.e. be the first window manufacturer in the world to start commercial sales of 3D printed windows in a modern, sustainable material. Also root cause analysis and cause-effect analysis was conducted numerous times in order to better understand the challenges in the project and agree on necessary actions to move the project towards its ultimate goal. The importance of sustainability in the project was eminent from the very start since NorDan is a supplier of wooden windows and doors, and has for decades marketed the environmentally friendly aspects of wooden products as opposed to e.g. PVC and aluminium windows and doors. Shaped windows (e.g. circular, half circular, angled) are among the most expensive and difficult to produce within the window and door industry. Wood parts are cut from a 6 m long wood profile and the pieces are glued together into a workpiece. This workpiece is then machined into a frame with the right dimension, shape and profile. After machining, the frame is vacuum impregnated and painted. In the final assembly, the frame and glass is fixed together, before packing and shipping of the final product. This is a time-consuming manufacturing process with many steps and a total lead time of 4 weeks from customer order to delivery of products.		

Note. More information about the award and how to apply can be found on the IAQ Quality Award homepage

The innovation by NorDan is to apply a large-scale 3D printer and biocomposite material to produce the workpiece and hereby eliminating the cutting process, gluing process and vacuum impregnation process. The total lead time from customer order to delivery is reduced by more than 50%. The cycle time of producing the work piece is reduced by more than 90%, direct hours reduced by more than 80% and the quality of final product is improved. Key technical information about the material used and the final product are as follows:

* The biocomposite material used is sustainable, modern and renewable with a calculated 97% rate in recovery of material. The material is DuraSenseTM from Stora Enso with more than 50% wood content. The bio content is wood fibres. Also other biocomposite materials were tested, including bio content of hemp and roots, but these were not as successful for 3D printing as wood fibres.
* The 3D printed windows in biocomposite have excellent properties for wind load Class 3 (EN 12210:1999), water resistance Class 9A (EN 12208:1999), U-value 0,87 W/m2K and is temperature- and wear resistant also in Scandinavian harsh climate. The products are CE marked, have DoP (Declaration of Performance) and are registered in different environmental declaration databases including Basta. Product testing has been conducted at the renowned Research Institutes of Sweden (RISE).

Another important aspect of this quality sustainability was the contribution it made to other companies, on the one hand with BLB Industries as supplier of the large-scale 3D printer and on the other hand with Stora Enso the supplier of raw material to the 3D printing process.

- NorDan's investment into a 3D printer that was large enough to print full-scale windows in was made to a Swedish start-up company, with the name of BLB Industries AB. NorDan ordered the second 3D printer ever sold by the company, and NorDan played a key role in BLB developing into a leading company in Europe for large-scale 3D printers. NorDan provided a good reference case to the company and NorDan gave input to improvements in the design and safety features of the 3D printer and helped the company to establish better processes and routines in its administrative processes, including quality management.
- 3D printing is by and large based on polymer material in some form, either as filament or granulate. Using biocomposite material for 3D printing was at the start of the NorDan quality sustainability in its very early stages and not readily available in the market. NorDan thus also participated in test-printing of different biocomposite materials from different suppliers. After an initial round of screening and testing, NorDan decided to focus its efforts on a cooperation with Stora Enso, who then by mid 2019 had developed a material receipt, DuraSenseTM, that worked in the large-scale 3D printer that NorDan had invested in. The material was also granulate-based, which is much more cost efficient compared to filament solutions. The wood fibres in the DuraSenseTM biocomposite material are FSC-certified, meaning they come from trees in FSC-certified forests (Forest Stewardship Council). The material can also be recycled into new raw material, through a grinding and compounding process.

The innovation by NorDan into 3D printed windows is part of the NorDan Group's "ecoDigital ready" strategy. ecoDigital ready is a Trade Mark of NorDan and is the name of the company's strategy for sustainability and digitalization. As part of this strategy the company has worked actively with the UN Sustainability Development Goals, and have made concrete plans for improvements and initiatives within six of the SDG goals.

Based on the successful quality sustainability project into 3D printing of windows, the company has launched additional projects into 3D printing of doors and non-shaped windows. Furthermore, NorDan are now in pilot phase with a key customer, about the recycling of old wooden windows and doors in the market and how to establish both business models and recycling processes for this. The potential of this sustainability project is very large.

RESULTS AND EFFECTS ACHIVED – LEVERAGE POTENTIAL – EFFECTS SUPPORTING SUSTAINABLE DEVELOPMENT

RESULTS AND EFFECTS ACHIEVED; *Describe and detail the results that have been achieved. What has been accomplished? Please describe your results, when applicable in numerical measurements/numbers. Refer to relevant UN Sustainability Goals and present measurable results and effects. (Max. 1000 characters)*

GOAL 9: Industry, Innovation and Infrastructure

- NorDan has launched 3D printed circular windows in the market, with the following result advantages vs conventional production methods: 50% reduction in lead time, 90% reduction in cycle times, 80% reduction in direct hours.
- The project successfully identified a biocomposite material with good 3D printing properties and with an acceptable cost level, almost similar to wood, emphasizing that biocomposite solutions forms an attractive solution for the future also from a cost perspective.
- The frame of the window can be recycled, as can any residue material from the 3D printing process.
- NorDan has made contributions to product developments / innovations in two other companies (BLB Industries and Stora Enso) through this innovation project.
- The innovation project by NorDan has received a lot of attention in the construction industry press throughout Europe and NorDan has thus in many ways been a pioneer to show that 3D printing using sustainable materials are possible and holds interesting opportunities. NorDan predicts that we in the future will see an increased number of 3D printing applications in most industries, and also that 3D printing could enable a shift in supply chain to more products being

produced at the customer premise, i.e. a construction site. This would reduce transports drastically, reduce lead times and enabling higher flexibility.
- The spin-off projects from this quality sustainability are many for NorDan, in particular the development of recycling process for old/used wooden windows and doors is very interesting. Also, NorDan, has invested in solar PV plats at all its three factories in Sweden during 2020.

GOAL 12: Responsible Consumption and Production
- Biocomposit materials holds a huge potential in the future, not only for 3D printed products but also for injection molding applications and extruded profiles and pipes. The volume of extruded PVC/polymer profiles is huge around the world as is injected molded PVC/polymer products. Examples are PVC profiles for windows, PVC pipes, plastic boards and plastic articles. If some of this volume were to be replaced by biocomposite instead of purely polymer, much more bio-based material would find its usage in producing new products. Also, as have been shown in the Innovation project by NorDan, it is possible to recycle biocomposite material at end of product life. It should also be mentioned that the biomaterial are often fractions that are not at all made use of in today's industry. Examples here are e.g. root material and non-used fractions in paper mills.
- The 3D printing process is clean and quiet, as opposed to the conventual production of circular windows in wood which uses noisy cutting machines, excess glue in the gluing process and chemical in the impregnation process. It also reduces the amount of floor space required in the factory and reduces de amount of waste material by using only the necessary material through additive manufacturing versus removing the extra material through traditional manufacturing.
- NorDan has worked actively with the UN Sustainability Development Goals, and have made concrete plans for improvements and initiatives within six of the goals.

GOAL 17: Partnerships to achieve the Goal
- The quality sustainability by NorDan would not have been a success without the strong industrial cooperation the project created along the way, in particular with BLB Industries and Stora Enso, but also with e.g. RISE Research Institutes of Sweden AB when it came to product testing.
- The partnerships together generated the sustainable solution for 3D printed windows from NorDan using biocomposite material.

LEVERAGE OF RESULTS AND EFFECTS; *Describe how you see that the results from the project can be used and leveraged by others. In what way can the project be replicated by others? How and where do you see the project principles and results could be used elsewhere, in other areas or applications/businesses? If the results already have been leveraged to other products, processes, activities, etc. make clear how and what the results are. (Max. 1000 characters)*

The quality sustainability has made NorDan more aware of the importance of innovation for the company. Even a medium sized player in the supplier industry to the construction industry in Europe Construction Industry, like NorDan, can gain a lot from making innovations and putting innovation on the agenda. Historically, a lot of engineers have worked on product development with clear routines and guidelines for how to work on product revisions and new products. However, true innovation projects were rare in NorDan. The company has now established an innovation process in its company.

It has already been highlighted earlier in this application that based on the successful project into 3D printing of windows by NorDan, the company has launched additional projects into 3D printing and is also looking at very interesting processes and business models for recycling of old wooden windows and doors.

Regarding additional options for 3D printing, NorDan has in subsequent projects managed to 3D print door leaves and also 3D print frame profiles to be used as a complete door set. NorDan has produced a couple of test door-sets, but not yet launched the product for commercial sales in the market. The work on frame profiles can also be extended to sash profiles and thus be used in the manufacturing of all types of windows. In the future it could well be possible for NorDan and other companies to place 3D printers at the customers' construction sites and produce products at the site with a significantly lower carbon footprint.

Regarding recycling of old/used wooden windows and doors it is common practice today that when windows and doors are changed to new ones, in refurbishment projects, the old windows and doors are most commonly burnt in an incinerator but also end up at landfills. The recycling into fractions of an old/used wooden window and door is considered to be too costly and difficult. NorDan are now in pilot phase with a key customer, about the recycling of old/used wooden windows and doors in the market and how to establish both business models and recycling processes for this. The potential of this quality sustainability project is very high.

The technology opens up for a flexible production, closer to the end-market and construction sites and thereby reduces transportation needs. Also, given that the technology is based on additive manufacturing using bio-composite material, it opens up for sustainable production of many different kinds of products in a wide range of branches, far beyond the applications within NorDan AB.

IMPORTANCE TO SUSTAINABLE DEVELOPMENT; *Please describe in what way you see that the project results are important to sustainable development. Describe the effects and results on sustainability achieved from the work carried out in the project. (Max. 1000 characters)*

This quality sustainability in NorDan had a very clear goal, i.e. be the first company in the world to sell 3D printed windows in the building industry using a modern, sustainable material. To also support the goal formulation with a good QFD-analysis might have given more nuance and additional aspects to consider. On the other side, the extremely clear goal setting was very important to the success of the project and made the project focus and take efficient and result-driven decisions. The technology opens up for a flexible production, closer to the end-market and construction sites and thereby reduces transportation needs. Also, given that the technology is based on additive manufacturing using bio-composite material, it opens up for sustainable production of many different kinds of products in a wide range of branches, far beyond the applications within NorDan AB.

USE OF QUALITY MANAGEMENT PHILOSOPY, METHODOLOGY AND TOOLS – LINK BETWEEN APPROACH AND RESULTS – UNIQUENESS AND BREAKTHROUGH

USE OF QUALITY MANAGEMENT PHILOSOPHY, METHODOLOGY AND TOOLS; *Describe how quality philosophy, methodology and tools have been used in the work leading to effects and results regarding sustainable development. It could for example be TQM, six sigma methodology, lean tools, root cause analysis, kaizen activities etc. all encompassed by the "Quality body of knowledge". (Max. 1000 characters)*

The 3D printer project by NorDan was from the very start driven by a clear overall goal, i.e. be the first company in the world to sell 3D printed windows in the building market using a modern, sustainable material. For the material it was important to find something as close as possible to wood since NorDan primarily sell wooden windows and doors, and because NorDan has for many decades marketed the environmentally friendly aspects of wooden products as opposed to PVC and aluminium products.

Instead of applying the Six Sigma innovation methodology DMADV (Define-Measure-Analyse-Design-Verify) it was decided to apply Deming's PDCA (Plan-Do-Check-Act) cycle and work in an agile way in trying to reach the overall project goal. The quality sustainability went through numerous PDCA-cycles from the first project meeting in 2018 and until the successful completion end 2019. At each PDCA iteration important progress and learning points were made that helped the project in the next iteration. Project meetings were held every week, with good follow up on outcomes, progress on to-do's and learning points. Along the way also fruitful co- operations with other companies were made such as supplier of 3D printer, supplier of sustainable and modern printing raw-material and testing laboratory. The knowledge and participation of these companies was very important in some phases of the project.

In the PDCA cycle work, it was often found that Plan and Do was rather easy to do, but that the real power of improvement and learning came from the work in the Check-phase. Where data was gathered from testing in the 3D printer, and root-cause analysis as well as cause-effect analysis was actively used and made a good basis for the Act phase where main learning and action points were agreed, forming the basis for subsequently moving into a new PDCA cycle.

At critical innovation stages of the quality sustainability, important decisions had to be made on how to reach the overall goal in the most time-efficient and best way. At these critical stages the thinking and practice of the Pareto Chart was most helpful. As one example, very early in the project it was decided not to pursue a solution to 3D print all types of windows, but instead focus on curved windows. It was agreed that by focusing on this "20%" of the product range, "80%" of the overall goal of the project could be reached, i.e. the be the first company in the world to sell 3D printed windows in the building market. If the principles of the Pareto Chart had not been applied the project would have taken much more time to complete and would most likely not still have been completed nor would it have given the results that NorDan has enjoyed from this successful project into modern production methods, sustainable material, processes and products.

LINK BETWEEN APPROACH AND RESULTS; *Describe how and why the project was planned and executed in the way it was. Describe why certain tools and methods were used and how they supported the project achieving the results planned. (Max. 1000 characters)*

The quality sustainability by NorDan into 3D printing of windows in biocomposite material, holds many learning points and experiences.

It was very good to apply the PDCA methodology in an agile way, mainly because the end result and solution was not known at the start of the project. Taking one step at a time in a systematic way using the PDCA cycle brought the project towards the overall project goal in a consistent way. There was also a good understanding in the project team that it was acceptable to fail in testing, as long as the project collected main learning points. The weekly project meetings also gave very good regularity and high attention among all team members.

3D printing was a completely new production technology to NorDan when the project started, and marked a big difference in approach and thinking, i.e. from traditional discrete process manufacturing of windows to a fully process-based process where all parameters in the room, in the material and in the printer (i.e. temperature, draft, moisture content in surrounding, moisture content in material, feed speed on printer) had much more influence than what the company is normally used to. Much time was used to make this transition and get process parameters under control. One reflection here is that the project could have been better at applying Design of Experient (DoE) as a tool in this phase. It was discussed a few times to do it, but it was not done. In future projects, DoE should be applied more actively and also to control confounding effects among the process parameters.

Fact-based decisions were applied throughout the project, which is very important in Quality Management. The fact-based approach as part of the PDCA cycle-methodology was experienced as very strong and helpful.

UNIQUENESS AND BREAKTHROUGH; *In what way are the results achieved from the project unique and outstanding and in what way do they represent a breakthrough? (Max. 1000 characters)*

NorDan AB has gained significant international attention and recognition for their pioneering efforts in 3D printing, in which the company developed a production technique, material solution, product documentation and marketing concept for the commercial selling of 3D printed windows in bio-composite material. The product was launched in the Scandinavian market in October 2019, as the world's first 3D printed window for commercial sales. NorDan AB continues to explore the possibilities with 3D printing and bio-composites and is currently working on high-volume production of profiles for windows and doors in bio-composites, including the use of recycled plastics in the composite fraction.

The technology opens up for a flexible production, closer to the end-market and construction sites and thereby reduces transportation needs. Also, given that the technology is based on additive manufacturing using bio-composite material, it opens up for sustainable production of many different kinds of products in a wide range of branches, far beyond the applications within NorDan AB.

Today, NorDan AB is considered a leader in the Swedish building industry when it comes to Sustainability, much because of its focus on the UN SDGs and its pragmatic, collaborative and project driven approach.

AGREEMENT AND ATTACHED DOCUMENTS

I agree that the attached summary (One-page summary) is being used by IAQ and the IAQ Think-tank QiPECTT members to promote sustainability development by using quality philosophy, methodology and tools. I agree that this summary also could be published by IAQ on the web.

Signature of responsible person

Attachment 1 (**Required**): One-Page Summary - Summary for publication
Attachment 2 (**Voluntary**): Technical report

Note. More information about the award and how to apply can be found on the IAQ Quality Award homepage